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The Effect of an Innovative Fertilizer of Digestate and Wood Ash Mixtures on Winter Garlic Productivity

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Abstract. **Garlic (*Allium sativum* L.) is a widespread crop in vegetable production. The popularity of garlic is due to its bactericidal and antioxidant properties. Digestate and wood ash are the by-products of cogeneration plants. The digestate is rich in nutrients, can provide a large part of the nutrients needed by the plant during the growing season, as well as improves the soil structure. Wood ash contains small amounts of phosphorus and potassium and is strongly alkaline (pH 8–12) due to the oxides in its composition, mostly calcium carbonate. The purpose of the study was to determine the effect of fertilizer rates of the digestate and wood ash mixtures on winter garlic productivity and harvest quality. Field trials with the winter garlic variety 'Lubaša' were established in sod clay, loamy soil. In the garlic plantation, different variants of fertilizer mixtures were used – they contained pig or cattle manure or plant residue digestate, and wood ash. The ratio of digestate and wood ash in the mixtures was 3:1; fertilizer rates for winter garlic were 15 and 30 t ha^{-1}. In the study, the different types of fertilizers showed different effects on the yield and quality of winter garlic.**

***Keywords**: digestate, fertilizer, winter garlic, wood ash, yield quality, yield.*

I. INTRODUCTION

Garlic (*Allium sativum* L.) is a widespread crop and one of the oldest cultivated vegetables. Its medicinal effects have been proven for thousands of years. The edible part of the garlic plant is the garlic cloves. Garlic contains antibiotics, enzymes, amino acids, and trace elements. It is eaten directly or added to food for flavor. It is also used in the preparation of smoked meat products and in some medicines. Today, garlic is valued for its essential oil content. The popularity of garlic is due to its bactericidal and antioxidant properties.

Digestate, or fermentation residue, is produced as a by-product in biogas production plants under anaerobic conditions and is considered one of the most valuable types of organic fertilizers. It contains valuable macro- and microelements and is a valuable fertilizer [1], [2], [3]. The digestate is rich in nutrients, can provide a large part of the nutrients needed by the plant during the growing season, as well as improves the soil structure. Approximately 35–81% of the total nitrogen content in the digestate is ammonia (NH_4), which is available to plants. Various products are used as a raw material for biogas production, such as manure, food waste, the waste of plant production, forest, and wood processing, as well as peat, sewage sludge, and various types of grass and corn silage. The most suitable material for biogas production is manure. In anaerobic conditions, in thermophilic mode, and during processing, manure remains safe for the environment and immediately usable.

Digestate contains dissolved minerals and unbroken organic matter, which are bacterial cells and substances with a high lignin content. Digestate as a fertilizing material is divided into two groups depending on its dry matter content: liquid fraction, with dry matter content below 15%, and solid or separated fraction, with dry matter content above 15%. The separated digestate can be used as a compost together with various organic waste products. The solid fraction is rich in phosphorus and organic nitrogen, but the liquid fraction contains much more nitrogen in a form available to plants [4], [5], [6].

Wood ash, the by-product of biomass combustion, can return important nutrients to the soil and prevent soil acidification. Soil pH can be adjusted using various soil liming materials (e.g., dolomite flour, lime) or wood ash. The burning of biomass for heat production has considerably increased recently, which remarkably increases the production of wood ash as a by-product. Wood ash consists of sand residues, inorganic compounds from harvested biomass, and a very small fraction of unburned organic material [7]. The element concentrations

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of the ashes, as well as their other chemical constituents, vary considerably depending on the incinerated material and the incineration technique [8], [9], [10]. Thus, wood ash contains all inorganic plant macro- and micronutrients from biomass, except for N [8]. Various oxides are formed during combustion, and subsequent aeration may lead to the formation of carbonates in wood ash, making the ash highly alkaline with a pH of 8 to 12 [10].

Unlike landfilling ash, recycling ash as a soil cond itioner will return important nutrients to the soil and prevent acidification [9]. Wood ash has a relatively low content of heavy metals and is more alkaline. High concentrations of Ag, Cd, Cr, Pb, Zn, and Cu in ash can appear when wood waste treated with industrial preservatives is burned. Wood ash is safer to use for fertilization if soot and slag fractions are broken down during combustion, as heavy metals (except zinc) accumulate in soot [9]. Ash is mainly used as a source of potassium, calcium, and phosphorus, which is especially lacking in acidic organic soils; the average potassium content in ash is 50–60 g kg^{-1}. In agriculture, in practice, digestate and wood ash are most often used separately to improve soil fertility; however, the use of both of these products separately can cause certain ecological problems. In order to at least partially prevent the pollution of the surrounding environment, an idea arose to mix digestate and ash together in certain proportions and use the obtained mixtures for crop fertilization.

The purpose of the study was to determine the effect of fertilizer rates of the digestate and wood ash mixtures on winter garlic productivity and harvest quality.

II. Materials And Methods

Field trials with the winter garlic variety 'Lubaša' were established during the two vegetation seasons of 2020/2021 and 2021/2022 in sod gley, sandy loam soil (56°66' N, 23°75' E).

Agrochemical indicators of the soil: pHKCl 6.7, organic matter content – 3.8%, phosphorus (P_2O_5) content – 199 mg kg^{-1}, and potassium (K_2O) content – 97 mg kg^{-1} soil. In the garlic plantations, different variants of fertilizer mixtures with the digestates of pig manure (from LLC "Latvi Dan Agro"), cattle manure (from JSC "Ziedi JP"), and plant residue (from the farm "Līgo"), as well as wood ash (from LLC "Gren Jelgava") were used. Using these components, mixtures of relevant variants were prepared in the Biogas Scientific Laboratory of Latvia University of Life Sciences and Technologies. The ratio of digestate and wood ash in the mixtures was 3:1, and fertilizer rates for winter garlic were 15 and 30 t ha^{-1}. To compare the types of fertilizers, the traditional mineral fertilizer NovoTec classic (NPK12-8-16), 500 kg ha^{-1}, was also used. Fertilizer options are shown in Table 1. The fertilizer norms of unfertilized winter garlic plantings and of all three types of digestates were used as control variants. The pre-plant – black fallow; the planting rate of winter garlic cloves was 1.6 t ha^{-1}. Fertilizer was incorporated into the soil and garlic was planted by hand. For recording the harvest, the plot area in replicates was 2 m^2. The placement of the variants in the trial was randomized, in three replications.

During the vegetation period, the development dynamics of winter garlic was registered, the harvest was recorded, and the quality of garlic bulbs was evaluated: the content of dry matter, crude protein, sulfur, phosphorus, potassium, and reducing sugars in dry garlic bulbs. To determine the quality of the harvest, two average garlic bulbs were selected from each replicate and put together for all variants, forming an average united sample.

Qualitative indicators were determined in the Biotechnology Scientific Laboratory (BSL) of the Latvia University of Life Sciences and Technologies. The samples were prepared for chemical analyses according to the LVS EN ISO 6498:2012 method. The dry matter content was determined using gravimetric analysis (ISO 6496:1999), the amount of crude protein was determined by the Kjeldahl method (LVS EN ISO 5983-2:2009), the phosphorus content was determined by gravimetric analysis of quinoline phosphomolybdate (ISO 6491:1998), the potassium content was determined by flame emission spectrometry (LVS EN ISO 6869:2002), and sulfur (S) was determined by using CS-500 analyzer method.

Data processing was carried out using the two-way analysis of variance (ANOVA) "Microsoft Excel" computer program.

III. Results An Discussion

In the study, the type of fertilizer differently affected the yield of winter garlic. Depending on the type of fertilizer, the yield varied between 8.92 and 9.15 t ha^{-1}. The use of different types of digestates, including mixtures with wood ash, ensured a significant ($p<0.05$) increase in the yield of winter garlic bulbs – on average by 0.71–0.94 t ha^{-1} compared to the control variant. The use of the mixture of plant residue digestate and wood ash as well as the use of horse manure compost (Table 1) ensured higher garlic yields. The highest yield - 9.35 ha^{-1} in this study was provided by the application of horse compost. The high efficiency of horse compost in garlic plantations is also confirmed by other studies [11].

Fertilizer rates of all digestates and their mixtures with wood ash did not significantly affect the yield of garlic. However, when using pig manure digestate and its mixtures, it is recommended to use higher fertilizer rates – 30 t ha^{-1}. The use of digestate and wood ash mixtures in neutral soils can sometimes have a negative impact on the yield due to the reason that the soil may become alkalescent. When using all digestates and their mixtures with wood ash for the fertilization of garlic, depending on the type and rate of fertilizer, the pH of the soil layer

increased by an average of 0.5–0.8 units. The application of these mixtures provided a significantly better effect in acidic and moderately acidic soils.

The health benefits of garlic are related to its chemical composition. The chemical composition of garlic is significantly influenced by the variety, growing conditions, and the agrotechnology applied.

In terms of taste and dietary properties, garlic is one of the most valuable vegetable crops. Garlic has a higher nutritional value compared to other onion species, it contains a large amount of carbohydrates, proteins, vitamins, especially C, B1, B2, B6, PP, antibiotics garlicin and allistatin, some enzymes and amino acids [12]. Winter garlic needs soils with available forms of nutrients, they respond positively to the use of easily soluble fertilizers. The correct use of fertilizers increases the commercial quality of products, early ripening, promotes the accumulation of dry matter, vitamins, sugars and nutrients [13].

Fertilization regime and soil properties can significantly affect quality indicators, such as mineral composition, dry matter, protein content and its composition. The mineral analysis of garlic is presented in Table 2. The results indicated high values in crude protein, sulfur, phosphorus, potassium and reducing sugars.

The dry matter content of winter garlic bulbs was in the range of 35.4–39.1 %. The high content of the dry matter is associated with a large amount of inulin (20–27%), which, under the action of gastric acids, turns into a valuable sugar for the human body – fructose. Dry matter is also an important indicator of the quality – the higher it is, the less susceptible garlic is to mechanical damage and the better it is stored during winter period.

TABLE 1 INFLUENCE OS DEGESTATE AND WOOD ASH MIXTURES ON THE YIELD OF WINTER GARLIC VARIETY 'ĻUBAŠA' (ON AVERAGE 2021-2022)

Type of fertilizer (F_A)	**Fertilizer rate, t ha^{-1} (F_B)**	**Digestate and wood ash ratio in the mixture (F_C)**	**Average winter garlic yield, t ha^{-1}**		
			(F_C)	***(F_B)***	***(F_A)***
			LSD$_{0.05}$ =0.30	LSD$_{0.05}$ ***=0.30***	LSD)$_{0.05}$ ***=0.36***
Control			8.21	-	-
Horse manure compost, 30 t ha^{-1}			9.35	-	-
Mineral fertiliser NovoTec classic (NPK12-8-16), 500 kg ha^{-1}			8.58	-	-
Cattle manure digestate	15	1:0	9.10	9.20	9.08
		3:1	9.29		
	30	1:0	9.31	8.96	
		3:1	8.62		
	15	1:0	8.98	8.82	8.92

Type of fertilizer (F_A)	**Fertilizer rate, t ha^{-1} (F_B)**	**Digestate and wood ash ratio in the mixture (F_C)**	**Average winter garlic yield, t ha^{-1}**		
			(F_C)	***(F_B)***	***(F_A)***
			LSD$_{0.05}$ =0.30	LSD$_{0.05}$ ***=0.30***	LSD)$_{0.05}$ ***=0.36***
Control			8.21	-	-
Horse manure compost, 30 t ha^{-1}			9.35	-	-
Mineral fertiliser NovoTec classic (NPK12-8-16), 500 kg ha^{-1}			8.58	-	-
Pig manure digestate		3:1	8.66		
	30	1:0	9.18	9.02	
		3:1	8.87		
Plant residue digestate	15	1:0	9.35	9.23	9.15
		3:1	9.11		
	30	1:0	9.00	9.07	
		3:1	9.13		

Fertilizer mixture norms did not significantly affect the changes in crude protein content in garlic – it fluctuated between 6.1% and 7.8% in the total dry matter of the studied variants (Table 2).

The main quality characteristic of garlic is the specific smell and taste of its cloves. Garlic is a particularly rich source of organosulfur compounds, which are thought to be responsible for its flavor and aroma, as well as its potential health benefits [14]. Many favorable experimental and clinical effects of the consumption of garlic preparations, including garlic extract, garlic oil, dehydrated garlic powder have been reported. These biological responses include reduction of risk factors for cardiovascular diseases and cancer, a stimulation of immune function, enhanced foreign compound detoxification, radioprotection, restoration of physical strength, resistance to various stresses and potential anti-aging effects.

Garlic has a relatively high sugar content among vegetable crops, and the presence of a large amount of sugar is not felt in the taste because of the presence of essential oils in onions. The sugar content in the experimental samples of garlic was in the range of 0.53-0.70%. The trend of accumulation of sugars in garlic bulbs depending on the application of fertilizers was similar to the dry matter content. When fertilizer was applied, the amount of sugars in garlic bulbs significantly increased by 0.13-0.3% compared to the control.

TABLE 2 INFLUENCE OF DIGESTATE AND WOOD ASH MIXTURES ON YIELD QUALITY OF WINTER GARLIC VARIETY 'ĻUBAŠA' (ON AVERAGE 2021-2022)

Type of fertilizer, (F_A)	Fertilizer rate, t ha^{-1} (F_B) and digestate and wood ash ratio in the mixture (F_C)	Average content in a natural product, %				
		crude protein	*sulfur*	*phosphorus*	*potassium*	*reducing sugars*
Control		8.84	0.98	0.51	1.17	0.40
Horse manure compost - 30 t ha^{-1}		9.35	0.98	0.54	1.28	0.55
NovoTec classic NPK12-8-16 - 500 kg ha^{-1}		8.90	0.87	0.51	1.23	0.57
Cattle manure digestate	15; D/P** 1:0	9.11	0.99	0.50	1.21	0.53
	15; D/P 3:1	9.05	0.89	0.50	1.19	0.67
	30; D/P 1:0	9.49	0.90	0.51	1.19	0.56
	30; D/P 3:1	9.09	0.90	0.56	1.30	0.66
	On average	**9.19**	**0.92**	**0.52**	**1.22**	**0.61**
Pig manure digestate	15 ; D/P 1:0	9.21	0.90	0.51	1.25	0.65
	15; D/P 3:1	9.01	0.94	0.52	1.35	0.64
	30; D/P 1:0	9.56	0.89	0.53	1.22	0.64
	30; D/P 3:1	8.93	0.84	0.50	1.39	0.67
	On average	**9.18**	**0.89**	**0.52**	**1.30**	**0.65**
Plant residue digestate	15; D/P 1:0	9.97	0.98	0.55	1.33	0.57
	15; D/P 3:1	9.08	0.98	0.50	1.23	0.65
	30; D/P 1:0	9.49	1.01	0.55	1.23	0.61
	30; D/P 3:1	9.85	1.01	0.57	1.30	0.70
	On average	**9.60**	**1.00**	**0.54**	**1.27**	**0.63**
LSD $_{0.05}$ F_A		0.523	**0.071***	0.048	0.086	0.039
LSD $_{0.05}$ F_B		0.427	0.058	0.040	0.071	**0.032***
LSD $_{0.05}$ F_{AB}		0.740	0.100	0.068	0.122	**0.055***

* LSD are not relevant; LSD in bold are significant at $p<0.05$.

** D/P- digestate and wood ash ratio in the mixture

In addition to taste properties, they also determine the medicinal properties of garlic. In the study, depending on the fertilizer rate and type applied, the sulfur content in total dry matter was 0.28–0.70%.

Sulfur content in dry matter had a weak non-significant ($p>0.05$) correlation with dry matter yield ($r=0.34$), crude protein content in dry matter ($r=0.41$) (Fig. 1, Fig. 2), and potassium content in dry matter.

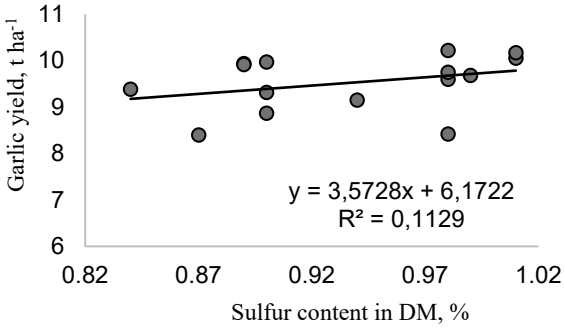

Fig.1. Correlation between garlic yield, and sulfur content in dry matter.

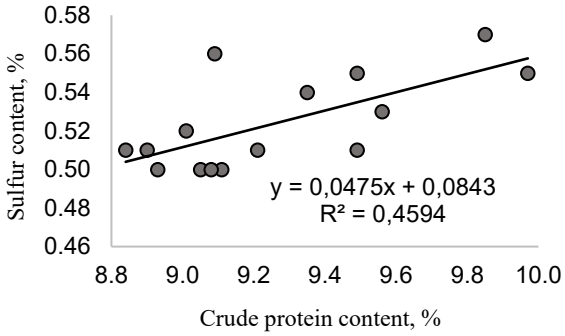

Fig. 2. Correlation between garlic crude protein content and sulfur content in dry matter.

Crude protein content in dry matter showed the only significant ($p<0.05$) correlations with yield ($r=0.63$) and potassium content in dry matter ($r=0.68$) (Fig. 3, Fig.4).

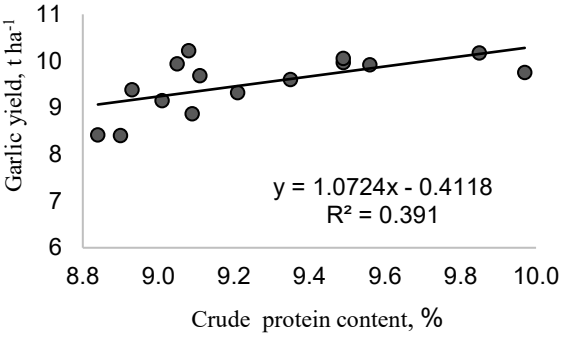

Fig.3. Correlation between garlic yield, crude protein content in dry matter.

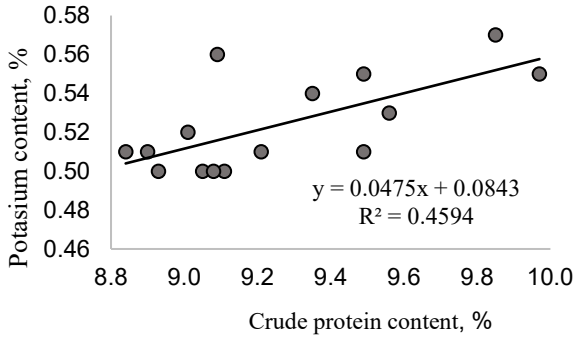

Fig. 4. Correlation between garlic crude protein content and potassium content in dry matter.

IV. CONCLUSIONS

Research results showed that by using digestate and wood ash mixtures, sufficiently high and good quality winter garlic yields can be obtained without using mineral fertilizers.

A higher yield was ensured by the use of plant residue digestate and wood ash mixtures.

In order to determine more precisely which fertilizer mixture and in what amount is the most effective, further research is required.

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The Efficiency of Using Alternative Fertilizers in Potato Plantations

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Abstract. **Field trials with the two potato variety were carried out in sod stagnogley soil. Soil agrochemical parameters: pH_{KCl} 6.7 organic matter (OV) content in soil 2.3%, phosphorus (P_2O_5) content - 149 mg kg^{-1} and potassium (K_2O) content - 200 mg kg^{-1} in soil. Potato plantations were created using different variants of fertilizer mix with pig (from SIA "Latvi Dan Agro") and cattle (from SIA "Ziedi JP") manure digestate and wood ash (from SIA"Gren Jelgava") in different ratio (digestate :wood ash ratio used: 4:1and 3:1). The rates of innovative mixed fertilizer for pig and cattle manure digestates for potatoes were 15 and 30 t ha^{-1}. Both norms for digestate manure from pure pigs and cattle were used as control options. The potato production norm was 3.0 t ha^{-1}. The placement of the variants in the trial was randomized, in triplicate. In the study, the two types of fertilizer had different effects on potato tuber yield. Using mixtures of pig manure digestate and wood ash in different ratios, the average yield was 34.2 t ha^{-1}, but using mixtures of cattle manure digestate and wood ash, the average yield was 27.8 t ha^{-1}. In the studied variants, its content in potato dry matter varied in the range of 9.15-11.42%. The amount of dry matter affects the culinary properties of the tubers. The application of fertilizer mixtures increased the dry matter content by an average of 1.7–2.7%. Fertilizer variants with higher tuber yield or higher starch content provided the highest starch yield. In general, the use of mixtures of wood ash and biogas digestate to fertilize crops and improve soil fertility can be an efficient way to process both products and can be an environmentally friendly alternative to fertilizers. The objective of the research was to study the influence of digestate and wood ash mixtures fertilizer rates on potato productivity and quality.**
Keywords: ***digestate, fertilizer mix, potatoes, wood ash.***

I. Introduction

Potatoes are one of the most important agricultural crops and are rightly called the second bread. In the world, in terms of cultivated areas, they occupy one of the first places along with rice, wheat and corn.

According to the literature, potato tubers contain on average 76-78% water and 13 to 36% dry matter, with 12-15% starch, 1-3% protein and about 1% minerals. Potato protein has a very high biological value because it contains an essential amino acid complex that is not synthesized in humans and animals and must be obtained from food or feed.

As a result of the operation of biogas and biomass cogeneration plants, production by-products are obtained - digestate and ash. It is a good source of plant nutrients because it contains many trace elements and macroelements important for plant growth, so digestate can be used as an effective fertilizer for crops [1], [2]. The physical and chemical properties of ash can vary significantly depending on the plant species, plant growth conditions, parts of the plant used for combustion, parameters of the combustion process and storage conditions [3]. Ash contains a variety of minerals that make it a valuable source of plant nutrients. They contain various macronutrients and microelements important for plant growth and development, with the exception of nitrogen, which is released into the atmosphere by flue gases during combustion [4], [5].

Studies have shown a positive effect of ash on soil properties, structure and water regime in the soil [3]. Ash fertilizer increased the amount of phosphorus, potassium, calcium and magnesium used in plants in the soil [5]. A decrease in nitrogen concentration in the upper soil layers and an increase in soil pH after ash application have been observed. They can be used to improve soil fertility, crop yields and crop quality. However, the use of both products separately can cause certain environmental problems. To prevent this, at least in part, the idea arose to mix digestate

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and ash in certain proportions and use them to fertilize different crops.

The aim of the study: to determine the effect of digestate and wood ash fertilizer norms on potato productivity and crop quality.

II. Materials and Methods

Field trials with the potato variety 'Rigonda' were set up (2020 and 2021) in sod stagnogley soil. Soil agrochemical parameters: pH_{KCl} 5.9, organic matter content in soil - 2.3%, phosphorus (P_2O_5) content - 149 mg kg^{-1} and potassium (K_2O) content - 200 mg kg^{-1} in soil. Potato plantations were created using different variants of fertilizer mixtures with pig (from LLC "Latvi Dan Agro") and cattle (from JSC "Ziedi JP") manure digestate and wood ash (from LLC "Gren Jelgava") in different ratios (used digestate: wood ash ratio – 4: 1 and 3: 1). The rates of innovative mixed fertilizer for pig and cattle manure digestate for potatoes were 15 and 30 t ha^{-1}. The amount of nutrients delivered to potatoes with this fertilizer rate can be seen in Table 1.

Both rates of digestion of pure pig and cattle manure were used as control options.

TABLE 1 AMOUNT OF NUTRIENTS INCORPORATED INTO THE SOIL (2020-2021)

Type of fertilizer	Fertilizer rate, t ha^{-1}	Digestate and wood ash ratio in the mixture	Amount of elements incorporated into the soil, kg ha^{-1}		
			N	***P_2O_5***	***K_2O***
Pig manure digestate	15	1:0	98	93	35
		3:1	75	131	139
		4:1	80	128	125
	30	1:0	196	186	70
		3:1	150	262	278
		4:1	160	256	250
Cattle manure digestate	15	1:0	81	54	86
		3:1	61	101	177
		4:1	66	85	150
	30	1:0	162	108	172
		3:1	122	202	354
		4:1	132	170	300

Table 1 shows how the addition of ash to fertilizer changes the nutrient input: the amount of nitrogen supplied to potatoes decreases and the amount of potassium and phosphorus increases. It is also possible to see a rather logical regularity that doubling the dose of fertilizer doubles the amount of nutrients supplied. The potato planting rate was 3.0 t ha^{-1}. Trials variants were conducted randomized in three replications. The harvest recording area in each replicate was 2 m^2, for each variant of trials - 6 m^2.

Potato variety 'Rigonda' is suitable for early harvest in Latvian conditions, ensuring a sufficient proportion of large tubers in the harvest, as well as good taste characteristics. In experiments performed in Latvia, in the organic farming system, where only manure was previously applied to the soil, the yields ranged from 23.3–30.0 t ha^{-1}.

For potatoes during the vegetation period, the dynamics of potato development and the number of stems were hoped for. At the end of the vegetation, for each experiment, the total yield was counted and distributed by tuber size in all replicates, and the yield quality was determined: dry matter content, starch content (naturally moist and dry matter), and crude protein, fat, ash, phosphorus and potassium. To determine the quality of the harvest, an average sample was prepared for each variant, consisting of two medium-sized potatoes selected in each replicate.

Qualitative indicators are defined in the Biotechnology Scientific Laboratory (BSL) of the Latvia University of Life Sciences and Technologies. The dry matter, fat and ash content were determined by gravimetric analysis, the crude protein content was determined by the Kjeldahl method, the phosphorus content of the samples was determined by quinoline phosphomolybdate analysis, the potassium content by flame emission spectrometry and the starch by natural polarimetry.

Data processing was performed using three-way analysis of variance (ANOVA) "Microsoft Excel" computer program.

III. Results and Discussion

The development of a quality potato crop is a complex process of plant interaction with growing systems and environmental conditions that affect the rate, metabolism and growth of photosynthesis. In the study, the two types of fertilizer had different effects on potato tuber yield. Using a mixture of pig manure digestate and wood ash in different ratios, the average yield was 24.93 t ha^{-1}, but using a mixture of bovine manure digestate and wood ash, the average yield was 22.78 t ha^{-1} (Table 2). There was a significant positive effect on yield on the fertilizer norm (F-factor> F-criterion), but no significant effect on yield was observed for the type of fertilizer, ash and digestate ratio. Potatoes are one of the most important foods for needed by humans in potato tubers determines its value as a food product.

TABLE 2 INFLUENCE OF DIGESTATE AND WOOD ASH MIXTURES ON YIELD OF POTATO VARIETY 'RIGONDA' (2020-2021)

Type of fertilizer (F_A)	Fertilizer rate, t ha^{-1} (F_B)	Digestate and wood ash ratio in the mixture (F_C)	Average tuber yield, t ha^{-1}		
			(F_C) *LSD$_{0.05}$= 2.62*	(F_B) *LSD$_{0.05}$ = 2.70*	(F_A) *LSD$_{0.05}$ = 2.38*
Pig manure digestate	15	1:0	25.43	24.66	24.93
		3:1	25.63		
		4:1	22.92		
	30	1:0	26.76	25,19	
		3:1	25.54		
		4:1	23.28		
Cattle manure digestate	15	1:0	25.20	22.71	22.78
		3:1	20.73		
		4:1	22.19		
	30	1:0	25.11	22.85	
		3:1	22.64		
		4:1	20.81		

Starch is the main ingredient in potatoes. The highest starch yield was provided by fertilizer variants with higher tuber yield or higher starch content. In our studies, the average starch content in the dry matter was 73.3% and 15.3% in the natural product, but the average starch yield was 3.55 t ha^{-1} (Table 3).

TABLE 3 INFLUENCE OF DIGESTATE AND WOOD ASH MIXTURES ON STARCH PRODUCTION OF POTATO VARIETY 'RIGONDA' (2020-2021)

Type of fertilizer (F_A)	Fertilizer rate, t ha^{-1} (F_B)	Digestate and wood ash ratio in the mixture (F_C)	Average tuber yield, t ha^{-1}		
			(F_C) *LSD$_{0.05}$= 0.45*	(F_B) *LSD$_{0.05}$ =0.63*	(F_A) *LSD$_{0.05}$= 0.71*
Pig manure digestate	15	1:0	4.21	4.16	3.90
		3:1	3.99		
		4:1	4.27		
	30	1:0	3.30	**3.63**	
		3:1	3.72		
		4:1	3.87		
Cattle manure digestate	15	1:0	4.15	**3.68**	**3.50**
		3:1	3.68		
		4:1	3.21		
	30	1:0	3.57	3.32	
		3:1	3.21		
		4:1	3.17		

Tubers with a low (<20%) dry matter content dissolve faster during cooking, while tubers with a higher dry matter content are denser, less prone to mechanical damage and easier to use for recycling. The application of fertilizer mixtures increased the dry matter content by an average of 1.4–2.0%, reaching an average of 21% (Table 4, Table 5). The tendency to increase the dry matter content is observed at lower fertilizer rates. The crude protein content of tubers determines the nutritional value of potatoes. In the studied variants, its content in potato dry matter varied in the range of 8.28–10.94%.

TABLE 4 INFLUENCE OF DIGESTATE AND WOOD ASH MIXTURES ON THE CHEMICAL COMPOSITION OF POTATO VARIETY 'RIGONDA' (2020-2021)

Type of fertilizer (F_A)	Fertilizer rate, t ha^{-1} (F_B)	Digestate and wood ash ratio in the mixture (F_C)	Content in dry matter, %		
			crude protein	*potassium (K)*	*phosphorus (P)*
Pig manure digestate	15	1:0	8.65	2.17	0.34
		3:1	8.28	2.20	0.33
		4:1	10.83	2.44	0.36
	On average (F_B)		**9.25**	**2.27**	**0.34**
	30	1:0	10.94	2.29	0.36
		3:1	10.83	2.52	0.39
		4:1	10.24	2.34	0.38
	On average (F_B)		**10.67**	**2.38**	**0.38**
On average (F_A)			**9. 96**	**2.23**	**0.36**
Cattle manure digestate	15	1:0	8.47	2.14	0.33
		3:1	9.53	2.20	0.36
		4:1	10.38	2.07	0.32
	On average (F_B)		**9.46**	**2.14**	**0.34**

Type of fertilizer (F_A)	**Fertilizer rate, t ha^{-1} (F_B)**	**Digestate and wood ash ratio in the mixture (F_C)**	**Content in dry matter, %**		
			crude protein	***potassium (K)***	***phosphorus (P)***
	30	1:0	10.76	2.30	0.36
		3:1	9.12	2.30	0.36
		4:1	10.61	2.64	0.39
	On average (F_B)		**10.16**	**2.41**	**0.37**
On average (F_A)			**9.81**	**2.28**	**0.35**

TABLE 5 INFLUENCE OF DIGESTATE AND WOOD ASH MIXTURES ON THE CHEMICAL COMPOSITION OF POTATO VARIETY 'RIGONDA' (2020-2021)

Type of fertilizer (F_A)	**Fertilizer rate, t ha^{-1} (F_B)**	**Digestate and wood ash ratio in the mixture (F_C)**	**Average content in natural product, %**	
			starch	***dry matter***
Pig manure digestate	15	1:0	16.54	22.22
		3:1	16.73	22.11
		4:1	14.41	20.34
	On average (F_B)		**15.89**	**20.56**
	30	1:0	14.90	20.25
		3:1	14.57	20.29
		4:1	15.17	21.06
	On average (F_B)		**14.88**	**20.53**
On average (F_A)			**15.38**	**21.05**
Cattle manure digestate	15	1:0	16.45	21.81
		3:1	15.49	20.91
		4:1	16.08	21.83
	On average (F_B)		**16.01**	**21.52**
	30	1:0	14.67	20.19
		3:1	15.40	20.39
		4:1	14.02	19.30
	On average (F_B)		**14.7**	**19.96**
On average (F_A)			**15.35**	**20.74**

Potassium plays an important role in human health because it is involved in regulating muscle activity and affecting the resistance of nerve cells to stress. Its content in the dry matter of potato tubers averaged 2.28% and the types and norms of mixed fertilizers had practically no effect on its changes (Table 4, Table 5).

Phosphorus is involved in maintaining the acid-base balance. Participates in fat metabolism and blood circulation, helps to restore muscles, liver, idneys. It stabilizes the condition of teeth, hair and ails [6]. The content of phosphorus in the dry matter of potato tubers averaged 0.35% and the studied factors did not change its amount.

In general, the use of mixtures of wood ash and biogas digestate to fertilize potatoes and improve soil fertility can be an efficient way to process both products and can be an environmentally friendly alternative to fertilizers.

IV. CONCLUSIONS

Using mixtures of pig manure digestate and wood ash in different ratios, the average yield of tubers was 24.92 t ha^{-1}, but using mixtures of bovine manure digestate and wood ash, the average yield was 22.78 t ha^{-1}.

The highest starch yield of 4.27 t ha^{-1} was provided by the pig manure digestate fertilizer variant, where the fertilizer rate was 15 t ha^{-1} and the digestate to ash ratio was 4: 1. Using mixtures of pig manure digestate and wood ash in different ratios, the average starch yield was 3.90 t ha-1, but using mixtures of bovine manure digestate and wood ash, the average starch yield was 3.50 t ha^{-1}.

Differences in the chemical composition of potato tubers have also been observed, but they do not have a single specific trend, each fertilizer variant has changed its chemical composition differently.

Higher crude protein content in potato tubers was observed in variants where pig manure digestate with the norm of 30 t ha^{-1} was used for fertilization, which was 10.67%, while higher potassium and phosphorus content was applied with bovine manure digestate with the norm of 30 t ha^{-1}.

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Theoretical and Methodological Aspects for the Development of a Creative Economy in the Context of the Formation of an Innovative Business Ecosystem

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Abstract. **The aim of the study is to analyze the theoretical basis of creative economy and its development trends in the context of innovative business ecosystems formation. The scientific novelty of the research consists in solving the most important scientific and applied problem - further development of theoretical provisions of creative economy, ecosystems, as well as substantiation of the conceptual approach to the formation of innovative business ecosystem as a coherent management model. In the process of research, general scientific and special methods were used: scientific abstraction, deduction, analysis and synthesis, system and critical analysis, structural-logical, ascending from the abstract to the concrete, and statistical analysis. It has been substantiated that the priority development of creative economy as a strategic driver of sustainable development is the formation of an ecosystem conducive to the development of complex non-linear dynamic innovation processes, development of value propositions and value chain. The analysis of theoretical and methodological aspects of formation and functioning of ecosystems indicates the lack of development of this problem and the need to develop scientific approaches to their identification. Generalization of the results of theoretical analysis allowed us to group ecosystems according to the identified attributes into five main types. It was substantiated that a sustainable business ecosystem is a favorable environment for innovation to increase its value and contribute to the achievement of sustainable development goals. It is proposed to consider a sustainable "business ecosystem" as a coherent management model with established characteristics, which describes an aggregate system of business ecosystem modules that interact with each other and are focused on co-creation and co-production of value.**

Keyword: business ecosystem, innovation, coherent model, creative economy.

I. Introduction

The global economy is currently undergoing processes of convergence associated with the creation of innovative technologies, digitalisation and exponential growth of knowledge, and increased intensity of international competition. The formation of an environment conducive to the development of complex non-linear dynamic innovation processes, the development of value propositions and value chains is among the priorities of the creative economy as a strategic driver of sustainable development. Its focus is now on building effective

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innovation ecosystems based on the Industry 4.0 paradigm. In this context, research into trends in creative economy development in the context of business ecosystem formation is becoming more relevant.

The papers of foreign authors Howkins [1], Higgs [2], Henry [3], Sung [4], Andres [5], Štreimikienė [6], Pratt [7], Rodrigues-Insuasti [8] provide a theoretical basis for the creative economy and, particularly, its conceptual approaches, formation mechanisms and intellectual structure development trends, assessment of its resources, degree of influence on competitiveness and other aspects. The concept of creative economy formed on the basis of the results of these studies acquires particular relevance in the context of interdisciplinary research into sustainable development and the socio-economic relations unfolding therein.

At the same time, the creative economy is changing traditional notions of economic development models, value proposition creation, environment and the mechanism of competitive business process management strategies based on the concept of ecosystems.

Moore was one of the first to use the term "ecosystem" in social sciences and humanities [9]. The problems of the formation and functioning of ecosystems are devoted to the works of Cennamo [10], Jacobides [11], Tsujimoto [12], Pidun [13], Senyo [14], Ehrensperger [15], Gueler [16], Dima [17] and other authors.

At the same time, the incomplete nature of the theoretical and methodological foundations of the ecosystem in the scientific literature indicates the lack of unified approaches to its terminology, definition of the structure formation factors, insufficient description of the essential characteristics and their impact on the development of creative economy, determines the relevance of further systematic research in this area.

The aim of the research is to analyze the theoretical basis of creative economy and trends of its development in the context of innovative business ecosystems formation.

The objectives of the study are to summarize the theoretical and methodological support of the investigated issues and substantiate the conceptual approach to the formation of innovative business ecosystems.

The scientific novelty of the research consists in solving the most important scientific and applied problem - further development of theoretical positions of creative economy, ecosystems, as well as substantiation of the conceptual approach to the formation of innovative business ecosystem as a coherent management model.

The research period is 2022-2023.

II. Materials and Methods

Achievement of the research goal and solution of the tasks set determined the use of general scientific and special methods of scientific knowledge: scientific abstraction, deduction, analysis and synthesis (to conceptualise the essential content of creative economy as a paradigm of modern economic development), systemic and critical analysis of the interpretation of the concept of "ecosystem", structural-logical, ascent from the abstract to the particular (to substantiate the conceptual approach to forming innovative business ecosystems)

III. Results and discussion

Over the last three decades the term "creative economy" has attracted increasing interest worldwide [4] as a way of adapting the economy and society to globalisation changes [4], [18]. Moreover, it is because of its adaptability that the creative economy is the driving force behind national economies to achieve sustainable development goals [6], [7], [17] by structuring the entire economic system on an intellectual basis and creating conditions for the unlocking of personal potential [4].

The creative economy is a paradigm of modern economic development based on the creation and management of innovation, enabling the transformation of industries in which value creation is the creation of creative ideas turned into goods or services.

Creative economy is an analytical category that covers a very wide range of economic activities - from culture, art to software development, forming the digital economy and influencing the future of the whole society [19].

Experts estimate the contribution of the creative economy to the global gross domestic product to be about 3%, and roughly equivalent to its contribution to world trade. It is expected to increase due to the introduction of digitalisation and advanced technologies that characterise Industry 4.0 [20].

The development of a creative economy is crucial for increasing a country's export potential, income growth, job creation and international trade [2], [3]. Moreover, it not only stimulates the development of innovation, but also acts as a catalyst in industry, energy, transport, agricultural production, trade and other sectors of the economy, as well as contributing to the process of social inclusion.

Due to the evolution of digitalisation and the changing behaviour of both producers and consumers of innovative goods and services, the creative economy is universal in generating and implementing change in the economic and social life of society.

Such versatility and knowledge-intensive nature of the creative economy has attracted much attention from the global scientific community and business world [21], [22], and allowed the development of theoretical, empirical and practical application bases based on different approaches to its study [2].

Thus, the results of a December 2021 study of the intellectual structure of the creative economy, using the Scopus database (by the scientific publishing house Elsevier, Amsterdam, Netherlands) and the VOSviewer bibliometric software application (developed by Leiden University, Leiden, Netherlands) in the subject area of business, management and accounting, indicate that the creative economy is a growing research field with 687 articles, 1340 authors and 64 countries represented [8].

It should be noted that, until recently, such research has been conducted in the subject area of social sciences, humanities, culture, art and urban studies.

Since the mid-1990s, scientists, government agencies and public organizations have used the concepts of "new idea", "creativity", "creative idea", "creative activity", "creativity", "intellectual capital", "intellectual property", "innovation" as the basis for defining the creative economy. [1], [9], [23], [24], "business innovation" [25], "creative industries" [26].

Thus, UNCTAD considers the artistic, cultural and industrial aspects of the creative economy. In 2008, together with the United Nations Development Programme (UNDP) «summarise the definition of the «Creative Economy» as follows:

1. The Creative Economy is an evolving concept based on creative assets potentially generating economic growth and development;

2. It can foster income generation, job creation and export earnings while promoting social inclusion, cultural diversity, and human development;

3. It embraces economic, cultural and social aspects interacting with technology, intellectual property and tourism objectives;

4. It is a set of knowledge-based economic activities with a development dimension and crosscutting linkages at macro and micro levels to the overall economy;

5. It is a feasible development option calling for innovative multidisciplinary policy responses and interministerial action» [20].

The creative economy is also sometimes referred to as the 'orange economy', which is a broader concept that includes the interaction of companies with consumers and other business entities based on creative activities such as research and development (R&D), which is not classified as a creative industry.

John Hawkins, the world's leading researcher of the creative economy, emphasizes the importance of her field in creating an enabling ecosystem for creativity [27].

In the final report on the state and prospects of the creative economy in Germany, UK, France, Italy, Spain, Turkey, Japan, South Korea and Australia, prepared by Deloitte LLP for Netflix International B.V. for the period 2011-218, the authors view it as an ecosystem made up of a large number of activities, characterized by opportunities for income and job creation through individual creativity, development and use of intellectual property [28].

The results of our theoretical analysis of the various definitions of the creative economy led us to conclude that they are based, depending on the subject area of research, on the categories of "economic value", "sociological value", "business value" and their combinations.

However, in our view, globalisation processes in the world are proceeding so rapidly that there is a need to review and change the development paradigm of the creative economy. For example, the digitalisation and greening of business processes, which affect business performance, has necessitated a transformation in company management strategies through the creation of successful innovation ecosystems. By operating on the basis of this concept, companies, transcending corporate boundaries, will be able to increase the speed of innovation, improve its quality and increase its value.

Over the last decade, interest in the concept of ecosystem as a new way of reflecting the competitive environment has increased significantly. Borrowed from biology, the term "ecosystem" is commonly used to describe a set of interacting and complementary companies that collectively generate ecosystem-level outcomes. It is widely used by academia and business in contexts related to strategic management, innovation policy, economic system development, industry and entrepreneurship. The concepts of industrial ecosystem, digital ecosystem, entrepreneurial ecosystem, innovation ecosystem and others have spread.

In our opinion, in order to understand the process of ecosystem formation, it is necessary to gain an understanding of the nature of its emergence, purpose, composition of participants, levels of formation and other specific characteristics.

To this end, we have conducted a theoretical study of the interpretation of the concept of "ecosystem" by various authors (table 1).

TABLE 1 THEORETICAL ANALYSIS OF THE INTERPRETATION OF THE TERM «ECOSYSTEM» (COMPILED BY THE AUTHOR)

Authors	Interpretation of the Concept
Moore J. [29]	Companies facing the challenges of implementing innovation in their operations experience radical changes in the external environment, often negative ones. To avoid them, companies need to be seen not as participants in an industry, but as part of a broader business ecosystem. In such an ecosystem, organisations, institutions and individuals come together around a focal company, working together and competitively to create shared value and customer satisfaction. The ecosystem of any company (other than itself and its owners) includes consumers, suppliers, intermediaries, government agencies and other stakeholders evolving through competition, cooperation and interdependence.
Dima, A., Bugheanu, A., Dinulescu, R., Potcovaru, A., Stefanescu, C., Marin, I.; Gueler, M., Schneider, S.;	Business ecosystem is a group of companies that pool their expertise around innovation to develop innovative products and customer satisfaction.

Ehrensperger, R., Sauerwein, C., Breu, R.; Senyo, P., Liu, K., Effah, J. [14] – [17]	
Pidun, U., Reeves M., Schuessler M. [13]	A business ecosystem is a dynamic group of largely independent economic players creating goods or services that are the result of agreed solutions. The authors propose to see the business ecosystem as a solution to a business problem, a way of organising to realise a particular value proposition. For this, the business ecosystem is a management model that competes with other ways of organising the creation of a product or service, such as a vertically structured organisation, a hierarchical supply chain or an open market model.
Eisenhardt, K. & Galunic, D. [30]	An ecosystem can be seen as a network of corporate organisations whose various interests are united by a common goal, and the effectiveness of each organisation depends on the other participants in the chain.
Tsujimoto, M., Kajikawa, Y., Tomita, J., Matsumoto, Y. [12]	The ecosystem is a community of companies that is constantly transforming because it needs to create new value through cooperation instead of competing alternatives.
Jacobides, M., Cennamo, C., Gawer, A. [11]	An ecosystem is a complex of organisations (multifaceted, mutually reinforcing) that is not fully controlled hierarchically.
Pidorycheva, I. Yu. [31]	Innovation ecosystem is an open, holistic, dynamic network, consisting of a spatial community of organizations and individuals with different competencies and roles, coevolving in a particular institutional environment under the influence of influenced by business, regulatory and innovation environments, sharing knowledge and resources, and allocating obligations, risks and benefits in the process of creating innovation and benefits in the process of creating innovations in which consumers are interested.
Burda, Y., Volkova, I., Gavrikova, E. [32]	Innovation ecosystem is a network of legally independent economic agents of different compositions who may be direct competitors but cooperate to create a comprehensive value proposition for customers.
Wareham J., Fox P., Giner J. [33]	The authors suggest that ecosystems should be seen as digital platforms - 'semi-regulated markets' that facilitate entrepreneurial activity under the coordination and guidance of the platform sponsor.
Cennamo, C., Santalo, J. [10]	The authors suggest that ecosystems should be seen as digital platforms - "multistakeholder markets" that allow transactions among specific groups of users.
Stevencon, H., Jarillo Mossi, J. [34]	The authors view the entrepreneurial ecosystem as 'a process of creating value by combining a unique combination of resources to exploit an opportunity'.
Malecki, E. [35]	The author argues that the entrepreneurial ecosystem emerged in the early 1990s, identifying contributions from Moore J.'s 'business ecosystem', Van de Ven's 'infrastructure for entrepreneurship' and the concept of a 'local entrepreneurial system'.

Summarizing the results of the theoretical analysis, we can conclude that at present there is no unified view among the authors on the interpretation of the concept of "ecosystem", the vision of its essence and expediency of application, the number of structural elements of which it consists and the relationships between them.

However, based on the results obtained, the following main approaches to its definition can be identified as:

1. A "business ecosystem" in which the participants focus around the focal company and its surrounding environment without reference to a specific geographical area;
2. An "ecosystem" as an environment formed at different spatial levels without reference to focal companies or innovations;
3. An "innovation ecosystem" centred around a specific innovation or new value proposition, and a group of supporting actors;
4. An "ecosystem as a digital platform" around which other stakeholders focus;
5. An "entrepreneurial ecosystem", which is a set of actors interacting within a geographically bounded entrepreneurial environment and enablers of productive entrepreneurship.

One of the most important tasks in this study is to justify a conceptual approach to the formation of innovative business ecosystems.

The business ecosystem is widely used to study a complex social and economic system from a business perspective. A key feature of such an ecosystem is that its members do not simply compete with each other using their own resources, but cooperate, interact and use shared resources, knowledge, networks and infrastructure to create value together.

The transition to a creative economy affects the shaping of the entire business ecosystem, as the process of managing the flow of value creation is based on the co-creation and capture of value.

It should also be noted that it is only recently that research into the creative economy has been carried out in the context of building a sustainable business ecosystem [23].

A sustainable business ecosystem is an enabling environment for innovation to add value, and therefore contributes to the achievement of sustainable development goals. Creating an aggregate framework not only provides a systematic approach to modelling the business ecosystem, but also provides a methodological basis for investigating the complex systems aspect of the business ecosystem.

We propose to consider the "business ecosystem" as a coherent governance model, which is characterized by:

1. Modularity. In contrast to vertically integrated models or hierarchical supply chains, in business ecosystems, supply options are designed independently of one another but function as a coherent whole. In many cases, the consumer can choose any or a combination of options.
2. Regulability. In contrast to the open market model, the contributions of ecosystem actors are usually adapted to the ecosystem and are mutually compatible. This means that participation in an ecosystem requires some investment in a particular ecosystem.
3. Multilateralism. Unlike open market models, the business ecosystem builds relationships between many partners that cannot be broken down into a set of simple bilateral relationships. This approach should be applied when it is important to achieve cohesion among all partners to create innovation as a common goal.
4. Coordination. Unlike vertically integrated models or supply chains, business ecosystems are not fully controlled hierarchically, but there is some mechanism for coordination - for example through standards, regulations or processes - outside the simple open market mechanism.
5. Cospecialisation. Partners are involved in the co-creation of new value (coproduction), but are involved in different but complementary activities. Each of the actors in the ecosystem contributes their inputs and resources to the development of the innovation.
6. Collaborative. Ecosystem members interact with each other by creating interactive collabora tive innovation networks (COINs) - self-organised, united by a shared vision, common goals and a shared value system, reflecting the growing complexity of the innovation process.
7. Coevolution. In business ecosystems, the activities of each actor cannot be viewed in isolation: changes in one part of the system can have long-lasting and often unanticipated consequences in other parts of the system. In such an environment, companies pool their capabilities around innovation - working together and competitively to meet consumer needs, support new products and ultimately take innovation to the next level.

Therefore, an effective governance model must establish an appropriate level of openness, balancing "open" elements (attracting partners, driving growth and enabling innovation) and "closed" elements (ensuring ongoing quality and consistency); be adaptive; be dynamic; and provide social, environmental or economic value to the business ecosystem.

It should also be noted that traditionally "a business model describes the rationale of how an organization creates, delivers, and captures value" [37]. [37], and our proposed coherent governance model describes an aggregated system of modules of an innovative business ecosystem that interact with each other and focus on co-creation and co-capture of value.

Companies that form such business ecosystems will be better able to innovate and improve capital efficiency while developing and implementing value propositions and value chains.

IV. Conclusions

Systematization of ideas about the creative economy as a paradigm of sustainable development made it possible to generalize the fundamental changes in innovation processes, their deployment and development associated with the acceleration of scientific and technological progress, digitalization and greening, the emergence of new conditions and models of cooperation between subjects of innovation activity, which created the basis for the emergence of the concept ecosystems.

As a result of a comprehensive study of the origins and views on ecosystems, the unformedness of scientific ideas about the essence and nature of ecosystems has been established, and the existing approaches to their identification have been grouped by us into five main types: “business ecosystem”, whose participants are concentrated around the focus company and its environment without reference to a certain geographical area; "ecosystem" as an environment formed at different spatial levels without reference to focus companies or innovations; an "innovation ecosystem" centered around a particular innovation or new value proposition and the group of contributors that support it; "ecosystem as a digital platform" around which other interested participants are concentrated; “entrepreneurial

ecosystem", which is a set of participants interacting within a geographic business environment and factors that contribute to the development of productive entrepreneurship.

Based on the analysis of the features of the ecosystem approach, it was found that a sustainable business ecosystem is a favorable environment for introducing innovations in order to increase its value, and, therefore, contributes to the achievement of sustainable development goals. The creation of an aggregate structure not only provides a systematic approach to business ecosystem modeling, but also provides a methodological framework for researching the complex systems aspect of the business ecosystem.

In this regard, we propose to consider the "business ecosystem" as a coherent governance model that will provide innovative approaches to assessing, comparing and effectively managing value streams, access to new knowledge, resources and the capabilities of all participants in the ecosystem, and as a result, will contribute to the achievement of a synergistic effect in managing the development of the intellectual environment.

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Measurement of sustainable development in Latvia

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***Abstract*. Current paradigm of economic development is sustainable development. Sustainable development is the challenge for governments, companies and households because significant additional investments and innovations, changes in production and consumption habits are required. These changes have to be made because resources are limited and existence of our world is endangered – too much resources are used and too much waste is generated by people. This problem is recognized by the United Nations that set 17 Goals of Sustainable Development in 2015. Review of scientific literature indicates that countries measure their sustainable development in different ways because countries have different development levels, as well as different social, economic and environmental problems. Thus the aim of this research is to identify Latvian approach measuring sustainable development and assess sustainable development in Latvia. Sustainable development in Latvia is measured by indicators defined in Sustainable Development Strategy in Latvia until 2030. The methods applied in this study are literature review and regression analysis. This study reveals Latvian progress in sustainable development and relationship among strategic indicators of sustainable development in Latvia.**

Keywords: Latvia, sustainable development.

I. Introduction

Sustainable development is current paradigm of economic development. It was formalized in 1995 when the United Nations adopted its 17 Sustainable Development Goals (SDG) [1], [2].

Sustainable development is the challenge for governments, companies and households because significant additional investments and innovations, changes in production and consumption habits are required. These changes have to be made because resources are limited and existence of our world is endangered – too much resources are used and too much waste is generated by people.

Analysis of scientific literature shows that countries measure their sustainable development in different ways because countries have different development levels, as well as different social, economic and environmental problems. Thus the aim of this research is to identify Latvian approach measuring sustainable development and assess sustainable development in Latvia. Sustainable development in Latvia is measured by indicators defined in Sustainable Development Strategy in Latvia until 2030. The methods applied in this study are literature review and regression analysis. They help to assess Latvian progress in sustainable development and relationship among strategic indicators of sustainable development in Latvia.

II. Materials and Methods

Measurement of economic development is relevant in any country in the world. International organizations (as the United Nations, the World Bank, the International Monetary Fund, the European Union), countries, economists and analysts are dealing with it. The main measure of economic development is Gross Domestic Product (GDP), but since the middle of the 20th of century there is tension to measure economic development with additional indicators and indexes, as inflation, unemployment, Human Development Index etc. [6], [7]. The problem of GDP is that it is not a perfect measure of well-being because it is materialistic indicator of economic performance of country measuring all output, all income

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and expenditure in economy but it does not measure quality of environment and quality of human life. For example, the United Nations Development Program (UNDP) is measuring the economic development with the Human Development Index, that was introduced to challenge GDP as the only measure of economic performance of national economy [8]. The Human Development Index eliminates such shortcoming of GDP as inequality and quality of life, including indicators characterizing life expectancy, education and income.

Nowadays we have one other trend in organizing and measuring development. It is sustainable development because mankind has reached the level of development when the world is overpopulated and there is a lack of resources and too much waste is generated. The main definition of sustainable development says that it is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [1], [9], [11]. It describes the essence of sustainable development relating it not only with the usage of resources, but also with fundamental economic concept of externalities, as pollution. Governments, firms and households have to move to more sustainable governance, production and consumption practices, e.g. circular economy and "blue" practices, reducing usage or resources and generating less pollution [4], [10].

There is no single method how to measure sustainable development, because not only SDG and its targets are applied, but also other approaches, as Footprint and different sets of indicators. The main problem of applying SDG in measuring sustainable development is that it is challenging to achieve and measure all SDGs together, accounting for the linkages between SDGs and possible synergies or trade-offs, e.g. one way to pursue food security (SDG2) for all would be by increasing food production which could lead to more fertilizer use and thus emissions of nitrous oxide (SDG13) [1]. Countries and regions often choose some SDGs as the highest priorities for particular place to achieve sustainable development [5]. One other good alternative in measuring sustainability is footprint that measures both carbon emissions and usage of resources, as cutting down forests and through agriculture [12]. Usually it is added to other indicators of development, as GDP, Human Development Index etc., representing sustainability.

III. Results And Discussion

Sustainable development in Latvia is assessed by strategic indicators set in Sustainable Development Strategy in Latvia until 2030. They are 7 indicators:

1) Number of inhabitants (mill.);

2) Gini coefficient;

3) GDP per inhabitant per year (EUR, according to purchasing power parity)

4) Regional differences of GDP per inhabitant – dispersion of regional GDP per inhabitant (%).

5) Ecological footprint (ha per inhabitant);

6) Human Development Index (place in the world);

7) Global Competitiveness Index (place in the world).

Authors of this study made analysis of indicators mentioned above to reveal if Latvian development is sustainable and if it is possible to find trends of Latvian economic development. It was chosen to obtain data about not only place, but also score of Latvia in Human Development Index and Global Competitiveness Index to have more comprehensive data. The data that are used in the study are summarized in Table 1.

TABLE 1 DATA SET USED IN THIS STUDY

Year	Number of inhabitants (Mill)	Gini coefficient	GDP per capita (thousand EURO)	Human Development index (score)	Human Development index (place in the world)	Global competitiveness index (score)	Global competitiveness index (place in the world)	Ecological footprint (ha/inhab)	Dispersion of regional (NUTS 3) GDP per inhabitant (%)
2005	2249724	39	9489	0.809	39	4.43	44	5.15	45.9
2006	2227874	35.6	10721	0.816	38	4.29	44	5.65	49.0
2007	2208840	37.5	11881	0.825	36	4.57	36	6.3	44.5
2008	2191810	37.2	11619	0.828	37	4.26	54	4.74	44.3
2009	2162834	36	10129	0.826	39	4.06	68	4.48	42.1
2010	2120504	35	9883	0.824	42	4.14	70	4.41	42.0
2011	2074605	35.8	10326	0.829	41	4.24	64	5	37.6
2012	2044813	35.2	11189	0.832	42	4.35	55	5.05	40.5
2013	2023825	35.5	11532	0.839	40	4.4	52	5.36	43.4
2014	2001468	35.1	11861	0.845	40	4.5	42	5.74	43.6
2015	1986096	34.2	12427	0.849	40	4.45	44	6.18	44.2
2016	1968957	34.3	12838	0.854	39	4.45	49	6.24	43.3
2017	1950116	35.6	13387	0.859	37	4.4	54	6.17	41.7
2018	1934379	35.1	14029	0.863	37	6.2	42	6.41	46.7
2019	1919968	34.5	14476						
2020	1907675		14021						
2021	1893223		14788						
2022	1875757							6.13	

Source: constructed by authors (sources of data – [8], [13]-[16].

At the beginning the full set of data and they trends were analysed. The units of measurement of data are different and it is not possible to represent them on a single coordinate plane. To be able to do it, indicators were normalized so that they are within the range from 0.5 to 1.5, applying the following formula:

$$X_{norm} = a + b * X$$

$$b = \frac{1}{X_{max} - X_{min}};\ a = 1.5 - \frac{X_{max}}{X_{max} - X_{min}} \qquad (1)$$

where

a; b coefficients of the normalization formula,

x_{max} ; x_{min} maximum and minimum value of the indicator.

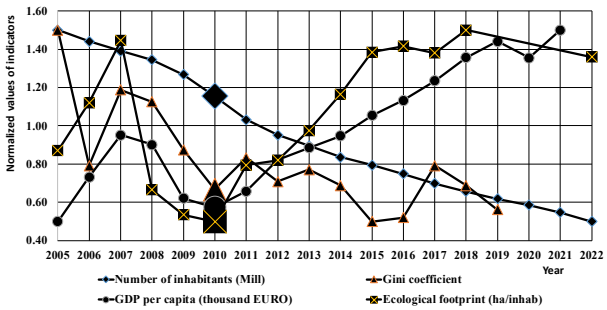

Fig. 1. Data on normalized scale, Latvia.

Such sustainable development indicators of Latvia as Number of inhabitants, Gini coefficient, GDP per capita and Ecological footprint are represented on Fig. 1. They are depicted in normalized values. A single trend throughout the entire time period is only the Number of inhabitants that is decreasing consistently. All other indicators on Fig.1 were strongly affected by recession. A period that is related to crises lasted until 2010. New development trend began in 2010 that is indicated with enlarged markers on Fig.1. This study is focused on studying current development trend of Latvia thus next analysis is done about the period since 2010.

The problem remains the same as before because the values of indicators are very different therefore it is necessary to use a unified graphic system for this analysis. It was chosen to use Temp of increase for base year 2010 as the most suitable method for this case. The calculation is as follows:

$$T_{xm\ base} = \frac{X_m - X_{base}}{X_{base}}\ \%; \qquad (2)$$

where

X_m current value of indicator,

$X_{base} = X_{2010}$ value of indicator in the base year 2010

For graphical analysis, it would be good to place all data on one coordinate plane but it is problematic because there are 9 indicators in total. It was decided to divide all indicators into 2 groups. In the first group there are such indicators as Number of inhabitants, GDP per capita, Gini coefficient un Ecological footprint. Results can be seen on Fig. 2. The figure shows the temp of increase in relations to the base year in 2010 and trend lines are added. Equations and coefficients of determination are visible on trend lines which gives information about an issue which part of the trend can be explained with the trend lines.

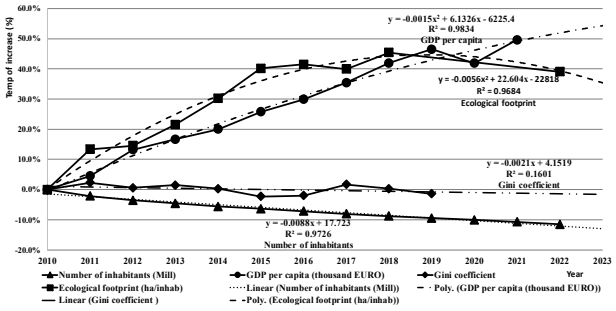

Fig. 2. Sustainable development indicators in Latvia (first group of indicators).

Data about GDP and Ecological footprint have positive trends. GDP continue to grow but its growth rate slows down. The coefficient of determination is 0.9834 and therefore, the quadratic relationship can explain 98.34% of trend. The Ecological Footprint is also developing prospectively. It should ideally be as small as possible. In the beginning, its growth rate increased and now it tends to the value of 2010. Using the quadratic relationship for the trend shows that it explains 96.84% of trend. The trend of decreasing inhabitants can be explained as negative. However, the Gini coefficient does not have any tendency, and it is indicated by the value of the determination coefficient of 0.1601. Looking at the Fig.2, it is also understandable, because there are simple fluctuations around the 0 line.

The second group of indicators includes Global competitiveness index (score), Global competitiveness index (place in the world), Human development index (score), Human development index (place in the world), Dispersion of regional GDP per inhabitant (NUTS 3). They are represented in Fig. 3.

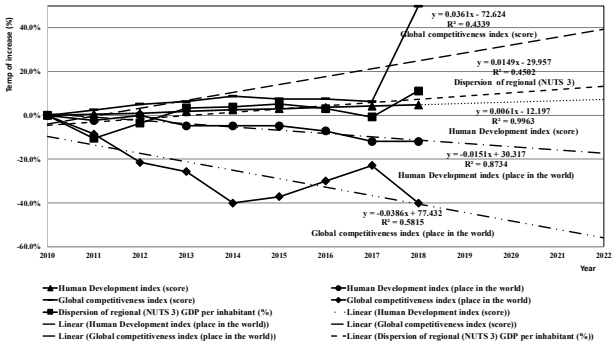

Fig. 3. Sustainable development indicators in Latvia (second group of indicators).

There is a pronounced trend only for both indicators in the case of Human development index: regarding its score, the coefficient of determination is 0.9963, but in the case of place in the world, it is 0.8734. Of course, both indicators measure practically the same thing. The Global competitiveness index also has two versions: score and place in the world. However, there has not been a strict trend here, although the direction is in the direction of development. Latvia has reached the group of developed countries here where changes are already difficult to achieve.

The indicator Dispersion of regional GDP per inhabitant (NUTS 3) also has no pronounced trend, which is indicated by the coefficient of determination 0.4502. The graph shows that there are fluctuations around the 0 state or close to it.

IV. CONCLUSIONS

Strategic indicators that are found in Sustainable Development Strategy in Latvia until 2030 can be used to assess direction of economic development and trends of sustainable development.

The analysis of development indicators shows that Latvia has perspective development in relations to most indicators, except number of inhabitants. The decrease in population may affect other development indicators in the future changing development trend.

This study reveals that Latvia has entered a period of sustainable development. The main indicators of sustainable development are GDP and Ecological

footprint. Positive trends can be observed here, because in 2020 a state has been reached when resource consumption begins to decrease, as GDP increases.

The next study could be devoted to comparing the Baltic States and at least one large developed country.

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Employer reputation building – a managerial challenge in HR marketing

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Abstract. Recruitment of desired employees in Latvia becomes increasingly challenging. Besides negative demography signals, competition between employers for talent is part of the tight job market. All of this and more is challenging for the businesses to effectively attract employees. Employer branding and recruitment marketing are widely known approaches used by businesses to fulfil their needs and speed up application quantities as well as promote employer attractiveness. Nevertheless, there is a lack of research discussing what effects external HR marketing brings to the labour market. The main task of this study is to analyse the recruitment marketing impact and determine how should recruitment marketing be evaluated. To achieve the goal, a literature review was performed and quantitative data from a survey were collected. The review of existing literature reflects the main factors that should be considered when evaluating recruitment. Additionally, attitudes shared by job seekers regarding recruitment marketing and expectations from employers were collected. The results of the survey showed that the recruitment marketing message can cause bias and encourages individuals to make biased decisions. This research provides a base for future studies by raising several questions – e.g., if the impact of recruitment marketing rises efficiency in the long term and if biases could be beneficial from a brand and an employee perspective, or they become less beneficial. Additionally, no research has considered whether the bias is increasing recruitment sustainability. Further research should be done to understand in what cases employer brand does not bring value to organizational image.

Keywords: Employer branding, recruitment marketing, Halo Effect, recruitment sustainability.

I. INTRODUCTION

Labour market tightness has changed it to candidate driven. That means that employers must put more effort into talent attraction in order to be more competitive. A widely used approach is employer branding, which allows to build and promote the employer brand internally in organization and externally. It offers to get more attention from desired potential employees and helps to ease talent acquisition. Researchers have discussed HR marketing components like – employer brand, employer branding, recruitment marketing, and how to increase employer attractiveness also what influences job seekers' intention to apply. In fact, in various sources value role is outlined when we get to the external HR marketing and the promise that should be delivered. Thus, the employer value proposition is the core of the employer brand promise, and it corresponds with business values. Moreover, they should be attractive to existing and potential employees. Regardless of the extensive analytical spectrum that already is done, there is limited research that analyses external HR marketing practices in tight labour market circumstances, and how external HR marketing should be communicated to avoid creating bias. To analyse this several research questions have been raised.

Q1: Do recruitment tactics differ in a tight job market?

Q2: Can employer branding cause bias?

Q3: What factors impact the results of recruitment marketing?

To answer the questions, a literature review and job seekers survey was done. It is important to analyse external employer branding practices in a tight labour market to clarify factors that bring recruitment marketing results and understand the impact on potential employees.

Limitations

As the job markets differ even in relatively small labour markets, this research and the survey is focused on the Latvian labour market. Also, this is academic research with

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the aim to understand if a bias occurs from recruitment marketing advertisements. Another deeper and wider research should be done to evaluate specifically, what kind of information or on which job seeker groups it applies Halo Effect with recruitment marketing.

II. MATERIALS AND METHODS

To answer the research questions of this study a literature review was performed, and the obtained answers were supplemented with empirical data analysis. Empirical data was collected by an online survey that was shared with 115 job seekers in the Latvian job market. To test the bias development component caused by recruitment marketing message Halo Effect was selected and correlation between the recruitment marketing message was tested in this research. Spearmen's correlation coefficient was used to analyse the received results.

III. DISCUSSION AND RESULTS

HR marketing, Employer branding and Recruitment marketing

Nowadays marketing is commonly used within HR. As Bejtkovsky points out, HR marketing is a broad concept. It promotes employer value proposition internally and externally, stimulates loyalty of existing employees and the interest of potential candidates. HR marketing's role is to help create positive contact for current employees, candidates, and society (Bejtkovský. 2020). Thus, HR marketing can be applied in all the HR cycle internally and externally and consist of two main directions – employer branding and recruitment marketing. In such an extensive researched field, it is important to clarify definitions, even more, regarding employer branding and recruitment marketing, which are interconnected Fig 1. Some of employer branding definitions, like:" *[…] Employer branding is thus basically how an organization markets what it has to offer to both potential and existing employees (Walker, 2007)."*
could seem to overlap with recruitment marketing, thus the difference should be pointed out. According to
recruitment marketing definition analysis by Alashmawy, it is used in the pre-applicant phase to engage and nature potential employees. The authors point out the recruitment funnel, which describes the main levels of potential employee attraction that can be covered with successful recruitment marketing approaches to get more attention from the potential employees and to deliver enough information and to stimulate intention to apply in the consideration phase. It is applicable to increase awareness of the employer both as an employer and as a potential workplace, to ease and ensure consideration outcome for the potential employee, and to generate interest in the career opportunities (Alashmawy, 2019). Mashiah points out that recruitment marketing is more like a tool that delivers an effective brand message while employer branding is a strategic approach where the employer brand is created and maintained. In some way, employer branding generates content that is used in recruitment marketing approaches. Therefore, to understand recruitment marketing results, we must discuss employer branding (Mashiah, 2021). From this perspective, recruitment marketing is a bridge between employer brand promise and potential employees. Employer branding builds the content or essence that should be delivered to existing employees and potential employees. Therefore, the main attention should be focused on employer branding as a process of promise creation and promotion. Employer branding is linked to employer value proposition, or in other words values that the employer is offering and promising to share with current employees and potential colleagues.

Figure 1. HR marketing components.
Source: Developed by authors.

Employer brand attractiveness and organizational reputation

The employer value proposition shapes content for any communication regarding the employer (Chhabra, 2011). It is linked to organizational values because these employer brand and organization brand are linked to each other. Similarly, as for the organizational reputation that can be a great asset to attract new employees, employer brand attractiveness can be the way how to build a desirable workplace image. Job seekers are looking for an organizational fit through social identification. By value angle, the goal is to find the best people organization fit, that increases retention possibilities. As reviewed in the literature a good corporate image can impact potential employees to align offered company values with theirs:"
[…] the effect of corporate image on intention to apply is a product of the job seeker's recognition of people-organization fit. Although a corporate image cannot make job seekers feel like insiders, the corporate image can induce the perception of having similar values to those of the company, raising perceived fit among some job seekers (according to social identity theory) and motivating them to apply (Wei, 2016)."
Thus, job seekers are seeking good employer brands to align them with their personal brand, and this leads to an increase in intention to apply. To achieve the goal, employers tend to exclude negative factors in communication, like responsibilities, risks, stress levels, etc. This is important in the consideration phase.

Moreover, based on Soeling's research, besides that employer brand attractiveness has influence on intention to apply, it also has influence on organizational reputation (Soeling, 2022). That indicates the significant influence of employer brand on reconsidering phase. Or in other words, nudges candidates to consider applying for the job based on employer brand attractiveness instead of considering it as an organization's reputation component. Thus, with a good employer branding strategy employer could succeed better than others regardless of organizational reputation. But with bad employer brand attractiveness organizational reputation could be impacted. Chhabra has developed a model that shows employer branding strategy to gain employer attractiveness advantage see Fig.2 (Chhabra, 2011). According to the findings from literature review, the first step is to build the brand, then develop the promise, and lately seek out channels where and in what format should the information be spread. Then the image of the employer gets a specific framing environment that influences employer attractiveness. This explains the importance of the employer value proposition role. The mentioned conceptual model helps to build awareness about the brand as an employer and illustrates phases that describe employer attractiveness.

Employer branding in tight labour market conditions

In turn, while the theoretical framework of employer branding is researched and well described, empirical research of recruitment marketing related to a tight job market situation is lacking. Thus, there is not enough empirical analysis to understand how external employer branding and recruitment marketing are used in a tight labour market and how they should be evaluated. Mashiah in his research outlines tech sector employer communication in challenging job market where is an increasing lack of talent for the past few years. The research was conducted by analysing
online activity of fourteen different global leading tech company websites, and valuable conclusions where done, that overall positive and only positive information was found on several levels.:

1. *Informative - general information describing the brand or the jobs he offers.*
2. *Inspirational – words intend to thrill and create a positive feeling.*
3. *Motivational – quotes boosting a candidate's motivation to be employed.*
4. *Persuasive - convincing words inviting the candidate to apply for any position* (Mashiah, 2021).

In a tight labour market, employers tend to spread only good news and limit or make softer any negative communication. The author concluded that tech companies encourage job seekers to visit their websites to find more information regarding the employer and job opportunities. In other words, they invite them to explore information prepared by themselves. That opens the question, of whether only positive information should be delivered to achieve the recruitment goals. By glorification of the workplace, more applicants will be reached so that in a tight labour market employers could attract more candidates. Also, employer approach is forced to be more inclusive because they should not discriminate or limit the candidate pool by company culture fit, etc., so their value proposition should fit the majority. Based on the literature review, employers spread information about themselves also to attract people from other segments and to get along with the tight labour market situation. Also, by value globalization values are becoming more broadly defined.

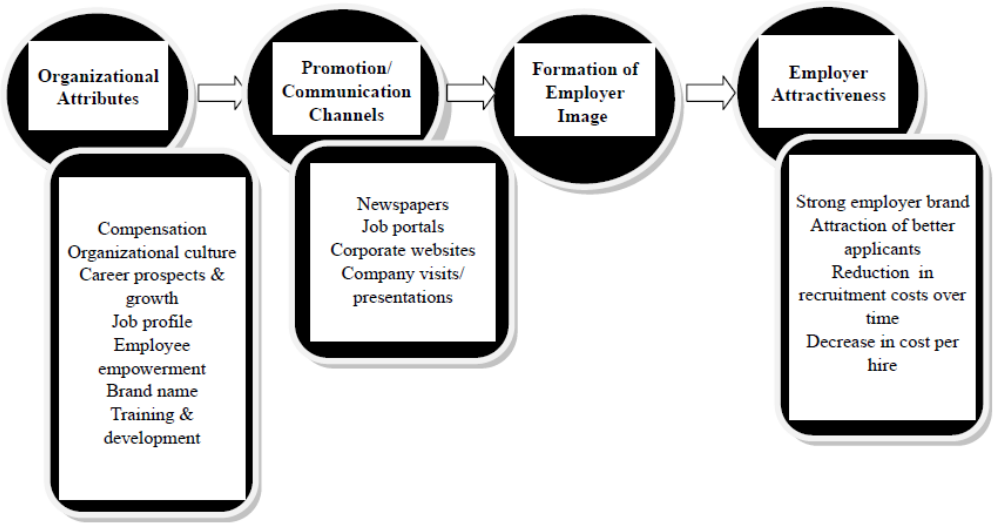

Figure 2. Employer branding process.
Source: Employer branding: Strategy for improving employer attractiveness (Chhabra and Sharma, 2011)

Q1: Do recruitment tactics differ in a tight job market? Indeed, employer branding increases recruitment results, but the strategy should be adapted within tight job market conditions. Focus on encouragement of candidates and self-glorification and limited values to offer for a job seeker are crucial to keeping up with competitors. As reviewed in the literature, employer value proposition influence employer attractiveness, thus increasing intention to apply for vacancies. In the literature review Soeling points out: "*[...] people tell good stories, company's reputation is positive. On the other hand, bad reputation happens when people start to tell bad things about the company. In other words, employer brand promise should be matching with reality (Soeling, 2022).*"

In other words, the more company spreads good and appealing information about itself, the higher employer attractiveness could be reached. It is reasonable, because the better we think we know something, the more likely we could believe in that and accept it as a truth. And finally, content positiveness is as much important as the fact that stories should match reality.

Recruitment marketing message and bias

In recruitment, it is important to communicate all the details and show realistic work conditions for both sides because of the long-term goal of cooperation. Psychological aspects nowadays are spotlighted as with deeper research that is done it is clear that they can significantly influence the outcomes of classical theories. In recruitment, it is similar. If the spread of information is not clear biased impressions could occur. J. Meng, referring to the work of E. Thorndike, states that the empirical study of the Halo Effect in science began in 1920. This effect implies that an individual's perception can create a positive or negative halo (Meng, 2022).

To clarify if a correlation between recruitment marketing message and Halo Effect exists, the Spearman rank correlation coefficient was used on collected data from the survey, see Table 1.

The results refer to one of the questions raised:

Q2: Can employer branding cause bias?

Recruitment marketing messages partly are corelating with Halo Effect statements. Thus, it is possible to assume that if only positive information is delivered to the job seeker, then an increase of intention to apply will be increased and employer attractiveness will benefit. However, we cannot exclude that it is causing biased decisions. A bias that decreases rational decision-making could benefit in the short term.

TABLE 1 CORRELATION BETWEEN RECRUITMENT MARKETING MESSAGE AND HALO EFFECT

Spearamen's correlation between recruitment marketing message and Halo Effect		
	Recruitment advertisement message	
Halo Effect	***Message 1***	***Message 2***
Statement 1	,295** ,001 115	,248** ,007 115
Statement 2	,169 ,072 115	,018 ,851 115

Source: Developed by authors.

For example, could fill the pipeline and nudge candidates to choose a specific employer over others, but in the long term or for retention it is a risk not to fulfil expectations. Thus, risk of decreasing employer reputation and increase rotation in the company. To human resources that in long term could harm more than help. If a company spreads only glorification regarding it, the Halo Effect could occur. Regardless there are no research that evaluate bias levels that could be healthy in job seeking. That leads to the final research question.

Q3: What factors impact the results of recruitment marketing?

Based on reviewed literature in Fig. 3 are pointed out employer branding process evaluation. Employee's decision to apply is influenced by both – organizational image and employer brand, although employer brand dominates.

Employers can choose which brand is more attractive for their targeted audience and how another component benefits from it. For example, if the strategy would be to put outstanding company image first, how does talent attraction benefit from it – does the talent pool get wider, does image values fit, etc? And if an employer brand will be dominating brand, how does it influence the organizational image? As it was discussed in the literature review employer branding shapes employer image, so it is important not only to clarify if candidates in the market are aware of the brand but how and what message they received to avoid causing bias. Lastly, the intention to apply is the result that shows if the employer is desired, but it should be combined with the labour market situation.

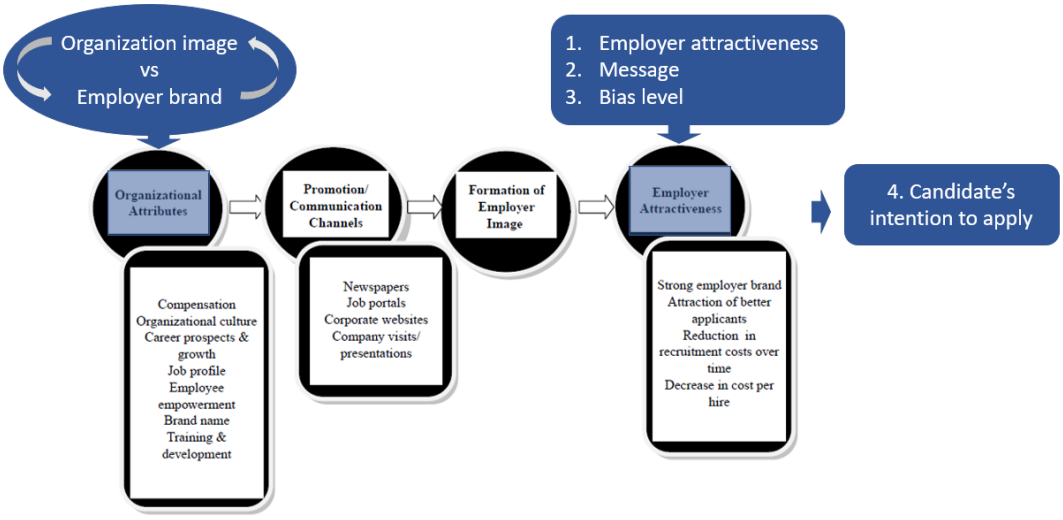

Figure 3. Employer branding process evaluation.
Source: Adopted by authors on basis of existing model: Employer branding: Strategy for improving employer attractiveness (Chhabra and Sharma, 2011).

IV. CONCLUSIONS

Organizational image can influence the candidate's intention to apply, as well as employer brand. The review of literature indicates that there are researchers that support different interpretations while they jointly support intent to perform further research in the context of talent acquisition. Also, according to the literature review, with high competition for talent, organizations tend to be encouraging, and diverse, and tend to glorify themselves as the best workplace to work in. If only good information is spread, biased opinions could occur. And lastly, to evaluate external employer branding communication, its organizational image, employer attractiveness, delivered message, bias level and attention to apply in the context of labour market situation should be measured.

Further research should be done to understand in what cases employer brand does not bring value to organizational image. Also, biased decisions caused by recruitment marketing should be examined wider along with testing of hypothesis whether only positive information should be delivered to gain recruitment goals, what content cause bias, and which job seeker groups are more biased. Also, it is advised to do empirical research on content analysis to compare content that is created by employers and spread by employees with a general public opinion to see how they are correlating and if any of them has a bigger impact on job or industry choice in a tight labour market situation.

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Opportunities and Challenges in Modeling an Environmental Management System

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Abstract. **The business ecosystem provides full integration of economic and environmental objectives. Every company, including those from the Bulgarian mining industry, implements specific actions, mechanisms, innovations for environmental management. The aim of the present study is to analyse the relationship between the economic and non-economic priorities of enterprises of the mining industry, especially now in the context of solving the global problem of transformation towards sustainable development. The following research tasks have to be settled for reaching the above-mentioned goal: 1. to analyze the influence of modern technologies, the remote control of machines underground, including remote control and self-learning drones in underground mines on the optimization and improvement of work processes and the protection of a cleaner environment; 2. to focus on some relevant aspects of green transformation of the mining industry, incl. in the development of environmental, social and new management models as a factor for successful business; 3. to research the impact of the initiated cycle of interest rate tightening on the implementation of the planned activities for environmental management of the mining industry. In the course of the study shall be justified the thesis that the future of the mining industry in Bulgaria is digital, green and sustainable. The methodology of structured interview was used. The sample was formed by the method of random non-recurrent selection. For the purposes of the research, we have carried out analysis of the whole assessment of the favourable opportunities and potential risks, as well as the strengths and weaknesses of the new model for an environmental management system. The results of the research are expressed in establishing the trend for digitalization and innovation, tracking the importance of environmental management and protection.**

Keywords: Bulgarian mining industry, business ecosystem, environmental management, natural resources.

I. INTRODUCTION

One of the objectives of the European environment policy is to encourage all types of businesses to reduce their harmful impact on the environment. Caring for nature and minimizing pollution and damage to the environment also applies to the mining industry. The pursuit of a full integration of economic and environmental goals by mining enterprises requires the analysis: *business-environment-technology-future*. The relevance of the research is determined by the complex circumstances in which the enterprises of the mining industry operate: 1) the consequences of the COVID-19 pandemic; 2) the war in Ukraine; 3) interest rates and inflation growth; 4) the bankruptcy of the American banks "Silicon Valley Bank" and "Signature Bank", which may affect Europe and their complex negative impact on the green economy, digitization, innovation in the context of the mining industry.

Modern Monetary Policy versus Green Transition

According to the Keynesian theory of money, monetary policy does not have an important impact on investment and consumption, resp. on economic activity.

M. Friedman believes that any change in the value of money does not lead to a change in the utility of wealth, but only to a change in its monetary value [1].

The goals of government – boost production or stagnation – determine how money affects the economy (monetary expansion or restrictive monetary policy). The Central bank is the institution that should coordinate, direct and control monetary effects, while the regulated increase or decrease of money in circulation is inextricably linked to unemployment and inflation.

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The early 1980s remain in economic history with a special focus on the fight against inflation. It was treated as the greatest evil of the economy [2].

Another evil was also born during this period. It has consequences for the planet and humanity - climate change and its acute threat to civilization. The period of awareness was long and difficult, but world leaders are on the right way to reach a global agreement. Now the world is beginning to adapt to the new reality of sustainable transformations of the 21st century [3]. This definitely applies to the mining industry as well. The expansion of mining business is impossible without a quick response for adequate management of natural resources, the implementation of an environmental management system, investment in nature-friendly technologies, investment in machinery that protects the environment, investment in intelligent mining of ores and minerals.

This means that at the moment there are threats to nature and the planet on the one hand, on the other – the need for investments in smart technologies for mining and on the third – the danger of the collapse of the sector due to emerging problems with investments in the industry, interest rates, inflation, bank failures in the USA and its impact on European business.

II. MATERIALS AND METHODS

The structure in the pursuit of a comprehensive and reliable study of opportunities and challenges in modeling an environmental management system, in the course of the study we refer to the Eco-management and Audit Scheme (EMAS). It was created by Regulation No. 1221/2009 (also known as EMAS III) and is directly applicable in all industries (including the mining industry) and all types of organizations in the public and private sectors that seek to improve their environmental performance. Special attention is paid to the key certificate ISO 14001:2015 (previously ISO 14001:2004). Its purpose is to help enterprises of the mining industry to achieve the intended outcomes of their environmental management system, which provide value for the environment, the organization itself and interested parties.

We have used environmental strategy papers in 1) Europe as follows: The UN 2030 Agenda, The European Green Deal: A New Growth Strategy to make the EU a fair, inclusive and prosperous society with a modern, knowledge-based, resource efficient and competitive economy; annual sustainable growth strategy for 2020; The Green Deal Investment Plan: the EU's strategy to promote sustainable public-private finance over the next decade; A strong social Europe for fair changes; ESG Standards; etc. and in 2) Bulgaria as follows: National strategy for the environment and an action plan for it, Strategy for transition to a circular economy of the Republic of Bulgaria (2022-2027 Category: Environment), National program for protection, sustainable use and restoration of functions of soils (2020-2030), the Environmental Protection Act, etc.

Innovative and digital solutions for facilitating planned and managerial activity, technological development of enterprises, intelligent and sustainable industry in the conditions of intensive business challenges have been discussed in works by various authors [4] – [12], etc. They have been presented at scientific forums and meetings; nevertheless, no complete scientific research even more in the context of the mining industry has been conducted on them. All ideas and conclusions expressed in those works establish the basis for the completion of the established tasks of this research. All ideas and conclusions in the developments are a good basis for implementation of the assigned tasks of the present research.

A research was made by the help of the structured interview methodology amongst enterprises of the mining industry in Europe, at which is provided full integration of economic and environmental objectives, using the method of random sampling without replacement. The methods of comparative analysis, induction, deduction, Crosstabs and SWOT Analysis were also used.

III. RESULTS AND DISCUSSION

A. Concept of digitalization and environmental protection in mining industry

Digitization of working processes and investments in modern technologies successfully implemented in open and underground mines create conveniences, minimize costs and time and keep the environment clean. In this way, business value is added and growth is achieved to transform the mining industry into a fair and inclusive business with modern, knowledge-based, resource-efficient and competitive management.

The improvement of technology finds expression in safe, fast and environmentally friendly solutions, of which more than ever the mining industry feels a gigantic need. The acquisition and implementation of modern technologies and digitalization in mines, remote control of underground machines, tele-management and self-learning drones in underground mines are the right direction for optimization of working processes. At the same time, these are the tools that positively affect the protection of a cleaner environment during the working process [13]. Are enterprises of the mining industry ready for major investments to care for nature? Because these technologies are expensive. Do they have the cash they need or they have to borrow from the banks at such high interest rates at the moment? Analysis of the attitudes and the perspectives of the stakeholders was carried out.

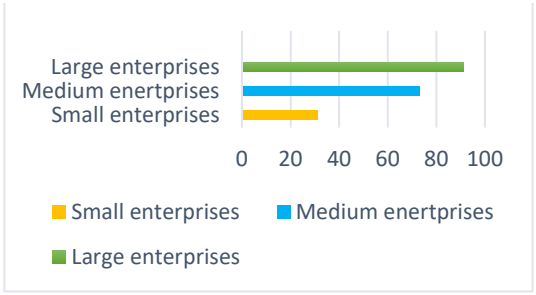

Fig. 1. Categories of businesses versus opportunities of achieving eco-efficiency solutions (in percentage).

The sample was formed from enterprises – open and underground mines in Europe by the method of random non-recurrent selection. Considering the mining industry,

there are no micro-sized enterprises in the sample. Period of the survey January 2018-January 2023. The results have found expression in (Fig. 1).

98% of respondents believe that digitization of working processes and investments in modern technologies implemented in open and underground mines create convenience, minimize costs and time while keeping the environment clean. More than 90% of respondents believe that this is the only way to add business value and achieve growth to transform the mining industry into a fair and inclusive business that is modern, knowledge-based, resource-efficient and competitive management. At the same time, this is mainly within the power of medium-sized and especially large enterprises of the mining industry.

B. The role of green transformation in the context of the mining industry – ecological, social and new management models, as a factor for successful business.

Our research aimed to identify the key components of the Environmental Management System by the example of [14]. The results are as follows (Fig. 2): key components for building an environmental management system are Organizational structure (OS), Target device (TD), Planning technologies (PT), Experience of implementation of environmental policies and solutions (E-EPS), Resource provisioning (RP). For the purposes of our study, the results are presented as a percentage.

As a result of our research, we can also propose a model for an environmental management system as follows (Fig. 3). Due to the fact that the Environmental management system cannot exist in isolation from the work processes and the external environment, the two-way connections that would be more often observed among the respondents are visualized. More than 75% of respondents highlight the key role of the leader in building and implementing this system. This shows that the role of the leader is as important as funds, investments, reliable accounting system, planning and budgeting.

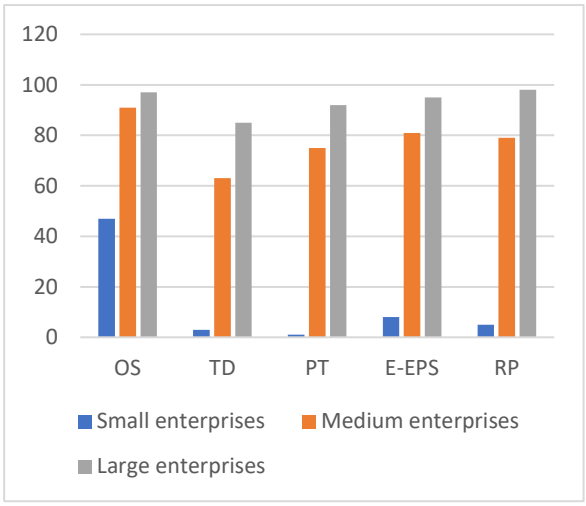

Fig. 2. The relationship "Importance of individual components-different types of enterprises".

In a complex situation, a very important process is about to occur in the European Union – the sustainable way of doing business will be imposed in a short period of time through ESG standards. Every company (including from the mining industry) must adapt its business models in accordance with the new standards for environmental and social impact and good corporate governance. Otherwise, it will suffer fines, have difficulty accessing bank financing and experience in raising capital through the stock exchange [15].

Fragmentary SWOT-analysis of the enterprises of the mining industry, that has a functioning environmental management system, indicate an objective picture of its implementation. The results have found expression in assessment of the perspectives of the enterprises of the mining industry by performing a fragmentary SWOT analysis. (Table 1)

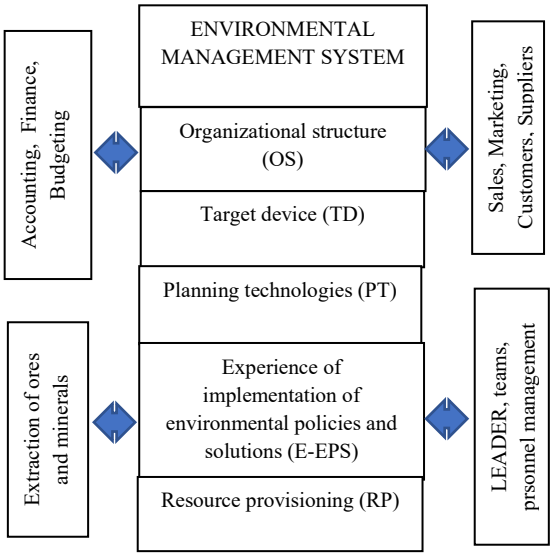

Fig. 3. Model of environmental management system – connections and dependencies with the internal and external world of the enterprise of the mining industry.

TABLE 1 FRAGMENTARY SWOT ANALYSIS

External Factors	
OPPORTUNITIES	THREATS
▪ easier access to new markets; ▪ better public image ▪ increased; opportunities to invest in innovative products.	▪ risk of losing markets in developing countries; ▪ risk of additional tightening of regulatory conditions in the future.
Internal Factors	
STRENGTHS	WEAKNESSES
√ increased competitiveness; √ better accordance with legislative decisions.	√ increased management costs; √ increased cost of some products (new technologies that are less wasteful).

Our next task is to evaluate the readiness of enterprises of the mining industry to adapt their business model

according to the new standards for environmental and social impact and good corporate management.

The results have found expression in Table 2 by Crosstab. Using it we visualize the readiness assessments in the enterprises of the mining industry to adapt their business model in relation to the indicators for the balance sheet value of the assets, net sales revenue and average number of personnel for the reporting period. Considering the mining industry, there are no micro-sized enterprises in the sample. The greatest degree of readiness is observed in large enterprises, followed by medium-sized enterprises. Small enterprises have the highest percentage of *analyze further*, which is explained by limited financial and human resources and limited new technologies available to them. And is it possible for the business model to be adapted in high interest rates and inflation? Is it possible that high interest rates to act as a brake on the implementation of large-scale company projects in the spirit of the policy for a green future for Europe? *High interest rates vs green transformation?*

C. *The role of the interest rates and monetary policy as key economic indicators in the context of environmental management and renewable energy resources, their rational and complex exploitation*

In the dynamic times in which enterprises of the mining industry operate, the overarching purpose is to keep prices stable and inflation at a reasonable level in the medium term. It is in unison with the general economic policies of the European Union. In the Eurozone, the main and most important of the three tasks of the European Central Bank (ECB) is maintaining price stability, maintaining high employment and balanced economic growth [16]. The leading behavior by the ECB – reaching inflation in the context of and measured by the harmonized index of consumer prices – close to but under 2%. Our analysis shows that the ECB uses interest rate benchmarks to maintain stable prices in the euro area. The change in interest rates reflect on the interest rates of commercial banks granting loans. This respectively reflects on business investments in the mining industry [17]. At the moment, however, the enterprises of the mining industry are witnessing how central banks are rapidly raising interest rates – more than sixty such hikes have been announced in recent months [18]. They can be analyzed as a projection of the drastic change of monetary policy adopted after the global financial crisis in 2008, further reinforced by the COVID-19 crisis, the war between Russia and Ukraine and the limited resources of the planet. How could the enterprises of the mining industry make sense of the monetary policy when inflation is at record levels, economic damage at national, European and international are constantly increasing, and 2022 would rightly go down in history as the year of the great expensive.

A jarring cycle of monetary policy tightening is ahead. Distinguish between previous cycles, inflation is too high and the US Federal Reserve (Fed) will no longer guide markets [19].

In contrast to the current moment, when inflation is too high, in previous periods the "tightening" of monetary policy was implemented preventively, i.e. purposefully in an effort to prevent inflation from accelerating rather than slowing it down [20].

In this regard, the results of our research have found expression in Table 3 by Crosstab, resp. we compare estimates of the impact of inflation and high interest rates on the green transition by the categories of businesses. There are no micro-sized enterprises in the sample. 90,38 % of the sample answered *yes, definitely*. Large enterprises have the largest share, followed by medium-sized enterprises and small enterprises. Nearly 6 % of all respondents answered *more than likely* and almost 4 % of them answered *we will analyze further*.t Rn the Context of

TABLE 2 FINANCIAL, HUMAN AND TECHNOLOGICAL ASSESSMENTS

			Categories of businesses (Accountancy Act, amm. SG/ 26 dated 22 March)		
			Small enterprises	Medium enterprises	Large enterprises
Are you ready to adapt your business model…	definitely yes	Count	3	9	19
		% within categories	25,00%	56,25%	79,17%
	more than likely	Count	3	5	4
		% within categories	25,00%	31,25%	16,67%
	we will analyze further	Count	6	2	1
		% within categories	50,00%	12,50%	4,16%
Total		Count	12	16	24
		% within categories	100,0%	100,0%	100,0%

(Source: authors' own research)

TABLE 3 INFLATION/ HIGH INTEREST RATES-GREEN TRANSITION

			Categories of businesses (Accountancy Act, amm. SG/ 26 dated 22 March)		
			Small enterprises	Medium enterprises	Large enterprises
Does inflation and high interest rates affect the green transf…	definitely yes	Count	11	15	21
		% within categories	91,67%	93,75%	87,50%
	more than likely	Count	1	-	2
		% within categories	8,33%	0,00%	8,33%
	we will analyze further	Count	-	1	1
		% within categories	0,00%	6,25%	4,17%
Total		Count	12	16	24
		% within categories	100,0%	100,0%	100,0%

(Source: authors' own research)

D. Analysis of the connection between the economic and non-economic priorities of the enterprises of the mining industry, especially nowadays in the process of solving the global problem of transformation towards sustainable development

A monetary policy with high interest rates that suppresses inflation, inhibits economic growth and investment, and especially negatively affects by hindering the implementation of the Sustainable Development Goals (SDGs). The complete replacement of fossil fuels with carbon-free alternative energy sources is the ultimate goal of climate change policies [21].

IV. CONCLUSIONS

The future of the mining industry in Europe is associated with modern technologies, digitalization of working processes, innovative software solutions and ways to protect the Environment. It is green and sustainable.

First. The empirical research, that was carried out in the enterprises of the mining industry from the target group, confirms that the environmental management system is a key factor for the eco-efficiency, management of natural resource and sustainable development.

Second. The observations in the practice of the mining industry and the analyzes carried out in the context of environmental management and its protection prove that a working ecological business system provides a complete integration of economic and environmental purposes.

Third. We need the wisdom of the past in making decisions and one and only integrated application of a complex approach with care about our unique Earth and its riches for the future.

The results of our research visualize the perspectives for the development of environmental management system with an emphasis on the enterprises of the mining industry in the short and long term.

The dominant idea is that the sustainability implementation of the environmental management system in the enterprises of the mining industry shall contribute to the successful realization of green transformation of the business sector, management of natural resources and protection of a cleaner environment, tracking the importance of digitalization and innovation of working processes, activities and green thinking.

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Protecting the Environment Around Polish Quarries from Harmful Seismic Vibrations Caused by Rock Blasting

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Abstract. **The paper presents the legal and scientific conditions for Polish researchers to determine the vibration velocity and the radius of the safe zone of seismic vibrations generated during rock blasting. Until now, in Poland and worldwide, it has been assumed that seismic vibrations generated during rock blasting with explosives [BM] propagate circularly with equal energy in each direction. However, this is not always the case. A theoretical analysis of the variation of the tangential magnitude Vy of the vibration velocity as a function of the change of the direction angle was carried out for a circular distribution of the vibration velocity. It was shown that the value of the vibration velocity component at the same distance from the vibration source depends on the directional angle between the line of the blast holes and the line connecting the centre of the surface of the excavated BM block and the measuring point. New relationships have been given that take into account the directional angle in the calculation of the maximum values of vibration velocity necessary for the determination of the resulting damage in the building from the SWD. A dynamic impact scale [SWD] for the assessment of building damage as the vibration velocity acting on the building increases is given and discussed. Vibration velocity diagrams measured during the excavation of BM rock have been presented for circular distributions in accordance with theoretical predictions. A vibration velocity diagram for an elliptical distribution, inconsistent with a circular distribution, measured during the excavation of BM rock is presented. It is shown that the directionality of the horizontal tangential component of the vibration velocity exists for both circular and elliptical distribution of vibration velocity in rock excavation with explosive BM. The technical safety of the building in the area of seismic vibrations is determined by the vibration velocity included in zone II of the scale of dynamic influences [SWD] Fig.6A, 6B.**

Keywords: ground vibrations, seismic vibrations, circular, elliptical, distribution of vibrations.

I. INTRODUCTION

Compact rocks are mined using blasting materials [BM], which cause vibrations in the mining medium and then in the ground outside the mine. These vibrations are transmitted by seismic waves propagating in all directions and have harmful effects on road and housing infrastructure. So far in Poland and worldwide is believed that seismic vibrations generated during mining rocks using BM propagate along a circular path with equal energy in each direction, like waves on water from a stone thrown into it [1].

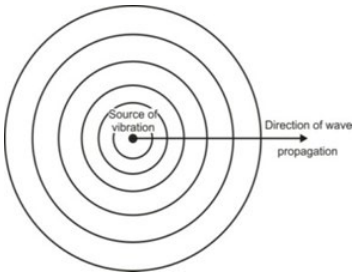

Fig. 1. Circular directional distribution of horizontal velocity Vxyz of vibrations [1,6,7].

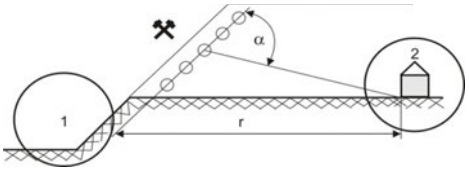

Fig.2. Outline of a place of vibration formation / mine "1', bench blasting / and the distance "r "between the mine and the building '2" which is affected by vibrations and the directional angle "α".[1].

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In Fig.2 the directional angle of measurement "α"=90º between the line of blast holes and the line connecting the measurement point/house/ with the central blast hole is marked and the distance between the vibration source and the protected object is marked.

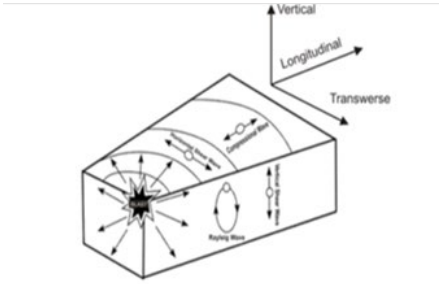

Fig.3 Types of waves ind their vibration and directions of measurements [1,7,8], longitudinal wave-X, transverse wave Y.

The waves that make up a seismic wave and the directions in which they are measured are shown in Fig.3. The direction of vibration measurement parallel to the line of boreholes is usually referred to as Y and perpendicular to the line of boreholes as X. Therefore, the parameters measured in the X direction have the indices Vx, and in the Y direction Vy. It can be seen from Figure 4,5 that for a circular distribution the tangential velocity Vy and radial velocity Vx have different values depending on the angle of inclination of the measuring direction "α"

II. Polish Legal Basis For Determining The Safe Zone In Relation To Seismic Vibrations

In Poland, the area of harmful seismic vibrations for the first blasting in a rock deposit is determined on the basis of the formula given in the Ordinance [2] and for subsequent blasting on the basis of field tests carried out by an authorised research and development unit. The radius of the dangerous seismic zone based on the regulation is determined by the formula [2]:

$$rs = [Q]^{½} / Ø \quad (1)$$

where:Q - instantaneous BM load or maximum BM load per deceleration /millisecond delay/ for deley fired in a series of holes, [kg]; rs - distance from the explosion point to the protected structure, [m]; the coefficient Ø is: for Cm < 2,000 m/s, Ø = 0. 030 - 0.026 for Cm = 2,001 - 3,000 m/s, Ø = 0.025 - 0.020; for Cm > 3,000 m/s, Ø = 0.019 - 0.015; where Cm - longitudinal seismic wave velocity characteristic of the ground on which the object stands, -1) sand, gravel, clay; Cm= 1000-1500 m/s, -2) soft moraine formations, limestone shale; Cm= 2000-3000 m/s, -3) granite, gneiss, sandstone, hard limestone; Cm = 4500-6000 m/s. If an explosive charge is fired in series, the radius of the zone increases by 1.5 times with a deceleration of 2 to 15 degrees. The determination of the safe charge per millisecond delay requires the correct assumption of the Ø value. The determination of the longitudinal velocity of a seismic wave requires an appropriate measurement under real conditions, or the assumption of this value from under real conditions, or the assumption of this value on the basis of data from the literature. The ministerial decree does not specify whether it is the radial or the tangential component of the seismic longitudinal wave. Polish research institutes [4] use the following relationship to predict the seismic radial velocity Vx and tangential velocity Vy=PPVy and the range of harmful seismic vibrations:

$$Vx=Vy=k * Qz^{a}/r^{n} \quad (2)$$

where: Vy or Vx - vibration velocity at the measuring point, tangential or radial, [cm/s], k, a, n - coefficients defining the conditions of emission and propagation of vibrations, determined on the basis of measurements, taking into account the effects of variations in technological parameters and measurement errors. Qz - size of the detonated MW charge, per one delay /one detonator number/, [kg], r - distance between the location of the detonated charge Qz and the object where vibrations occur, [m]. Assuming that a=1/2 for long hole firing and n=1, it is obtained that ρ=[Qz]^(½)/r. Depending on the type of deposit, it is also assumed that a=1/3. Substituting ρ in relation 2. we obtain V=c*ρ, where c is the constant determined on the basis of the statistical characterisation. Using the safe value of the seismic velocity from the scale of dynamic actions [SWD] for the planned MW load size, the safe distance of the ignition point Qz from the protected object is calculated using formula (2). Depending on the maximum value of the horizontal, tangential or radial vibration velocity vector and its frequency, the degree and type of damage caused to the building is determined using the SWD. In the case of circular distribution, the equations (1) and (2) used to calculate the tangential velocity Vy and radial velocity Vx do not take into account the value of the angle of inclination of the measuring direction "α".

III. Theoretical Analysis And Measurement Results

From the analysis of the unit circular distribution of the tangential component Vy of the vibration velocity as a function of the directional angle "α" Fig.3 it follows that the tangential component Vy of the vibration velocity for the directional angle in the range "α" = 0-90º has the shape of a semicircle in each quarter of a circle a variable value in the direction of the Y-axis, for α =90º, Vy=0, for α =0º, Vy=Vy max.

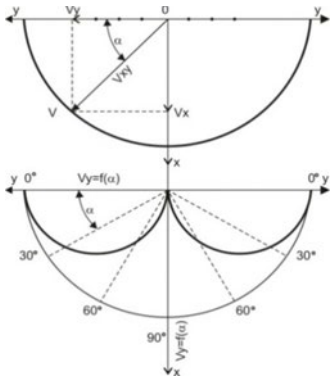

Fig.4 Fig.4 Graphical representation of the shape and value of the unit vector of the resultant velocity Vxyz and the tangential velocity Vy of the seismic wave as a function of the directional angle "α"/circular distribution [3].

Fig.4 shows that the radial vibration velocity Vx and the tangential vibration velocity Vy have different values depending on the measurement angle "α". The Y-axis is in line with the direction of the blast hole lines and the velocity Vx is perpendicular to the Y-axis. The horizontal components of the radial velocity Vx and the tangential velocity Vy=PPVy are measured on the sample in the X and Y directions. The unit value of the resulting velocity vector for a circular distribution can be written as the sum of the component vectors, $Vxy^2 = Vx^2 + Vy^2 = R^2 1$ (3) From Figure 4 it follows that Vx=Vxy*sinα=1*sinα, Vx=Vy*tgα (4) and Vy=Vxy*cosα=1*cosα, Vy=Vx/tgα (5) R- radius of the unit velocity vector Vxy. The actual distribution of the tangential vibration velocity Vy measured during the excavation of the BM of inhomogeneous overburden in the Adamów brown coal deposit [4], Fig.5, is similar to the theoretical Fig.4.

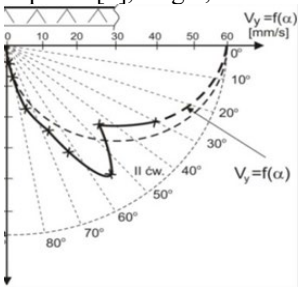

Fig.5 Circular directional distribution of horizontal tangential velocity Vy of vibrations as a function of directional angle α-II quadrant. [4].

In Figure 5, α=55º is the angle of inhomogeneity of the medium with the highest value of the horizontal tangential peak particle velocity (PPVy)=Vy of the vibration. The dashed line is the theoretical circular distribution for (PPVy)=Vy, as in Fig.4, x-marked values of measurement points-Vy.

IV. Vibration Velocity Hazard Scale, Polish Standard [5]

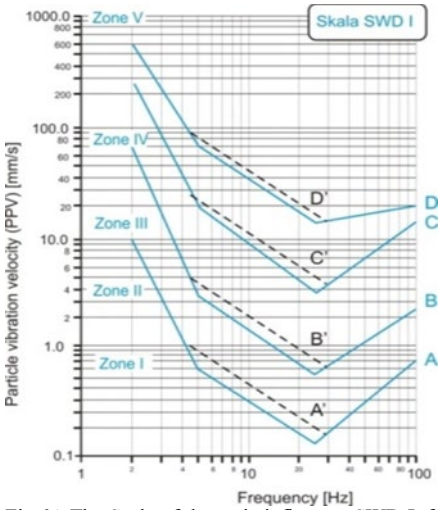

Fig.6A.The Scale of dynamic influence, SWD I, for buildings up to two storeys [5].

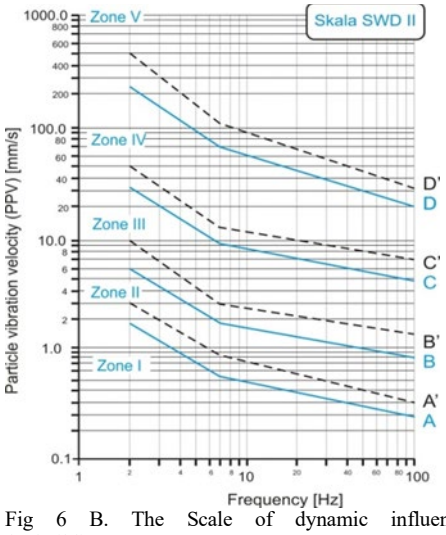

Fig 6 B. The Scale of dynamic influence, SWD II, for buildings up to 5 storeys [5].

The magnitude of the permissible vibration velocity acting on the building without visible damage to the structural elements ensuring its technical safety is the B limit (Figures 6A, 6B). Other velocities cause strictly defined damage to buildings, which are given in with the Polish standard [5]. On this basis, it is assumed that the technical safety of the building within the range of seismic vibrations can be determined by the vibration velocity marked by the B line included in Zone II of the Dynamic Influence Scale [SWD], Fig. 6A, 6B. The damage limits of each zone are given in two variants: A, B, C, D solid line and A', B', C', D' dashed line. The solid line applies to old, damaged, converted buildings. Buildings of masonry, cinder block, stone elements, without foundations, large openings or irregularities in the walls, not carefully constructed, low stiffness substrate (silty or loose sands), discontinuous foundations of varying height. Dashed lines apply to undamaged buildings with no structural changes. The solid brick walls, the reinforced concrete foundations, the walls connected by an edge with the edges of the ceilings, all carefully constructed.Rigid ground - hard plastic clays, flat foundations.

V. Ellipsoidal Tangential Velocity Field Of The Vibration For A Basalt Deposit

The basalt deposit is located within the pre-Sudetic mountain block in the north-eastern part of the Niemczańsko - Strzeleckie Uplands [4]. The basalts belong to the Central European Tertiary volcanic province. The basalt found in the deposit is a predominantly massive, poorly weathered rock, so aggregates made from it are of high quality. The building vibration values were measured for the tangential peak particle velocity (PPVy). The peak particle velocity of the medium is responsible for the magnitude and type of damage to buildings and depends largely on the maximum charge per delay, the distance between the vibration source and the measurement point, and the physical properties of the MW and the excavated BM rock [4]. The blast induced vibrations were recorded using a seismograph. The seismograph also recorded the

vibration frequency of the peak PPVy, the horizontal tangential vibration velocity of the medium particle. Measurements of vibration velocity and frequency were made at an average distance of 313.0 m from the source of the vibrations using a UVS-1504 instrument. A map of the deposit [4] shows the existing houses and the place where the rock was excavated, the line of the blast holes, field survey points on protected houses. From the map of the deposit, the directional angles of the following survey points were measured in front of the excavated rock block on the basalt deposit. The results of the horizontal tangential peak particle velocity (PPVy) of the vibration measurements under industrial blasting conditions in the mining of the basalt deposit for different values of the directional angles are shown in Fig.7.

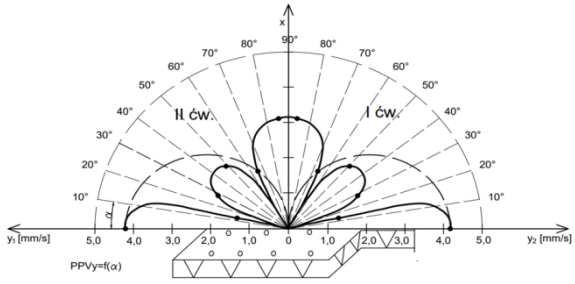

Fig. 7. Ellipsoidal dependence of the value PPVy of the tangential vibration velocity as a function of the direction angle "α"[4].

Fig.7 shows the ellipsoidal distribution of PPVy as a function of the directional angle "α" occurring during blasting operations in a basalt deposit. Fig.7 shows the directional characteristics of the vibration source: a) - axes Y1 and Y2 with marked measuring points "x" PPVy [mm/s] on the axes and directional angles on the same scale. b) - slope VVV of the slope, i.e. the face of the rock block made by blasting, c) graph of the unit vector of the tangential velocity Vy Fig.3 - 7.0 times larger, semicircular theoretical distribution of the unit ground vibration vector Vy marked with a thin dashed line with two semicircles of 7.0 [mm/s] velocity in quadrants of circle I and II on axis Y1 and Y2, d) dashed lines; - grid of directional angles from 0° to 90° dividing the semicircle every 10°, e) - quadrant I, "α" - an example of an acute directional angle "α" is marked. The ellipsoidal diagram of the PPVy tangential vibration velocity measured on the buildings as a function of the directional angle "α" over an area of 180 degrees (semicircle) is presented as the total perimeter of three ellipsoids and two semi-ellipsoids. The largest ellipsoid with the longest axis on the x-axis is the longitudinal wave ellipsoid L, and its maximum value is at an angle of 90°. The longitudinal wave ellipsoid in quadrants I and II passes through two oblique full transverse wave ellipsoids T, with a directional angle of the longer axis of about α = 38°, into two surface wave semi-ellipsoids R. Their longer axes lie on the Y1-Y2 axis of the diagram and have a directional angle of α = 0°. The ellipsoids and semi-ellipsoids in quadrants I and II of circle are symmetrical about the X axis and are similar.

VI. SUMMARY AND CONCLUSIONS.

There are no formulae in the world mining literature for determining the radius of the safe seismic vibration zone and the size of the safe explosive mass, taking into account the directionality of the vibrations by measuring the directional angles of the measurement points. The results of the seismic vibration measurements presented in Figure 7 show that there is an ellipsoidal directional distribution during industrial blasting in a basalt deposit in three rows of 11 blastholes each, with a burden of B=3.5m and a hole spacing of a=3.8m at a bench height of H=18.5m. To predict the radius of the safe zone for buildings in relation to seismic vibration and the safe amount of explosives, the highest measured value of the tangential horizontal vibration velocity PPVy must be used for safety reasons. For an ellipsoidal distribution, this is the higher value of the velocity for a direction angle α; α = 90° or α = 0°. The technical safety of buildings is ensured if the horizontal tangential velocities PPVy according to SWD do not cause scratching or cracking of structural elements. Figure 7 clearly shows the main directions of the ground motions in relation to the lines of the blast holes. From Figure 7 it is possible to determine the safe angles / areas of lowest vibration /. Knowing the directional characteristics of the source of the vibrations, it is possible to change direct the direction of rows of blast holes and direct the highest vibrations in the direction of undeveloped terrain. The value of the vibration velocity depends on the directional angle α and should be taken into account during measurements.

When BM rock is excavated, there is a circular and ellipsoidal distribution of the velocity vibration of the medium particle through which the seismic wave passes. With a circular and ellipsoidal distribution of the vibration velocity, in order to ensure the technical safety of buildings, the value of the vibration velocity acting on them should not exceed the limit line B, Fig. 6A and 6B.

1. For the same distance, the value of the vibration velocity depends on the type of wave and the direction angle α and should be taken into account when measuring and predicting the vibration velocity.

2.The assessment of the technical safety of a building with a circular distribution of the tangential vibration velocity for a seismic wave can be performed on the basis of measurements taken at any directional angle, taking into account its influence on the predicted value of the vibration velocity.

3. The assessment of the technical safety of the building in the case of an elliptical distribution of the tangential velocity vibration of the seismic wave shall be carried out on the basis of measurements made at the directional angles α=0º and α=90º

4. 4. For the analysed vibration velocity distribution, the built-up area should be located in the directional angle between 13° and 25° and between 50° and 70°, Fig.7.

Declaration of competing interests

The author declare that has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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INFLUENCE OF METEOROLOGICAL ELEMENTS IN ACCIDENTS IN ENTERPRISES WITH RADIOACTIVE ELEMENTS OR DANGEROUS CHEMICAL SUBSTANCES IN BULGARIA

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Abstract. **In the analysis of the meteorological elements that influence the spread of radioactive particles, radioactive isotopes and dangerous chemical substances on the territory of Bulgaria, the winds and air currents that form in the airspace over Bulgaria are considered. These are the main meteorological elements that most strongly influence the change in the radioactive background. Another element that has an impact is precipitation in its various manifestations - horizontal and vertical in appearance and depending on the aggregate state of the water. Due to their negligible influence on the radiation environment, we will exclude the remaining meteorological elements from the factors forming the natural indicators of the state of the atmosphere, water and soil. Their influence in areas where there are located large enterprises working with such substances is presented.**

The report examines the influence of the main factor - the movement of air masses at different altitudes in the atmosphere in the Ludogorie region and the Danube River as an area where NPPs are located in Bulgaria and Romania and which, in the event of an accident, would cause the greatest consequences. The winds in 3 cities from this region, which are located near these enterprises, are described and the corresponding analysis is made.

Keywords: air flow, chemical accident, hazardous chemical substances meteorological element, nuclear accident, precipitation, radionuclide, wind.

INTRODUCTION

Meteorological elements may have an impact on the radioactive contamination of our environment - atmosphere, soil and water, and each indicator has a different weight in forming the radioactive background. Naturally, the strongest influence on the spread of radioactive contamination in the event of a nuclear incident, accident or terrorism is the winds at different heights from the surface of the earth's crust. In the different layers of the Earth's atmosphere, the direction and speed of air currents sometimes have radically different values. Different types of horizontal and vertical precipitation and the permeability of the atmospheric layer to the solar radiation reaching us also have an influence. The other meteorological components have a negligible influence on the distribution of radioactive rays, particles and isotopes and are therefore not the subject of this report [1], [2].

In this area are located 2 NPPs in Bulgaria and Romania and there is a selected site for the construction of another nuclear power plant. Here there are also enterprises of the chemical industry of both countries and former enterprises that are currently not working, but have worked and have raw materials or can work again. All of them can have an impact on people and our surroundings in the event of an accident. There are also many medium and small enterprises that work with hazardous substances and we

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should not ignore their influence in the event of a release of hazardous or toxic substances.

An analysis of the results of the movement of air masses in the last nearly 40 years has been made, and relevant conclusions and recommendations have been made based on them.

II. Materials and methods

A. Influence of winds

Wind and air currents have the strongest influence on the change of the radiation background after the occurrence of an accident in a nuclear power plant or other nuclear facilities. The direction and speed of the mean wind determine the position, extent, and degree of contamination of the radioactive cloud trail. Therefore, when assessing the radiation situation, the parameters of the air currents must always be taken into account. In the event of an accident or an increase in the radioactive background, we must constantly monitor the change in air currents, as well as inform ourselves about the possible changes that meteorologists give in their forecasts. It is also necessary to quickly collect information about the usual winds in the given area, in order to predict the direction of spread of radioactive contamination, using also local signs to determine the winds and their future development. In Bulgaria, you can use the National System for Continuous Control of the Radioactive Background at the Ministry of the Environment and the website of the National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences, where you can see what the spread of radioactive particles will be after a certain set time and at a certain height on the earth's surface for a specific nuclear power plant from the European continent.

Wind direction and speed data allow us to solve the following tasks:

1. Determining the direction of propagation of the radioactive cloud and the scale of the radiation, as we can define it for a certain time segment;

2. Determining the time of arrival of the radioactive pollution to the designated area with the current and predicted air currents;

3. Determining the level of the assumed change in the radioactive background in a certain time range.

B. Influence of phase transitions of water in the atmosphere

Air humidity has a significantly weaker effect on the change of the radioactive background, but it should not be neglected as a factor for the spread of radioactive contamination [3], [4], [5].

In case of relatively heavy precipitation or fog, a decrease in pressure is observed in the front of the spread of the radioactive cloud, especially at greater distances from the place of the explosion. As the radioactive contamination moves away from the epicenter of the event, the amount of radioactivity decreases. In explosions in medium rain (5 ml/h) or fog (0.2 g/m3), the shock wave pressure is 5–15 % lower than in normal conditions. In heavy rain (25 mm/h) or dense fog (1 g/m3), the pressure in the shock wave decreases by 15–30 %. In nuclear accidents in snowfall, the pressure in the shock wave decreases slightly and may not be taken into account in practical calculations.

Rains, to varying degrees, influence changes in the radioactive background after a nuclear accident. During the formation of the trace of the radioactive cloud, the raindrops entrain the particles of the radioactive dust and together with them fall on the earth's surface [2]. This results in:

1. Increasing the rate of settling of the radioactive cloud;

2. Increasing the degree of infection of individual small areas of the locality;

3. Stronger infection of the population, living and non-living nature [1], [6], [7].

C. Influence of the topography of the area

In some cases, the topography of the area can significantly influence the nature of the spread of radioactive contamination that occurred as a result of a nuclear accident or a nuclear explosion on the surface of the earth.

On a flat area. such as the terrain with a slope of no more than 10°, the influence of the relief on the spread of radioactive contamination and the change of the radioactive background is insignificant and can be neglected. Such a character of the relief is characteristic of the central part of Southern Bulgaria, namely the Upper Thracian lowland.

Characteristic of the hilly area is the presence of hills with a height of up to 200 m and with slopes greater than 10°, ravines, slopes and other sharp folds of the area. When spreading in such an area, the front of radioactive contamination is reflected from the front (facing the accident or explosion) slopes of the hills, passes over them and to the side, enters ravines and slopes. The predominant part of Northern Bulgaria is of this type - the Danube Plain and the Ludogorie.

The increase in pressure on the front slopes of hills and ravines depends on their slope and on the intensity of the change of radioactive rays, particles and isotopes in the atmosphere and is determined by a special schedule. The pressure in the shock wave of the reverse slopes is determined by the graph. These graphs are available to the competent authorities, who are the first to fight to reduce the impact of radioactive contamination on people and infrastructure. This is characteristic of the transition from the Danube Plain to Stara Planina or the Pre-Balkans.

Behind hills and elevations with slope inclination greater than 20°, a zone of increased pressure is observed, the length of which is equal to 3–4 heights of the hill [3]. The pressure in this zone is 10-20% higher than the pressure in the passing shock wave. The front of the shock wave on the reverse slopes is slightly disturbed. The time to increase the pressure to the maximum can reach 0.01-0.05 s. At the bottom of deep depressions and ravines with steep slopes and a long length, the orientation of which coincides with the direction of propagation of the shock wave, the pressure is 10-20% higher than on the surface. This relief is characteristic of the greater part of Bulgaria, due to the presence of mountainous sections, although a large part of them are below 2000 meters above sea level.

In a mountainous area, the influence of the relief is more pronounced than in a hilly area.

D. Influence of other meteorological elements

Air density, aerosol concentration, atmospheric pressure, air and soil temperature also affect the rate of change of the natural radiation background after a nuclear accident or other action that is accompanied by radioactive radiation, but their influence is very small and therefore when determining the radiation situation, they are not taken into account. Bulgaria is located in South-Eastern Europe, it is characterized by a moderate climate and there are no anomalies in the presence of abnormal amounts of the components of the atmospheric air at different heights above the earth's surface [2], [8], [9].

III. RESULTS AND DISCUSSION

The analysis was made on the basis of detailed statistical data on the direction and strength of the wind and air currents over the territory of Bulgaria during the last 40 years after 1985 from the database of the National Institute of Meteorology and Hydrology (NIMH) at the Bulgarian Academy of Sciences (BAS).

In addition to the daily data for the period after 2014, generalized values for the direction and strength of the winds were used, both near the border areas with neighboring countries and over the territory of our entire country. Here, data for a period of 30 years is used, which is quite sufficient to capture the trends in the change of the atmospheric masses and the adjacent water and land surfaces. I must point out that the tracking of air masses over the last 30 years only gives us the trends and the main directions of movement, but as we all know these processes are too dynamic and do not obey cyclical uniform repeatability and predictability. Therefore, at the same time as the in-depth research and data processing, we must not stop the constant monitoring of our environment and its parameters. Over the past 3 years, a change in the direction of movement of air masses has been noticed in some of the studied points, with significant values - Elhovo, General Toshevo and others. Of particular interest to us are the changes in the direction of the movement of air currents in the border regions, near which there are nuclear facilities, and this applies most strongly to the cities along the Danube River and the region of North-Eastern Bulgaria.

This is explained by the fact of the presence of our Kozloduy NPP, the working site of the planned Belene NPP and Cerna Voda NPP on the territory of Romania, which is 40 kilometers from the border with Bulgaria.

TABLE 1. WIND FREQUENCY IN 8 DIRECTIONS AND AVERAGE SPEED IN THE CORRESPONDING DIRECTION FOR THE PERIOD 1992 - 2022 FOR THE AREA OF THE TOWN OF SILISTRA

Wind direction	N	NE	E	SE	S	SW	W	NW
with wind, %	6.2	14.1	7.1	3.8	5.9	8.2	15.6	7.6
no wind, %	9.0	20.7	10.3	5.6	8.6	11.9	22.8	11.1
V, (m/s)	4.7	4.4	2.6	2.9	3.6	3.4	3.8	3.0

Table 1 shows that the main wind direction in this region is west and northeast. Northeast of Silistra is the Cerna Voda NPP, and it is from there that 20% of the winds originate. Adding in the nearby northerly and easterly winds, it turns out that more than 40% of the winds in this area would help increase radioactive contamination in the event of a nuclear accident in our neighboring country. This is a prerequisite for us to monitor both the radiation situation around the Chrna Voda NPP, as well as the meteorological situation and, in particular, the movement of air masses in this region. Here, the wind speed must be taken into account when assessing the situation. Table 1 clearly shows that the northeast wind has the highest speed - more than 4.4 m/s, with a higher speed only the pure north wind - 4.7 m/s.

TABLE 2. WIND FREQUENCY IN 8 DIRECTIONS AND AVERAGE SPEED IN THE CORRESPONDING DIRECTION FOR 2022 FOR THE AREA OF THE TOWN OF SILISTRA

Wind direction	N	NE	E	SE	S	SW	W	NW
with wind, %	9.1	20.7	9.0	2.9	4.6	7.0	11.5	5.3
no wind, %	13.0	29.6	12.9	4.2	6.4	10.0	16.4	7.5
V, (m/s)	4.3	3.6	2.4	2.5	2.3	2.6	3.2	3.1

Table 2 shows the similar study, but taken only for the year 2022. Here the trend with the prevailing direction of the winds is even more clearly outlined - almost 30% of the days with wind it was from the northeast and when adding the north and east winds, more than half of the windy days were predominantly from Romania and more specifically from NPP. This shows us how necessary the functioning of

the systems for monitoring the radiation situation and meteorological forecasts is mainly with preventive activities.

The wind roses in other border regions of Bulgaria, which are located next to potential sources of radiation pollution, are of interest, but due to the limited volume of the report, I will present them in detail in another development. Similar are the results obtained in Svishtov, Kozloduy and Vidin, which are located along the Danube River and are respectively located east, next to and west of the Kozloduy NPP. Predominantly, the winds are westerly and are along the Danube River, with 33% being purely westerly and another 12-16% northwesterly.

In parallel with the national automated system for continuous control of the radiation gamma background in the Ministry of Environment and Water, in the National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences, a system for forecasting the spread of radioactive contamination in the event of a major nuclear accident in the Northern Hemisphere region works on Earth, where more than 95% of the working nuclear power plants on our planet are located. This system, which is known only to some narrow specialists in the field of radiation protection, shows us in real time the distribution of air masses and their movement in time. It presents the results of the operational calculation of prognostic trajectories from certain nuclear power plants located in the region of Europe and the Northern Hemisphere. The stations are divided into groups for greater visibility of the results, and they are selected so that the movement of the atmospheric currents can be clearly seen and there is a good resolution between the individual stations. Each of the pictures shows the trajectories of the arranged NPPs, grouped into 5 groups. Three trajectories corresponding to three ejection heights start from each station:

- 100 m - red color;
- 300 m - pink color;
- 1000 m - green color.

The starting moment of each trajectory is the synoptic time (0 or 12 hours GMT), and the points that the ejected particles will reach after 12, 24, 36,.....72 hours are marked with the corresponding colored points on each trajectory. The locations of the plants are indicated by an asterisk and the numbers correspond to those in the list shown in Table 2 [2], [4].

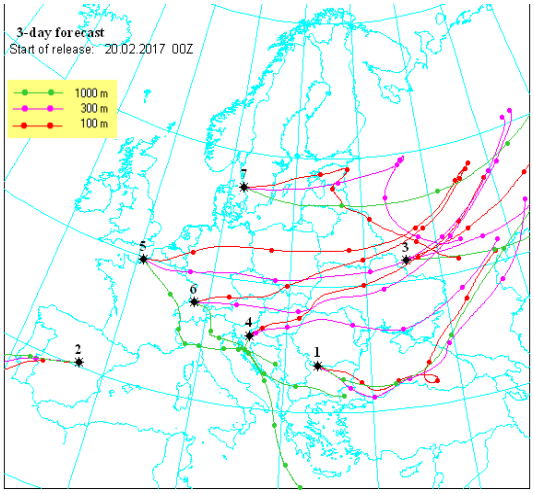
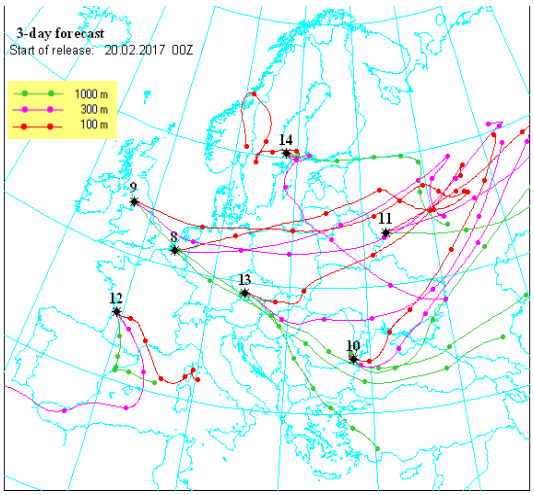
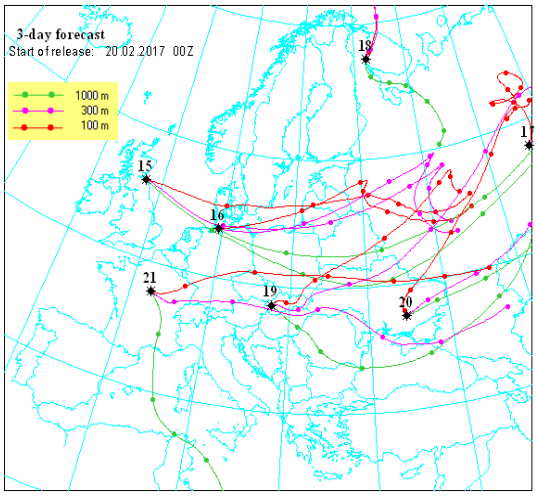
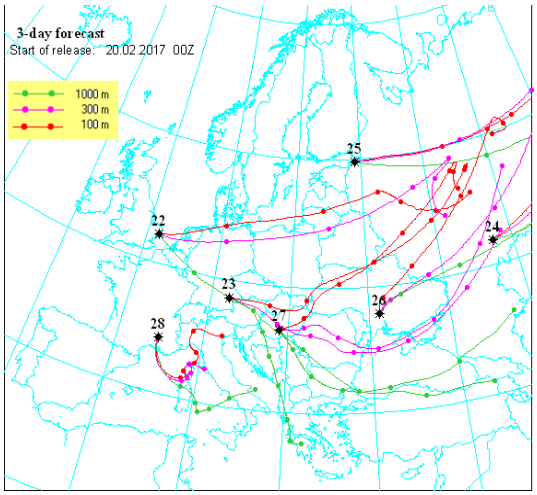


Figure 1a. Three-day forecast distribution of air currents in a suspected nuclear accident at major nuclear power plants in Europe.

When analyzing the results of the forecast movements of the air masses and the distribution of the radioactive particles as a result, it is observed that, in addition to the Kozloduy NPP and the Cherna Voda NPP, which is located close to Bulgaria, at different time intervals, radioactive contamination can also occur in result of an accident at the Zaporizhia NPP, Ukraine; Kursk NPP, Russia; South Ukraine NPP, Ukraine; Rovno NPP, Ukraine; Paks NPP, Hungary; Leningrad NPP, Russia; Philipsberg NPP, Germany and others. The nuclear power plants are listed in descending order of possible impact on the air, water and soil of Bulgaria as a result of a radiation accident. The results of February 20 for the air currents at a height of 100, 300 and 1000 meters above sea level are shown in Fig.1. From the actual results of the movement of air masses at different altitudes, according to NIMH data, it can be seen that these processes are very dynamic and on each of the three days the impact of a possible nuclear accident in different points of Europe will be quite heterogeneous. This confirms that it is necessary to continuously monitor the radiation background, the movement of air masses and the state of the main nuclear facilities [2], [10], [11], [12].







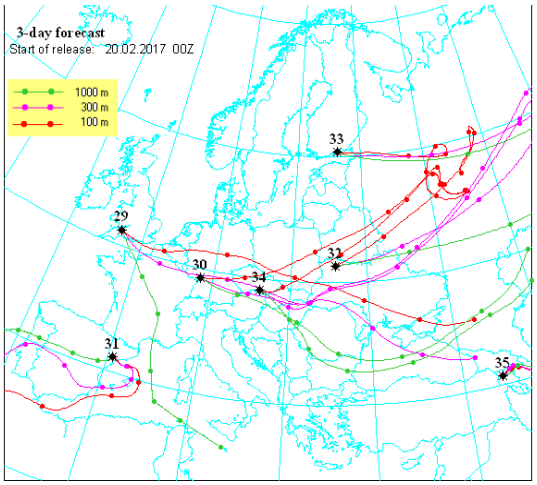


Figure 1 b, c, d, e. Three-day forecast distribution of air currents in a suspected nuclear accident at major nuclear power plants in Europe.

TABLE. 3. VISUALIZATION OF THE FORECAST AIR CURRENTS IN CASE OF AN ACCIDENT AT THE NPP

Map №1	Map №2	Map №3	Map №4	Map №5
1. Kozloduy, BG	8. Doeller, BE	15. Tornes, UK	22. Siswell, UK	29. Hinkley Point, UK
2.Jose Cabreras, ES	9. Hashem, UK	16. Brockdorf, DE	23. Isar, DE	30. Philippsburg, DE
3. Kursk, RU	10. Cerna Voda ,RO	17. Beloyarski, RU	24. Balakovo, RU	31. Asko, ES
4. Crush, SL	11. Smolensk, RU	18. Kola, RU	25. Leningrad, RU	32. Rivne, UA
5. Paluel, FR	12. Blaise, FR	19. Bohunice, SQ	26. South Ukraine, UA	33. Loviza, FI
6. Labshad, CH	13. Temelin, CZ	20. Zaporozhye, UA	27. Paksh, HU	34. Dukovi, CZ
7. Ringgils, SE	14. Forsmark, SE	21. Dampier, FR	28. Tricastin, FR	35. Armenia, AR

Figure 1 shows the predicted movements of air masses up to 72 hours after a possible accident in 35 plants from Europe. The points on the drawn trajectories in different colors show the location of the atmospheric particles during 12 hours or how the front will spread and what its position will be during the specified interval. The data is for 20.02., and it can be seen from the cartographic drawings that the dynamics are too great and the direction of movement is very different. This emerges even more clearly when consistently monitoring the data over time, where certain trends in the movement of air masses can be detected. Some sites that are most interesting for Bulgaria on the specified date are - Kozloduy NPP, Leibstadt NPP Switzerland, Doelr NPP Belgium, Temelin NPP Czech Republic, Paksh NPP Hungary, Dukovany NPP Slovakia and others almost in the opposite direction [5], [13], [14]. From intermediate data, inconstancy in wind directions and speeds can be observed in different parts of Europe and in Bulgaria in particular. Due to the volume of the report, I cannot present more complete data, which are available and will be summarized and presented in other reports. Data on the movement of atmospheric currents must be continuously monitored in order to be able to respond promptly in the event of possible radioactive contamination as a result of a nuclear accident in one of Europe's nuclear power plants [1], [15], [16], [17].

We must not ignore the difference in the movement of air parts at different heights from the earth's surface. The figures clearly show the differences in the direction of propagation and the length of the traveled path. This suggests that the movement of air masses at different altitudes must be known in order to react adequately. It is not enough to know only the surface winds, but it is necessary to know the movement of air masses at different heights above the earth's crust in order to be able to predict the spread of radioactive contamination and take effective preventive and follow-up actions. In view of the military actions on the territory of Ukraine in the last year, 4 nuclear

power plants, which are located on its territory, are of particular interest. Particular attention should be paid to the Zaporizhia NPP, in the immediate vicinity of which military operations are being conducted and numerous provocations have been carried out and numerous fake news have been generated. And the operation of any nuclear power plant is an extremely responsible activity and in no case should it be allowed to violate the normal technological and operational regime.

IV. CONCLUSIONS

1. Air currents exert the greatest influence of the meteorological elements on a possible change of the natural radioactive background and spread of radioactive particles during a nuclear accident in some of the nuclear power plants in Europe. The availability of data for previous years enables us to make predictions about possible impact and take preventive measures to limit the impact.

2. The topography of the area also has a significant influence on the natural radioactive background and its change in the case of radioactive contamination. A good knowledge of the surrounding area significantly increases the possibilities for adequate behavior and limiting the impact in the event of an accident or emergency.

3. Air currents are a very dynamic process both over time and at different heights above the earth's surface. This change must be continuously monitored in order to be able to react promptly and adequately in the event of a nuclear accident. It is desirable to use forecasts for air transformations at different heights above the earth's surface.

4. The state of the natural radioactive background over Bulgaria in different periods of time is influenced by NPPs located in different parts of Europe, but the Zaporizhia NPP, Ukraine; Kursk NPP, Russia; South Ukraine NPP, Ukraine; Rovno NPP, Ukraine; Paks NPP, Hungary; Leningrad NPP, Russia; Philipsberg NPP, Germany has the biggest impact according to data from the last 3 years. The situation around NPPs, which are located in a territory where military operations are taking place, must be monitored with great care.

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Impact of Types of Electromagnetic Radiation on Living Nature

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Abstract. **In our daily life we are exposed to electromagnetic radiation in a very wide range. In our century, these radiations are constantly increasing, and we do not always know how to protect ourselves from them and how they affect people and the rest of living nature. An attempt has been made to analyze the impact of emissions from a different frequency spectrum - from power supply with a frequency of 50 Hertz to high-frequency mobile communications with a frequency of up to 300 GHz. Studies in countries of Europe and the world were taken as a basis, and a study was made about the impact of these electromagnetic radiations in Central Northern Bulgaria and the Veliko Tarnovo region. It is shown how morbidity changes when they affect the peripheral and central nervous systems of people and what effect they can cause at high powers and high intensity at short distances.**

Keywords: broadcasting; electromagnetic radiation; light; mobile cells; power grid; radio frequencies; ultraviolet light; Wi-fi.

INTRODUCTION

In the development of physics over the last 100-150 years, when describing many physical phenomena and laws, in parallel with the concept of matter, the concept of field is also used, including electromagnetic, gravitational, nuclear force fields, etc [1, 2, 3]. Or to put it in scientific language it is assumed that two forms of existence are possible - matter and field, which are characteristic of our surroundings.

The fundamental concepts of the electromagnetic field were developed by independent study of the various forms of electric and magnetic phenomena, and first its independent laws were formulated, and one later united the researches and the achieved results and spoke already about its integrity and indivisibility. These phenomena include the creation of electric fields by charges (Gauss's law), dependent magnetic fields (Faraday's induction), as well as the creation of a magnetic field by electric current (Ampère's law). This is how the theory of electromagnetic fields, their propagation and impact on the substances found in them was created [4, 5, 6].

Electromagnetic interaction, although studied and described as far back as the Middle Ages, is one of the four main types of fundamental interactions in nature. Electromagnetic fields are a combination of the invisible electric and magnetic fields of varying strength that operate around us. They are generated both by the resulting natural phenomena and by human activities in various manifestations, but mainly by the use of electricity. The most heterogeneous sources of electromagnetic field are known.

Most man-made electromagnetic fields are within a large perimeter of the generated frequency. Starting with high radio frequencies - such as those used by mobile phones, radio broadcasting, telecommunications, moving through medium frequencies - such as those generated mainly by monitors and television receivers to extremely low frequencies - such as those generated by electrical wires and power grids [7, 8].

II. MATERIALS AND METHODS

In the technique, we use electromagnetic radiations of the most diverse frequency. Each type of radiation has certain characteristics of physical characteristics and biological action, both on man and on the living and non-living nature that surrounds us. Living tissue placed under the influence of an electromagnetic field changes as the

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frequency increases, increasingly loses its dielectric properties and approaches the conductors. This change is uneven and depends on the type of tissue, the characteristics of the emitted electromagnetic waves, the surrounding environment and many other factors, some of which have been studied in detail, but for others such studies have yet to be conducted. Research in this area is extremely varied and too often with conflicting results. Here, what results we aim to prove as a result of the research - whether a positive impact or a negative impact - have a huge influence. Here the results are relatively comparable, and the reading of the results is varied [9, 10].

Exposure to electromagnetic fields causes immediate biological effects and sometimes even irreversible tissue processes if the fields are strong enough. The effects range from stimulating nerves and muscles to heating and even burning the body's tissues, depending on the frequency. To protect against these influences, standards for exposure to electromagnetic fields have been created, which are detailed in various regulatory documents in individual countries around the world. In many cases, these norms have very different values in different countries of the world. It should be noted that the biological characteristics of the specific study, the geographical location, the mental state and a number of other factors also have a great influence.

III. RESULTS AND DISCUSSION

Purpose of the study

The purpose of the present study is to show whether there is a dependence of diseases of the peripheral and central nervous system on the impact of electromagnetic radiation and on their parameters - intensity, power and distance. The research was carried out in Central Northern Bulgaria and in particular in the Veliko Tarnovo region in the second half of 2022 by measuring the electromagnetic fields in the vicinity of the power transmission network for household and industrial power supply with different voltages and transmission cells of mobile operators with different locations in populated areas and different transmitted signal power**.**

In the last 50-60 years, with the rapid development of electricity, radio and television broadcasts, radar, mobile connections, etc. the intensity of the Earth's electromagnetic fields increases significantly. The mobile, radio and television transmitters that surround us create a "radiophone" whose intensity is more than 10 times greater than the intensity of natural electromagnetic fields. In densely populated areas, areas near radio broadcasting stations and antenna complexes and power transmission networks, the intensity of the electromagnetic field is tens of times higher than the maximum permissible norms in the relevant regulatory documents. In large settlements, where there are many transmitters of mobile operators in their vicinity, the intensity of electromagnetic fields is significantly greater and can reach up to 10-15 times above the permissible norms. With the construction of 4G and 5G networks, discussions have begun for and against their construction, due to insufficient information about the broadcast signals and the power of electromagnetic radiation that affects people and living nature that are in close proximity to them. Close to power lines, transformers, etc. an electromagnetic field with a frequency of 50 Hz occurs. They decrease quite quickly with distance, but near the sources they can be quite intense, and their impact on people living near power grids has not yet been fully investigated.

Electromagnetic radiation from power transmission networks is characterized by a constant frequency of 50 Hz, as it is in most countries of the world, and with varying intensity depending on the voltage flowing on this network, the distance from the conductor, weather conditions and other indicators. A study conducted on the territory of several large European cities (Paris, Prague and Moscow) proved an increased state of headaches in people who live in the immediate vicinity of the power transmission network with medium and high voltage according to generally accepted standards. At the same time, as the tension increases, so does the percentage of people experiencing headaches and nervousness among those living in the immediate vicinity. Morbidity drops sharply as the place of residence moves away from the power grid. And this has been done so far only by studying the dependence of headaches on proximity to electromagnetic field sources. It has been proven by a number of researchers that with a prolonged stay in a room near such a source less than 200 m, the incidence of headaches increases by 21%, at a distance of 100 meters, the incidence increases to 68%. At a distance of less than 50 m, the cases are already 94-97% in various studies, and there is no dependence on the location of the city, but there is a dependence on the age of the people - as the age decreases, the cases of headaches and other nervous disturbances increase [2, 5, 11, 12].

In the study, the intensity and power of the electromagnetic field were measured in homes that are located near the power transmission network with low (220-380 V), medium (40 kV) and high (220-440 kV) voltage. Numerous transmission lines with different voltage values run through the territory of Veliko Tarnovo region, with Gorna Oryahovitsa being the distribution center for the power transmission network in Northern Bulgaria. The measurements were made in residential and industrial buildings in Veliko Tarnovo, Gorna Oryahovitsa, Pavlikeni and Svishtov, which are respectively 50, 100, 150 and more meters away from the power grid.

The results of the impact on people living or working near these networks were studied by conducting a survey with them and based on their judgments. No medical examinations were conducted because a large part of the respondents did not seek specialized medical care and were not registered in the outpatient lists. For information, the medical documentation of the workers in the enterprises serving the power transmission networks and mobile operators was taken, because they undergo periodic medical examinations for their health, including the impact of electromagnetic radiation. Such are 48% of the respondents in this study.

The survey was attended by employees working in Energo-pro networks in Gorna Oryahovitsa, Veliko Tarnovo, Pavlikeni and Svishtov, whose workplaces are located in close proximity to the power transmission networks, BDZ Gorna Oryahovitsa, Sviloza, Zarya and other enterprises that have their own substations with an average voltage and living in houses and cooperatives that are located near the power lines. A total of 216 respondents participated, of which 110 work in these conditions and 116 live near the low and medium voltage transmission networks.

The results of the study are shown in Tables 1 and 2.

Table 1. Dependence of headache in people on the distance from the power grid and age at medium voltages

Distance/ age	50 m	100 m	150 m	200 m
Up to 18 years	65%	41%	18%	5%
18-60 years	95%	68%	46%	21%
Over 60 years	98%	75%	60%	44%

Table 2. Dependence of headache in people on the distance from the power grid and age at low voltages

Distance/ age	50 m	100 m	150 m	200 m
Up to 18 years	55%	36%	14%	2%
18-60 years	88%	62%	40%	12%
Over 60 years	92%	70%	55%	38%

From the tables, it can be seen that the voltage with a larger value and the electromagnetic field induced by it affects more strongly and causes a greater headache than the low voltage power grid. The tendency to reduce headaches with distance from the source of electromagnetic radiation is also clearly outlined - At low voltages at a distance greater than 200 meters, the headache among the respondents decreases from 2.5 to 27 times in the different age groups. With medium voltage, the situation is similar, as here the figures are from 2.25 to 13 times. With high voltage on the transmission lines, the number of respondents was less than 50 people, and therefore the results obtained are not presented, because there is not a sufficient number of participants and the results do not have the necessary credibility.

In modern society, everyone is exposed to electromagnetic fields from a number of sources, including electrical equipment, broadcast radio and television broadcasts, and communication devices. However, the most common sources in recent decades have been cell phones, cordless phones, local wireless networks, and radio transmission towers. Medical scanners, radar systems, and microwave ovens also use radio frequency fields. Radio frequencies range from 100 kHz to 300 GHz. All of them are superimposed in the space and have an impact on the living organisms located in them.

In telecommunications, 5G (5th generation) is the fifth-generation technology standard for cellular broadband networks that cellular phone companies began deploying globally in 2019 and is the planned successor to 4G (4th generation) networks that provide connectivity to most modern mobile phones. 5G networks are projected to have more than 1.7 billion subscribers and account for 25% of the global mobile technology market by 2025, according to the GSM Association and Statista [2, 13, 14].

Electronic transitions occur in atoms and molecules due to the absorption or emission of electromagnetic radiation (usually UV or visible). The energy change associated with the transition is related to the frequency of the electromagnetic wave by Planck's equation.

In 5G, frequencies range from 3 to 30GHz.

The number of 5G global connections is expected to reach one billion in 2022 – a figure expected to double to two billion by 2025 – by which time 5G connections will make up a quarter of all mobile device connections.

Every day, the human body is exposed to the effects of radio frequency fields around us, and it accumulates energy over time. How much RF energy a person accumulates on a daily basis is unknown, as exposure depends on many factors, especially the distance and power of the sources.

At a frequency of 100 kNz, a break occurs, which leads to a change in the character of the change, after which the monotonicity is preserved up to a frequency of 1 - 10 GHz. Most of the energy absorbed in electromagnetic radiation is converted into heat. The conversion of electromagnetic energy into thermal energy is due to dielectric losses [3, 9, 15].

In the last 5 years, with the introduction of 5G technologies, there has been more talk about the impact of mobile networks on wildlife. A1 is the largest mobile operator in Bulgaria and naturally the interest in its network is the greatest, due to the presence of the most repeater cells. Measurements were carried out on the A1 network in Bulgaria using a NetMonitor mobile application. It has the ability to display advanced 2G / 3G / 4G / 5G (NSA and SA) cellular network information and monitor cellular network status by collecting cell tower data. Also detects aggregate media. The information is presented and reviewed in different sections:

The Cell tab is the home screen showing the mobile operator, mobile network type and generation, network status, frequency range and duplex mode. The section also has information about the serving cell: TAC (Location Area Code/Tracking Area Code), CI (Cell Identification), PCI (Physical Cell ID), EARFCN(E-UTRA Absolute Radio Frequency Channel Number), RSSI(Received Signal Strength Indicator), RSRQ(Reference Signal Received Quality), RSSNR(Reference Signal Signal to Noise Ratio), address as assigned during the programming of the serving cell, TA(Timing Advance), which indicates the approximate distance to the cell. Some of the same information is also shown for neighboring (not currently serving) cells that are expected to be used at a later time.

The Log tab displays a unique identifier, frequency, and set address for recorded cells that have been used at a previous time. A database with the same cell information downloaded from the Internet can be displayed in the tab.

In the Map section, a map is shown with the exact locations, set address and distance to the previously used cells.

According to the generation and technology of the network for which the antennas and cells are used, they differ from each other. They can be broadly divided into GSM(2G), WCDMA(3G-UMTS), LTE(4G), NSA(5G) [6]. Separately, each generation is characteri zed by a particular frequency, frequency slot, access system and a different network core.

The effective surface area of the human body is a function of the field frequency and may differ substantially from the body projection area on planes perpendicular to the incident wave. Substantial differences in the electrical properties of the skin, subcutaneous fat, muscle and other tissues determine the complex picture of distributed, radiated energy to the body. Accurate calculation of the distributed heat energy released in the body during irradiation is practically impossible. The obtained results should be accepted with a certain approximation.

The research was done during the period from 14.10.2022 to 25.10.2022 when connected to different cells belonging to A1 Bulgaria in the 5G NSA network in the Veliko Tarnovo region. Each cell corresponds to the coverage of a geographical area in which it has access to the radio signals emitted by a transmitter in a certain channel and a certain network generation. Cells were selected in different areas of the district, with different parameters and coverage. 224 participants took part in the study, 48 of whom work in mobile cell service and maintenance companies and 176 live near mobile cells. The survey results are shown in Tables 3 and 4.

Table 3. Dependence of headache in humans on the distance from the mobile cell and age at medium and high emitter powers

Distance/ age	50 m	100 m	150 m	200 m
Up to 18 years	50%	38%	15%	4%
18-60 years	90%	63%	44%	25%
Over 60 years	96%	78%	62%	48%

Table 4. Dependence of headache in humans on the distance from the mobile cell and age at low emitter powers

Distance/ age	50 m	100 m	150 m	200 m
Up to 18 years	35%	26%	10%	2%
18-60 years	72%	52%	30%	8%
Over 60 years	87%	67%	50%	28%

In the survey conducted, the results obtained are similar to the results obtained from low-frequency irradiation, but the values are lower. The trends of increasing the impact with increasing emitter power and the age of the subjects, as well as decreasing the negative impact with increasing the distance between the source and the studied object, are preserved. The study did not distinguish the influence of other factors on headaches or other diseases of the peripheral and central nervous system from electromagnetic radiation. But there is a tendency to increase diseases as a result of the impact of electromagnetic fields on the human body. It is necessary, if financial means are available, to continue the research with medical means to prove the obtained results. These are studies that have been done in some countries, but the medical indicators and evidence are not yet sufficient to fully describe the impact.

The changes caused by the irradiation can be reversible, and in the case of high intensity or systemic irradiation with a small but above the limit intensity - irreversible. They lead to changes in the structure and appearance of the tissues and organs in the human body, burning, killing, hemorrhages, changes in the structure of the cell, disruption of the nutrition of the tissues, organs or the organism as a whole. Changes are observed in the tissues of the peripheral and central nervous system — their functions are disturbed, nerve nodes are destroyed, the structure of nerve cells changes. This is observed at different frequencies.

People working under excessive electromagnetic radiation usually get tired quickly, complain of headache, general weakness, pain in the heart area. With them, sweating increases, irritability increases, sleep is restless. Individuals experience spasms, memory loss, voice loss, nail brittleness, etc.

A quantitative assessment of the danger of electromagnetic impact is made both from the intensity of the field and the density of the power flow, as well as from the duration of the irradiation. The maximum permissible norms are dependent on the frequency range and differ for electric and magnetic fields. In different countries, these requirements and standards are sufficiently different, and in some cases there is a difference of tens of times. In technologically developed countries, these standards are significantly lower than in underdeveloped countries, and this is also a reason for the export of productions and complexes that have higher emissions.

Research results show that electromagnetic fields have high biological activity in all frequency ranges. At relatively high levels of the electromagnetic field, modern theory attributes the impact to the thermal mechanism. At a low level of electromagnetic field (for example, at radio frequencies above 300 megahertz, which is less than 1 mW/cm^2), it is accepted to consider that it has a non-thermal effect on the body or an informational character. The modes of action of electromagnetic fields in the second example are still little studied.

IV. CONCLUSIONS

The following conclusions can be drawn from the summaries of conducted research on the impact of electromagnetic radiation on humans and living nature:

1. The presence of sources of low-frequency electromagnetic radiation affects the human body, and the closer the location is to the source, the more the diseases of the nervous system and headaches increase. As age decreases, the body's sensitivity increases.

2. In the case of high-frequency electromagnetic radiation, the impact on humans also increases as the intensity and power of the electromagnetic field increases. High-frequency radiation has an impact on living nature, and this also leads to the blocking of certain functions in humans, birds and animals. There is still not enough research on the impact of the latest generations of mobile networks, due to the short time of their implementation and a lack of sufficiently proven research results.

3. The conducted research has no analogue in the region of Central Northern Bulgaria, where it was conducted and should be continued with medical research on the electromagnetic impact not only on humans, but also on other living animal and plant organisms.

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Physiological Response of Some Wheat Cultivars to Thermal Stress

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Abstract. **Plants are exposed during their development to the influence of various stressful factors, both abiotic and biotic in natural conditions of habitation. Thermal stress is likely the most important abiotic factor that adversely affects plant growth and development. Wheat (Triticum aestivum L.) is one of the most economically important crops worldwide. In this study, three Latvian winter wheat cultivars ´Creator´, ´Galerist´, and ´Skagen´ were used as a research model that were subjected to short-term high temperature (42°C, 1 h) and analyzed for the following growth parameters (maximum length of root, length of first leaf and coleoptile as well as seedlings weight). In general, short-term high temperature caused an insignificant reduction in almost all growth criteria like the first leaf growth, coleoptile growth, seedlings weight, and maximal root growth in wheat cultivars ´Skagen´ and ´Galerist´ at the 6th day of development. Furthermore, almost all growth characteristics were stimulated by short-term high temperature in the wheat cultivar ´Creator´. A slowing of the growth processes under the influence of short-term thermal stress revealed varietal specificity on the impact of this stressor on the morphological structure of cereal, which makes it possible to diagnose the stress tolerance of wheat cultivars.**

Keywords: high temperature, growth parameters, Triticum aestivum L., wheat cultivars.

I. INTRODUCTION

As a consequence of climate change, the prevalence of extreme environmental conditions, including extreme weather events and increased average temperatures cause significant loss of production and a decrease in yield for cereals and other cultivated plants leading to huge economic losses. IPCC has projected a temperature increase of 1.8 - 4°C by 2100 [1]. Rising global average temperature leads to increasing irregular and unexpected warm spells during autumn, and therefore natural chilling requirements to break dormancy are at risk. Therefore, modeling and studying the possible effects of climate change on some morphological and physiological processes in agricultural plants is extremely relevant.

Temperature is one of the major factors controlling plant development, in particular germination of seeds. As non-moving organisms, plants rely on physiological responses and morphological alterations in order to survive under environmental factors such as high light intensities, extreme temperatures, drought, or high salinity that adversely affect plant growth and development. Among the environmental stresses, thermal stress is one of the most limiting factors of plant growth and productivity that has a great impact on agricultural production causing a variety of physiological, biochemical, and morphological dysfunctions in living organisms [2-3]. Morphologically the most typical symptom of heat stress injury to plants is the reduction of growth [4]. At the physiological level, heat stress inhibits the rate of photosynthesis and increases the level of reactive oxygen species and oxidative stress parameters [5]. To overcome problems caused by such an unpleasant environment plants developed a defense system through hormonal and antioxidant responses. Usually, under heat stress

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conditions, increasing stress level is detrimental to plant growth and may result in marked alterations in its morphological features including shoot and root growth inhibition, and diminishing of leaf area and total biomass production [6]. Therefore, to maintain the high productivity and quality of wheat cultivars under thermal stress, detailed knowledge of their impact on plant development and growth regulation is crucial for studying plant adaptation which is important both for basic research and application in agriculture.

Wheat (*Triticum aestivum* L.) is one of the important domesticated cereals in worldwide production that is cultivated on about 217 million ha in a range of environments largely temperate as well as under tropical and subtropical temperatures, which an annual production of about 651 million tons [7]. This distribution implies that the crop is versatile and adapted to different growth conditions [8]. This crop represents a major resource for food and feed; especially in Europe and North America as well as in Latvia it provides approx. 54.9% (2021) of the total cereal production [9]. It was shown that when wheat plants were exposed to thermal stress, many growth parameters, including plant length, fresh and dry weights, the relative growth rate as well as leaf area tended to decrease [10-11]. The growth, development, reproduction, as well as defense, and acclimation of higher plants, are influenced by various stressful factors, both abiotic and biotic. Since adverse climatic weather events are likely to continue, there is therefore an urgent need to use rational and system-based approaches to develop crop plants with increased tolerance to both biotic and abiotic stress factors.

The present study was designed to elucidate the morphological alterations in three Latvian wheat cultivars (cv. 'Creator', 'Galerist', 'Skagen') exposed to short-term high temperature.

II. MATERIALS AND METHODS

Plant material and growth conditions

Three Latvian commercial etiolated winter wheat (*Triticum aestivum* L.) cultivars: 'Creator', 'Galerist', and 'Skagen' that are common in Latvia were used in this study. The seeds were germinated under the controlled condition at 26°C on moist filter paper in darkness for 24 h. After 24 hours of germination on moist filter paper, containers with etiolated wheat seedlings of equal length were transferred to a plant growth chamber maintained at 26°C and 75% relative humidity in the darkness. On the 4th day of development etiolated wheat seedlings of equal length were separated into two groups: one group of three winter wheat cultivars continued growth at 26°C, but another experimental group was subjected to short-term (1 h) high temperature (42°C). After a short-term (1 h) high temperature (42°C) plant material (first leaves, coleoptiles, and roots) was harvested and analyzed for the following growth parameters (maximum length of root, first leaf, and coleoptile length).

Morphological parameters

To assess the impact of short-term high temperature on some plant growth parameters e.g. maximum length of root, length of first leaf, and coleoptile, seedlings weight, the 6-day-old wheat seedlings were chosen randomly and the lengths in cm were measured using a graduated ruler with a precision of 1 mm. The growth parameter values were compared with those of the control groups. Fresh wheat seedlings were weighed to determine their weight (g/seedling) from 30 seedlings.

Statistical analysis

All the data are reported as mean ± standard deviation (SD). Each value was the mean (n=30) of 3 replicates. The significant difference between the experimental and the control group was set at $P \leq 0.05$.

III. RESULTS AND DISCUSSION

Many crops often encounter extreme heat stress during the growing reproductive periods, which brings greater loss of agricultural production, thus highlighting a greater need for understanding how plants respond to adverse conditions with the hope of improving the tolerance of plants to environmental stress. High temperature affects germination, seedling growth, and overall wheat crop growth and productivity [12]. The morphological alterations of plants are closely subjected to environmental influences. Morphological responses such as accelerated stem elongation allow a plant to escape from stressful environmental conditions [13].

The obtained results indicate that among wheat cultivars used in this study, wheat cultivar 'Skagen' showed more susceptibility to short-term (1 h) high temperature (42°C) since it showed declined all growth parameters, especially leaf length (8%) when compared with 'Creator', and 'Galerist' (Fig. 1). Recent researchers have demonstrated that high-temperature stress causes a loss of cell water content for which the cell size and ultimately the growth is reduced [14]. On the other hand, the inhibition of wheat growth characteristics under high-temperature stress would also be due to the reduction in net assimilation rate which is also another reason for the reduced relative growth rate [15]. It has been previously reported that the length of the first leaf and the maximum length of roots significantly declined in etiolated wheat seedlings exposed to prolonged high-temperature stress [16].

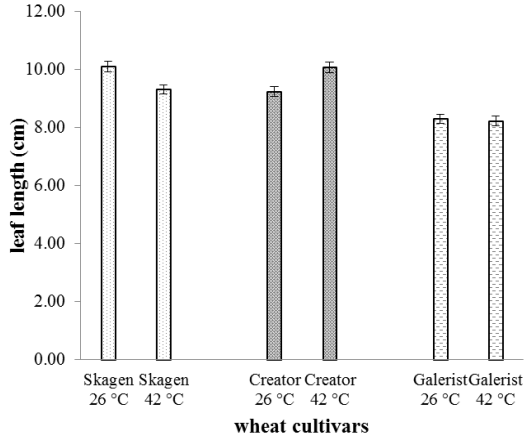

Fig. 1. Length changes of the leaf after exposure to short-term (1 h) high temperature (42°C) of Skagen, Creator, and Galerist cultivars. Each value is mean ± SE of three replicates.

Wheat coleoptiles are cylindrical organs that function for a relatively short period at the early stage of ontogenesis that sheath the first leaf [17]. The data presented revealed that short-term high temperature practically did not change the coleoptile length in studied wheat cultivars 'Skagen' and 'Galerist' compared with the control (Fig. 2).

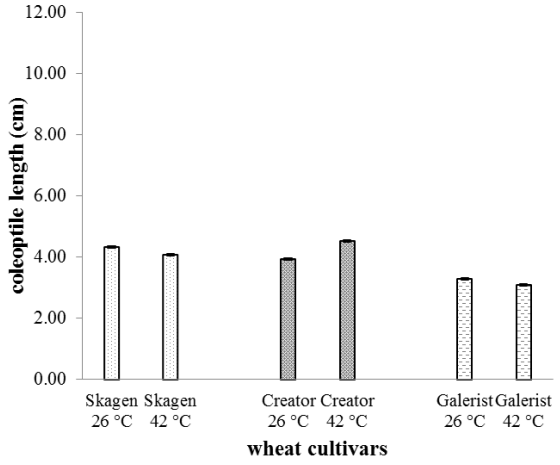

Fig. 2. Length changes of the coleoptile after exposure to short-term (1 h) high temperature (42°C) of Skagen, Creator, and Galerist cultivars. Each value is mean ± SE of three replicates.

The present results are supported by that of researchers [18], who reported that the maize coleoptile was heat tolerant at all stages of seedling development. Furthermore, our previous studies have shown that prolonged high-temperature exposure did not significantly affect the coleoptile length at the early and late stages of *Triticum aestivum* L. development (cv. Harmony) [16]. Wheat seedlings adapt to stress environments by different mechanisms, including changes in the morphological and developmental patterns as well as biochemical and physiological processes. Moreover, the current results showed that in wheat cultivar 'Creator', the lengths of the first leaves and coleoptile were stimulated by 14% under short-term high temperature. The stimulation of coleoptile growth at the early stages of development would almost certainly be due to active DNA synthesis [17] and most likely thermal stress stimulates cell division and therefore can influence growth processes.

The current results showed that short-term high temperature practically did not change the seedlings' weight in etiolated wheat cultivar 'Galerist'. The extent of reduction was more obvious in wheat cultivars 'Skagen' (11%) and 'Creator' (13%) (Fig. 4).

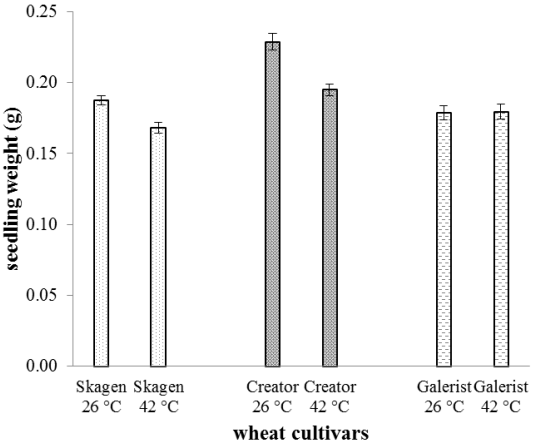

Fig. 4. Seedlings' weight changes after exposure to short-term (1 h) high temperature (42°C) of Skagen, Creator, and Galerist cultivars. Each value is mean ± SE of three replicates.

These results were in agreement with those of many authors [19-20] who reported that high temperature reduced the weight of plants. The deleterious effect of thermal stress on growth characteristics under thermal stress may be attributed to the alteration in cell division and cell elongation [21]. Additionally, the decrease in growth attributes of wheat seedlings under thermal stress may be probably due to the production of reactive oxygen species (ROS) which can pose a threat to cells by causing peroxidation of lipids and ultimately programmed cell death (PCD) [22]. Our previous findings demonstrated that in leaves and coleoptiles of etiolated wheat seedlings and grown under normal daylight conditions enhanced ROS production was induced leading to membrane biochemical and functional alterations [23-24].

The present work showed that the maximum length of the root is insignificantly affected by short-term heat stress in wheat cultivar 'Skagen' but it stimulated in wheat cultivars 'Creator' (23%) and 'Galerist' (16%) (Fig 3).

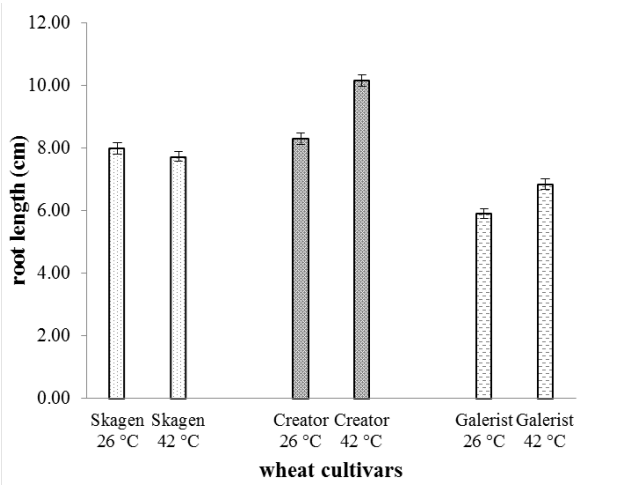

Fig. 3. Length changes of the root after exposure to short-term (1 h) high temperature (42°C) of Skagen, Creator, and Galerist cultivars. Each value is mean ± SE of three replicates.

These results were supported by researchers [25] who observed that heat-tolerant genotypes of wheat seedlings had insignificant root lengths in response to thermal stress. However, results from the previous experiments indicated that prolonged high-temperature exposure completely inhibited the growth of the root [16]. Thermal stress is assumed to reduce root growth of heat-stressed wheat plants by inhibiting root formation, branching, and growth of the existing roots. Therefore plants must develop a vigorous root system that allows them to grow and overcome any stress conditions. In this respect, morphologically, the most typical symptom of a thermal stress injury in plants is growth retardation due to the inhibition of cell expansion and a decrease in wall extensibility. The slowing of the growth processes under the influence of thermal stress revealed varietal specificity on the morphological structure of cereal, which makes it possible to diagnose the stress tolerance of cultivars in adverse conditions. That stimulates local organic farmers to use wheat cultivars that are better adapted to local environmental conditions and have the ability to resist the stress of abiotic factors.

IV. CONCLUSIONS

The *Triticum aestivum* L. growth was insignificantly affected by short-term high temperature in three Latvian cultivars ‘Creator’, ‘Galerist’, and ‘Skagen’ in comparison to non-stressed plants. According to the obtained results, wheat cultivars ‘Skagen’ and ‘Galerist’ would be classified as a species susceptible, because its growth, such as maximum length of root, length of first leaf, and coleoptile as well as seedlings fresh weight was affected by thermal stress in comparison to ‘Creator’. Furthermore, in the wheat variety ‘Creator’, the almost all growth characteristics were stimulated under short-term high temperature. Finally, measuring the morphological parameters of three Latvian wheat cultivars gave a good indication of the plant status under short-term high temperature revealing varietal specificity on the morphological structure of cereal, which it possible to define stress tolerance of variety in stress conditions for future epigenetic study.

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Temperature and Precipitation Regime Impact on Spring Barley (Hordeum Vulgare) Growth in Priekuļi Case

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***Abstract*. In Latvia, the effects of drought and extreme temperatures on spring barley have so far been little studied due to the availability of data and the fact that meteorological conditions are only one of the multi-influencing factors that affect the agricultural sector.**
Barley usually flowers before or at the same time as ear emergence. During the flowering period high ambient temperatures are critical for yield formation. If the air temperature during flowering is above 22°C the flowers of spring barley become sterile. From 2004 - 2022, a significant and positive correlation (R = 0,57) was observed between the average maximum daily temperature from sowing to ear emergence and the number of empty flowers in the main spike. A significant negative correlation (R = 0,55) was observed between plant height and the sum of precipitation from sowing to ear emergence and spike length and the sum of precipitation from ear emergence to maturity (R = −0,54), drought also negatively affects tillering rate and number of productive stems per plant.
The combination of all the above-mentioned conditions significantly impacts the yield of barley. The following and relevant findings are very important for the agricultural sector, especially in the context of climate change.

Keywords: drought, extreme temperature, spring barley, yield.

I. Introduction

Ambient temperature and precipitation regimes have a significant impact on the agricultural sector. More frequent extreme weather events are one of the most visible manifestations of climate change and may cause severe crop yield losses [1].

Drought and very high ambient temperatures are among the most significant climate-related stressors affecting the crop industry. They can significantly reduce crop yield and quality or cause complete crop failure [2]. High temperatures hinder the absorption of sunlight, thus the photosynthesis and the circulation of nutrients in plants deteriorate, growth may be interrupted, and premature aging of plants may begin [3]. Water stress causes many changes in the morphology and anatomy of plants [4]. In addition, heat and drought stress can indirectly promote the spread of pests and diseases - weakened plants are more susceptible to the effects of harmful organisms, and drought and increased air temperature limit the possibilities of using plant protection products. The frequency of hot temperature extreme events and the impact of heat and drought is predicted to increase in the future [5].

In the studies carried out so far in Latvia, the influence of temperature and precipitation regimes on the growth and yield of cereals is mostly not evaluated separately, in most studies it is mentioned as one of the influencing factors, along with agrotechnical measures, characteristics of variety, and soil conditions.

The study aimed to evaluate the impact of temperature and precipitation regimes on spring barley (*Hordeum vulgare*) growth in the Priekuļi case.

II. Materials And Methods

Data of the main growth and yield indicators were used for the period from 2004 to 2022 when the variety

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'Ansis' was grown in barley plant breeding as a standard variety in the Institute of Agricultural Resources and Economics Priekuļi research center. Barley was grown in an organic farming system. It means that the results are not influenced by using fertilizers and plant protection products. Yield and growth parameters were counted for 10 plants and the average value was calculated. Barley development stages are marked according to the BBCH scale where BBCH00 – dry seed, BBCH49 – first awns visible, BBCH51 – beginning of heading, and BBCH89 – fully ripe [6]. In this study, BBCH00 is used to indicate sowing time. The study uses data from Priekuļi (57°18'56.1" N, 025°20'16.8" E, 122 m a.s.l.) meteorological observation station (obtained by the Latvian Environment, Geology, and Meteorology Centre). Daily mean temperature (DMT), daily mean maximum temperature (DMMT and the sum of precipitation were calculated for two periods – BBCH00 – BBCH49 and BBCH51 – BBCH89. Also, the number of summer days (days with daily maximum temperature >25ºC [7]) was calculated. Data was processed and visualized in the R environment particularly using the *tidyverse* set of packages [8].

III. Results And Discussion

Although barley is considered one of abiotic stress most tolerant cereals [9] it is sensitive to drought throughout whole its development period, especially during the four development phases – at germination, at the beginning of flowering, at the anthesis, and at the beginning of a milky stage of grain. The intensity of the effects of drought depends on how long the plants are exposed to moisture deficit [10], [11].

To better show the precipitation effect on spring barley growth and yield, three years with very different weather conditions were compared. 2019 is chosen as a year with weather conditions representing the long-term average for the period from April to July and average growth and yield parameters. In 2017 none of the periods with precipitation less than 1 mm exceed 6 consecutive days but in 2018 from sowing till heading there were only 9 days with rainfall and two drought periods – 13 and 11 consecutive days when the sum of precipitation was less than 1 mm. In 2017 during the spring barley growth period, there were 11 days with heavy (≥ 10 mm) and very heavy (≥ 20 mm) precipitation but in 2018 only 3 days with heavy and very heavy rainfall. These differences were reflected in both growth and yield indicators. In 2017 the yield was 27.2 centners higher than in 2018. Significant differences in weather conditions were reflected in tillering rate, plant height, thousand-grain weight, and yield (TABLE 1). The number of grains per spike in barley species may also be affected by moisture deficit [12]. However, this study does not show a strong correlation between precipitation and number of grains per spike.

TABLE 1 GROWTH AND YIELD IN THREE DIFFERENT YEARS

Parameter	Year		
	2017 (wet)	***2018 (dry)***	***2019 (typical)***
Tillering rate, productive stems per plant	3.00	2.20	2.80
Plant height, cm	79.60	55.40	66.10
Spike length, cm	6.04	7.20	6.44
Thousand-grain weight, g	50.30	41.70	46.25
Yield, centners per hectare	58.90	31.70	45.92

Unlike other cereal species, barley flowers before anthesis. It means that the temperature right before anthesis is critical for fertility. Usually, it is in the second or third decade of June. The relatively large number of sterile flowers in the main spike in 2016 and 2021 (Fig. 1) can be explained by extreme heat when the daily maximum temperature exceeded 25°C for several days in a row immediately before or simultaneously with the beginning of the heading (BBCH51). Whereas in the years when the daily maximum temperature at the approximate time of flowering did not exceed 25°C like it was in 2004 and 2015 average number of sterile flowers in the main spike was 0.30. Considering the morphology and development characteristics of barley it is not possible to detect the exact time of flowering stage.

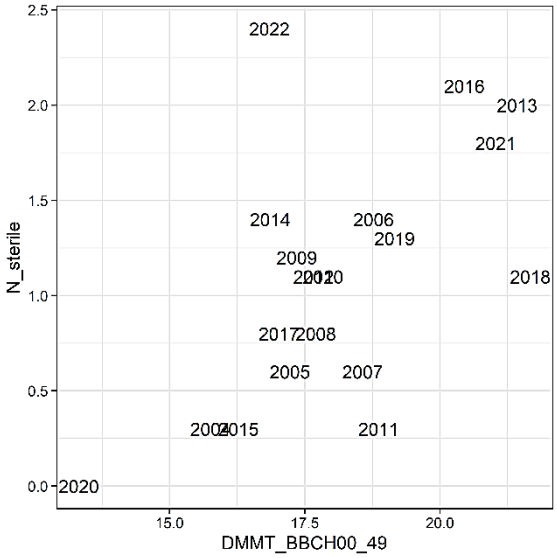

Fig. 1. Number of sterile flowers in the main spike depending on daily mean maximum temperature BBCH00 – BBCH49.

Some of the yield parameters are both affected by moisture and temperature. For instance, negative relation was observed between precipitation and mean air temperature at late development stages (from BBCH51 to BBCH89) and 1000 grain weight (TGW) (Fig. 2). Very dry weather during the grain ripening phase, especially at its beginning, accelerates grain maturation, inhibits nutrient uptake and normal grain maturation, resulting in low 1000-grain mass [13]. Higher TGW was obtained in years with moderate temperatures and relatively high levels of precipitation.

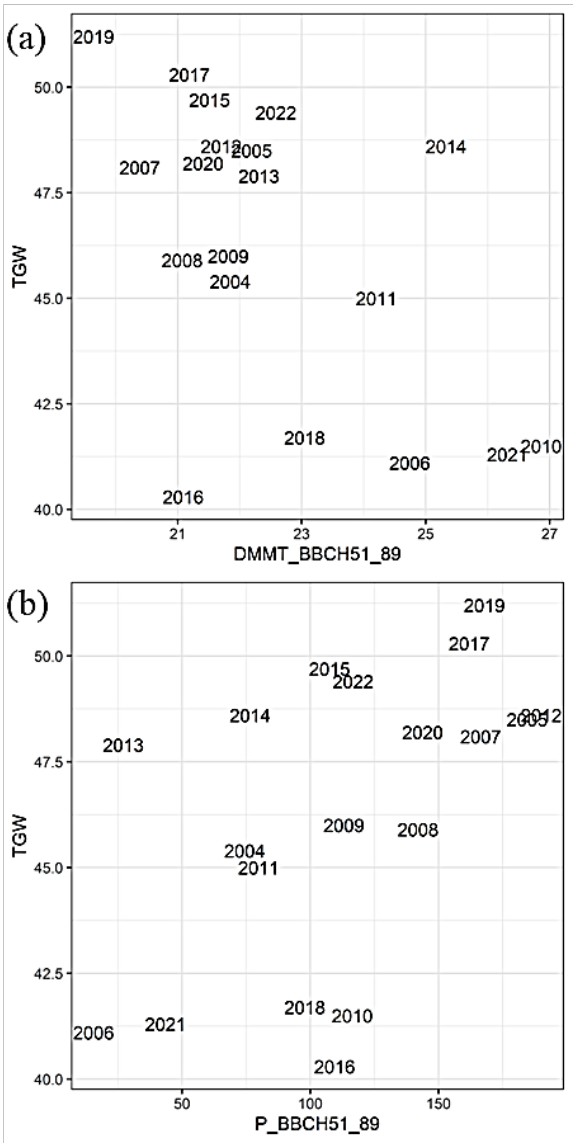

Fig. 2. Thousand-grain weight (grams) depending on daily mean maximum temperature BBCH51-89 (a) and the sum of rainfall BBCH51-89 (b).

The study shows a negative relation between yield and daily mean maximum temperature both in the early and late development stages (Fig. 3).

In a study carried out in Scotland, results highlighted that rainfall is more important than the temperature for spring barley yield [14]. Our study does not show such a relation. This difference is explained by the fact that in Latvia air temperature more often reaches an optimum above which there would be a negative effect on yield and growth of barley.

Weather conditions, including extreme weather events like drought periods, heavy rainfall, and heat waves, may also affect the length of the barley growing season. The growing period for spring barley runs on average from the first decade of May to the first decade of August (Fig. 4). The timing is mostly affected by weather conditions between April and July.

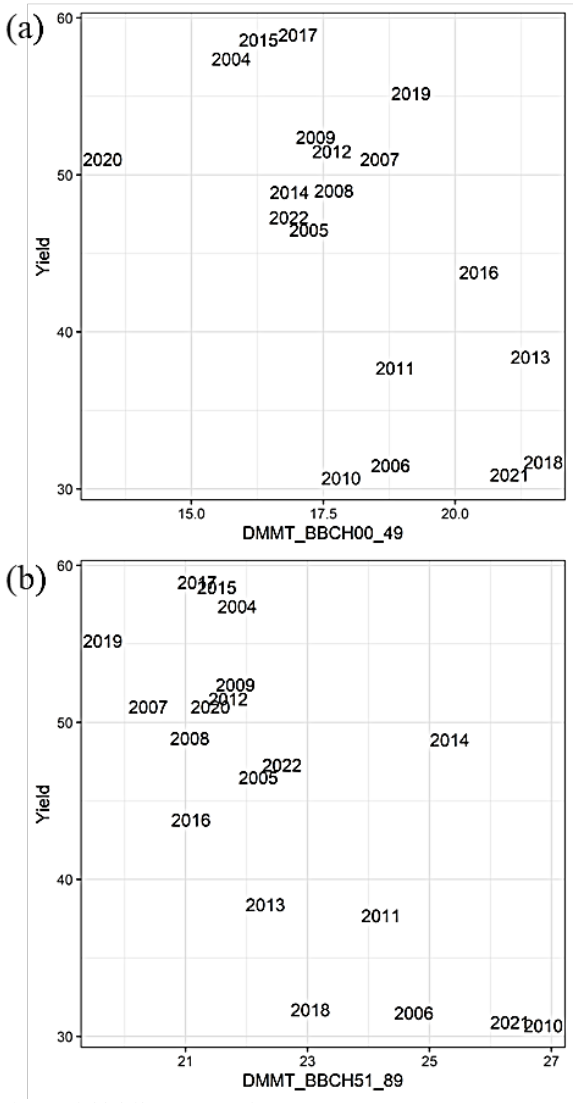

Fig. 3. Yield daily mean maximum temperature BBCH00-49 (a) and BBCH51-89 (b).

In warm and dry springs barley is sown earlier, but in cool and wet springs sowing occurs later. These observations are in line with the general trend in northern Europe, where crop development depends more on changes in air temperature than on precipitation, as is the case in southern Europe [15]. In Priekuļi a negative correlation ($R = -0{,}81$) between the daily mean maximum temperature from sowing to ear emergence and the length of the period from the beginning of heading to the end of the ripening stage has been observed. As shown in Fig. 5 high ambient temperatures in early development stages accelerate grain formation and maturation.

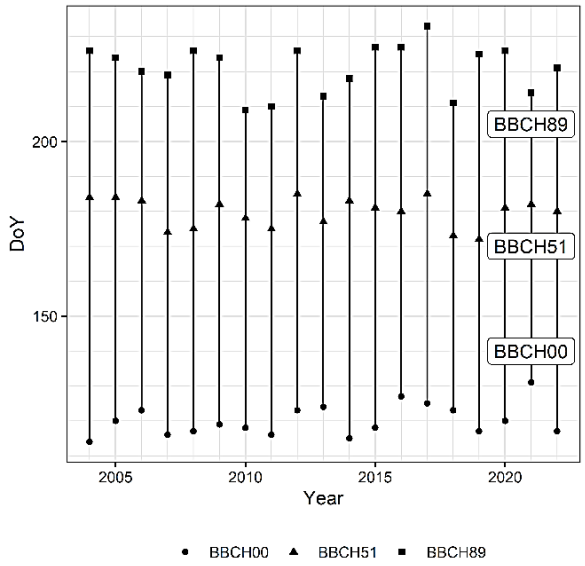

Fig. 4. Time of onset of development phases, days from the beginning of the year.

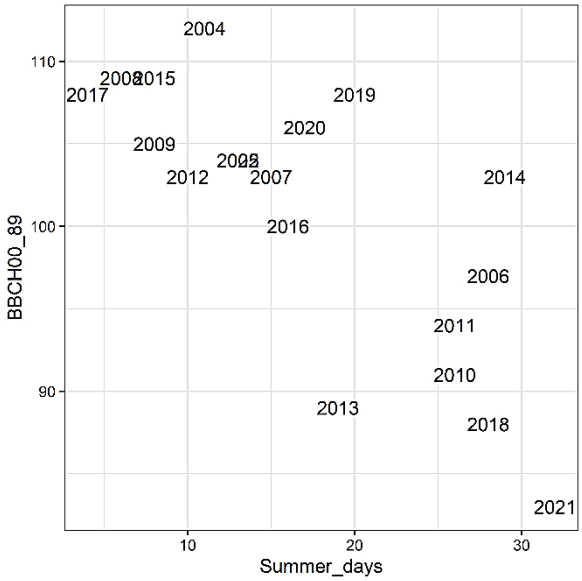

Fig. 6. Relation between the duration of days from BBCH00 to BBCH89 and the number of summer days.

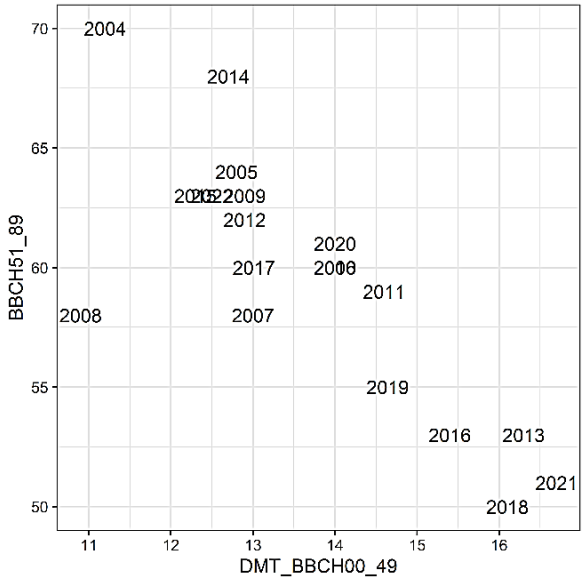

Fig. 5. Daily mean maximum temperature BBCH00-49 and duration in days from growth stages BBCH51 to BBCH89.

The optimum temperature during spring barley growth is 15 – 22°C [16]. A significant negative correlation (R = –0.76) was observed between the number of days from sowing to full ripening and the number of summer days. In years when the daily maximum temperature during the barley growth period frequently exceeded 25°C, the growing period was shorter than in years with just a few summer days (Fig. 6).

In 2021 32 summer days (from BBCH00 to BBCH89) were observed, but in 2017 there were 4 summer days during the period of 108 days. The largest number of tropical nights when the daily maximum temperature was above 20°C was also observed in 2021. in the other years examined in the study, it does not exceed 3 tropical nights from sowing to the full ripening stage.

IV. Conclusions

The results confirm that temperature and precipitation significantly affect barley in both early and late development stages. In years with frequent and long drought periods (more than 10 consecutive days) and many days with daily maximum temperature above 25°C throughout the period from sowing till full ripening, yields were significantly lower than in years when rainfall was more frequent, and temperatures mostly did not exceed species optimum. Our data also show that weather conditions at the beginning of barley development play a major role in subsequent development and yield formation.

Since barley, like other cereal species, is very sensitive to climate change, it is important to better understand its response to different temperature and precipitation regimes. This can be a good basis for developing adaptation strategies.

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Sustainability of Tourism and the Environment

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Abstract. **The tourism sector faces many important sustainability challenges. Specific challenges to be addressed include CO_2 emissions, water consumption, landscape degradation and biodiversity loss. Environmentally sustainable tourism can be considered as a level of tourism that can be realised on the basis of a sustainable or stable environment. The aim of the work is to illustrate the compromises linked to the quest for sustainability in tourism in terms of the environment. The study uses a monographic method for mapping the theoretical frame, quantitative research methods. Bibliometric analysis of academic studies on sustainable tourism and the environment have been carried out. The author conclude that tourism is sustainable, taking full account of its current and future economic, social and environmental impacts in meeting the needs of visitors, industry, environment and business communities.**

Keywords: environmental impact, sustainability, visitor behaviour.

I. INTRODUCTION

Sustainable tourism (ST) concept in its essence is based on the concept of sustainable development (SD). Historically SD has been defined in different ways [1], [2]. The SD term is comprised of two words "sustainability" and "development", which have been defined differently. Sustainability and SD usually have been viewed as synonyms, however SD is a process, while sustainability is the goal [3], [4].

In most cases the definition of SD by the Brundtlande comission, in which it is defined as development, tad responds to the needs of the current generation, whilst not underming the ability of future generations to satisfy their needs[5]. Respectively the SD aims at increasing the standard of living while not undermining the stability of environment and ecosystem. This relationship appears on the UN 2030 Agenda "Sustainable Development and its Sustainable Development Goals" (UNO Agenda for 2030 "Sustainable Development and its Sustainable Development Goals" (SDGs)], which highlighted, for example, the dependence of the importance of air quality on water, cleanliness and hygiene [(SDG6), (SDG11), oceans (SDG 14) and terrestrial ecosystems [on terrestrial ecosystems] (SDG15) [6], [7].

Unfortunately, tourism was not mentioned in the original SD concept. The fact that tourism provides economic benefits while preserving diversity in the environment was based only at the Johannesburg World Summit in 2002 [8], because previously the ST relation with environment was focused on exclusively in UN Rio Earth Summit that was held in 1992 [9].

ST was defined as tourism that takes full account of its current and future economic, social and environmental impacts, addressing the need of visitors, the industry, the environment and host communities" pēc The United Nations Environment Program and World Trade Organization [10].

The relevance of sustainable tourism to climate change, ecotourism, carbon emissions, economic growth and energy consumption are topical in academic literature. Bibliometric analyses techniques for sustainable tourism have been used by researchers mainly in terms of climate [11] and ecotourism [12], but the contribution of research to sustainable tourism in terms of the environment and its problems (STE) is insufficient.

This work provides an overview of studies on how sustainable tourism is part of a sustainable environment and in itself serves as a driving force when it is balanced with the environment and those involved in the process. The study contribution is innovative in analysing 397 Scopus STE documents published during 2013-2022. This research aim to cover four Research Questions (RQ):

RQ1: What are the STE research trends?
RQ2: How STE is associated with other industries?
RQ3: What countries, organizations and which researchers have more generated STE publications?

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RQ4: Who has the the highest number of documents and the most cited source?
RQ5: What problems have been identified in STE publications and how to overcome them?

II. Materials And Methods

The study included monographic study method for framework mapping, quantitative research methods and through bibliometric analysis techniques analyzed academic studies on sustainable tourism in terms of environmental problems and compromises to address them. The data of this study are derived from the most widely recognised international database Scopus, which includes the most dedicated high-standard journals [13]. The suitable publications where allocated by using Scopus TITLE-ABS-KEY (sustainable AND tourism AND environment AND problems). Since the bibliometric analysis allows you to identify research trends over a given period, the author limited her search to ten years. The publication search restrictions were imposed to document type article (ar), conference paper (cp) and English language ("English").

The criteria based search results including publications authors, country, institution, journals, keywords, and bibliography information was downloaded in the "CSV Excel" format. The visual map of the names resulting from these analyses and the publications quoted was obtained using the VOSviewer software [14], a tool widely used in bibliometric literature, as it is suitable for exploring large datasets [15], [16].

In order to identify environmental problems caused by tourism or its indirect effects, the texts of the articles were read and analysed on the basis of a qualitative analysis of content and a method of recursive abstraction [17], [18]. Content was collected under topics without encoding, the relevant information was re-collected based on keywords and phrases. An in-depth analysis of the text of the articles was carried out to identify problems and compromises, grouping problems by geographical breakdown (coast; islands; cities; country; parks) and social, economic and other environmental problems.

III. Results And Discussion

The monographic method for theoretical framework mapping, quantitative and bibliometric analysis are based on a March 2023 dataset comprised of 726 documents. Further 397 publications published from 2013 to 2022 on the topic of STE were selected. These publications make up nearly half (54.7%) of 726 documents. Of which Articles allocate for 66.5% and Conference papers for 21.4%. After 2015, only a few articles were published on the subject of STE (Fig .1). After 2000, the number of publications on the subject of STE showed a growing trend in response to RQ1. Fig. 1 shows the trend curve with a good degree of fit ($R^2 = 75.3$).

Publications from 2015 to 2022 accounted for 72% of the amount of documents for 2013-2022, unfortunately in 2022 a decrease of 12% in number of articles compared with 2021 was observed, possibly related to the Covid pandemic [19].

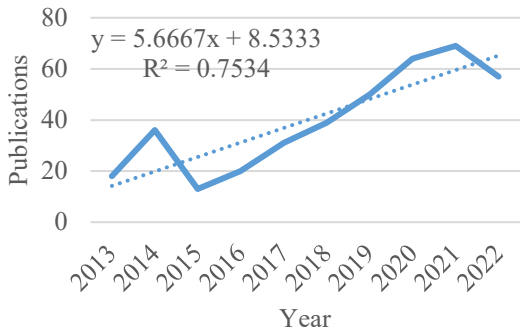

Fig. 1. Search string for sustainable tourism and environment problems.

In response to RQ2, Table 1 shows the top 10 categories with STE articles. Investment in Environmental Sciences (22.5%), followed by "Social Sciences" (15.5%) and "Earth and Planetary Sciences" (11.9%).

TABLE 1 CATEGORIES WITH THE HIGHEST NUMBER OF PAPERS ACCORDING TO SCOPUS (2013-2022)

Ranking	Category	Paper
1	Environmental Sciences	186
2	Social Sciences	128
3	Earth and Planetary Sciences	98
4	Business, Management and Accounting	90
5	Energy	69
6	Engineering	65
7	Computer Science	44
8	Agricultural and Biological Sciences	39
9	Economics, Econometrics and Fonance	27
10	Mathemathics	15

In view of the association of the tourism sector with a large business which is energy-intensive, the number of links to engineering and computer sciences studies is still insufficient and accounts only for 7.9-10.9% of all documents by subject area.

The author analysed the STE publications most produced by countries and researchers (RQ3). Top 10 countries with STE publications: China (114); Indonesia (26); Russian Federation: (23); Spain (21); Italy (18); United States (17); Australia (14); Taiwan (14); Poland (12); India (11). Fig. 2 show clearly, that China's PR has maintained a leading position in academic research with its largest contribution to academic research in recent years. Chinese Academy of Sciences, Sichuan University and Institute of Geographical Sciences and Natural Resources Research Chinese Academy of Sciences are the three leading education institutions that hold leading positions in STE Research.

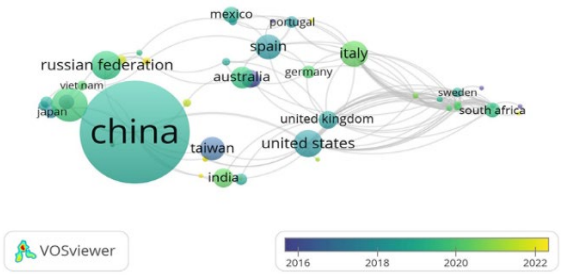

Fig. 2. Top countries with sustainability of tourism and the environment problems publications, Scopus, 2013–2022.

Chinese researcher contribution in terms of publication citations: Li, Y. cited 30 times, Wang, Y. 11, but Liu, H. 4 times.

Of the total number of 190 with a minimum number of documents of a source 5, the author selected and analysed 11 with the highest number of documents and the most quoted source (RQ4). The largest number of documents 19 is of IOP conference series: *Earth and Environment* and E3S web of conferences, while *Sustainability (Switzerland)* 11 documents and *Journal of sustainable tourism* 9 documents. The latter is with the highest number of citations – 216, *Ocean and coastal management* 216 times and in third place is the *Sustainability (Switzerland)* 125 times cited from 2013-2022.

The study analysed environmental problems and trade-offs identified in the articles for tourism (RQ5). An in-depth analysis of the text of the articles was carried out to identify problems by geographical breakdown (coast; islands; cities; fields; parks) and social, economic and other environmental problems.

Coastal environment. Suffering from the erosion caused by human behaviour: The solution is to promote better knowledge of coastal sustainability based on the results of past human actions to avoid such errors in the future. Coastal load problem: solution to create an alternative to spatial planning based on capacity building for the sustainability of the coastal zone. Lack of awareness of the main problems related to their physical functioning and the inability to resolve them, related to the complex administrative system whereby the coastal system is regulated inefficiently. Option: An integrated approach to full and efficient management of the coastal environment.

Islands. Waste treatment problem: integrated processing programme approaches and composting methods. Mass tourism: an efficiency-oriented green growth approach, proposes a unique mitigation strategy resulting from the use of natural rest.

Cities. Uncontrolled tourism development: the problem was tackled through tourism ecvinocracy. Sustainable tourism management capacity: preparing a sustainable development plan for the tourism sector.

Country. Rural areas against urbanisation. Sustainability of livelihoods: the answer is the development of rural tourism.

Parks. Lack of funding, the need to change behaviour at both national and local level of governance, challenges related to park attendance and transport: using a five-pillar system that includes economics, the environment, society, good governance and reasonable science.

Social challenges. Awareness of the growing global environmental challenges leads to changes in consumer behavior: students perceive negative demand for sustainable tourism in Slovakia. Differences of opinion between the sexes and the level of education. Social concerns: diagnosing the challenges facing local populations, offer management opportunities so to limit the impact on the environment. Educating actors and stakeholders in relation to the introduction of responsible and sustainable tourism practices. Young people's wishes to collect natural souvenirs: demarketing activities. Overcoming the traditional “business as usual” approach: setting up an effective governance framework, effectively distributing the benefits of tourism among local and key stakeholders, thereby promoting sustainability. Gray Business: Introducing a model of private accommodation. Building a private accommodation association.

Economic challenges. Conflict between the development of eco-tourism and economic benefits: a tool designed to assess the interactive effectiveness of the economy and the ecological environment.

Environmental problems. Problems with infrastructure and accessibility: The compromis is to develop a destination management model. Cooperation and coordination have been highlighted as key functions. Major consumer behaviour challenges of a sustainable environment: a systematic review and a theory perspective established in tourism and environmental psychology

On the one hand, there are reports of social vulnerability caused by excessive land use, intrusion of external crops, and air and water pollution due to traffic, accumulation of solid waste, waste water and carbon emissions, environmental and landscape degradation, tourist intervention in local society lifestyles. On the other hand, the results of the study revealed that people perceive socio-economic benefits, infrastructure development from tourism development and growth, as indicated by O.B. Baloch, et al. [20]. However, as has been identified in the analysis of the articles, there have been compromises and ways to address the environmental problems caused by tourism.

IV. Conclusions

This article uses monographic, quantitative and bibliometric methods to review relevant literature in the field of STE, clarify what compromises related to sustainability tourism in terms of the environment need to be overcome and anticipate further research.

A total of 726 articles derived from the Scopus database are being examined. Selecting the most relevant for the STE topic, with selection criteria defined by the author, tested 397 articles obtained for scientific mapping analysis. On the basis of the results of the analysis, the following conclusions have been reached:

From 2013-2022, the number of articles on the subject of STE shows a growing trend ($R^2 = 75.3$), overcoming the decline of articles due to the Covid pandemic.

The most popular articles on STE are 'Environmental Sciences', 'Social Sciences' and 'Earth and Planetary Sciences', but not enough studies with engineering and computer sciences.

In terms of number of STE documents the leading state is Chine, followed by Indonesia and Russian Federation. The leading three institutions in the PR education are from China: Chinese Academy of Sciences, Sichuan University and Institute of Geographical Sciences and Natural Resources Research Chinese Academy of Sciences. The Chinese scientist with the highest document citations is Li, Y., Wang, Y., and Liu, H.

The largest number of documents is IOP conference series: Earth and Environment and E3S web of conferences, and Sustainability (Switzerland). The highest citation is for Ocean and Coastal Management. The Sustainability journal (Switzerland) has been cited 125 times from 2013-2022.

The analysis of articles identified certain remedy solutions to given environmental problems caused by tourism as follows: (1) legal framework and quality standards; (2) imposing restrictions on excessive tourism; (3) promoting the preservation and protection of social cultural, historical, antique and natural resourses; (4) providing budget support for the preservation of ecosystems and biodiversity; (5) an integrated approach; full and efficient environmental management; (6) changes in behaviour of tourists and local populations; (7) training of participants, including young people and all stakeholders responsible and sustainable tourism; (8) diagnosis of problems; (9) effective planning and management; (10) cooperation between all those involved in tourism, communities and organisations in sustainable tourism development.

This research indicates the insufficient focus of research activity on the topic of sustainability of tourism especially in solving the problems related to the sustainability of tourism and the environment.

The author's recommend focusing the future research on the topic of tourism and environmental sustainability whilst paying attention to the change in tourist behavior in solving environmental sustainability problems.

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The Distribution of Cash Expenses for the Creation of Bioenergy Willow Plantations in Ukraine

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***Abstract*. The economic cost analysis of creating energy willow plantations in Ukraine is provided in the present paper. The experience of creating bioenergy willow plantations at scientific and industrial institutions in Ukraine has been used in the paper. The purpose of this scientific work is to conduct an analysis of the structure of cash expenses for the creation of bioenergy willow plantations based on the experience of various institutions of Ukraine. The analysis is based on a technological map created during the study on drained peat lands at Panfyly Research Station. Analyzing the cost structure by category, the data obtained during the creation of bioenergy willow plantations of Salix Energy LLC and the Institute of Bioenergy Crops and Sugar Beet were also taken into account. After analyzing all the technology stages of growing bioenergy willow, it was revealed that the most expensive is the second stage associated with the preparation for planting and planting willow cuttings in the context of the pricing policy in Ukraine. In general, more than 60% of all expenses fall upon the first year of cultivation. According to the experience of Ukrainian institutions, the cost structure will have a significant shift towards planting material - 55-60%. The remaining costs are distributed during the use of equipment in the field, which constitute 26-30% and transportation costs respectively are 12-19%.**

Keywords: biofuels, willow, renewable fuels, economic efficiency, energy willow, bioenergy plantation.

I. INTRODUCTION

To gain positive results in becoming an energy-independent country Ukraine should develop alternative energy sources. Reducing the level of Ukraine's energy dependence on the traditional fuel export countries and the transition to environmentally friendly alternative energy sources is validated in the Energy Strategy of Ukraine for the period until 2030 [1]. This strategy declares indicators of the growth rate of alternative energy sectors and the field of biomass energy as the most economically attractive renewable energy source. Therefore, the issue of its effective sustainable production is extremely relevant.

It is known that the theoretically expedient potential for growing woody biomass to meet energy needs in Ukraine is one of the largest in Europe, but the level of use of these opportunities remains insufficient. Thus, the volume of planting and use of plantations of woody energy crops in real conditions underperforms the potential production volumes declared in the strategy. In addition to external facts that today affect life in Ukraine as a whole, one of the main reasons for this is the low investment attractiveness of such projects, which is due to the high level of initial costs and the long term of obtaining the first income (it is 3-4 years for energy willow) [3, 4].

Taking into account the national course towards European integration, it should be noted that according to the European Union Directive No. 2009/28/EC (Promotion of the use of energy from renewable sources), plantations of fast-growing energy plantations should be located on the lands that are not used for growing crops [5]. Using the existing potential for the creation of bioenergy willow plantations in unproductive and cultivated lands could help

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solve energy problems at the local level and would significantly reduce the volume of natural gas imports. To ensure the positive dynamics in the development of this sector, it is necessary to use modern approaches to the development of technological maps, taking into account the current situation in the capital markets and the abilities of national producers.

Research on the economic efficiency of growing perennial bioenergy crops in Ukraine was carried out in many scientific institutions, for example, based on experimental plantations of Research and Breeding Centers in Yaltushkivtsi, Uladovo-Liulyntsi, Bila Tserkva, Ivanivtsi, Veselyi Podil and DPDG «Salyvinkivske» of the Institute of Bioenergy Crops and Sugar Beet [6-7].

Fundamental scientific and practical research on using biomass energy for energy needs in Ukraine, the creation of willow plantations and the study of economic efficiency were carried out by V. Sinchenko, H. Kaletnik, M. Roik, H. Heletukha, I. Sliusar, I. Hnap and others [8-16]. However, the issue of the cost-effective use of bioenergy potential of drained peat lands requires further research.

The research work is carried out in the joint Ukrainian-Polish educational and scientific laboratory "DAK GPS" of Higher Education Institution "Podillia State University" within the framework of the scientific topic "Agrobiomass of Ukraine as the energy potential of Central and Eastern Europe" (registration number 0119U103056). The laboratory studies are focused on the development, justification and economic evaluation of the technological processes of energy willow and the designing of an automated machine for its planting [17-19]. Employees of the laboratory are also working on finding opportunities to optimize technologies for growing various agricultural and energy crops and evaluating the energy potential of plantations [20-22].

The purpose of this scientific work is to conduct an analysis of the structure of cash expenses for the creation of bioenergy willow plantations based on the experience of various institutions of Ukraine.

II. MATERIALS AND METHODS

The article material is based on the processing of data from the study on the cultivation of bioenergy willow, that was conducted at Panfyly Research Station of the NSC "Institute of Agriculture of the NAAS" (Panfyly, Yahotynskyi district, Kyiv region) on drained peat lands withdrawn from cultivation. More than 20 species, hybrids and forms of willow were selected for the analysis. Scientists have found that almond-leaved willow (Salix triandra L) and rod-shaped willow (Salix viminalis L) are the most appropriate for a given soil and climatic conditions. The use of these species provides a yield of up to 54.1 tons of absolutely dry biomass per hectare once every two years [23].

The traditional methods were used in the present study. Economic characteristics were calculated using technological schemes and methodological approaches developed at the Institute of Bioenergy Crops and Sugar Beets of the National Academy of Sciences of Ukraine [6, 25].

The whole process of creating a bioenergy plantation was divided into four technological stages:

- Preparation of the site for the plantation
- Soil preparation and planting shoots
- Plantation care
- Harvesting on an industrial basis

The main emphasis in the choice of agricultural machinery is on its accessibility in the Ukrainian market and minimization of initial investments. The calculations were carried out taking into account the minimization of the use of any chemical agents in the production process due to the environmental characteristics of drained peat lands and the legislation relating to the protection of the water bodies of Ukraine. The technological map of the bioenergy plantation creation process at Panfyly Research Station is presented in Table 1.

TABLE 1 COST STRUCTURE AT THE FIRST STAGE OF CREATING A BIOENERGY PLANTATION (1 HA) ON DRAINED PEAT LANDS

№	Technological operations	Time frame, quarter	Units of measure	Scope of work	The composition of the unit		Total, $	Note
					Tractors	Agricultural machines		
The 1st year								
STAGE 1 – Preparation of the site for the plantation								
1	Area preparation (mulching)	II	ha	1	MTZ-892	Mulcher RKR-1, 5M	20,15	
2	Peeling (two-time treatment)	II	ha	2	MTZ-892	AG-2.4	19,79	The depth of tillage is 10-12 cm.
3	Ploughing	III	ha	1	MTZ-892	PLN-3-35	19,55	to a depth of 20-25 cm
4	Continuous tillage	III	ha	2	MTZ-892	ZPG-15	5,47	
Total for the first stage							**64,96**	
STAGE 2 – Soil preparation and planting shoots								
5	Presowing tillage	IV	ha	1	MTZ-892	Europack AP-3	11,14	to a depth of 5-6 cm.
6	Loading packs of cuttings	IV	pack	600	By hand		305,21	25 cuttings per pack
7	Transportation to the place of planting	IV	pack	600	MTZ-892	2PTS-4	12,93	
8	Planting shoots	IV	ha	1	John Deer 8295 R	2-row EGEDAL Energy Planter	21,60	depth 18-19 cm, planting density 15000 pcs/ha)
Total for the second stage							**350,87**	
Total for the year							**415,83**	
The 2nd year								
STAGE 3 – Plantation Care								
9	Continuous tillage	II	ha	2	MTZ-892	LNG-15	5,47	(harrowing) when weeds appear

№	Technological operations	Time frame, quarter	Units of measure	Scope of work	The composition of the unit		Total, $	Note
					Tractors	Agricultural machines		
10	Planting cuttings	II	pcs.	2250	By hand	Kolesov sword	84,06	in places, not sprouted, if less than 85% of those planted remain
11	Loosening the soil between the rows twice	II	ha	2	MTZ-892	LSD-3.1	9,74	
12	Technological cut	IV	ha	1	John Deer 8295 R	Ny Vraa JF Z200-HYDRO/E	38,07	
13	Transportation of bio-raw materials to the place of preservation or use	IV	mt	10	MTZ-892	TSP-10	13,53	(10 km)
Total for the second year							**150,88**	
The 3rd year								
14	Loosening the soil between the rows twice	II	ha	2	MTZ-892	LSD-3.1	16,23	
Total for the third year							**16,23**	
Total for the third stage							**167,11**	
The 4th year								
STAGE 4 – Harvesting willow on an industrial basis								
15	Willow harvesting with chopping into chips	IV	ha	1	John Deer 8295 R	Ny Vraa JF Z200-HYDRO/E	36,07	
16	Transportation of bio-raw materials to the place of preservation or use	IV	mt	70	MTZ-892	TSP-10	80,70	(10 km)
Total for the fourth year and stage							**116,77**	
Total at the time of receiving the first harvest							**699,71**	

A site with soil and climatic conditions typical for drained peatlands was chosen for the cultivation of Salix willow at Panfyly Research Station.

Stage I. Preparation of the site for the plantation.

The preparation of the site consisted of the following technological operations: mulching, peeling (2-times), ploughing, and continuous cultivation. The available general-purpose tillage machines can be used for the cultivation of the site for the plantation. In the present study, mulching was carried out with the help of an RKR-1.5M rotary mulcher, since there were young trees and dense herbage on the site. Although, the specialists of the Educational and Scientific Center of "The Institute of Agriculture of the NAAS" note that its need in most cases can be considered as 25% of the total area of the site. To trim rhizomes, and destroy wheatgrass and other weeds, a two-time peeling was carried out to a depth of 10-12 cm with an AG-2.4 tillage disk unit. The next technological operation was ploughing to a depth of 20-25 cm with PLN-3-35 general-purpose plough. After that, two-time continuous tillage was carried out using the ZPG-15 harrow. This enabled us to destroy sprouted weeds and level the surface of the field.

It should be noted that high-quality preparation of the field is fundamentally important since the life of the plantation is usually 8-12 two or three-year harvest cycles [16]. The preparation of the field for planting energy willow is generally similar to the technologies for growing traditional crops, so there is a similar cost structure at this stage.

Stage II. Soil preparation and planting shoots.

Soil cultivation before planting is an integral part of a single process of growing energy willow and should be carried out without a gap in time and outpace planting by two-four aisles of the planting unit. Such cultivation is aimed at maximizing the preservation of moisture, warming up the soil, creating optimal conditions for engraftment and further growth of cuttings, and ensuring a finely lumpy top layer of soil [24].

Europack AP-3 unit was used for pre-sowing tillage and it ensured high-quality loosening of the soil, improved aeration, reduced the number of weeds and created optimal conditions for engraftment and growth of willow cuttings. The plantations were laid in strips of 2 rows. The Egedal Energy Planter was used for the mechanized planting of bioenergy willow. The cuttings were planted to a depth of 18-19 cm, the distance between the cuttings in the row is 0.60 m, and the distance between the rows is 0.70 m. The Europack AP-3 unit was used for pre-sowing tillage, which ensured high-quality loosening of the soil, improved aeration, reduced the number of weeds and created optimal conditions for engraftment and growth of willow cuttings. The plantations were laid in strips of 2 rows. For the mechanized planting of bioenergy willow, the Egedal Energy Planter was used. The cuttings were planted to a depth of 18-19 cm, the distance between the cuttings in the row is 0.60 m, and the distance between the rows is 0.70 m. According to this scheme, the density of plantings was 15000 pcs/ha [23].

Stage III. Plantation care.

In the case of laying bioenergy plantations on drained peat lands, the care of the sites is of decisive importance. Weeds pose the greatest danger to the first cycle of growing willow since the planted shoots themselves cannot effectively resist them. If you do not carry out adequate control in the first cycle, then in the future the plant will not be able to provide the planned yield.

In early spring, continuous tillage was carried out with ZPG-15 (MTZ-892) harrow before germination of cuttings to control the number of weeds. The cuttings were planted manually with the help of a Kolesov sword to avoid omissions, due to the death of cuttings. Such an operation is recommended if less than 85% of plants are rooted.

Loosening of the soil between the rows is carried out to improve the water-air regime and the conditions for the growth and development of plants. The need, frequency and depth are determined by taking into account the following factors: the state of plant development, the amount of precipitation, soil density and the presence of weeds.

During the first year of the growing season, the planted cuttings produced 1-3 shoots with a maximum height of up to 3m. At this stage, a technological cut was made to stimulate willow to better

noting that in recent years there has been a discussion in the scientific community regarding the need for technological cutting. Therefore, it is advisable to conduct such research in the future for specific soil-climatic and hydrological conditions.

The complex agrotechnical means should provide reliable control of the number of weeds (especially in the first harvest cycle), soil aeration and moisture level control. It is worth noting that the costs of planting cuttings in different fields can vary significantly even within the same farm. The main factors affecting their size are the consignments of planting materials, compliance with planting technology and weather conditions.

Technological cutting is performed by the same technique as harvesting.

Stage IV. Harvesting willow on an industrial basis.

Harvesting of bioenergy willow begins after the end of sap flow in the 3rd year of the growing season. Cutting is carried out at a height of 5-10 cm from the surface of the soil.

Mechanized harvesting with grinding into chips was carried out using Ny Vraa JF Z200-HYDRO/E mounted unit to John Deer 8295R tractor. The resulting biomass was transported to the place of storage by the TSP-10 dump trailer (tractor MTZ-892). The same technique was used for technological cutting in the third stage. The method of harvesting and transporting biomass may vary depending on the capabilities and needs of the farm. If necessary, natural drying is carried out at the edge of the field in piles. However, it is generally accepted practice to transport wet biomass to an energy-generating facility immediately after harvesting [25].

The analysis results of this technological map were compared with the data obtained during the laying of bioenergy willow plantations of Salix Energy by LLC and the Institute of Bioenergy Crops and Sugar Beet.

III. Results and Discussion

The data of the technological map of energy willow cultivation developed at Panfyly Research Station (Table 1.) allow us to analyze costs in terms of the course of individual technological operations and in the time dimension in general, which will afford to plan the need for future investments when laying a bioenergy willow plantation. It will also be important to analyze the cost structure, which involves assessing the prospects for choosing optimal economically sound decisions.

The costs of individual technological operations are presented in Figure 1. The cost diagram shows that operations 6 and 10 require the largest peak expenditures of funds, which are associated with the purchase and preparation of planting material, as well as operations related to the collection (12, 15) and transportation (13, 16) of the collected products.

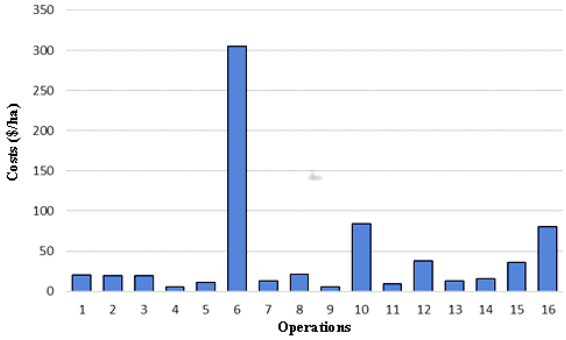

Fig. 1. Distribution of costs for individual operations in the cultivation of bioenergy willow.

Also, the cost structure over time should be analyzed to assess peak investment needs. Figure 2 demonstrates the costs required by the technology of planting a bioenergy willow plantation per quarter of each of the four years of the first growing cycle. As can be seen from the schedule of quarterly expenses, the main financial burden falls on the first two years of cultivation with a clear peak in the fourth quarter of the first year. This is correlated with the previous schedule of transaction costs (Fig. 1), where this peak falls on the operation associated with the acquisition of planting material. In addition, this graph shows that after the second year of planting the plantation, costs for some time are practically minimized, followed by a peak at the end of the cycle during harvest.

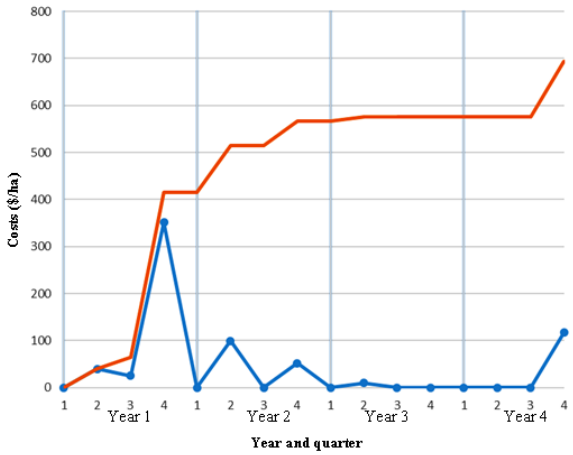

Fig. 2. Cost dynamics during the first cycle of creating an energy willow plantation at Panfyly Research Station: blue – expenses by quarters of the year, red – total accumulated costs for the entire four-year cycle.

More generally, such data demonstrate the size of costs for growing energy willow for the years of the first cycle (Fig. 3a) and the main stages of technology (Fig. 3b)

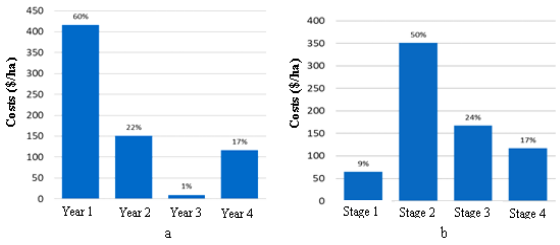

Fig. 3. Distribution of costs for growing bioenergy willow: a) by years of the first cycle; b) by the main stages of cultivation.

Peaks can be clearly distinguished during the first year of cultivation and the second stage of technology in these diagrams. The largest part of the costs at this stage is formed by the cost of planting material (laid down in point No. 2 – a load of packs of shoots). That is, these costs can be influenced by the search for more or less costly sources of obtaining cuttings of energy willow, the price of which varies widely depending on the type of willow and the nature of its origin. in this technology, The cost of planting material was 0.02 USD / pcs under mentioned above technology according to the reports of Panfyly Research Station, which is also specialized in the selection of willows.

There are three main categories of costs based on the data in Table 1:

- the cost of planting material
- the cost of using equipment
- transportation costs

To determine the cost structure by category, a grouping of technological processes from Table 1 into certain categories was carried out (Table 2).

TABLE 2 COST STRUCTURE AT THE FIRST STAGE OF CREATING A BIOENERGY PLANTATION BY COST CATEGORIES

№	Cost category	Expenses, $/ha	Note
1-4	Tillage	64,96	mulching, peeling, ploughing, harrowing
5	Tillage	11,14	presowing treatment
6	Planting material	305,21	600x25pcs
7	Transportation	12,93	
8	Planting	21,60	
9	Tillage	5,47	harrowing
10	Planting material	84,06	2250 pcs
11	Tillage	9,74	inter-row processing
12	Technological cut	38,07	10mt; 10km
13	Transportation	13,53	10mt
14	Tillage	16.23	inter-row processing
15	Harvesting	36,07	70mt
16	Transportation	80,70	70mt; 10km
Total for the use of agricultural machinery (tillage, planting, harvesting)		**203.28**	Operations: 1-4; 5; 8-9; 11-12; 14-15
Total for transportation		**107,16**	Operations: 7; 13; 16
Total for planting material		**389,27**	Operations: 6; 10
Total		**699,71**	

Figure 4 shows the share of each of these categories. About 56% of all costs fall upon the purchase of planting material. Such a high percentage focuses our attention on this component of the technology.

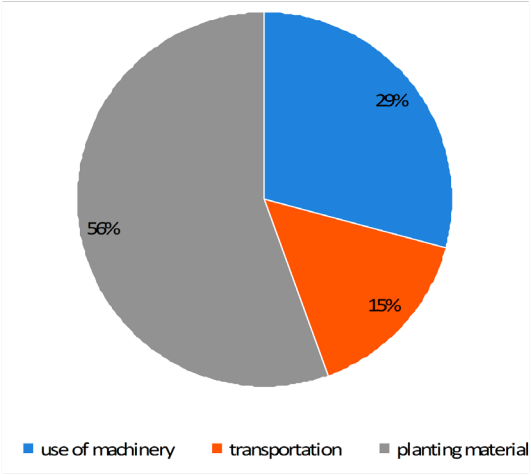

Fig. 4. Cost structure for the first cycle of creating a bioenergy plantation at the Panfyly Research Station.

Comparing these cost structures in the studies of Salix Energy LLC and the Institute of Bioenergy Crops and Sugar Beet (Fig. 5) with the previously analyzed data (Fig. 4), it can be noted that they also take into account such components as land lease, which also generates significant expense. In addition, the costs of fuel-lubricating materials, depreciation of technical means and wages (Fig. 5b) are separately taken into account, which in other cases are included in the costs of soil preparation, planting, care and other operations for the use of equipment.

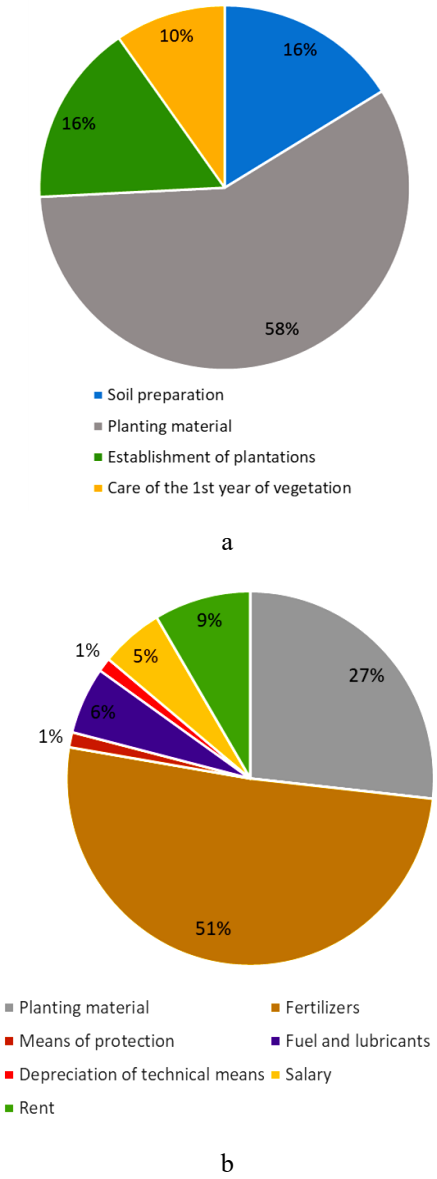

Fig. 5. Cost structure: a) for laying an energy willow plantation in Salix Energy LLC [27]; b) in the first year of rod-shaped willow (Salix viminalis L) cultivation at unproductive lands according to data of the Institute of Bioenergy Crops and Sugar Beet data [7].

The costs of fertilizers and plant protection products (about 51%) are the main difference in the research of the Institute of Bioenergy Crops (Fig. 5b). As noted above, during the study at drained peat lands of Panfyly Research Station, the need for mineral fertilizers and herbicides was not established. Whereas the costs presented in Fig. 5b relate to the cultivation of willow on unproductive lands. If we hypothetically discard these costs, we see that the cost structure for the main categories for all three studies remains approximately the same. That is, if in the cost structure we leave only those that are obligatory for all technologies, then the cost of planting material is 55-60%, and the rest of the costs are distributed during the use of equipment in the field, which is 26-30% and transportation is 12-19%.

IV. Conclusions

The theoretically relevant potential of growing wood biomass for energy needs in Ukraine is one of the greatest in Europe. Using the existing potential for the creation of bioenergy willow plantations on unproductive and cultivated lands could help solve energy problems at the local level and would significantly reduce the volume of imports of fossil energy sources. The present study uses the experience of creating bioenergy plantations of willow at scientific and industrial institutions. The analysis is based on a technological map created during the study on drained peat lands at Panfyly Research Station. The total costs at the time of receiving the first harvest from the bioenergy plantation amounted to 699,71 USD / ha. The period shows the heterogeneity of investment in the process during the four-year cycle before the first harvest. The technology was divided into 4 stages. After analyzing all the technology stages of growing bioenergy willow, we can conclude that the most expensive is the second stage, where the price of planting material plays the greatest role. In general, the first year of cultivation accounted for 60% of all expenses.

Analyzing the cost structure by category, the data obtained during the creation of bioenergy willow plantations at Salix Energy LLC and the Institute of Bioenergy Crops and Sugar Beet were also taken into account. Each approach and individual technologies have its characteristics, however, when considering specific natural climatic and production conditions, additional costs may incur, but if they are not taken into account, then according to the experience of Ukrainian institutions, the cost structure will have a significant shift towards planting material - 55-60%, the rest of the costs are distributed during the use of equipment in the field, which is 26-30% and transportation is 12-19%, respectively.

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Rapid Prototyping of Pear Detection Neural Network with YOLO Architecture in Photographs

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Abstract. **Fruit yield estimation and forecasting are essential processes for data-based decision-making in agribusiness to optimise fruit-growing and marketing operations. The yield forecasting is based on the application of historical data, which was collected in the result of periodic yield estimation. Meanwhile, the object detection methods and regression models are applied to calculate yield per tree. The application of powerful neural network architectures for rapid prototyping is a common approach of modern artificial intelligence engineering. Meanwhile, the most popular object detection solution is YOLO architecture. Our project team collected the dataset of fruiting pear tree photographs (Pear640) and trained YOLOv5m with mAP@0.5 95% and mAP@0.5:0.95 56%. The obtained results were compared with other YOLOv5-7.0 and YOLOv7 models and similar studies.**

Keywords: artificial intelligence, deep learning, smart horticulture, yield estimation.

INTRODUCTION

Pears are the third most economically important fruit crop globally [1], [2], reaching 25.7 million tons in 2021 [3]. Although it is not the most important fruit crop in Latvia, it forms a very important niche product with high added value, and the area of pear growing is about 200 ha [4]. Pear growing faces various challenges beyond our control: environmental conditions and their changes and biotic factors such as diseases and pests. The grower's options are choosing appropriate cultivars, adjusting cultivation technologies to reduce environmental impact, and obtaining the optimal yield. One of the solutions is the development of a yield model, in which by changing the parameters of the yield-forming components and the applied agrotechnical practice, it is possible to predict the potential yield and evaluate how a change in a specific agrotechnical technique could affect it. Considering pear orchards' longevity and induced effects' time lag, such a forecasting system can significantly assist growers in their decision-making process. Timely and accurate prediction of fruit yield is also of great economic importance to optimally plan post-harvest activities, storage facilities and sales. Developing such yield forecasting systems has been going on for a long time for various fruit plant species [5]. For example, for apples, the 'Bavendorf' yield forecast model is still recognized as the best one, which is based on such parameters as the characteristics of the analyzed trees (cultivar, rootstock, orchard age), orchard characteristics (slope, elevation and area), the fruit-set density in the given year and the average fruit mass at a harvesting time [6]. However, the disadvantage of all these forecasting systems is the need for high-quality, large-scale data because the accuracy of the developed model and the correspondence of the forecasted and real harvested yield depend on it [7]. Manual collection of such data is time-consuming and complex and may be affected by the subjectivity of the evaluator, which in turn may affect the

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usefulness of the forecasting system. Therefore, tools that provide accurate and automated evaluation of characteristics involved in pear fruit development should be developed, including through pear imagining.

YOLO ("You Only Look Once") is a well known and popular object detection architecture, which was firstly presented in 2016 [8]. The advantage of YOLO is its unified architecture with real-time image processing speed. The previous solutions were based on a sliding-window approach or the region proposals.

YOLO is a complex system, which can have minor and major improvements. At this moment, there are many versions of YOLO architecture, which are developed by different authors. For example, YOLOv4 is based on CSPDarknet53 backbone, Spatial pyramid pooling (SPP) additional module, PANet path-aggregation neck, and YOLOv3 (anchor based) head [9]. YOLOv5 is relatively similar to YOLOv4, the focus layer can be mentioned as the difference [10]. Meanwhile, YOLOv5 has technological advantages such as PyTorch framework, code readability, easy configuration of environment and other user-friendly things [11]. Speaking about YOLOR, it was based on the new concept with a unified model, which connected explicit and implicit knowledge [12]. At the beginning of 2023, YOLOv7 [13] and YOLOv8 [14] can be mentioned as the youngest architectures. YOLOv7 presented Extended Efficient Layer Aggregation Network (E-ELAN). Meanwhile, the anchor-free model is presented in YOLOv8 for performance and accuracy improvement.

YOLO was already applied for yield estimation tasks. For example, Wnag et al. (2022) obtained next accuracy results for yield estimation of litchi fruits (mAP): YOLOv4 - 82.87%, YOLOv5s - 88.9%, YOLOv5 improved by them - 92.4% [15]. Meanwhile, Lyu et al. (2022) experimented with yield estimation of green citrus (mAP@0.5): YOLOv5 97.51% and improved YOLOv5-CS 98.23% [16]. One more example, banana detection solution was presented by Fu et al. (2022): YOLOv3 - 93% mAP and YOLOv4 93.69% mAP [17]. However, despite the existing experiments, there is a restricted number of studied cultivars that is mainly related to the limited number of datasets or their open access availability. Another knowledge gap is the most suitable YOLO model for rapid prototyping of yield estimation solutions, because each YOLO architecture traditionally provides different models with different size and accuracy (Pareto front).

Our study proposes two original things in this article: 1) open dataset with natural images of pear trees in the fruiting stage, which we called Pear640; 2) the accuracy comparison of YOLOv5-7.0 and YOLOv7 templates for the rapid prototyping of yield estimation models.

Additionally to our pear dataset Pear640, two open datasets were selected for experiment: grape dataset "WGISD" [18] and apple dataset "MinneApple" [19]. Considering to the YOLO architectures: YOLOv5n, YOLOv5m, YOLOv5l, YOLOv7 and YOLOv7-X models were selected.

The YOLOv5m was the most suitable model (trade-off solution) for rapid development in our experiment. YOLOv5m achieved accuracy mAP@0.5 95% and mAP@0.5:0.95 57%. YOLOv7 showed the worst result in the cases of Pear640 and MinneApple, but YOLOv5n showed significantly smaller accuracy in the case of WGISD. Meanwhile, the accuracies of YOLOv5m and YOLOv5l were relatively similar, therefore YOLOv5m was more suitable due to its smaller size (latency).

I. MATERIALS AND METHODS

A. Pear640 Collection and Annotation

Digital images of pear fruits were collected in the experimental site of the Institute of Horticulture (LatHort) with cultivars 'Suvenirs' and 'Mramornaya' on seedling rootstocks 'Kazraushu' with planting distances 4×5 m (500 trees per 1 ha). (Krimūnu parish, Dobeles district: 56.610169, 23.305956). Collection of fruit images of 'Suvenirs' and 'Mramornaya' was done at the end of August (105 days after full bloom) prior to the harvest.

The collection of digital images was carried out using a digital photo camera Nikon D40 (Image size: 3008×2000; 6.0 MP).

The collection of images was carried out in field conditions, in the orchard at the distance from the tree planting point 2.5 m (middle of alleyway). The whole canopy of trees was photographed as separate objects. The images were taken in front of the tree (tree trunk, planting point), perpendicularly the tree row from the west side of rows (the rows of pear trees oriented from north to south) around noon (11:00–13:00) at clear sky natural light conditions.

The dataset annotation process was performed manually using MakeSense annotation tool. The annotations consisted of bounding boxes around a pear in the photographs, indicating the location of the pears within the image. Then the annotated images 3008x2000 were automatically cropped out on 640x640 images with overlap 30% and validated manually, because YOLOv5 and YOLOv7 work with input size 640x640, but image reduction was not possible due to small bounding boxes, which could achieve size until 25x25. Once all the images were annotated, they were stored in a YOLO format. The result dataset is available in Kaggle repository under CC-BY license [20].

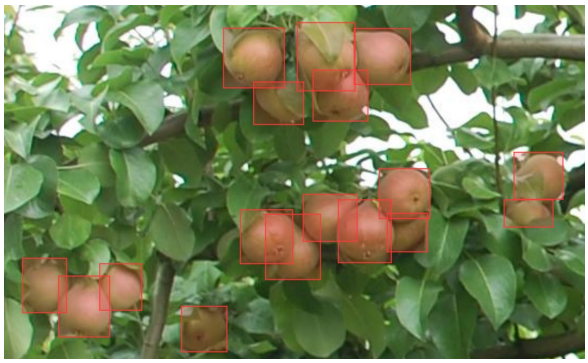

Fig. 1. Pear640 image example.

B. Comparison Datasets

WGISD dataset [18] is a dataset consisting of 300 images containing 4432 grape objects identified by bounding boxes (see Fig. 2). The dataset was used for several reasons. Firstly, it uses a format of annotation that is easy to adapt to the YOLO algorithms. Additionally, the dataset is diverse in terms of variety. The dataset consists of images taken of different grape varieties in different weather conditions. The images were not cropped, because objects were sufficiently large.

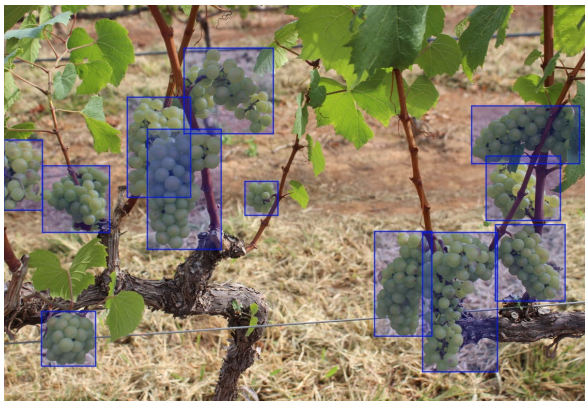

Fig. 2. WGISD image example.

MinneApple dataset [19] contains over 1000 images with over 41000 labelled instances of apples (see Fig. 3). This dataset was used for comparison for several reasons. Firstly, it contains a large number of images with also a lot of annotations. Additionally, the apple dataset is much more similar to pears than grapes. Images were cropped on 640x640 due to small objects. The annotation was not improved to save possibility to compare results with other experiments.

Experiment Design

In this experiment, we utilized YOLOv5 [21] and YOLOv7 [22] models, specifically YOLOv5n, YOLOv5m, YOLOv5l, YOLOv7 and YOLOv7-X.

The experiment was conducted on an NVIDIA RTX 2070 GPU, which provided sufficient performance for training and testing the models.

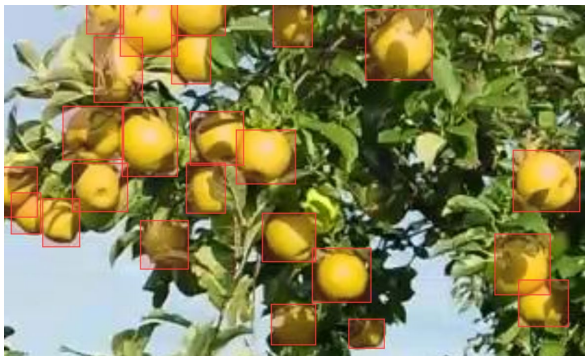

Fig. 3. MinneApple image example.

Pear640 dataset was randomly distributed across training, validation and test folders using the Python random shuffle method. This was repeated 5 times to generate five distinctive data splits, ensuring that the images in each data split contained the same images but with varying locations across the three folders. The data splits were 70% of the images would be in the train folder, 20% of the images would be in the validation folder and 10% images would be in the test folder. This was also then repeated for WGISD and MinneApple datasets respectively.

The augmentation was applied in the experiment: we modified scaling, mix-up and shearing to 0, rotation parameter to 30° and increased mosaic to 1, which takes multiple images and combines them into one.

For each data split, YOLOv5 and YOLOv7 models were trained independently, resulting in five trained models for one specific model type. Subsequently, the trained models were then tested with the test images on their respective data splits to evaluate their performance and ensure an extensive comparison.

RESULTS AND DISCUSSION

If results are analysed in the scope of one dataset, the type of YOLO model can increase accuracy until 8.2% (Tab. 1, median). In the case of our dataset (Pear640), it was not so impressive - only 4.1% (Tab. 3, median). The analysis of YOLO models among different datasets showed the more interesting distribution of obtained accuracies (see Tab. 2-3, Fig. 4). YOLOv7 showed the worst result in the cases of Pear640 and MinneApple, but YOLOv5n showed significantly smaller accuracy in the case of WGISD. Meanwhile, the accuracies of YOLOv5m and YOLOv5l were relatively similar, but YOLOv5m has smaller size (latency). Therefore, YOLOv5m was the most suitable model (trade-off solution) for the rapid development in our experiment.

YOLOv5m showed next accuracy: mAP@0.5 95% and mAP@0.5:0.95 56%, precision 93%, recall 90%.

Analysing results with WGISD, it can be mentioned, that Santos et al. (2020) trained Mask R-CNN with accuracy 71.9% mAP@0.5 [18]. Thomas et al. (2023) completed similar study applying YOLOv5 models for WGISD object detection. They obtained sufficiently similar results: YOLOv5n - 89.4%, YOLOv5m - 89.5%, YOLOv5l - 90.5% [23].

Considering to MinneApple dataset, its authors proposed achieved accuracy equal to 77.5% mAP@0.5 by using Mask RCNN method [19]. Meili et al. (2022) presents BFP Net model, which provides 84.6% mAP@0.5 accuracy [24]. Meanwhile, Li et al. (2021) compared exactly YOLO models: YOLOv4 CspdarkNet53 - 90.53% and YOLOv5s - 80.11% mAP@0.5 [25]. In our experiment, the better results were obtained for all YOLOv5 models, but YOLOv7 provided close results. The better results can be explained by the image crop on 640x640, that was intuitive for our team. At the same time, other authors mentioned problems with small objects.

Experiments with pear detection were completed by other authors too. Sun at al. (2023) proposed the modified

YOLOv5 model called YOLO-P, which was obtained by completing redevelopment of the backbone part for orchard picking robots. YOLO-P achieved 97.6% mAP@0.5 and 39.4% volume improvement and was tested on pear dataset [26]. Li et al. (2022) presented another modified YOLOv5 model called YOLOv5s-FP, which was tested on a pear dataset. It achieved 96.12% mAP@0.5. The modification was oriented to increase image processing speed [27].

Summarising, the yield detection accuracy 90% mAP@0.5 is a relatively good achievement at this moment, which can be obtained in the rapid development stage. Considering to our experiment, YOLOv5m is preferable model for the rapid development, because YOLOv7 was unstable, YOLOv5l provided similar results to YOLOv5m, but YOLOv5n in the case of WGISD showed accuracy smaller than 80%. Speaking about studies related to yield monitoring, artificial intelligence engineers try to optimise the backbone of YOLO architecture to minimise latency for edge solutions (unmanned aerial vehicles, unmanned ground vehicles, fruit pickers, mobiles, etc.). However, it may be more suitable to simply retrain YOLO backbone on the huge dataset of rural content domain comparable with ImageNet and COCO collections. That is challenging at this moment, because there are too few public agriculture datasets as well as selected categories must be well planned.

CONCLUSIONS

In this article we presented our public dataset Pear640, which is available in Kaggle under CC-BY licence.

Completing the pilot experiments directed to develop yield estimation solutions, we wanted to identify the suitable architecture and model for the rapid development of fruit detection. Our pilot experiment showed that YOLOv5m is a preferable model for the rapid development of yield estimation solutions. The best trained YOLOv5m model showed the following results for the Pear640 dataset: mAP@0.5 95%, mAP@0.5:0.95 56%, precision 93%, recall 90%.

TABLE 1 EXPERIMENT RESULTS WITH WGISD

YOLO	Test Dataset WGISD (mAP@0.5)				
	v5n	*v5m*	*v5l*	*v7*	*v7-X*
min	0.799	0.833	0.842	0.880	0.861
mean	0.831	0.877	0.879	0.899	0.902
median	0.825	0.890	0.889	0.888	0.907
max	0.881	0.918	0.930	0.933	0.932

TABLE 2 EXPERIMENT RESULTS WITH MINNEAPPLE

YOLO	Test Dataset MinneApple (mAP@0.5)				
	v5n	*v5m*	*v5l*	*v7*	*v7-X*
min	0.885	0.894	0.894	0.802	0.812
mean	0.891	0.903	0.905	0.881	0.865
median	0.890	0.904	0.907	0.896	0.883
max	0.896	0.909	0.914	0.912	0.914

TABLE 3 EXPERIMENT RESULTS WITH PEAR640

YOLO	Test Dataset Pear640 (mAP@0.5)				
	v5n	*v5m*	*v5l*	*v7*	*v7-X*
min	0.927	0.932	0.936	0.834	0.737
mean	0.935	0.941	0.940	0.915	0.874
median	0.938	0.940	0.940	0.928	0.897
max	0.943	0.951	0.942	0.955	0.945

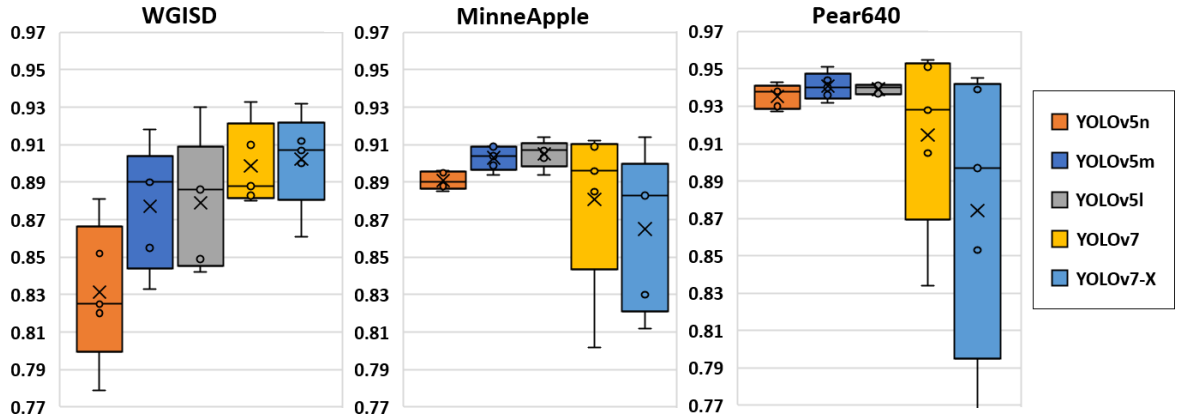

Fig. 4. Box-plot diagram of YOLO model accuracy (mAP@0.5).

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Study of the Application of Pellets from Textile Material Waste and Biomass Mixture in Industrial and Residental Heating Systems

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Abstract. **The efficient waste management hierarchy is based on four priorities, reuse, recycle, energy recovery, deposit.**
Efficient energy recovery from non-recyclable textile materials (waste to energy) principles we study in this paper.
Energy recovery from the fuel pellets consisting of waste textile materials and biomass depends on many factors. One of the main is to create a competitive form for the newly offered fuel (pellets from a mixture of biomass and textile), as well using a new generation of small-scale energy production facilities. Using already existing applications for efficient waste management is one of the circular economy aspects we lay on in this paper.
Roughly estimated that the quantities of textiles separately collected will increased from 65 000 to 90 000 tons per year across the EU-27 from 2025. Reuse and recycling outlets will need to be created, as the current sorting and recycling capacities are not sufficient to process the anticipated volumes. However, it is also expected that at least half of these additional volumes will comprise non-reusable textile waste with specific flame retardant (FR) treatment. It is known that flame retardant is hazard by its adverse environmental impacts of FRs in their production and disposal phases.
The objective of the paper is to review opportunities of elaboration a new type of the fuel pellets, and using them in industrial heat pellet boilers and combined heat and power CHP systems.
Elaborated the new pellets from biomass (prepared by plasticization method) and chopped textile waste sized till 2-3 mm (by method separative milling) were tested in controlled combustion processes.
Experiments were carried out by adding different proportions of textile waste to biomass pellets and the results obtained are summarized in the article

Keywords: Efficiency, waste to energy, sustainability introduction.

Latvia is on its way to achieve the European union EU climate neutrality goals – by 2050 40 % of the energy produced from Renewable Energy Sources (RES) from total energy consumption (EU average goal for 2030 is 20 %) [1]. A significant part of the energy produced by RES, is wood biomass (in 2018 62.6 PJ or 80.4 % of the

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total RES consumption)[2]. Energy production from biomass, although less than from fossil energy sources, causes greenhouse gases (GHG) emissions [3].

Use of energy recovered from waste materials promotes implementation of circular economy principles in household sector [4] [5] .

Circular economy principles are present on Fig.1, Efficient use of municipal waste to energy is one of the ways to decrease landfill of textile[5] .

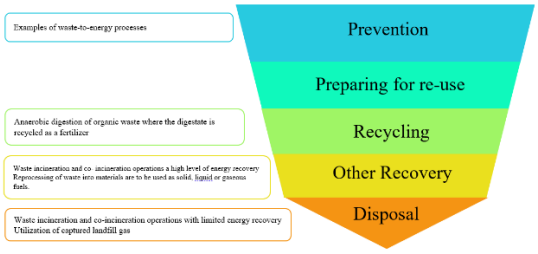

Fig 1. Circular economy principles of waste to energy[5].

In the field of textile material recycling, as a one part of the renewable energy source [6] it can be seen that most of the waste is burned in specifically constructed waste incineration factories. but only the smallest part is used for transplanting [5], [7], unless share of waste for recycling is annually growing [5].

It is indicated that a significant amount of textile materials is stored in landfills for future recycling[8].

The guidelines of the European Green Course [1] promote the use of RES in the production of heat and electricity, as a result of which an increase in the use of biomass can be observed. An increase in the use of granulated biomass in the production of heat and electricity is observed [9]. Pellet heating equipment is one of the most efficient currently available technologies for obtaining energy from biomass[10] . The directives and policy documents of the European Union on the use of biomass for heating promote the efficient and sustainable use of this resource, as a result of which energy sector companies that use biomass as fuel for heat and electricity production are expected to face greater competition for the extraction of raw materials for fuel production [10], [11].

In this perspective, the boundaries of using composite materials for recycling can be expanded, including polymer structures with various inclusions of natural/synthetic particles [12] [13], [14] [14], [15] [16] including nanomaterials[13], [17] [18], as well as widely used polymer matrix composite materials, such like concrete reinforced with fibrils [19]–[21].

Textile waste incineration currently takes place in specialized waste incineration plants, but no waste incineration is observed in heating facilities[22].Taking into account that a significant part of textile waste is deposited for later processing, it can be assumed that in the future technologies and opportunities for efficient processing of textile waste will be available. Therefore, the preparation of new type the pellets and responding of the EU ISO 17225-2:2021standard is very relevant and timely.

By developing a new type of fuel, which would consist of biomass/wood processing residues and a mixture of waste textile materials, it would be possible to use the waste to efficiently process it in already existing heating facilities, without using specialized waste incineration plants.

As the significant part of landfill after some period of time is to be planned for recycling and there are indications that in near future textile materials recycling process will be more common and specially build textile waste incineration factories become useless.

Finding new opportunities and technologies to The research explores in an experimental way the possibilities of creating fuel that could be used in already existing pellet heating facilities.

Objectives of the research:

- Develop novel pellets from the waste of synthetic/natural textile materials and biomass, which cannot be recycled into new textile material, for using in household pellet heating boilers.
- To reach the objective, a new manufacturing approach from the waste synthetic/natural textile with biomass will be developed, the prototype of the pellets will be manufactured and experimentally tested (mechanical and thermal characterizations according to EN 14961-2; ISO 17225-2:2021).

I. MATHERIALS AND METHODS

A. Test sample preparation

To prepare the textile fibers (organic/synthetic textile material) of short length was used an experimental laboratory module: high-speed grinding-separation system DS - 37/21 (TalTech, EE), that provides the high-speed separative milling of small volumes of various types of textile waste in order to obtain fibres of the required length.

The method of dry high-speed grinding-separation of worn-out textile materials was applied to prepare a short length textile fibers or powdered fibers (3±1 mm).

The concept of fiber preparation using high-speed grinding-separation (HSGS) consists of the following main stages: fiber processing goes through the feeding and mechanical pre-treatment stage, following grinding and the final separation.

The feeding system consists of a screw conveyor that transports the pieces of the material through a unit of preliminary mechanical processing. The drive power is 1.5 kW, the power of the pre-treatment systems is 2 kW, the maximum length of the pieces of material was about 0.5-1 m.

The prepared material was milled in the grinding system, and the obtained fibers flied to the separation unit with the airflow. The power of the grinding drive was 3 kW. The maximum engine speed was 3000 rpm. The range of linear processing speeds was 70 m/s.

Then, the milled fibers were divided in the separation system. The fibers of the required size (3±1 mm) were separated (under the influence of inertial force) and fed to the finished product collector. Large/insufficiently chopped/milled fibers were fed for re-processing.

The performance of the system (depends on the degree of preliminary processing, material properties) was organic/synthetic textile material - 2 kg/h, cotton material – 1.5 kg/h. Other characteristics (in first approximation), like as type of weaving, relative humidity, structure and thickness of the thread, linear speed and configuration of the milling cutter and the required particle size of the product did not take in consideration in this manuscript, and were regarded like a constant.

Cotton material was used: woven fabric; purchased in the store of illiquid raw materials shop "Abakhan", Tallinn, Estonia; plain weave, surface density 244±5 g/m². The specimens of the powdered fibers (24 h were technological deposit, room temperature 22±1°C; moisture content 60%, according to ISO 139:1973) were used to prepare the pellets. PES (Polyester) material was used: knitted fabric; purchased in the store of illiquid raw materials shop "Abakhan", Tallinn, Estonia; combined knitted weave, surface density 185±5 g/m². The specimens of the powdered fibers (24 h were technological deposit after the grinding process, room temperature 22±1°C; moisture content 60%, according to ISO 139:1973) were used to prepare the pellets. Final grinded textile material used for mixture with biomass see on Fig. 1

Fig. 1. Grinded textile, left cotton, right synthetic.

Pinewood chips were received from woodworking factory.

The equipment to prepare the pellets is the pellet machine ZLMP400, Fig. 2.

Fig. 2. Pellet mashine and process.

Four combinations of the pellets and one type from the pure pine wood chips were prepared Tab 1.

TABLE 1 PELLET SAMPLES

Nm	Types of combination	Composition, %
1	Pinewood chips and powdered fibers (Cotton material)	87.5% & 12.5%
2	Pinewood chips and powdered fibers (Cotton material)	80% & 20%
3	Pinewood chips, powdered fibers (Cotton, and PES material)	90% & 5%; 5%
4	Pinewood chips and powdered fibers (PES material)	90% & 10%
5	Pinewood chips	100%

Fig. 3. Pellet specimens.

B. Testing procedure

To determine the length and diameter of the received pellets was used the Electronic digital calliper (Resolution: 0.1 mm/0.01"; Accuracy: ±0.1 mm/ 0.01"; Battery: SR44/LR44 1.5 V; GE).

Moisture content of all five specimens was detected according to the standard LVS EN ISO 18134-1.

Clean, dry container was weighed with an accuracy of up to 0.1 g. The mass of the specimens should be at least 300 g (it is the weight of the container with the specimens).

To determine the floating effect, before drying, the weight an identical empty and clean reference container with an accuracy of up to 0.1 g.

The dish with the specimen and the reference dish were placed in a drying oven with a temperature of 105±2°C, the drying process lasts until the mass of the specimen becomes constant, but no longer than 24 hours (to prevent the release of volatile compounds).

The container with the specimens and the empty reference container were weighed on the scale within 10-15 seconds after removing them from the drying oven; a heat-resistant plate must be placed on the scale.

The specimens should be placed in the drying oven so that air can freely flow between them, and moisture has somewhere to evaporate.

Ash content for dry mass was detected according to standard LVS EN ISO 18122.

Empty and cleaned crucibles are placed in a muffle furnace and heated for at least 60 minutes at a temperature of 550±10°C;

Place the crucibles in a desiccator fitted with a thermocouple and allow to cool for 25 minutes to reach a constant crucible mass, after which the temperature is recorded, which is recorded in the work report. The cooling time of the dishes is determined to reduce the mass changes caused by temperature and to reduce the measurement error. When the crucibles have cooled, determine their mass with an accuracy of 0.1 mg. The sample materials were mixed and put about 1 g in the specimen crucible in an even layer, no more than 0.1 g/cm2.

Crucibles with specimens were placed in a muffle furnace and heated within 30 to 50 minutes, heat the muffle furnace evenly to 250°C (temperature rise 4.5-7.5°C/min), maintained at 250°C for 60 minutes to evaporate volatile substances before igniting. The temperature was raised evenly to 550±10°C during 30 minutes and maintained at 550±10°C for at least 120 minutes.

As soon as the specified temperature is reached in the desiccator, previously recorded in the work protocol, the mass of the crucibles and ash begins to be determined.

Gross and Net calorific value was detected according to standard LVS EN ISO 18125.

The determination of the heat of combustion consists of two separate experiments.

The calorimeter is first calibrated using a benzoic acid calibrant, which has a known highest heat of combustion. Calibration is necessary to ensure accurate measurements.

After the calibration of the calorimeter, a test to determine the heat of combustion of the fuel is performed. At least two replicates are required for a representative result. The value of the heat of combustion of the analyzed specimen cannot differ by more than 120 J/g for both replicates.

To determine the amount of heat [J] produced by the combustion of an acetobutyrate capsule or crucible, they must be weighed on an analytical balance and their mass [g] multiplied by the heat of combustion [J/g] of the acetobutyrate capsule or crucible. The calorific value of combustion of auxiliaries is excluded from the calorific value of fuel.

The mass of the pellet of the fuel specimen is indicated in the calorimeter, as well as, if necessary, the heat of combustion of the used ignition aids (cotton thread, acetobutyrate capsule, ignition crucible) is entered.

After the test work, the heat of combustion H0 [J/g] of the specimen burned in the calorimetric bomb is recorded in the protocol.

Pellet combustion test ware performed in pellet boiler, Fig. 4.

Fig. 4. Combustion test stand.

II. Results

In the first phase of research the physical parameters of the pellets were measured according to the standard ISO 17892. We researched the average length (from 15.3 mm to 21.51 mm) and diameter (from 6.19 mm to 6.62 mm) of the pellets, and the results were compared with the standard ISO 17892, where it is seen that physical parameters of the pellets are in a proper range allowed in the standard for all five specimens. Studies have shown that, the powdered fibres (both types: cotton and PES powder) added in pinewood chips are not influencing on the pellets size (as follow from testing results shown in Table 2).

TABLE 2 THE PHYSICAL PARAMETERS OF THE PELLETS

Nm	**Types of pellets**	**Average length, $n_{al} = \Sigma n_{100}/100$; (mm)**	**Length (mm) according to standard ISO 17829**	**Average diameter, $n_{ad} = \Sigma n_{100}/100$; (mm)**	**Diameter (mm) according to standard ISO 17829**
1	Pinewood chips and powdered fibers (Cotton material)	15.45	3,15 < L ≤ 40	6.62	6 ± 1
2	Pinewood chips and powdered fibers (Cotton material)	17.84	3,15 < L ≤ 40	6.19	6 ± 1
3	Pinewood chips, powdered fibers (Cotton, and PES material)	15.57	3,15 < L ≤ 40	6.28	6 ± 1

4	Pinewood chips and powdered fibers (PES material)	15.3	3,15 < L ≤ 40	6.27	6 ± 1
5	Pinewood chips		3,15 < L ≤ 40		6 ± 1

The standard LVS EN ISO 18125 controls the ash content after pellet combustion. Ash contains factor may depends on many factors[23]–[25], but our research shows correlation between cotton powder adding and ash contain[26]. The first two specimens of the pellets (Table 3) contain wood chips and cotton powder in different proportions (1st specimen - 20%, 2nd specimen - 12.5%), and show the ash content higher than in a specimen with 10% synthetic (PES) powder (4th specimen, Table 3). Test results of all five specimens indicates increasing of the ash content in the specimens with textile powder (as additives); the less ash content 5th specimen (without textile powder) is 0.35% and the highest ash content 1st specimen (with 20% cotton powder) is 1,58%. Investigation of the 4th specimen (wood chips with 10% PES powder) shows lowest ash contain 0.43% (among specimens with additives). This result of ash can be explained by the fact that in time of combustion PES powder the products comprised of carbon (C), hydrogen (H2), oxygen (O2), and nitrogen (N2), where hydrogen, oxygen, and nitrogen are gases[27], [28].

TABLE 3 COMBUSTION PROCESS LABORATORY RESULTS

Types of pellets	**Moisture content, %**	**Ash content, %**	**Gross heating value (GHV), MJ/kg (Tables in the standard LVS EN ISO 18125)**	**Net heating value (NHV), MJ/kg**
Pinewood chips, powdered fibers (Cotton material)	17.23	1.58	19.7	14.77
Pinewood chips, powdered fibers (Cotton material)	14.38	1.05	19.74	15.40
Pinewood chips, powdered fibers (Cotton, and PES material)	12.50			
Pinewood chips, powdered fibers (PES material)	12.59	0.43	20.39	16.34
Pinewood chips	12.68	0.35	20.48	16.87

In order to explain how the energy density of the fuel changes, it is necessary to take into account its constituent raw materials. Pellets energetic dencity values have influence by lignin content in the pellets (one of the biomass components), and concentration of the lignin in the pellets has influence on energetic density of the fuels and ash content after pellet combustion[29]. The ash content has affected by non-combustible ingredients in the fuels[32]. This follows from the research, that is, the 1st specimen has higher ash content 1.58% and the lowest fuels energetic value 14.77 MJ/kg comparing with other specimens. On energetic value has influence on the moisture of the raw material in the specimens, for example, 1st specimen: moisture is 17.23% and energetic value is 14.77 MJ/kg, 2nd specimen: moisture is 14.38%, energetic value is higher 15.40 MJ/kg (comparing with the 1st specimen). Obviously, this result was influenced by the content additionally textile cotton powder in the pellets. The first two specimens have higher moisture content, number of research[30]–[32] justify corelation between biomass moisture content and energetic value. The high moisture content of the specimen's 1st and 2nd may be affected by the hygroscopicity of the cotton fibers. It is known that cotton fibers have high hygroscopicity (the ability to absorb moisture). The fibers during swelling increases by about 40% in volume[30], [33].

The low heating value (LHV) or net heating value is the energy value of fuel combustion, obtained depending on the actual composition of the pellet material and its moisture content. The high heating value (HHV) or gross energetic value depends on fuels composition where humidity not included in calculation[33] and gross energetic value of each type of material is determined according to the tables with the standard LVS EN ISO 18125. The comparative analysis between the HHV and LHV is representing in very less difference between energetic values of the specimens, that are: 1.3% for 1st and 2nd specimens, and 1.17-1.25% for 3rd, 4th and 5th specimens. From this research follow the textile powder adding practically has not influencing on the gross energetic value. The net LHV is depending on water content in specimens[33], represents correlation between moisture content and LHV, what shown in Table 3. The

most higher 17.23 MJ/kg value of the LHV shown the 3rd specimen (90% pinewood chips, 5% of cotton powder, 5% of PES powder), as the optimal result of the content of additives for this particular study, despite on the middle ash content 0.71% (with comparison among of all five specimens). Latvian average hgousehold heat energy demand is about 170kWh/m^2 annual,

III. CONCLUSIONS

The powdered fibers (both types: cotton and PES powder) added in pinewood chips are not influencing on the pellets size, where average length is 17.13 mm, and average diameter is 6.37 mm.

The pellets containing pinewood chips and cotton powder (1st specimen - 20%, 2nd specimen - 12.5%) showed the highest moisture content (1st specimen - 17.23%, 2nd specimen - 14.38%) and, as a result, the LHV (1st specimen - 14.77 MJ/kg, 2nd specimen - 15.40 MJ/kg) less that other three specimens.

The ash of 1st and 2nd specimens is in 2.65% higher than the other three specimens.

The most higher 17.23 MJ/kg value of the LHW shown the 3rd specimen (90% pinewood chips, 5% of cotton powder, 5% of PES powder), as the optimal result of the content of additives for this particular study, despite on the ash content 0.71%.

Physical and mechanical parameters of the all-tested specimens meet pellet standards.

Significant amount of non-reusable textile waste might be used for heat energy production.

Gaseous and fine particle emission measurements for further research should be performed to approve complience to the emission standards.

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Challenges of SSF Process for Pea and Wheat Bran Valorization Using Trichoderma Spp. for Biocontrol Agent Production

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Abstract. **Fungal strain *Trichoderma spp.* is a known bio control agent (BCA), which are difficult to obtain using more prevalent industrial-scale biofermentation methods such as submerged fermentation (SmF) However, difficult up-scalable solid-state fermentation (SSF) are appropriate for such BCA production. An automated semi-rotating drum bioreactor was developed and built to explore SSF scale-up using pea and wheat bran as substrates to valorise food-industry by-products into viable BCA 's. Estimation of biomass using CO_2/O_2 analysis in exhaust gasses revealed that mix of pea and wheat bran can produce a viable BCA 's using gentle mixing technique with possibilities of industrial scale-up.**

Keywords: Biocontrol agent (BCA), Food waste valorisation, Solid state fermentation (SSF), Trichoderma.

I. INTRODUCTION

In recent years biopesticides have been seen as an alternative to their agrochemical pesticide counterpart and are being increasingly studied for their beneficial properties of leaving no harmful residue, which enters the food chain and reduction of environmental impact as dangerous waste water runoff [1]–[3].

When comparing solid-state fermentation (SSF) to submerged fermentation (SmF) the SSF process uses less resources, energy and has a significantly lower environmental impact than SmF methods for the production of similar products and is less resource intensive in terms of process control [4], [5]. Furthermore, SSF fermentation can be utilized to valorise various food waste products and process waste such as residue from biomethane plants and carbon rich seed shells into useful biomass for agricultural industry [1], [6], [7].

In recent years SSF has been implemented in various industries including agricultural biocontrol agents (BCA) and has a potential to produce a viable biopesticide with an extended shelf life when comparing to the same process being carried out in SmF. Some microorganisms such as *Trichoderma spp.* cannot produce viable antifungal properties within SmF cultivations due to shear forces being exerted in hyphae and lack of free oxygen [8]–[11].

However, SSF fermentation lacks the precise process controls which are available in SmF processes such as on-line O_2, pH, optical density (OD) measurements within the substrate, therefor the process is less controllable as the substrate pH and O_2 cannot be effectively controlled during the fermentation as local pH adjusting solutions (such as H_2SO_4 and NaOH) volume can 't be effectively estimated. Furthermore, heat transfer and fermentation substrate itself is heterogeneous which manifests itself as significant temperature and moisture gradient within the substrate which in turn often can lead to viability loss or death of the microorganism due to overheating and/or lack of moisture, which lowers the water activity below the threshold where microorganisms can survive [11]–[15].

Trichoderma spp. is a free-living fungi species and it has been proven to be effective BCA against various plant diseases by releasing fungi toxic substances to inhibit the growth of fungal pathogens which inhibit agricultural plant growth and diminish production potential. With biopesticides becoming more popular their production is

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still a going concern [16]–[18]. Various studies have shown that *Trichoderma spp.* exhibits a greater biomass growth and greater production of several extracellular products when the growth is undertaken in SSF in comparison to SmF. In SmF *Trichoderma spp.* doesn't exhibit significant antifungal properties only the liquid surface layer is considered to be viable BCA where free O_2 is plentiful for *Trichoderma spp.* to produce hyphae [19]–[21].

Although several substrate variations have been researched for the purpose of *Trichoderma spp.* cultivation, there is not a unified standard for food waste and utilizing food waste is challenging as the constituents are widely variable between geographical locations and food industries [7], [22], [23]. SSF imposes several challenges when process scale-up is performed in comparison to laboratory experiments such as high number of microbial variant development, large scale inoculum development as SSF requires generally higher level of inoculum compared to SmF, medium sterilization, aeration is impeded as medium tends to cake together and forced aeration takes the path of least resistance through heterogeneous system, agitation is impeded, heat removal as microorganisms excrete heat with metabolic activity, solid moisture content and water activity may decrease below sustainable threshold, pH control is impractical, heterogeneity of the medium is high, difficult downstream processing, waste management of exhaust gases and solid handling is generally more difficult in comparison to liquid handling in SmF processes [21], [24]–[29].

II. Materials and Methods

A. Microorganism and substrate parameter identification

The study was conducted with microorganism *Trichoderma asperellum* (MSCL 309) initially obtained from local soil. Initially wheat bran and pea bran were heated to 105°C for 7 days to determine the free water content in which the bran initially arrives from the production plant. Each sample was weighted before and after the drying process. Properties of each substrate are shown below in table 1. Initially tests with petri dishes were carried out, to approximate the initial starting conditions for scale up of *Trichoderma spp.* Petri dish cultivation tests with the microorganism were carried out to determine the starting parameters for SSF cultivation experiments. Each petri plate was filled with 6 grams of substrate (two with only what bran or pea bran and two with 50/50 mix with three sets for each experiment). Predetermined amount of distilled water (pH 5,6 and 7) was added to each plate twice throughout the cultivation (10, 15 and 20ml) to determine the optimal moisture content of substrate. The plates were inoculated with 10ml of *Trichoderma spp.* with an optical density (OD) of 1 at 540nm. In the last repetition inoculant was mixed thoroughly in the substrate to determine the growth characteristics of mixed vs unmixed samples. Incubation was performed in 22°C and 28°C for 168 hours. The growth activity was determined visually after the experiment and cross-compared to other samples.

B. Bioreactor and controls

Based on petri dish experiments Raimbault column type static bed laboratory bioreactor was built to perform small scale tests of SSF processes. Schematic of the preliminary tests is shown in Fig. 1 where air flow and air humidity are constant throughout the entire fermentation process and the flow was set for all preliminary tests 84 to 2 g/l*min^{-1} (calculated depending on the mass of dry substrate in the reactor) with Cole-Parmer 150mm flowmeter (type - GY-3219-19). Reactor air inlet humidity was supplemented by sparger tube inline of the reactor air inlet and was at the saturation point for air (0.017 kg/m^3) to achieve highest possible water activity without flooding the substrate. All preliminary tests within Raimbault type bioreactor were conducted for 168 hours.

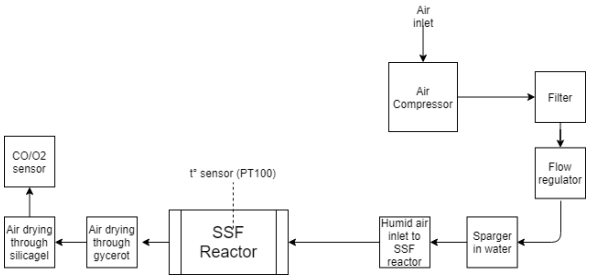

Fig. 1. Schematic of the preliminary tests is shown: Air is pumped from environment, filtered and flow is preset with flowmeter. Air is pumped through SSF reactor where it is passed from below and is exhausted through drying agents Exhausted air is ported through CO_2/O_2 sensor.

After the preliminary tests prototype for SSF cultivation was constructed by A/S "Biotehniskais centrs" (Riga, Latvia) which features air preparation with thermostating and humidification capabilities, semi-rotating drum with mesh bottom for humid air flow to the substrate. The prototype reactor is controlled by process logic controller (PLC) Siemens Simatic-S7 which controls the revolution amount, cycle count, reactor air inlet temperature and monitors temperatures within the reactor with temperature probes (PT-100) with length 150mm on top and bottom and 300mm in centre of the vessel to determine the temperature within the substrate. Air is pressure is reduced and regulated through rotameter, where it further enters the humidification column with rashig rings for maximizing surface area of air within the column. Two loop circulation system with one loop being thermostated water which heats or cools the feed water to the reactor through tube-within-tube heat exchanger. Schematic of the prototype is visualized in Fig. 2 and prototype reactor is visible in Fig. 3.

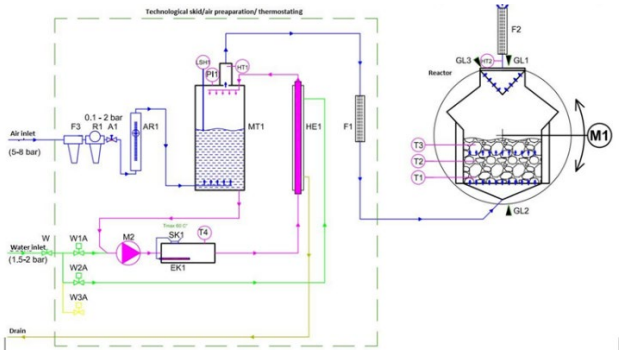

Fig. 2. Schematic representation of semi-rotating SSF reactor prototype and its principle of connections.

Fig. 3. SSF prototype reactor.

SSF cultivation of *Trichoderma spp.* was performed using wheat bran (supplied by: AS 'Rīgas dzirnavnieks') and pea bran (supplied by: SIA 'ALOJA-STARKELSEN'). The substrate required wetting and sterilization, which was performed initially just for the substrate by autoclaving the substrate at 121°C for 130 minutes, but due to overwhelming contamination issues the sterilization for later fermentations was performed for the whole vessel in the autoclave and direct steam injection on dry substrate was also explored to mitigate the contamination issues encountered during the process, experiment substrates and sterilization techniques used are overviewed in Table 1.

Fermentation process was set to run for 168 hours from the inoculation to full stop, rotation cycles were varied throughout the process with the set points for rotation count, delay of initial rotation since the process start, interval between rotation cycles and hold time when the vessel has rotated 180°.

TABLE I. TABLE 1 FERMENTATION SUBSTRATE PARAMETERS

Process No.	Pea waste (g)	Wheat bran (g)	expanded clay 0-4mm (g)	Water (g)	Autoclaved time (min)	Autoclaved temp	Moisture g/g	Moisture g/g
1	0	3,300	0	6,450	35	121	1.95	1.95
2	0	5,500	0	10,000	35	121	1.81	1.81
3	0	5,500	0	5,000	35	121	1.81	1.81
4	5,500	0	0	5,500	35	121	1.00	1.00
5	5,500	0	0	4,000	90	121	1.00	1.00
6	0	5,000	0	4,000	90	121	0.80	0.80
7	0	5,000	0	10,000	90	121	2.00	2.00
8	0	5,000	0	10,000	90	121	2.00	2.00
9	0	5,000	0	10,000	90	121	2.00	2.00
10	0	3,615	4,695	7,000	120	121	0.84	0.84
11	0	3,615	4,695	7,000	120	121	1.94	1.94
12	0	3,615	4,695	7,000	120	121	1.94	1.94
13	7,050	0	0	6,650	120	Direct steam injection	0.94	0.94
14	3,650	1,750	0	3,700	120	Direct steam injection	0.69	0.69
15	0	3,200	1,950	3,150	180	Direct steam injection	0.61	0.61

Fermentations were run both with additional humidification and without humidification to combat infection issues which might be present if the water in humidification column was contaminated. To mitigate contamination issues which might be present in the humidification system 10 grams of $KMnO_4$ was added to the water and separatory sedimentation bottle was added in line with the air food to the SSF reactor in order to catch any remnants of potassium permanganate before entering the reactor itself.

Before each experiment filters, tubes, connectors and all adjacent accessories were autoclaved at 121°C for at least 30 minutes to ensure sterility. Substrate was weighted, wetted and autoclaved in polypropylene bags and poured into vessel while hot. Before each process SSF reactor was washed, and disinfected with ethanol spray and hydrogen peroxide.

After repeated failed fermentation expanded clay was added to aid the aeration of the substrate as well ass to improve substrate drainage properties alongside with clumping issues which were observed initially. With ongoing failed attempts and contamination issues the vessel itself was autoclaved in processes No.3 and No.4. The room dedicated to the vessel was irradiated with short wave UV light to improve the sterility of the environment.

With persistent contamination issues the vessel was filled with dry substrate and steam was directly injected into the substrate at atmospheric pressure while condensing wetting the substrate and disinfecting the vessel thus lessening the operations where contamination might be introduced into the vessel.

In the start of each process when the substrate and vessel was still too hot for the microorganism it was let to cool down naturally and *Trichoderma spp.* was introduced only when substrate had cooled at least below 30°C.

III. Results And Discussion

A. Initial Trichoderma harzianum. growth specifics with variable water activity, substrate 104 composition and pH

After incubating for seven days the samples at 22 º C, it was observed that *T. harzianum* has grown in all wetted substrate samples. The highest growth activity was found in a sample containing 10 ml of distilled water, respectively a growth activity value of 4 out of 5, in a sample of 15 ml and 20 ml of water, a value of activity of 3 out of 5. It could be visually established that in samples where *T. harzianum* was not further mixed into the substrate, mycelium has grown more evenly into the substrate. *T. harzianum* grows best at 10 ml distilled water humidity 22 º C see Fig. 4.

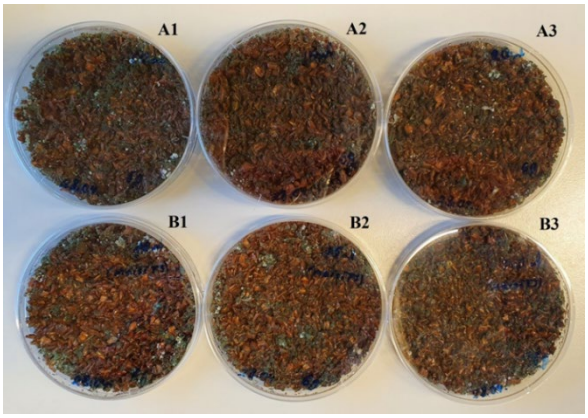

Fig. 4. T. harzianum growth activity at different humidity values. A – suspension not mixed into substrate, B-suspension mixed into substrate; 1-10 ml, 2-15 ml, 3-20 ml.

After incubating the next samples for seven days at 22 º C, it could be established that *Trichoderma harzianum*. has grown in all samples, regardless of pH values or the variety of the substrate. The highest growth activity was found in a substrate consisting of three grams of pea bran and three grams of wheat bran, and the pH of the distilled water required for humidity was 7. A growth activity value of 5 of 5 was assigned.

Samples using six grams of pea bran for growth activity could be assigned a value of 2 out of 5 as a substrate, while the best was found at pH 7. In a sample using six 120 grams of wheat bran as a substrate, *Trichoderma harzianum*. was visually different from all other samples within seven days, possibly the secondary growth characteristics began to appear, a given growth activity value could not be objectively assigned to the sample concerned, nor did the pH values differ between the samples. All samples were moistened with 10 ml of water and incubated at 22 º C see Fig. 5.

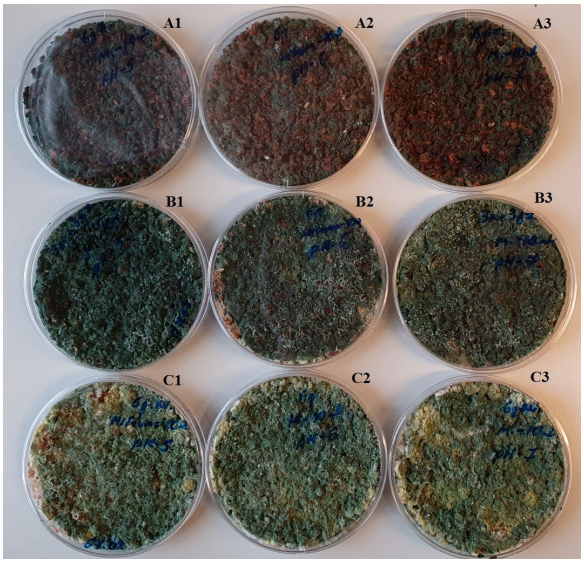

Fig. 5. T. harzianum growth activity at different pH values and different substrates. A - pea bran, B-pea bran + wheat bran, C-wheat bran; 1-pH 5, 2-pH 6, 3-pH 7.

After incubating the samples for seven days at 22°C and 28°C, it could be established that *Trichoderma harzianum*. has grown in all samples, regardless of temperature values or substrate diversity. The highest growth activity was found in a substrate composed of three grams of pea bran and three grams of wheat bran, and incubated for seven days at 22°C. For the sample concerned, a growth activity value of 5 was assigned. Samples using six grams of pea bran for growth activity could give a value of 2 out of 5 as a substrate, while the best was found at 22°C, respectively activity was 3 out of 5. All samples were moistened with 10 ml distilled water with a pH value of 7.

After the test results in petri dishes the initial parameters for SSF could be established that the best temperature to achieve is 22°C, the substrate should have a pH of 7 and substrate of pure wheat bran demonstrated the highest growth potential.

B. Initial Trichoderma harzianum. Initial scale-up and experiments in static raimbault column type bioreactor

SSF processes were evaluated in smaller scale static column repurposed and rebuilt submerged cultivation bioreactor (4L) with inlet water humidification and CO_2/O_2 exhaust gas analyser. However, the scale up solution includes a custom-built prototype with an intermittently rotating drum, which has the internal shape of a uniform cube to mitigate the effects of preferential path development during the substrate forced aeration processes.

Relative humidity in the delivered substrate constituents was determined by drying five samples of approx. 5g in weight over three days in a vented oven with internal temperature control setpoint of around 105 °C for 70h each. The drop in weight was accounted as water separation through evaporation over time. The same amount (5 grams) of the same substrate from the same batch of substrate was soaked in water over 24h and the swollen substrate was then placed on sieve and allowed to separate of all the excess water until there is no dripping observed and the maximum water absorption was determined by weight gain. Relative humidity and maximum non-drip water absorption were determined for both substrates, with wheat bran produced delivered humidity determined to be at W.

During the SSF fermentation the lag phase was observed to be around 22 hours from the inoculation of the substrate and exponential growth was observed until 64 hours regardless of the substrate. Wheat bran with initial moisture of 65%.

After the fermentation the wheat bran substrate had interwoven with fungal strands (see Fig. 6) and was difficult to extract from the reactor as the whole substrate had transformed from loose mass to a uniform piece. Coffee bran substrate did not encounter the similar problems as the substrate was loose even after the fermentation.

Fig. 6. T. harzianum Trichoderma SSF fermentation in wheat bran in static raimbault type column from left to right - 0h, 64h, 168h.

C. Fermentation in SSF prototype reactor

The experimental procedure is aimed at achieving the best possible results and each process parameters are evaluated continuously. The initial process parameters are based on the preliminary tests and are scaled-up based on the weight of the substrate in the reactor. Recorded data from probes T1, T2, T3, HT1, HT2 were monitored continuously and logged within the PLC unit of the SSF prototype bioreactor.

The fermentation results were variable and the rotation of the vessel in combination with wetted substrate introduced clumping issues which were further exacerbated by the fungal hyphae growth. First batch of SSF prototype with wheat bran was unsuccessful due to contamination and the process had failed. Improved methods for SSF reactor preparation had been devised and the procedure was reviewed to make a successful fermentation using *Trichoderma spp.*

The second fermentation with wheat bran and the parameters shown in Table 3.2 was successful and the process was carried out for 104 hours. Results from the sensors are shown in Fig. 7, which correspond to the sensors shown in Fig. 2.

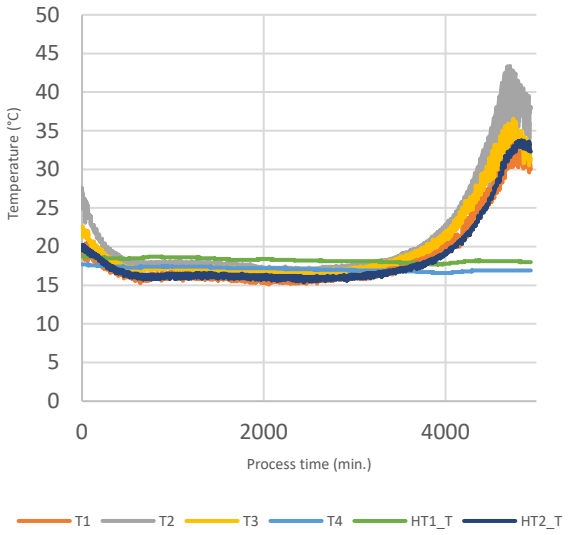

Fig. 7. SSF prototybe bioreactor sensor data from SSF fermentation No2.

From the process temperatures it is clearly visible, that every rotation cycle has a temporary decrease of temperature within the bioreactor, however the sensos T2, which is in the centre within the substrate recorded a maximum temperature if 43°C, which is significantly higher than the temperature for sustainable *Trichoderma spp.* Growth and inhibits the process.

The lag phase of the process is quite long (approx. 3000 minutes) when no activity can be measured by temperature increase, however temperature increase is not representative of the biological activity as the heat generated by biological activity was lower before the 3000-minute mark because the excess heat was exhausted with humid aeration gasses. Exhaust gas O_2/CO_2 content analysis should be performed to determine the lag phase properly.

Fig. 8. Wheat bran directly after fermentation.

After fermentation wheat bran had formed various size agglomerates with hyphae stands as their structure elements and being held together by them. These agglomerates are undesirable within the SSF reactor as they inhibit the air circulation within them and introduce a path of least resistance for air to travel through. After leaving the product in the room and covered with plastic wrap, it developed typical fungi fuss and exhibited significant biological activity (Fig. 9).

Fig. 9. SSF fermentation product from process No.2 after a week of storage.

The reproduction of the processes in pilot scale semi rotating drum bioreactor were unsuccessful, the experiments were not successful as the unknown contamination (suspected contamination from bacillus processes) was overwhelming the fermenting vessel while Trichoderma was outcompeted by the contaminants within the vessel.

During the experiments there were numerous approaches and attempts to eliminate the contamination source which included and were performed in various combinations.

- Disinfection of the room with 70% ethanol solution including outer exterior of the vessel, walls, ceilings, floor etc.
- Irradiating the whole room with disinfecting UV-Ray lamps
- Disassembling the whole reactor vessel and autoclaving the vessel with wetted substrate in autoclave at 121°C for up to 120 minutes
- Disinfection and flushing of the whole humidification column with fresh water and hydrogen peroxide
- Adding potassium permanganate to humidification column as a disinfectant to assure that no foreign microorganisms could enter the humidification column
- Performing the SSF fermentation experiments without usage of humidification as to eliminate humidification columns as a source for infection
- Before each process all filters, tubes and any removable hardware was autoclaved separately at 121°C for 30 minutes and installed upon bioreactor only when substrate was added

- Disassembling the barrel from the skid as and performing direct steam injection at atmospheric pressure for at least 120 minutes
- Replacing the silicone seals before the process as a precaution to eliminate possible source of infection which has remained in potentially micro ruptures in the seals
- Changing the media from wheat bran and pea bran to whole rye grain, which had a limited success as to rule out contaminant possibility from the initial substrate

All the processes had very heterogenous structures, where the top layer and bottom layers had the most microbial activity, although it is hard to draw conclusions as many of the processes were contaminated and repeatability was very low.

Temperatures were usually higher than a maximum permissible temperature of 35°C, (see Fig. 10) which is significantly higher than the temperature for sustainable *Trichoderma spp.* Growth and inhibits the process, it is clear from the process temperatures that every rotation cycle has a temporary decrease of temperature within the bioreactor.

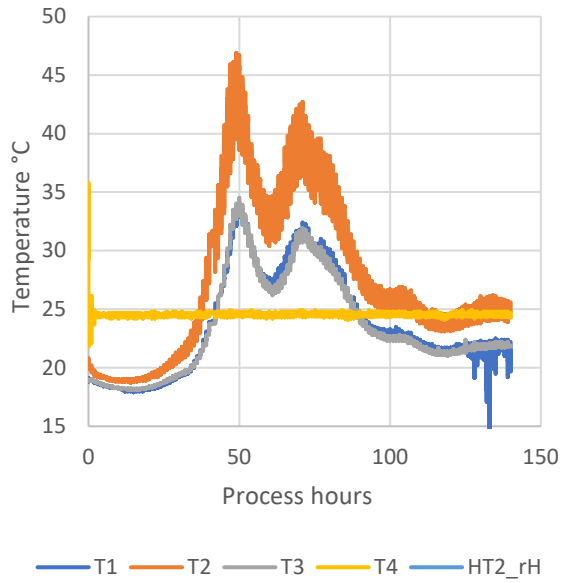

Fig. 10. Process No.15 of unsuccessful, contaminated fermentation.

IV. Conclusions

SSF fermentation is a challenging process, where several limiting factors are to be taken into account, which usually are mutually conflictive and the production of optimum environment for *Trichoderma spp.* cultivation is difficult to achieve.

The prototype reactor itself served the purpose as initially planned and only minor technical difficulties were encountered such as plugged filters and pumping inefficiencies in humidification column, however the scale-up technology for cultivation of BCA`s the reactor design is not suitable due to numerous problems associated with continuous infection within the reactor by an unknown microorganism.

For scale-up purposes SSF continues to be labour intensive with difficulties of setting up the process, autoclaving the substrate, vessel and accessories as well as manual labour involved when the reactor is discharged and cleaned for preparation of the next process, which has to be done manually while in SmF type reactors the operations are significantly less labour intensive due to established CIP (Clean in place) and SIP (sterilisation in place) procedures as well the fact that the substrate within the vessel is easily transferred with various types of pumps.

To achieve successful SSF processes it is suggested that the prototype reactor should be designed with vastly different assumptions of SSF process as rotation of the reactor itself introduced variable voids and clumps within the substrate itself where water activity was low the aeration was high, as well as dead zones where no aeration was observed it led to anaerobic fermentation conditions.

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Influence of Intercropping on Soil Microbial Activity and Strawberry Development

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Abstract. **Strawberry is one of the most important berry crop grown around the world and their consumption increases every year. The introduction of new practices promoting farm sustainability and long-term soil health in strawberry production systems is very essential. Towards environment- and climate-friendly farming practices intercropping can be used to improve soil microbiological activity and biodiversity, and reduce the use of pesticides and mineral fertilizers, while the right choice of intercropped plants is of great importance to achieve these goals. The trials on strawberry intercropping were established in Latvia in 2021. Three treatments with different intercropping plant rotations, including crimson clover, pea, garlic, marigold, and winter rye mix with vetch, were compared to conventional strawberry growing using straw mulch. Trial was installed in three locations: two organic farms and the Institute of Horticulture (LatHort). Thus representing climatically different regions and different soil conditions. Strawberries were grown in 1.2 m distant rows, where in the intercropping treatments, each second interrow was occupied by companion plants. Soil microbial activity was evaluated during vegetation seasons by determining soil respiration rate (SRR) and dehydrogenase activity (DHA) several times per season in 2021 and 2022. Strawberry vegetative development was evaluated at the end of each vegetation season. During the investigation period, soil microbial activity fluctuated during vegetation seasons, depending on growing conditions. In 2021, SRR varied from 1.9 – 3.3 CO_2 mg L^{-1}, while in 2022, from 2.1 - 3.4 CO_2 mg L^{-1}. DHA varied from 46 – 134 INTF, µL×L−1 × h in 2021 and 60 – 101 INTF, µL×L−1 × h in 2022. Intercropping had low influence on microbial activity and results differed within each location. Strawberry plant biomass differed among locations and treatments with the highest above-ground biomass observed in LatHort during second growing season in conventional growing system (790 g $plant^{-1}$).**

Keywords: companion plants, DHA and SRR, Fragaria x ananassa Duch., plant biomass.

I. INTRODUCTION

Strawberry is one of the most widely grown and consumed small fruits in the world with a tendency to increase. In 2021, according to FAO data, the total world production exceeded 9175384 t [1].

The development of growing technologies, giving higher income per unit of area and/or reduce pest and disease problems as well as improve soil properties, is of great importance nowadays and are in line with producers' possibilities and needs in implementing environment-friendly and sustainable farming practices. One of growing practices towards sustainability is intercropping. Intercropped plants can serve as biological and physical barriers against pests and diseases [2]. They can suppress weed growth [3], improve soil nitrogen content [4], positively influence the physical condition of the soil as well as growth and crop characteristics of the plants, improve the quality of crops, and the organic substance introduced into the soil restores its aggregate structure and fertility [5]. The right choice of intercropping plants is very important to obtain a positive effect not only on the main crop, but also on soil properties. Previous research on strawberry was mostly concentrated on strawberry – legume intercropping [6]-[9], while less attention was paid on strawberry relationship with other plants. In Nordic countries, strawberries mostly are grown as perennial crops [10] that allow some plant rotation in interrows during growing period of several years. This research was carried out to evaluate some intercropping plant rotations in strawberry plantation to determine their impact on strawberry growth and soil microbial activity.

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II. Materials And Methods

The trial on strawberry intercropping was established in May of 2021 at the Institute of Horticulture (LatHort) Pūre Research Centre (57°05'25"N, 22°90'55"E) and on two organic farms - Atvases (56°80'27"N, 24°41'83"E), and LM Product (56°70'56"N, 24°89'68"E).

Experimental design and treatments. Strawberries (cultivar 'Malwina') were planted in rows with a planting distance 1.20 m between rows and 0.4 m between plants in rows. In the trial, three treatments with different intercropping plant rotations were compared to conventional growing with application of straw mulch. In treatments with intercropping, companion plants were grown in every second interrow, while other interrows were mulched by straw. Treatments: 1) 1st growing year – Crimson clover (*Trifolium repens* L.) in interrows; 2nd growing year – marigolds (*Calendula officinalis* L.) following by winter rye (*Secale cereale* L.) + winter vetch (*Vicia villosa* L.) in the autumn; 2) 1st growing year – Crimson clover; 2nd growing year – green peas (*Pisum sativum* L.) following by winter rye + vetch; 3) 1st growing year – Crimson clover following by winter garlic (*Allium sativum* L.) planted in autumn; 2nd growing year – winter garlic following by winter rye + vetch; 4) control, without intercrops, straw mulch applied in all interrows. The technological processes (sowing, weeding, watering, cultivation) were performed according to the local conditions and technologies according to organic farming principles.

Each plot included 4 rows of strawberry of 6 m length with 15 strawberry plants in row and 4 interrows. Plots were arranged randomly in the trial field in four replicates.

Soil characteristics and meteorological data. All three trial locations differed not only by different geographical location, but also by soil conditions (Table 1).

TABLE 1 THE SOIL TYPE AND CHARACTERISTIC IN TRIAL LOCATIONS BEFORE ESTABLISHMENT

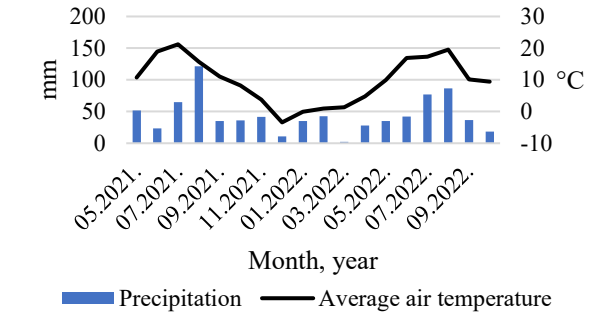
Location	Soil type	pH KCl	Organic matter, %	P_2O_5, mg kg^{-1}	K_2O, mg kg^{-1}
LatHort	Loamy sand	5.8	2.5	58	71
Atvases	Loamy sand	6.0	11.7	<14	82
LM Product	Clay loam	5.7	3.4	123	95

LM Product had the most heavy soil among trial locations, whereas Atvases is characterized by soil with high organic.

All three locations were characterized by low content of plant available mineral nutrients, therefore the basic fertilization was applied before establishment of trial, by using organically certified fertilizers. The fertilizer Physio Natur PKS 47 (0-13-15) with a dose 66 g m^{-2} was applied in farm LM Product. In the farm Atvases, fertilizers PHYSALG 25 with a dose 60 g m^{-2} and potassium magnesium (Patentkali) with a dose 50 g m^{-2} were applied. In LatHort, the organic fertilizer FERTIPLUS (4-3-3 65 OM) was applied with a dose 230 g m^{-2}. In the next year in LatHort and LM Product, strawberries were additionally fertilized by cattle slurry with a dose 1.2 L per strawberry row meter, which was diluted by water. No side-dressing was done in farm Atvases.

Meteorological data were recorded in two locations: LatHort in Pūre and LM Product, by using an automatic weather monitoring station (Davis Instruments Corp.).

Years of study differed in weather conditions (Figure 1).



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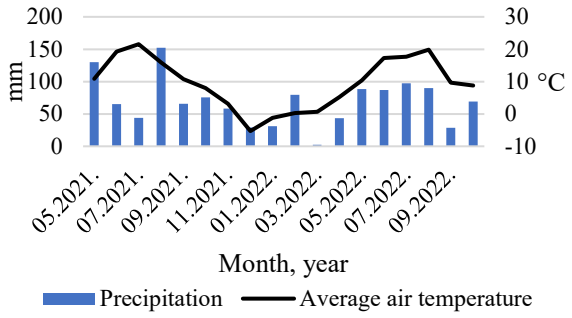

Fig. 1. Mean air temperature and amount of precipitation from May, 2021 to October, 2022 in two trial places: a) LatHort; b) LM Product.

In total, the vegetation season of 2021 had a higher average air temperature and higher amount of precipitation than the season of 2022. Comparing both places, a higher amount of precipitation was observed at LM Product in both years, while air temperature was similar in both places.

In 2022, soil temperature and volumetric moisture was measured at 15 cm depth in all three locations using Soil Scout™ wireless sensors. During vegetation season the highest average soil temperature was observed in August in all trial places with the highest value at farm Atvases and the lowest at LatHort (Table 2).

TABLE 2 AVERAGE SOIL TEMPERATURE AND VOLUMETRIC MOISTURE AT 15 CM DEPTH IN 2022 IN TRIAL LOCATIONS DURING VEGETATION SEASON

Month	Soil temperature, °C			Soil moisture, %		
	Atvases	*LM Product*	*LatHort*	*Atvases*	*LM Product*	*LatHort*
April	5.2	4.7	4.5	50.2	44.3	24.1
May	10.6	9.5	9.5	43.3	42.0	22.6
June	16.8	15.5	15.6	50.4	41.9	22.9
July	18.0	17.3	16.7	42.5	36.6	22.9
August	18.1	17.7	17.1	46.3	35.4	21.0
September	12.3	11.8	11.8	44.9	31.4	23.7
October	10.1	9.5	9.5	49.1	40.1	22.3

At Atvases, the highest average soil moisture was observed in June, while at LM Product and LatHort, the highest was in April. At Atvases, the lowest average soil moisture was observed in July, at LM Product – in September and at LatHort - in August.

Measurements and analysis. Soil dehydrogenase activity (DHA) and soil respiration rate (SRR) were evaluated during both seasons as indicators of soil microbial activity. The soil samples were collected during the vegetation season in all three locations from every treatment in four replicates. In 2021, soil samples were collected from the end of May to end of September and, in 2022, from the middle of May till the middle of October several times per season. Soil analyses were performed in the Soil Laboratory at LatHort.

DHA activity was detected according to Kumar et al. method [11] as modified by Dane and Sterne [12]. One gram of soil sample was exposed to 0.2 mL of 0.4% INT (2-p-iodophenyl-3-p-nitrophenyl-5-phenyltetrazolium chloride) and 0.05 mL of 1% glucose in 1 mL distilled water for at least 6 hours. The formed INTF (p-iodonitrotetrazolium formazan) was extracted by adding 10 mL methanol and actively shaking for 1 min. INTF was measured spectrophotometrically at wave length 485 nm.

Soil respiration was evaluated by a closed container method, where a soil sample (50 g) was placed in a jar where a low container with 5 mL of 0.1 M KOH was placed inside. After exposing it for 24 hours at 28 °C in the dark, the liquid was titrated with 0.1 M HCl [9].

In all three trial locations, every year at the end of growing season the strawberry plant development was accessed by weighting of aboveground plant biomass. The measurement was performed for 4 plants per every plot.

Descriptive statistics, analysis of variance, followed by Fisher`s *LSD* (least significant difference) test (P≤0.05) and Pearson`s correlation were used for data analysis. The statistical analyses were performed using the MS Excel 2013.

III. Results And Discussion

Soil microbial activity. Soil dehydrogenase enzymes are one of the main components of soil enzymatic activities participating in and assuring the correct sequence of all the biochemical routes in soil biogeochemical cycles [13] and measurement of changes in soil enzyme activities may provide a useful index of changes in soil quality [14]. In our trial, DHA significantly varied during season and among locations.

In the farm Atvases in 2021, the highest DHA was observed in the middle of August, while the lowest was at the beginning of June, when the first soil sample was collected (Fig. 2). DHA significantly varied also among treatments (p=0.020) with the highest average activity observed in the treatment 2, where Crimson clover was grown all season in interrows, and the lowest it was in the treatment 3, where Crimson clover was cut and incorporated in soil at the end of September and later garlic planted.

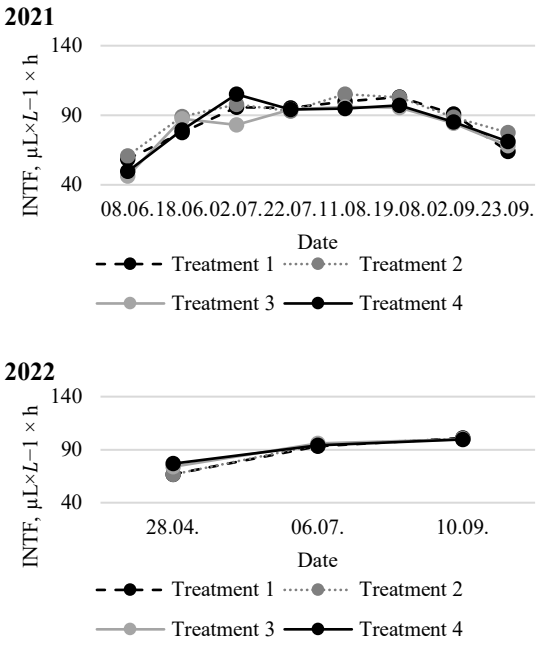

Fig. 2. DHA activity in soil at Atvases in 2021 and 2022 in different intercropping treatments.

In 2022, soil samples at Atvases were collected only three times. The highest DHA was observed in September, while the lowest was in April, when soil was still cold and wet (Fig. 2). Significant difference among treatments was not observed (p=0.102).

In the farm LM Product in 2021, DHA significantly varied among sampling dates (p=0.000) and treatments (p=0.016). The highest DHA was observed in the middle of July, while the lowest was in the middle of September, when the last soil sample was collected (Fig. 3). Among treatments, the highest average activity was observed in treatment 1, where Crimson clover was grown all season in interrows. The lowest DHA was in the treatment 3, as in farm Atvases.

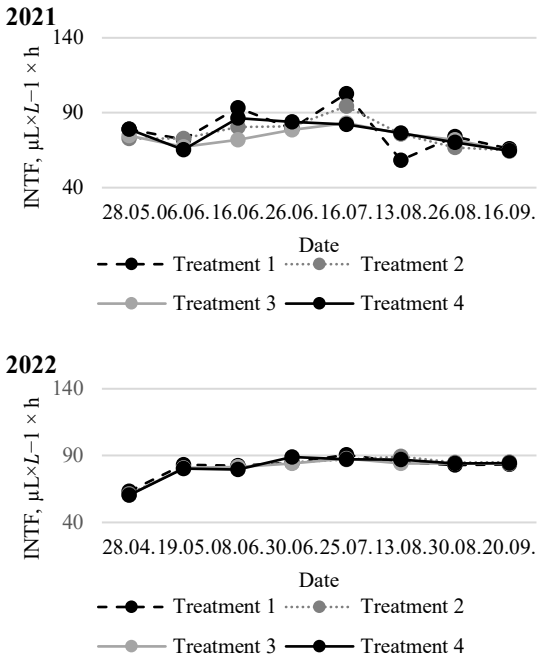

Fig. 3. DHA activity in soil at LM Product in 2021 and 2022 in different intercropping treatments.

In 2022, the highest DHA was observed at the end of July, while the lowest was in April (Fig. 3). Significant difference among treatments was not observed (p=0.726).

At LatHort in 2021, similar to both farms, DHA significantly varied among sampling dates (p=0.000) and treatments (p=0.024). During season the highest DHA was observed at the beginning of July, when the weather was warm and wet, while the lowest it was in June and at the end of season (Fig. 4). Among treatments the highest average activity observed in the treatment 2, where Crimson clover was grown all season in interrows, and the lowest it was in treatment 4 (control).

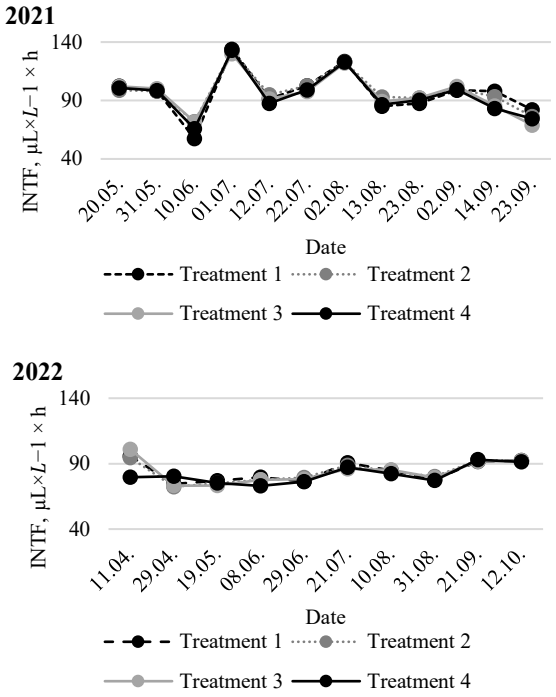

Fig. 4. DHA activity in soil at LatHort in 2021 and 2022 in different intercropping treatments.

In 2022, the highest DHA was observed at the beginning and at the end of season, while the lowest was at the end of April and May. Similar to other locations, significant difference among treatments was not observed (p=0.052).

In total, the highest average DHA was observed in the soil of Atvases, probably because of higher content of organic matter in the soil and higher soil moisture than in other locations (Table 1, 2). Among the most important functions performed by DHA is the biological oxidation of soil organic matter [15]. It is also stated that *DHA* is strongly influenced by water content and its activity reduced with the decrease of soil moisture [16, 17].

In our trial, also a significant positive correlation among DHA and average air temperature was found in the soil of LM Product (r= 0.60; n= 64) and LatHort Pūre (r= 0.25; n= 84). In Atvases, air temperature was not recorded and correlation was not calculated.

Similar to DHA, SRR significantly varied throughout the season and among locations. In the farm Atvases in 2021, SRR significantly varied among sampling dates (p=0.000). The highest SRR was observed at the end of September, when the last soil sample was collected, while the lowest was at the beginning of July (Fig. 5).

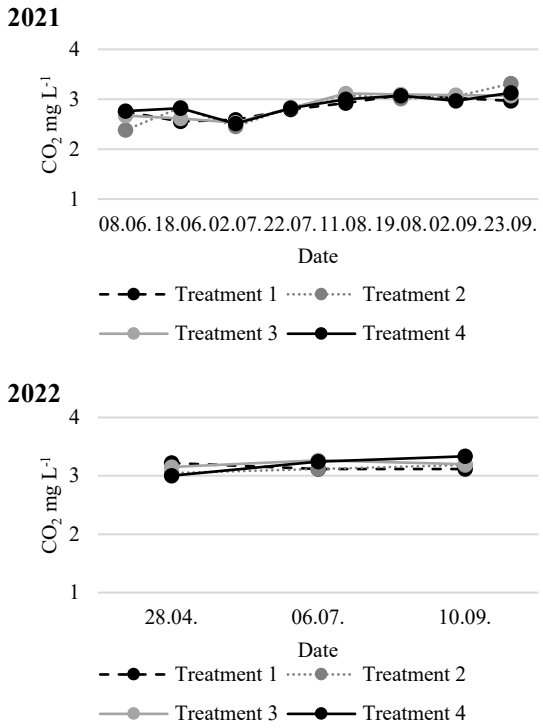

Fig. 5. Soil respiration rate at Atvases in 2021 and 2022 in different intercropping treatments.

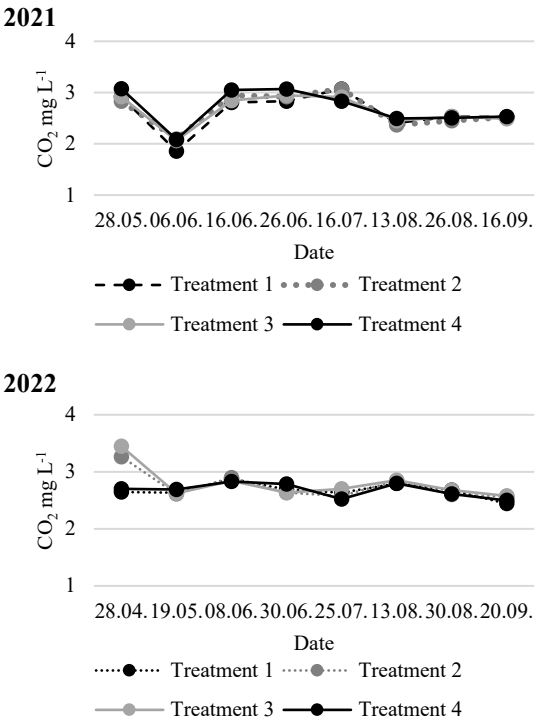

Fig. 6. Soil respiration rate at LM Product in 2021 and 2022 in different intercropping treatments.

In 2022, significant difference during vegetation season and treatments was not found ($p>0.05$).

In the farm LM Product, SRR significantly varied among sampling dates in both years ($p=0.000$ in 2021; $p=0.012$ in 2022). In 2021, the highest SRR was observed in July, while the lowest was at the beginning of June (Fig. 6).

In 2022, the highest SRR was observed at the end of April, while the lowest was at the end of September. A significant difference among treatments was observed only at the end of April, where the highest SRR was in the treatment 2, where pea was grown in interrrows, and treatment 3, where garlic was grown in interrows.

At LatHort in 2021, SRR significantly varied among sampling dates ($p=0.000$) and treatments ($p=0.016$). During season, the highest SRR was observed at the end of May, while the lowest was at the beginning of June and the end of September (Fig. 7). Among treatments, the lowest season`s average SRR was observed in the treatment 2, where Crimson clover was grown in interrows. At the same time in other treatments, where also Crimson clover was grown, SRR was similar to control.

In 2022, the highest SRR was observed in August and October, while the lowest was at the beginning of April. Significant difference among treatments was not observed ($p=0.644$).

In total, the highest average SRR was observed in soil of Atvases like for DHA. SSR significantly correlated with content of organic matter in soil ($r= 0.23$; $n= 192$).

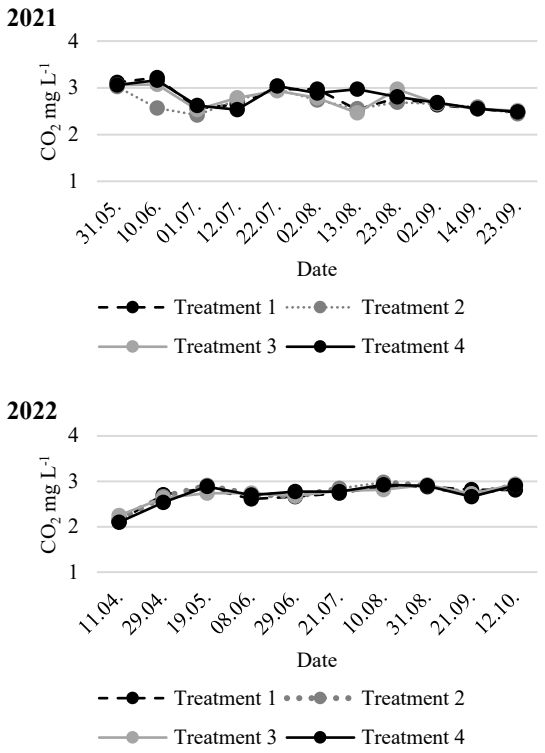

Fig. 7. Soil respiration rate at LatHort in 2021 and 2022 in different intercropping treatments.

Strawberry plant development. In 2021 at the end of vegetation season, significant difference in strawberry above-ground biomass among treatments was not observed in all locations (Table 3).

TABLE 3 AVERAGE WEIGHT OF STRAWBERRY ABOVE-GROUND BIOMASS AT THE END OF SEASON IN THREE LOCATIONS, G PLANT^{-1}

Treatment	Atvases	LM Product	LatHort
2021			
1	84	35	104
2	81	36	94
3	67	45	93
4	87	35	127
$LSD_{0,05}$	44	17	41
P-value	0.738	0.531	0.280
2022			
1	239	294	663
2	298	204	627
3	323	141	629
4	256	184	790
$LSD_{0,05}$	131	64	140
P-value	0.486	0.003	0.031

Better plant development was observed in LatHort, followed by Atvases and the weakest growth was in farm LM Product, probably because of harsh soil conditions.

In 2022, the strawberry above-ground biomass was significantly increased compared to 2021 in all locations. Similar to 2021, the best plant development was observed in LatHort and the weakest growth was in farm LM Product.

Comparing the strawberry growth in different treatments, at LatHort the highest plant biomass was observed in control treatment, following by treatment 1, where Crimson clover was grown during 1st growing year in interrows and marigolds were grown during 2nd growing year. In farm LM Product in treatment 1, plant above-ground biomass was the highest among treatments and it was significantly higher than in control treatment. In farm Atvases, significant difference among treatments was not observed.

IV. CONCLUSIONS

Soil microbial activity significantly fluctuated during the vegetation season depending on meteorological conditions and soil characteristics. Positive influence of soil organic matter content on soil microbial activity was observed. Intercropping, using different plant rotations in strawberry interrows, had lower influence on soil microbial activity and showed different results within each location.

Strawberry plant above-ground biomass increased with plant age. It was not influenced by intercropping during the first growing year, while in the second growing year the biomass differed among growing locations and intercropping treatments. In two of three trial places, the most positive impact of intercropping on strawberry above-ground biomass was observed, when Crimson clover was grown during 1st growing year and marigolds were grown during 2nd growing year in interrows.

V. ACKNOWLEDGEMENTS

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Place Marketing in Planning Sustainable Development

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Abstract. **Research background: Municipalities, as part of the public sector, have to use various methods to achieve their goals, including the ones that are indispensable for successful entrepreneurship. Local authorities plan, manage and control events of public importance. These activities must be in line with national policies and accepted in their development documents. It is logical for municipalities to formulate and communicate their strategies and spatial development perspectives to the public. The improvement of a sustainable development strategy is especially important because the administrative-territorial reform was completed in 2021. After this latest reform, the boundaries of districts, management and distribution of funding were changed significantly. Today several towns and communities have developed their marketing strategies, and each municipality has public relations or development departments that take care of the image of the area.**
Purpose of the article: The aim of this study is to analyse the importance of local marketing in the current sustainable development strategies of individual districts. Tasks of the research are to describe the essence of local marketing, to study the peculiarities of strategic planning in local governments, to analyse the current sustainable development strategies of Cesis, Valmiera and Smiltene counties in connection with local marketing and to draw conclusions on the research results.
Methods: The work uses a monographic research method, analysis of scientific literature, analysis of regulatory enactments, a logically constructive method - for the formation of judgments and analysis of results, a method of synthesis - to combine elements into a single system.
Findings & Value added: As a result of the study, the importance and impact of place marketing on the regional planning process was identified.

Keywords: municipalities, districts, sustainable development strategy, place marketing, public sector.

JEL Classification: M31; M38; M39.

I. INTRODUCTION

Nowadays competition as an integral part of the market exists in practically any field. A free and equal business environment is an essential precondition for development, which is equally important at national, regional and urban level. Companies that compete with each other offer consumers better prices, higher quality and other benefits that help them win the economic competition. The public sector is often involved in the provision of various services.

Municipalities, as part of the public sector, are interested in promoting the development of their territory. Territories compete with each other for population, resources, investment. Raising the level of the development of the territory can be achieved through territorial marketing in connection with the strategic goals of the municipality. Municipal sustainable development strategies are the most significant long-term development planning document of the municipality, on the basis of which the spatial plan and local plans are developed [1].

After the administrative-territorial reform of 2020, it is necessary to develop new sustainable development strategies by merging several local governments. The existing strategic goals have to be evaluated and reviewed. Within the framework of the administrative-territorial reform, drafting of development planning documents shall be co-financed from the state budget by 1 December 2020.

Novelty and quality, constant development, changes and the desire to learn must be promoted in local governments [2]. Therefore, municipalities apply planned activities in which the county is portrayed as a suitable place to live, work, shop and spend one's free time in order to carry out the vision and achieve the goals and long-term priorities of the sustainable development strategy.

The aim of the research is to analyse the role of place marketing in the sustainable development strategies of individual territories after the administrative-territorial reform of 2021. The tasks of this research are to describe

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the essence of place marketing, study the peculiarities of strategic planning in local governments, analyse the current sustainable development strategies of Cesis, Valmiera and Smiltene districts in connection with place marketing and draw conclusions on the results of the research. The key issue of the research is - whether place marketing is used in the district planning of sustainable development. In order to achieve the goal, the essence of local marketing and its connection with the sustainable development strategies of local governments was studied. The reserach methods applied: analysis of scientific literature, analysis of regulatory enactments, logically constructive method - for making judgments and analysis of results, synthesis method - to combine elements in a unified system for researching sustainable development strategies of Cesis region, Valmiera region and Smiltene region.

II. Characteristics of Place Marketing

Various places - small municipalities, cities, towns, regions and districts - have taken part in the competition for advantageous contracts for important events. They take over the principles and teachings traditionally used in business. On a global scale, the European Union and the United States compete with each other, countries compete with each other and local governments compete with each other and towns [3]. Public sector marketing is a branch of management science that applies to the public sector, describing management methods in a competitive environment. Of course, the involvement of public bodies in commercial activities often creates an unequal competition for entrepreneurs, as the rules of this competition are affected by various types of advantages enjoyed by public persons or their established entrepreneurs. Private entrepreneurs, on the other hand, do not have such an advantage.

Marketing is a part of the company's management system. At the same time, marketing-type thinking must take place at all levels of management [4]. According to M. Pukis, the main benefit in the public sector is economic and social benefit. In the meanwhile, the use of private sector methods has brought many improvements, and there may continue to be great opportunities in this area. Marketing as a science explores essential elements of business that evolve in interaction with other areas of research in management organizations. In a narrower sense, marketing is concerned with building a product or company image, but in a broader sense it involves a strategy for achieving economic, social and political goals, as well as the implementation of this strategy. As R.Seliga points out, - as regards local governments, marketing methods create an opportunity to adopt and develop business management methods in the public sector. Marketing also describes the operation of the market. In this market, municipalities can be both competitors and partners. First of all, already in the market, municipalities can compete with the central government, because higher organizations may try to reduce the socio-economic aspirations of individual municipalities due to different political reasons or different economic views [3].

In relation to local governments, marketing methods create an opportunity to adopt and develop business management methods in the public sector [3]. Philip Kotler, one of the world's leading marketing specialists has written that marketing is the art of creating true consumer value, it is the art of consumer welfare, and the slogans of marketing are quality, service and value [5]. Municipal decisions should be focused on their territory and marketing should focus on understanding the needs of the entities living on the territory. Article 15 of the Law "On Local Governments" provides for the autonomous functions of more than 20 local governments, starting with public utilities and ending with the implementation of the protection of children's rights. The functions of local governments include the obligation to organize public services for the population (water supply and sewerage; heat supply; collection and disposal of solid waste; collection, disposal and treatment of sewage). Ainārs Brencis sees an increased need for marketing methods in connection with Article 15, - to promote economic activity on the relevant administrative territory, to take care of the reduction of unemployment [6].

One of the most visible examples in the public sector is the place marketing used by many cities and countries. Inga Vilka - a municipal researcher suggests using the term “urban marketing”, which is different from the previously treated marketing of places. Urban marketing is characterized by a much broader view of the place and territory - it includes everything that the city (municipality) owns - territory, population, government, natural environment, economic, political and legal environment, infrastructure, various objects. The author acknowledges that there is no common definition of urban marketing and no common view on urban marketing. Although the name includes the word “urban”, it refers to different administrative territorial units (state, district, parish, and town) [7]. As in marketing in general, urban marketing is usually understood only as the promotion of the town in the market, which includes advertising and public relations, therefore, urban marketing strategies are developed for the purposeful implementation of marketing. V. Praude emphasizes that several concepts can be found in the scientific literature that reflect the theory of marketing approach to management, for example, “regional marketing”, “local marketing”, “municipal marketing”, “territorial marketing” or “intra-territorial marketing”, however, in his opinion the use of the concept of territorial marketing would be the most appropriate, as it allows to highlight a specific management object-territory [8].

Inga Vilka lists the characteristic features of "urban marketing":

- customer orientation (user, customer) - thus the marketing of the municipality covers both the center and the suburbs;
- meeting of the interests of all social groups of the population of the social municipality (entrepreneurs, labor force, retired people, etc.);
- obtaining regular information on the interests of user groups;
- coordinated cooperation between the municipality and the private sector;
- intra-sectoral cooperation.

- improving the structure of the governing bodies by setting up a service to work with citizens and other user groups;
- orientation towards the implementation of the marketing concept in life, planning, adaptation to changing circumstances and control over the implementation of each measure [7].

If the classic basic elements of marketing or "marketing mix" are product, price, place, promotion in the market [5], then Praude and Voznuka offer a similar division. His product is the diversity of the area's resources, their qualities, quantity, brands, which are interested in the geographical position of the target markets, natural objects, infrastructure, standard of living, business activity, etc. It is not for nothing that cities (now counties) are trying to establish their name as a brand. The territory can also be the owner of the brand. The peculiarity of the product is that it cannot be moved - consumers have to move to get the product. The price depends on the peculiarities of the given territory- the interests of the inhabitants, solvency and values in the specific territory. The interests of potential residents, tourists and investors can also influence the price. V. Praude describes the place as the concentration of material resources, intellectual and technological potential and availability to interested groups. The product cannot be separated from the area. Promotion - creation of information and determination of distribution channels, methods, content, forms, media, volume and implementation time. According to V. Praude, only two elements - product and location are relatively independent (see Figure 1) and depending on the needs of the target market, certain product features are selected and emphasized in the promotion process, which will determine the product price, promotion methods and means of the territory [9].

H. Buurma offers to look at 3-7 elements of the marketing mix - product, price, place, marketing, personnel, process, material approval, indicating that this addition complements the range of marketing concerns, paying attention to the organization of contacts with the customer [10]. Marketing techniques include market segmentation and targeting to specific customer groups. Both V. Praude and I. Vilka admit that the territory or city is used as a product by residents, entrepreneurs, guests (see Table 1).

Residents are local residents who use the city's services and infrastructure to meet their daily needs. In terms of products, people are interested in a clean and safe environment, opportunities and diversity in the labour market, quality social services - education, culture, health care, convenient transport, leisure and shopping, social and physical security. Entrepreneurship uses the city's territory, its infrastructure, services and workforce. Essential conditions for business are location, infrastructure, low prices, tax rates, the quality and quantity of labour supply, the availability of various institutions and suppliers, market demand, the quality of the environment, the availability and quality of services. Visitors should be understood as guests of the city or region visiting the city for business or personal reasons. Visitors use the city's services and infrastructure to achieve their individual goals. Visitors to the city are attracted by entertainment opportunities, museums, cultural events, climate, nature views, etc., followed by hotels, restaurants, shops, conference centres, etc. [11].

TABLE 1. CHARACTERISTICS OF THE MUNICIPALITY AS A PRODUCT CONSUMER

	Municipal users		
	Inhabitants	***Employers***	***Visitors***
The target audience	Local residents	Antreprenierus	Guests visiting the city for business or personal reasons
Interests	Town services and infrastructure to meet their daily needs	Urban area, its infrastructure, services and workforce	Town services and infrastructure to achieve their individual goals
Wishes	Clean and safe environment, opportunities and diversity in the labor market, quality provision of social services - education, culture, health care, convenient transport, leisure, recreation, shopping, social and physical security	Location, infrastructure, low prices, tax rates, quality and quantity of labor supply, availability of various institutions and suppliers, market demand, quality of the environment, availability of services and quality	Museums, cultural events, climate, nature views, etc., followed by hotels, restaurants, shops, conference centers, etc.

The sustainable development of the territory is based on the human factor - population. According to the existing system, the number of inhabitants in the respective territory plays an important role, because from the salaries of the inhabitants the part of the personal income tax, which forms the largest part of the local government revenue, is transferred to the local government budgets. The budget is a financial plan that includes the implementation of all statutory functions and is not the only plan that must be approved by local governments. Section 14, Paragraph two of the Law "On Local Governments" determines the responsibilities of local governments and how to plan the development of the territory first, developing their implementation and administrative supervision. Both the Development Planning Law and the Spatial Development Planning Law stipulate that the municipality plans sustainable spatial development in its territory, using the territory efficiently and rationally and developing the economy in a balanced way to improve the quality of life of the population.

III. STRATEGIC PLANNING IN MUNICIPALITIES

Laws and other regulatory enactments occupy the most important place in public administration. There are a number of regulations that determine the types of plans and planning principles. One of them is the Development

Planning Law, which in Section 6 defines the following types of public administration development planning documents: policy planning documents, institutional management documents and territorial development planning documents [12].

The planning is based on public policy. It is formed in the Saeima, the Cabinet of Ministers, state and local government institutions. The aim of the policy is to promote the sustainable, stable development of the country and the improvement of the quality of life of the population, observing the principles of sustainable development, harmonization of interests and public participation, financial opportunities and territorial development [13]. Like any organization, the country as a whole must have a strategic plan - a long-term plan that sets out strategic goals and ways to achieve them. Strategy can be called both a science and an art, because it is not easy to plan and allocate available resources or use a situation to achieve the goal in the most efficient way. The goal or mission is the general goal of the existence of the organization (also state institutions, counties). Several districts link this goal to the well-being of the population. Public administration has not always known what to do next. At one time, the goal of Latvia's economic policy was to join the European Union, and this was achieved on May 1, 2004. As the then Foreign Minister Artis Pabriks admitted - "Latvia's only goal was to join the EU, now we have to start thinking about what we really want to achieve with it" [14].

Since 2004, Latvia's experience in planning has been developing. The Ministry of Environmental Protection and Regional Development (MEPRD) has developed Guidelines for the Development of Municipal Sustainable Development Strategies after the Administrative Territorial Reform of Municipalities in 2021 and the newly established municipalities in the strategic part recommend formulating a vision – long-term development vision for the future, which is simple for every inhabitant [1].

In the public sector, objectives are usually formulated in general terms. Analysing Article 15 of the Law on Local Governments, where the functions of local governments are defined, it must be concluded that they begin with the words "organize", "provide", "determine", "take care", "ensure", "promote", "participate", which does not reflect specific actions. Therefore, the recommendation to use the rational planning model in public administration, which includes five points: formulate specific tasks, set priorities, start planning after setting goals, forecast, analyse, experiment and regularly evaluate the manager, and provide feedback to the manager to stop ineffective activities [15].

Medium-term and short-term plans are also being developed at national level. The national long-term plan is Latvia's Sustainable Development Strategy "Latvia 2030", which sets the following priorities – investment in human capital, paradigm shift in education, innovative and eco-efficient economy, nature as future capital, spatial development perspective, innovative governance and public participation, and development of cultural spaces [13].

The medium-term plan is the National Development Plan and short-term plans can cover annual budgets covering one year. Municipalities must coordinate their SDS with the long-term plans of the state and the respective planning region (Riga, Vidzeme, Latgale, Zemgale or Kurzeme), with the medium-term tasks of the state and the region. Local level development planning documents are hierarchically subordinated to regional and national level development planning documents. Regional level development planning documents are hierarchically subordinated to national level development planning documents. Development planning documents are developed at national, regional and local levels.

Cabinet Regulation No. 628 Regulations on Local Government Territorial Development Planning Documents defines both the content of the local government SDSand the procedure for the development of the SDSFigure 1 shows the stages of the Sustainable Development Strategy (SDS). SWOT analysis, identified problems, identified trends and forecasts, and evaluation of problem solutions in terms of effectiveness and prioritization are the basis for strategy development. Then set the vision, goals and priorities. In the planning process, this stage is especially important in the new situation after the administrative-territorial reform. The vision is formulated as a long-term vision for the future.

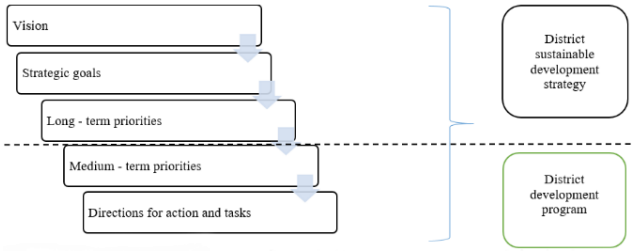

Fig. 1. Linking the development stages of a sustainable development strategy and planning documents.

According to the information available to the Ministry of Environment and Regional Development (MERD) almost all municipalities have already developed sustainable development strategies (SDS). After the administrative-territorial reform that has taken place, it is necessary to develop a new SDS by merging several municipalities, therefore the existing strategic goals are to be reviewed. (https://www.varam.gov.lv). Strategic goals are a focused set of policy settings aimed at achieving a vision. Strategic goals must correspond to the settings of the vision - each theme of the vision must be covered by a strategic goal. Goals have to be more specific than the vision, and each goal has to be limited to one idea. The strategic goal serves as a basis for setting priorities and identifying further actions [1]. Long-term priorities derive from strategic goals and are the most important directions of development or areas that contribute to the achievement of strategic goals. At the same time, the strategic goals and priorities of the municipalSDS must be linked to the development goals and priorities set at the national and regional level. The set goals and priorities must be aimed at creating an attractive living and working environment, which in turn is a precondition for the economic growth of the region [1]. Municipalities represent the interests of local people, so the Ministry recommends that the goals s should be subordinated to the well-being of the population (see Figure 2).

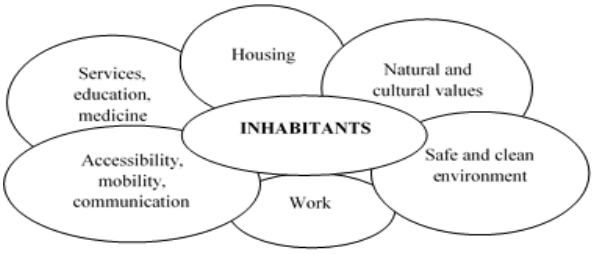

Fig. 2. Relationship and Interaction of Framework Conditions.

Municipalities compete to attract people to the region, so they use various marketing methods - develop the brand of the place, organize events and compete for large-scale cultural events, improve the environment. The author acknowledges that the most important factors for the population as a target audience are the place to live and work. Factors that rank differently for each person are high-quality social services, leisure opportunities, a clean and safe environment, and convenient transport infrastructure. The long-term development strategies of Cesis, Valmiera and Smiltene districts will be further analysed, determining whether or not the use of local marketing is used in this planning document.

IV. General Characteristics of Cesis, Valmiera and Smiltene Districts

Cesis municipality, Valmiera municipality and Smiltene municipality are neighboring municipalities that border each other in Vidzeme planning region. The district centers are relatively close: from Cesis to Smiltene is about 47 km, from Smiltene to Valmiera is about 37 km and from Valmiera to Cesis is about 35 km.

After the 2020 Regional reform, two cities in Cesis have merged - Cesis and Ligatne, as well as 21 parishes. Four cities have been united in Valmiera region - Valmiera, Seda, Rujiena and Strenci and 26 parishes. The most interesting changes have taken place in Smiltene municipality, for the cities of Smiltene and Ape and 14 parishes, including the former territory of Cesis district - Rauna parish and Drusta parish.

The largest of them is Valmiera region – 2948 square kilometres and 51,048 inhabitants (see Table 2).

Table 2. Characteristics of Cesis, Valmiera and Smiltene districts in the analysis of the current situation

	Cesis district	***Valmiera district***	***Smiltene district***
Total area	2668,2 km2	2941 km2	1800,55 km2
Population	41 177	51 048	19 165
Distance to Riga	87 km	107 km	132 km
Registered companies	4564	4430	1652
Forest area	146 983 ha	50%	55%
Agricultural land	31%	34%	33%
Unemployment	data not mentioned	data not mentioned	3.8%
Highlighted value	Cultural and historical heritage	Territorial development index among national cities 4th place in the country	Business development in relation to available resources

Vidzeme has the highest highland in Latvia. The following description of the territory can be found on the website of Vidzeme Planning Region, which must be taken into account in determining the SDS and can be used for positioning the site. Climate with early frost in autumn, relatively long winters, high rainfall, relatively short growing season. In the highest places, the snow cover falls a month later than in the lowlands of Central Latvia and around Riga.

Forests cover half of the region's territory, and forest products not only serve local consumption, they are also an important component of the mosaic landscape and have a significant recreational potential. The highlands are a watershed between the Gauja and the Daugava basins, so there are many rivers with large falls and deep valleys (on the slopes of the highlands). There are quite a lot of lakes in the Vidzeme highlands. The highland landscapes are very diverse. Vidzeme does not stand out against the background of other regions with significant mineral reserves: the relatively widespread resources of building materials are sand, sand-gravel, dolomite, clay, which are mostly found in small, local deposits, peat resources, and sapropel is found in most lakes. Quality drinking water. There are potentially large reserves of underground drinking water in the region, and water supply can be provided throughout the region [16].

In view of the above-mentioned characteristics of the region, which would apply to all three counties, it can be concluded that the values that could be of interest to potential residents, businesses and tourists could be largely due to their favourable geographical location, attractive living environment and tourist attractions, objects. The potential for entrepreneurship could be for forestry and wood processing companies, as well as for agricultural companies.

V. Analysis of Sustainable Development Strategies in Relation to Place Marketing-Example of Cesis, Valmiera and Smiltene Districts

The most visually extensive plan of the districts is for Smiltene. For the Smiltene district, the current situation, the strategic part and the perspective of spatial development are described in some detail.

Each district has uniquely described the current situation and linked this document with other territorial development planning documents. It is interesting that all three counties have marked the mutual connection of Cesis municipality, Valmiera municipality and Smiltene municipality both verbally and on the map of the region (see Figure 3). This marks the marketing feature of the territories - cooperation with other municipalities.

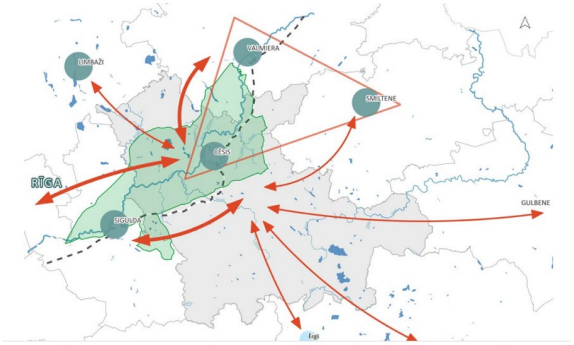

Fig. 3. Link between Valmiera, Cesis and Smiltene districts.

In describing the current situation, all counties lack SWOT analysis in the usual sense. Each region highlights its positive features – successful geographical position, distance to the capital Riga, roads, educational opportunities, potential for business, health care, as well as the most popular leisure and tourism facilities, weaknesses and threats are called challenges. The challenge for Smiltene municipality is gradual population decline, efficient management, availability of services to all residents of the municipality, improvement of transport infrastructure. Cesis district is concerned about the efficient transportation of students from their place of residence to the educational institution and road infrastructure by renovating and rebuilding roads. In the description of the current situation in the development plan of Valmiera district, the challenges are not emphasized, however, it is proudly announced that the Territorial Development Index for Valmiera is one of the highest in the country – the 4th place.

The slogan as a component of the brand is not mentioned in the county SDS, but in the author's opinion the slogan should express the core values of the county, expressed in the wording of visions or goals in the planning documents. The mission or overarching goal in Cesis and Valmiera counties is a human factor - Valmiera has a population, Cesis has a broader wording - a person, then Smiltene has a place (see Table 3).

TABLE 3. THE GOALS OF CESIS, VALMIERA AND SMILTENE DISTRICTS

	Cesis district	***Valmiera district***	***Smiltene district***
Slogan	The place for opportunities!	Let's live green!	Succeed in Smiltene region!
Overar ching goal	man and his goodness	the well-being of the population	a place to live, to work and to be
Vision	The basic value of Cēsis region is man and his well-being. Cēsis sets goals to create conditions for the implementation of the wishes of the population, creating a high quality of living space. The set of created conditions promotes the attraction of the population in the territory of the district	Valmiera region is a well-known territory of economic development, knowledge and excellence of public life in the Baltics. The town of Valmiera as a development center of national significance in Vidzeme interacts in the triangle of Vidzeme towns (Valmiera-Cesis-Smiltene)	Smiltene district is a people-created, recognizable, economically active, accessible, balanced, sustainable and scenic region in Vidzeme - a place to live, to work and to be

The visions are formulated in 1-2 sentences, with an explanatory text about the special values of the county. The formulation of the vision of Valmiera region is permeated by ambitions to be recognizable in the Baltic States, which are based on the fact that business is developed in Valmiera more than in the neighbouring regions. As a significant town, Valmiera is proud of Vidzeme University College and strives for excellence in all fields, it is proud that it is the only city in the trio of regions and is ready to cooperate. The wording of the vision for Cesis district is a bit different, which more emphasizes the "well-being" of a person, giving a promise to do everything so that people would like it there and they would like to live in this territory or return again. In its turn, the vision of Smiltene district shows similarities with the visions of both Cesis and Valmiera counties - joint emphasis on economic recognition and activity with Valmiera, emphasis on residence in Cesis region.

The SDS of all three counties emphasize the link with the long-term and medium-term plans of the state and at regional level, which is reflected in particular in the plans of Cesis and Smiltene districts.

TABLE 4. STRATEGIC GOALS AND LONG-TERM PRIORITIES OF SMILTENE REGION FROM 2022

	Strategic goals (SG)	***Long - term priorities (LP)***
1.	SG1 Socially active, educated and inclusive local community	LP1 A self-sufficient and growing society
2.	SG2 Economy -dynamic and competitive	LP2 Entrepreneurship based on local resources and innovation
3.	SG3 Sustainable and quality living environment	LP3 Available public infrastructure and services

The strategic objectives, as a set of policy options, serve as a basis for further prioritization and identification of future actions in the medium term. Analysing the strategic section of the SDS, Smiltene municipality has set three strategic goals (SG) and the resulting long-term priorities (LP) (see Table 4).

The first goal reflects that the main value of Smiltene region is the person and the local community. The second goal declares that Smiltene wants to be the most economically active region in Vidzeme region and with the third goal a promise is made to arrange public infrastructure and services to adapt to climate change.

Valmiera municipality has formulated four goals and four long-term priorities correspond to them (see Table 5).

TABLE 5. STRATEGIC GOALS AND LONG-TERM PRIORITIES OF VALMIERA REGION FROM 2022

	Strategic goals (SG)	***Long - term priorities (LP)***
1.	SG1 Personality growth	LP1 Service environment conducive to education, health, participation and creativity of the population
2.	SG2 Business development	LP2 Environment for attracting investment and economic growth, development of nationally and internationally competitive business
3.	SG3 Functional, aesthetic and green urban and rural environment	LP3 Innovative, environmentally friendly and balanced urban and rural environment
4.	SG4 Synergies between urban and rural areas	LP4 LP4 Baltic Center for Economic Development in Vidzeme and Strong Countryside

In essence, these formulations of goals represent similar visions for the future as in Smiltene district, only the connection between the city and the countryside is especially emphasized. The inclusion of Valmiera in the European Transport and Single Transport, Information and Trade Area of Northern Europe and the Baltic Sea has been set as a priority in achieving SG4. The third goal is in line with the slogan "Let's live green!"

Cesis region has set five strategic goals (see Table 6), emphasizing the development of cultural heritage, tourism sites and digital literacy. The development of digital services in the municipality for citizens and businesses would promote the use of e-services by all parties involved.

TABLE 6. STRATEGIC GOALS AND LONG-TERM PRIORITIES OF CESIS REGION FROM 2022

	Strategic goals (SG)	***Long - term priorities (LP)***
1.	SG1 Innovative resource-based, investor-friendly economic environment	LP1 Creating an efficient business ecosystem and creating new jobs
2.	SG2 High quality of life of the population	LP2 Customer-oriented high-quality management and a municipality dedicated to innovative ideas
3.	SG3 Recognition of culture and tourism at European level	LP3 Competitive county identity based on creative, cultural and tourism industries
4.	SG4 Environmentally friendly, sustainable and climate-neutral region	LP4 Efficient and sustainable use of the county's resources and preservation of the natural environment
5.	SG5 High digital literacy of the population and digital transformation of the economy	LP5 Municipally promoted digital transformation management

Spatial development perspectives graphically depict the desired structure of the territories in the end period of the SDS plan. These include guidelines for population structure and services, the structure of natural areas, industrial sites, transport and traffic infrastructure, and also priority areas.

Although all municipalities have developed SDS according to common recommendations and the content is slightly different, each of the surveyed counties has invested a lot of work in aligning long-term goals and priorities with national and regional development plans, joint territorial development strategies and neighbouring SDS.

VI. CONCLUSIONS

The concept of social marketing and aspects of sustainability are implemented with place or territorial marketing. The stages of regional and district development planning partially overlap with the stages of place or territorial marketing, which indicates the similarity of the marketing concept to strategic planning. Place marketing includes solving the problems of corporate social responsibility, which is important in the management of local governments.

The territory as a product is positioned as a special place with a competitive offer for residents, entrepreneurs, tourists. A long-term plan creates a positive image of the area in question.

In the sustainable development strategies of the counties, the market is segmented and the offered products are oriented to certain target segments, according to their needs. Emphasis is placed on the internal market - the support of local residents and companies. As a result of the development and application of place marketing, the strategies of Valmiera, Cesis and Smiltene districts have a discernible similarity with the marketing strategies of companies and they include elements of marketing strategies.

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Risk Analysis for Apple Orchard Survey and Monitoring Using UAV

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Abstract. **Risk analysis is an integral part of modern business management because successful business largely depends on the effective implementation of risk analysis. Agriculture is an important sector in the national economy, therefore Industry 4.0 increasingly provides digital solutions in orchard management, which facilitate and simplify decision-making in daily tasks. Meanwhile, unmanned aerial vehicles are applied as the agriculture sector's main monitoring and data acquisition tool. However, this means that it is necessary to pay attention to risk analysis due to the process of managing the orchard, where not only a person and the mechanized equipment controlled by him, which moves on the ground but also flying automated equipment participates. The purpose of the article is to perform the risk analysis for the survey and monitoring of orchards for yield estimation using unmanned aerial vehicles by considering commercial apple orchards in Latvia. The main thing is that most risks are predictable, but planning is necessary to reduce the probability of their occurrence.**

Keywords: decision-making, risk analysis, unmanned aerial vehicle, security, SORA.

I. INTRODUCTION

Like other agricultural sectors, fruit growing faces a series of development challenges today. On the one hand, it is the impact of environmental factors and climate changes: extreme weather conditions such as unforeseeable spring frosts, periods of excessive drought or precipitation, shifts in the phenology of plant development, and emerging new pathogens or the broader spread of existing ones. On the other hand, society demands healthy, pesticide-free, and competitively priced horticultural products. These are pretty contradictory wishes that are difficult for the farmer to fulfill. Therefore, improved cultivation technologies are needed, i.e. see, smart fruit-growing solutions. Smart fruit-growing includes a modern way of farming based on the application of advanced technologies, which includes all cultivation processes to increase efficiency rather than capacity. This means that the tasks of smart fruit-growing are to create an efficient and optimal ratio of input and output through intelligent and goal-oriented analysis, planning, and observation. In order to realize these tasks, it is necessary to have a fast, accurate and sufficient amount of information (data), which the use of UAVs can provide, especially automated data collection and immediate transfer to decision-making systems.

As technology continues to advance, Unmanned Aerial Vehicles (UAVs) have become increasingly popular for various applications, including agriculture. In the context of orchard survey and monitoring, UAVs offer a convenient and efficient way to collect data and monitor, for instance, the health of trees. However, the use of UAVs also comes with potential risks that need to be identified and managed. In this article, the authors will explore the risks associated with using UAVs for orchard surveys and monitoring and discuss how these risks can be mitigated through a comprehensive risk analysis. By analyzing these risks and implementing appropriate measures, fruit

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growers, and orchard managers can ensure that the use of UAVs is safe, efficient, and effective in achieving their agricultural goals.

Risk analysis is currently an integral part of process management. For the implementation of a successful project, it is necessary to evaluate the risks in order to be aware of the potential threat and its impact. Risk assessment is not only a voluntary decision of the project implementer but in some sectors and areas, it is regulated with the help of regulatory acts. In order to be able to fly with a UAV, it is necessary to develop a risk analysis plan, which must be coordinated with the relevant institutions (Latvian Civil Aviation Agency (hereinafter - LCAA)).

The purpose of the article is to perform the risk analysis for the survey and monitoring of orchards for yield estimation using UAV by considering commercial orchards in Latvia.

II. Materials And Methods

In the study, the risk analysis is based on the Specific Operations Risk Assessment (SORA) methodology, as the authors develop Unmanned Aerial System (UAS), which includes a UAV, Android control (Android mobile application), and a base station.

SORA is a methodology for classifying the risks posed by UAV flights into a specific operational category and establishing risk mitigation and safety objectives. It helps the operator to determine operational limitations, training objectives for personnel, as well as technical requirements for the UAV and develop appropriate operating procedures, which are the operator's manual [1] (Fig. 1.).

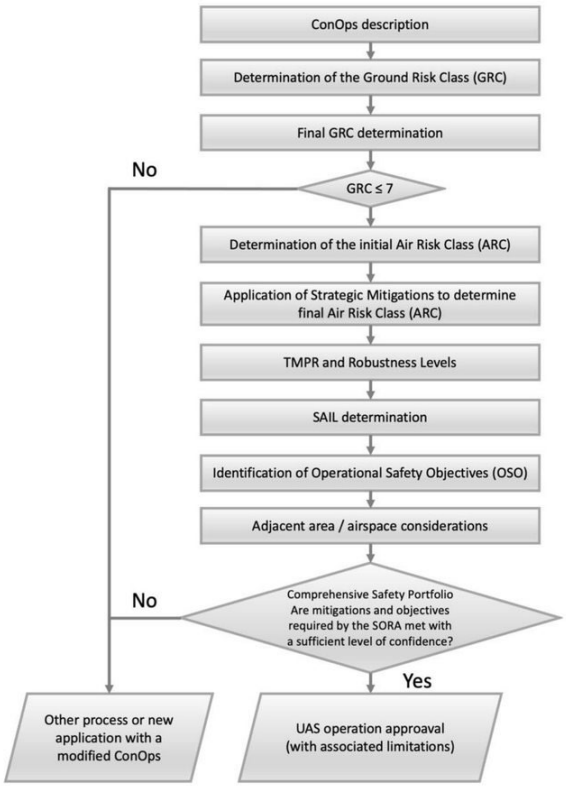

Fig. 1. SORA methodology 10 steps [2].

(ConOps – Concept of Operations)

Our study is scoped by orchard monitoring and yield forecasting. It provides a possibility to apply small and light UAVs of C0-C1 models because it is not required to transport any kind of cargo like pesticides. Therefore, authors restricted analysis with C1 maximal parameters, which define the functional requirements like maximum take-off mass less than 900 g, including payload; a maximum speed in level flight of 19 m/s, etc.; considering to Regulation (EU) 2019/945 (R945).

Existing Institute of Horticulture agrotechnical trial plantations were chosen for UAV test flights, yield development data collection, and risk analysis. These plantations are designed according to the trends of modern fruit growing. The modern commercial orchards are structured as fruiting walls of trees on tree-height-reducing rootstocks providing corridors of space for harvesting and orchard management tasks (Fig. 2).

Fig. 2. Photo of commercial orchard.

The experimental trial, where UAV flight tests took place, represented a diversity of apple cultivars ('Alesja', 'Antonovka', 'Beforest', 'Belorusskoje Malinovoye', 'Dace', 'Daina', DI-3-90-45, DI- 93-4-22, 'Edite', 'Eksotika', 'Felicita', 'Gita', 'Lora', 'Monta', 'Saltanat', No. 28-97-4, 'Zarja Alatau'), grafted on dwarfing (B.396, M.9, B.9) and semi-vigorous (MM 106) rootstocks. The distance between rows of trees was 4 m for dwarfing rootstocks, while for semi-vigorous rootstocks - 4 - 5 m, with the distance between trees in a row - was 1 to 3 m. Some orchards can have bird nets. Therefore, it was considered to fly between fruit walls. Meanwhile, the photo is obtained after each N meters to simplify the geopositioning of trees (Fig. 3).

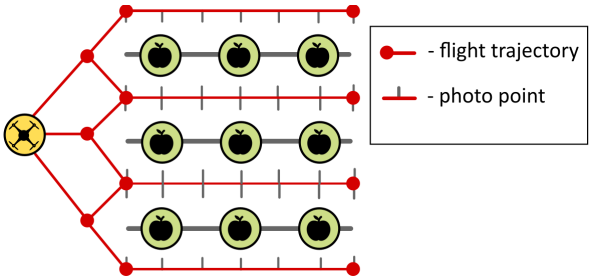

Fig. 3. Flight trajectory of UAV for orchard monitoring.

When performing a risk analysis according to the UAV and flight location mentioned in the methodology, the following and restrictions apply: flights are conducted in the territory of Latvia and flights are conducted over private property up to 30 m belonging to the UAV operator.

The CORAS method was applied for the security risk analysis of UAS [3]. The high-level analysis was completed including approval stage. The objective of the high-level analysis is to get an overview of the main risks, which will identify the non-functional requirements of UAS.

Risk assessment is performed based on the two-dimensional risk assessment matrix, assessing the probability of risk occurrence and possible consequences (Tab. 1., 2., 3.). According to Tab. 3, low risk (L) - 1-2, medium risk (M) - 3-6, and high risk (H) - 7-12.

TABLE 1 CHARACTERISTICS (DEFINITIONS) OF THE CATEGORY "PROBABILITY"

Probability	***Characterization***	***Quantitative assessment***
Rare	So rarely possible during UAV operations that no compliance is required	1
Unlikely	This is not expected to occur, but may still occur during UAV operations due to certain circumstances	2
Often possible	It is expected that this may occur during the operation of the UAV	3

TABLE 2 CHARACTERISTICS (DEFINITIONS) OF THE CATEGORY "IMPACT"

Impact	***Characterization***	***Quantitative assessment***
Insignificant effect	Failure conditions that would not affect UAV operation, data and human safety	1
Low impact	Conditions that do not significantly reduce UAV performance apply.	2
Dangerous	Refers to conditions that reduce the UAV's ability to perform tasks accurately or completely. Conditions that result in danger for non-human objects	3
Catastrophic	Covers conditions that render the operation of the UAV no longer possible to use Conditions that result in dangerous conditions for human health or life apply.	4

TABLE 3 RISK PROBABILITIES - IMPACT ASSESSMENT MATRIX

Impact Probability	***Insignificant effect***	***Low impact***	***Dangerous***	***Catastrophic***
Rare	*1*	*2*	*3*	*4*
Unlikely	*2*	*4*	*6*	*8*
Often possible	*3*	*6*	*9*	*12*

III. RESULTS AND DISCUSSION

The latest technological advances allow UAVs to become an effective monitoring tool for improving orchard management, which can provide growers with much more detailed and accurate information about the health status of fruit plants, geometric variables, physiological variables, etc. [4]. However, various challenges have to be faced in the use of UAVs in the inventory and monitoring of orchards.

The diversity of the natural outdoor environments and the vast amount of diversified data types required to plan and deploy autonomous agri-field operations still comprise significant bottlenecks. Indicatively, challenges exist even at the seemingly superficial level, for example, calculating an autonomous vehicle's optimal route planning (i.e., generating a safe path between a source and a destination point) [5], [6].

Orchards (the source of the fruit industry chain) require site-specific or even individual-tree-specific management throughout the growing season—from flowering, fruitlet development, ripening, and harvest—to tree dormancy. The recent increase in research on deploying UAVs in orchard management has yielded new insights but challenges relating to determining the optimal approach (e.g., image-processing methods) are hampering widespread adoption, largely because there is no standard workflow for the application of UAVs in orchard management [7] but automation and precise orchard management not only brings more profits to growers but also reduces the damage to the environment [2].

The constantly growing number of operations employing UAVs requires not only the identification of hazard sources or risk assessment recommended by the applicable regulations but also comprehensive risk management [8].

The use of UAVs for apple orchard survey and monitoring is subject to certain risks, particularly in adverse weather conditions (Fig. 4). UAVs are susceptible to wind, rain, fog, and other weather conditions that can affect their stability and maneuverability. For example, strong winds can cause a drone to drift off course or lose altitude, which could result in a collision with a tree or other obstacles in the orchard. Rain or fog can also interfere with the drone's sensors and camera, which could lead to poor data quality or even a complete loss of data. Therefore, it is important to assess weather conditions before deploying a UAV and to avoid using it in

unfavorable conditions. By doing so, the risk of accidents, equipment damage, and data loss can be minimized, ensuring a safe and successful apple orchard survey and monitoring operation.

To ensure continuous and reliable monitoring using UAVs, regular maintenance is essential (Fig. 4). Routine maintenance tasks include checking the UAV's batteries, propellers, and sensors for signs of damage or wear, and cleaning the camera lens and other components to ensure optimal performance. It is recommended to perform maintenance tasks before and after each flight to ensure that the UAV is in good working condition. In addition to routine maintenance, regular calibration of the UAV's sensors is also important to ensure accurate data collection. Calibration should be performed periodically based on the manufacturer's recommendations or after any significant changes to the UAV's hardware or software. It is also important to keep the UAV's firmware up-to-date to ensure that it is operating with the latest security patches and software updates. By performing regular maintenance and calibration tasks, the risk of equipment failure and data loss can be minimized, and the UAV can continue to provide reliable and accurate data for apple orchard surveys and monitoring.

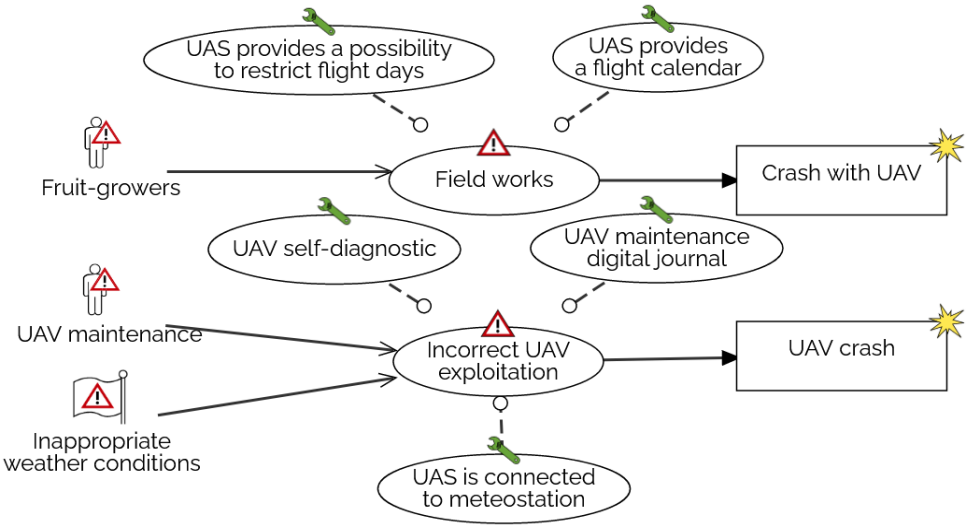

Fig. 4. Treatment of UAS exploitation risks.

Considering the generally accepted management practices of orchards, the inter-rows are used as movement lanes for employees and equipment and are used in all orchard care activities: tree training, soil treatment, pesticide application, harvesting, and yield transport. UAVs also use the same lines to navigate during data collection. Therefore, it is essential to coordinate time and space between UAV flying and orchard management activities (Fig. 4). Therefore, the principal risks of using UAVs could be the following:

- Collisions and injury to garden management personnel who are not warned in time and are in the garden during the operation of the UAV. This can be especially relevant for workers who work with mechanical tools (electric tree training shears, hand-held pesticide sprayers) that make noise and thus mask the approach of UAVs.

- Collision with garden equipment (tractors that do soil management, pesticide spraying) whose drivers are entirely focused on the work to be done, while the cabin of the equipment and the noise it makes mask the approach of the UAV.

Speaking about software development and algorithms, it is important to verify flight regions considering restricted and private territories. Another requirement for UAV fly mission planning is power battery consideration, which is called the drone arc routing problem. The more novel idea is the vehicle-drone arc problem, which considers mobile UAV stations, which is an interesting solution for future studies [9]. If the planning algorithm is correct, another challenge is GPS coordinate precision, which must be sufficiently accurate, because the distance between rows of trees can be 1 meter (Fig. 5).

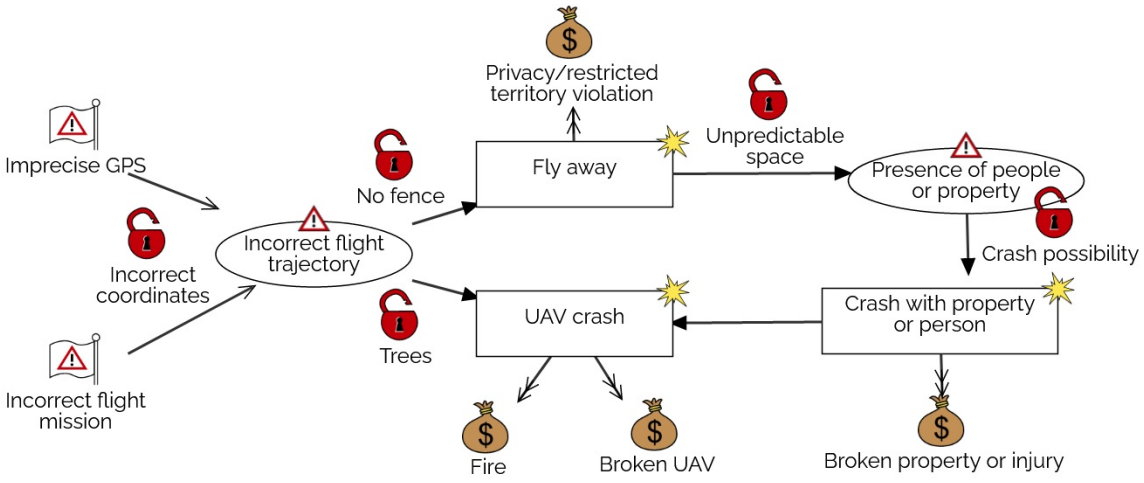

Fig. 5. Risks of uncontrolled flight.

For successful risk management, a risk register is created, where it is possible to easily see the risks that need attention, what risk mitigation measures need to be implemented to reduce risk (Tab. 4). The risk register was created from a business point of view, assessing the risks of possible financial losses that may occur to the owners of commercial gardens.

TABLE 4 RISK REGISTER

Name of the risk	***Description of the risk***	***Consequences of risk***	***Probability***	***Impact***	***Risk: L, M, H***	***Risk mitigation measures***
Risks arising between the UAV and the objects being surveyed						
Getting tangled up	The UAV gets caught by the branches or bird nets of the object while in flight	The UAV is damaged or destroyed	2	2	M	Determining the exact flight path. Using sensors to avoid
Crashing into the survey object	The UAV crashes into the survey object during flight	The UAV is damaged or destroyed	2	3	M	Determining the exact flight path. Using sensors to avoid hitting the tracked object.
Risks arising between UAV and human						
UAV collision with a person doing work in the orchard	A UAV crashes into a person in flight, who is working considering work plan	The UAV is damaged and/or a person is injured	1	4	M	The location time of people in the orchard and the flight time of the UAV are coordinated by UAS.
		The UAV is damaged or destroyed	1	4	M	
	A person disturbs the UAV (unauthorized presence)	The UAV is damaged or destroyed	1	4	M	Place warning signs about a possible UAV flight, limit private territory
Risks arising between the UAV and another technique						
UAV collides with machinery employed in a commercial orchard	During the flight, the UAV crashes into the machinery employed in the commercial garden	The UAV is damaged or destroyed	1	4	M	The location time of the machinery employed in the commercial orchard and the flight time of the UAV are coordinated by UAS.
		Equipment damage is caused	1	3	M	

The UAV flies while the machinery is working in the garden	The liquid damages the UAV	The UAV is damaged or destroyed	1	4	M	
Risks arising under the influence of weather conditions						
Wind too strong	UAVs cannot fly short time period	Necessary data is not collected	3	2	M	Work planning and coordination considering meteorological conditions
Heavy rain	UAVs cannot fly	Necessary data is not collected	3	2	M	
Thunderstorm	UAVs cannot fly	Necessary data is not collected	3	2	M	
Risks arising from the operation of UAVs						
Inadequate UAV technical condition	UAV breaks down under normal use due to failure to properly assemble/test before the flight.	The UAV is damaged or destroyed	1	4	M	Follow UAV operating requirements carefully. UAS provides a maintenance journal.
Departure outside the designated flight area	During the flight, the UAV violates the boundaries of the territory intended for flight	A UAV is lost	1	4	M	Geo-fensing, return-to-home
		A person is injured	1	4	M	
		Third party property is damaged	1	3	M	
		The restricted area is being violated	1	4	M	

All of them are medium risks, they depend on human activity, and they can be reduced if appropriate risk mitigation measures are implemented. The highest risks are related to weather conditions, on which possible risk mitigation measures are conditional.

The future trend of UAV development is related to trustworthy UAS development, which complies with ideas about robots and Industry 5.0.

IV. Conclusions

In order to be able to fully use UAVs for the survey and monitoring of commercial apple orchards, it is necessary to comply with the legislative requirements of the specific country where flights are planned. Determine exactly the technical parameters of the UAV intended for flight and then comply with the rules and requirements that are set according to the SORA methodology. Identify potential risks, assess them, and develop appropriate measures to reduce the impact of risk. Our study was related to the orchards located in Latvia

Risk management is widely used in various industries. From the IT point of view, risks are potentially perceived as a negative phenomenon that can cause possible losses.

Acknowledgments

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Digital Solutions for a Climate Neutral Economy: International Framework of Eco-Digital Projects

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The research reveals practical side of a twin green and digital transition in terms of a global path to climate neutral economy. Digitalization is considered as a driving force behind the transition towards a low-carbon economy. The article focuses on wide international experience of IT implementation for industrial decarbonization. Analytical database of the research covers more than 200 different eco-digital projects in various areas of climate regulations given by international organizations. This allows to outline international framework of eco-digital projects based on geolocation, regional features, IT decisions, level of technological support and climate influence. International differentiation of climate-digital projects was established by region. Comprehensive analysis of these data is provided to identify the gap in digital capabilities and climate targets. The rating of IT applied in climate-digital projects was built. As a result, the research proposes key project ways of the twin green and digital transition that are the most attractive for achieving climate neutrality on a global scale.

Climate neutrality, green economy, eco-digital, twin transition.

I. Introduction

Climate neutrality has become a major challenge for global society on its vital path to the greener future. This case poses the greatest difficulties for the modern economy since decarbonization implies complex transformation of global manufacturing processes, consumption chains and entrepreneurial behavior patterns. Despite the fact, that international actors are more likely to engage in lobal climate initiatives such as Paris Agreement, Green Deal, European roadmap 2050, Fit for 55 and others, the pace of change remains insufficient to achieve "zero" emissions and prevent irreversible climate change [1]. Moreover, the mentioned year 2050 was not chosen by chance as a year of achieving climate neutrality of the economy. Delaying this countdown may lead to the irreversibile climate change and global struggle for natural resources [2], [3].

With this in mind, digitalization could be considered as a driving force for the climate neutrality, enabling a wide range of digital tools and applications in climate governance and regulations.

Furthermore, European Commission declares the necessity of namely "twin green and digital transition" of the economy [4]. Modern scientists maintain the idea of synergetic linkages in "eco-digital" space [5], [6], [7], [8] and emphasize fundamental role of technology clusters in climate stability, particularly in metallurgy, agriculture, energy consumption and transportation [9], [10], [11], [12]. We also have to admit such remarkable global initiatives as "Climate Neutral Now" by United Nations, "Sustainability in the Digital Age" by Future Earth Canada Hub, "Breakthrough energy" by Bill Hates and "Sustainable digitalization" by European Digital SME Alliance. These platforms collect data about eco-digital projects and make first attempts to arrange them according to the climate neutrality targets.

However, the scientific discourse lacks consistency in the presentation of the global digital paradigm of the green transition. Besides, there is still insufficient understanding of the digital impact on climate results caused by different industries and world regions. Technological differentiation of eco-digital projects also deserves additional attention. The outlined issues formed the basis of our research.

II. Materials and Methods

The research provided complex assessment of international framework of climate-digital projects aimed at the climate neutrality. Quantitative analysis was built on the basis of comprehensive open data provided by Future

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Earth Canada Hub on the web platform "Sustainability in the Digital Age" [13]. This data was chosen as a major statistical material because of 3 main reasons. First, this database provides relevant information for more than 225 climate-digital projects, collected worldwide. Second, this database was arranged on clear principles and methodology. Thus, it includes only those eco-digital projects, that help to reduce the sources or increase the sinks of GHG; leverage digital tools; influence or/and inform governmental and non-governmental players. Third, all information is presented in the original tabular form without distortion. This allows each researcher to build their own models and assumptions, define labels, logical markers and criteria.

Thus, the data was sampled, filtered and ranked with the diversification of the following categories and subcategories: region of the project; form of leading (academic institution; civil society; partnership; private sector); applied digital decisions; strategy and focus of the project.

We also used metodological approach given in the analytical report [14] and expanded the study of digital tools in climate projects. At the next stage of the research, key elements of abstract and logical, systematisation and generalisation methods were applied to rethink systemic linkage between digital and green transition.

III. Results and Discussion

The implementation of digital technologies may effectively address ecological concerns, caused by modern manufacturing. Moreover, there are at least three areas in which digitalization can contribute to environmental sustainability.

The first area focuses on reducing greenhouse gas emissions throughout digitalisation and optimization of production processes, resource consumption and transportation logistics.

The second area involves eco-innovations to absorb harmful substances in urban environments and mitigate the impact of the greenhouse effect.

Finally, the third area implies regulating framework for climate neutrality within the creation of digital platforms for monitoring and controlling environmental impacts, both positive and negative, while also engaging stakeholders in this process.

International experience of climate-digital projects allows to assume the following effective digital initiatives aimed at climate neutrality and stability [8], [15], [16]:

– web platforms with open access to data in all areas related to the use of natural resources, subsoil and environmental impacts of production;

– digital registers that continuously update the country's natural wealth and track changes caused by GHG emissions;

– digital maps that integrate geo-data for effective resource management;

– digital "investment atlases" and digital auctions providing transparent sale of natural resources for various industries;

– integrated system of digital permits. On the hand, it provides clear subsoil use enabling to streamline the process and create a transparent register of subsoil management. On the other hand, it also includes wide range of "digital tickets" for individuals as permitions for hunting, fishing, logging, etc.;

– digital monitoring systems that track emissions in both industrial zones and public sector, with generating automatic protocols for environmental violations.

However, the demand for climate programs differs significantly depending on the region, as well as the possibility for their implementation. Based on the analysis of statistical data [13], the following international differentiation was established (Fig.1).

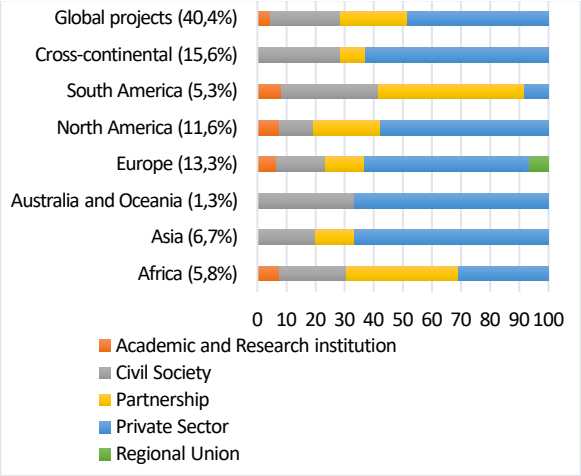

Fig. 1. International diferenciation of climate-digital projects by region.

The diagram represents, that lion's share of the climate-digital initiatives regards to global projects and cross-continental initiatives, that are highly versatile in use worldwide. In addition, most of them are provided by private sector (48%), civil society (24%) and in partnership and consortium (23%). We have to admit infinitesimal share of academic institutions involved in climate-digital project management (4%), although they will have to develop global paradigm of green-digital transition.

A large amount of climate-digital projects concern ecological issues in Europe (13,3%) and North America (11,6%), while African, Asian and South American decarbonization path is still under-served. Low indicator of project activities in Australia may be derived from the fact that Australia rather joins global and cross-continental eco-digital initiatives.

Another remarkable fact is that the most effective model for twin green and digital transition in "ecologically deprived" regions as Africa and South America led to partnership and civil society. Thus, voice of the society

will play crucial role in fighting climate change in the nearest future. Analysis confirmed the global willingness to support third-world countries in their path to climate neutrality. Over 30 cross-continental projects (15,5 %) are elaborated by the institutions of EU and USA directly for Africa, Asia and South America [14].

Considering the strategies for climate-digital management, we pay attention to the Philanthropy's model, that outlines 4 appropriate levels of green governance [17]:

1. Data mobilization to strengthen decision-making (S1).
2. Digital optimization of existing strategies (S2).
3. Modeling behavioral change (S3).
4. Participation and empowerment (S4).

Systematization of existing database of 225 projects by this criteria allows to represent the following space model (Fig. 2).

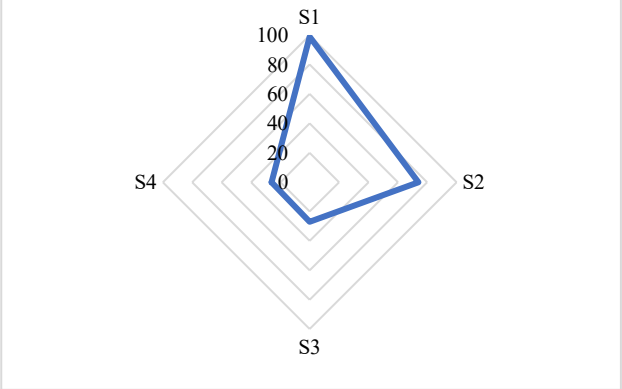

Fig. 2. Space model of strategical priorities of climate-digital projects.

The diagram depicts apparent focusing on data mobilization and digital optimization of existing strategies. Despite the fact, that such tendency contributes to industrial adaptation and likely strengthen decision-making process, this is not enough for qualitative changes and achieving the climate neutrality in the nearest future. There are only a few project initiatives about participation and empowerment of the society. Meanwhile, climate neutrality implies profound and systemic behavioral change of economic actors.

Thinking this way, we assume a possibility to engage more academic and research institutions, international organizations, and unions to refocus climate-digital projects into the spheres of behavior change and empowerment.

The majority of contemporary databases containing information on climate-digital projects concentrate on several key areas. These include the expansion of carbon offsetting, carbon credit, and other environmental commodity markets. Additionally, there is a focus on biodiversity and ecosystem conservation, as well as the involvement of local communities. There is also an emphasis on promoting food and water security through sustainable agriculture practices, as well as improving air quality. The adoption of renewable energy sources is also a key area of interest. Other notable focuses include supporting various environmental policies, strengthening private sector sustainability accounting and reporting, and reducing emissions by improving efficiency and optimizing energy use.

No doubt, overall effectiveness of climate-digital initiatives results not only from the institutional ability, but directly from the technological level and access to innovation. Digitalization provides a wide range of IT decisions for the economy. Some of them are successfully applied in climate governance (Fig. 3)

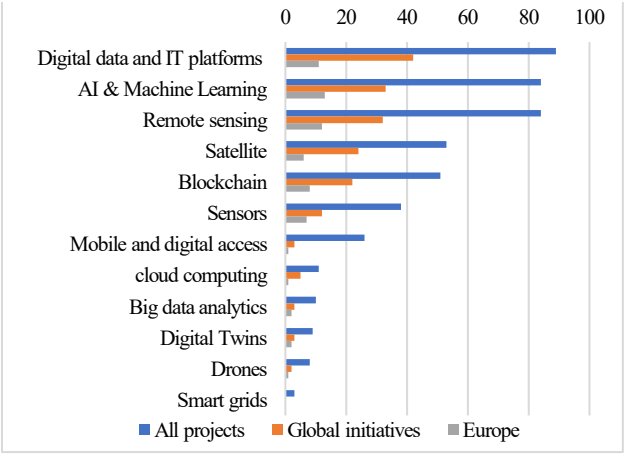

Fig. 3. Rating of IT applied in clamate-digital projects.

As we can see, the most popular technological decisions for climate regulation include digital data and IT platforms, artificial intelligence, machine learning, remote sensing, satellites and blockchain, while digital twins, drones and smart grids are used in separate projects.

Moreover, the quantitative analysis of applied IT showed its significant differentiation depending on the project scale (Table 1).

TABLE 1 FREQUENCY OF IT USE IN CLIMATE-DIGITAL PROJECTS (BY EACH 100 PROJECTS)

Number of IT applied in the project	**1**	**2**	**3 and more**
IT, that could be used individually or in groups			
Digital data and collaborative platforms	38	47	36
AI & Machine Learning	22	33	63
Blockchain	27	24	15
Mobile and digital access	10	14	13
cloud computing	1	0	14
Digital Twins	1	8	6
Smart grids	2	0	1
IT, that could be used directly in groups			
Satellite	0	27	56
Sensors	0	6	49
Big data analytics	0	2	13
Drones	0	2	10
Remote sensing	0	37	92

The table above reveals that the most important technologies for modern climate neutral targets are collaborative IT platforms, AI and Machine learning, and blockchain. These digital decisions are widely applied in climate digital projects individually or in groups with other technologies. In contrary, satellites, sensors, drones and remote sensing need additional support and are used in groups with another IT. Such differentiation reflects current demand of the climate neutral economy and its overall orientation on adaptive strategies (S1, S2 at Fig. 2).

In general, international framework of climate-digital projects contributes to overcoming regional barriers on the way to global neutrality of the economy. We came to the conclusion about the most important ways of the "green-digital" development:

1. Monitoring systems and data analysis of climate change. It implies wide application of sensors, drones, satellite technologies for in-depth analysis of climate changes and emissions in the context of the activities of individual industries and world regions.

2. "Big data" as a tool for assessing the current state of climate change and forecasting its consequences.

3. Launching the information platforms and international R&D clusters for the direct development and implementation of innovative technologies in the field of energy efficiency, renewable energy and other areas related to the reduction of GHG emissions.

4. Integration of the digital tools into the climate diplomacy and green communications all over the world. In particular, the development of web portals, mobile applications, social networks and educational materials to involve the society, business and government in the decision-making process in order to increase their awareness about opportunities, directions and sources of green transformation projects.

5. Development of digital educational platforms and joint scientific programs in the field of climate management aimed at the overcoming the gap in resource provision of projects and formation of ecological thinking.

Thinking this way, digitalization could be considered as follows.

First, digitalization as a set of applied digital tools and technologies to ensure climate neutrality at the level of individual industries and institutions.

Second, digitalization, as a process of optimization of green transition processes, integration of technologies into the production cycle with the aim of increasing its environmental friendliness, productivity and energy efficiency.

Third, digitization as a dimension of the global information environment, which covers a wide range of stakeholders: the public, authorities, business, specialized experts, scientists, educators for the joint development and formation of climate policy instruments, which will ensure a wider understanding and support of climate-oriented programs by all players of the international economic space.

IV. Conclusions

Modern international framework of climate-digital projects covers a wide range of digital decisions on the global way to a climate neutrality.

The demand for climate programs varies significantly depending on the region and the feasibility of implementation. The majority of climate-digital initiatives are focused on global projects and cross-continental initiatives that are highly versatile and applicable worldwide. These initiatives are predominantly provided by the private sector, civil society, and through partnerships and consortia.

Modern climate-digital projects prioritize data mobilization and digital optimization of existing strategies. While this trend supports industrial adaptation and strengthens decision-making processes, it is not sufficient for achieving qualitative changes and climate neutrality.

Quantitative analysis indicates that the most important technologies for achieving modern climate-neutral targets are collaborative IT platforms, artificial intelligence, machine learning, and blockchain. These digital solutions are commonly used individually or in conjunction with other technologies in climate-digital projects. In contrast, satellites, sensors, drones, and remote sensing require additional support and are often utilized in combination with other IT technologies. This differentiation reflects the current demand for climate-neutral economy and its overall focus on adaptive strategies rather than development. However, in the nearest future global eco-digital projects may shift the focus into the modeling of behavior change and empowerment.

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Prerequisites for the Creation of the "From Farm to School" Model in the Klaipeda Region: the Study of Target Groups' Expectations and Perceptions

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Abstract. **The focus of the article is on school meal programs that are common throughout the world and are implemented to promote students' healthy eating habits and bring added value to their learning outcomes. In recent years there has been increasing emphasis on the possibility of improving school meals by including locally grown products, thus contributing to the development of local economic systems. This model has acquired the name "Farm to School" in practice of some countries and, according to its supporters, emphasizes public procurement of locally grown food as a key market opportunity for farmers. The article has been prepared within the BSR Food Coalition project (funded by Interreg Baltic Sea Region Program, contract #S002). The project seeks to create the conditions for the emergence of the "From farm to school" model in the Baltic States. The study presented in the article aims at disclosing the conditions and opportunities for the promotion and use of foods produced by local farmers in general education schools in Klaipeda region, Lithuania as well as at defining necessary educational efforts to increase healthy nutrition, develop general health habits, and agricultural and food system literacy within general education schools and their communities. To achieve the aim the surveys with project target groups (school administration, students and their parents) have been carried out in Klaipeda region. The objectives of the survey were to gather data on target groups' perceptions of local school food procurement and to disclose their opinion, needs and expectations related to model development. The findings of the study would be helpful for designing the further steps of collaboration between schools and local farmers in Klaipeda region.**

Keywords: cooperation between farmers and educational institutions, food chains, "From farm to school".

I. INTRODUCTION

Today's world tendencies such as increasing population, growing consumption, the problems of climate change, anthropogenic pollution of the environment, are becoming more prominent and raise the relevant issues of food quality and sufficiency. The priorities of the world, European, including Lithuania, strategic documents are related to the goals of implementing sustainability and food strategies. In order to ensure the sustainable development of countries, in 2015 The UN has approved 17 Sustainable Development Goals, which cover the areas of improving the social environment, economic development, environmental protection and cooperation [1]. All UN member states are committed to the implementation of these goals. As a result of this, the project "Towards a Sustainable Lithuania: Integration of

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Sustainable Development Goals into State Strategic Documents" [2]. was implemented in Lithuania by the Ministry of Environment of the Republic of Lithuania, where one of the strategic issues addressed was to eliminate hunger, ensure food self-sufficiency and better nutrition, promote sustainable agriculture. Sustainable and resilient food production systems are key to achieving this goal. Transitioning to sustainable agriculture will help ensure food security in the future as demand increases and the climate changes. Policymakers will need to promote sustainable food production systems and ensure the proper functioning of food markets and access to market information. One of the relevant areas for achieving this goal is improvement of school meals systems.

School meal programs are common throughout the world and are used to promote healthy eating in children and improve learning outcomes [3]. In recent years, there has been increasing emphasis on the possibility of improving school meals by including locally grown products, thus contributing to the development of local economic systems [4]. This model has been called "Farm to School" in practice of some countries and, according to its proponents, emphasizes public procurement of locally grown food as a key market opportunity for farmers [5]. Farm-to-school and similar programs are common in developed and developing countries in South America, North America, Asia and Europe [6], e.g. "Farm Safe Schools" (Ireland), "Food for Life" (England), "From Farm to Cafeteria" (Canada), etc. [7].

The National School Lunch Program (NSLP) is the largest in the United States, serving more than 100,000 public and private schools and child care centers. Consistent research is being conducted to uncover various aspects of this program. According to researchers, the program is an important link connecting school canteens and local farmers [8]. Studies show that this program not only contributes to improving the quality of food for students in schools, but also creates added value for the rural economy [9]. By establishing direct links with schools, small and medium-sized farmers can access a stable and reliable market that ensures a fair price for their products [10]. Farm-to-school programs in the United States include a wide variety of activities, such as harvest festivals, field trips, school gardens, and farmer educational visits.

In Europe, the issue of school meals in cooperation with local farms has only recently begun to be addressed. In October 2022, the StratKit+ project, financed by Interreg Baltic Sea Region funds, started. The project aims to create guidelines for the public sector, food providers and other institutions on the integration of sustainable public catering regulation in schools, day care centers, hospitals and public sector institutions. Today, when facing with extremely rapid changes, public sector organizations are in great need of support, guidance and communication with the intended target groups, in order to enable consumers to receive meals that meet their nutritional needs. However, there is also a strong focus on the local network of suppliers and, of course, sustainability in order to achieve an increased amount of sustainable products supplied by the catering sector [11]. In January 2022, the SchoolFood4Change project funded by the European Union was also launched, which consists of as many as 43 European partners, which include environmental, governmental and non-governmental organizations, scientists, scientific institutes, schools, chefs and food and health professionals. The key aspects and goals of the project are: 1) To make the food served in schools innovative, climate-friendly, healthy, tasty, without waste and most importantly with a local identity; 2) Holistic long-term approach to food provided in schools for a long-term period; 3) Creation of a sustainable catering regulation. This is only part of a long-term strategy enabling the study of universally important aspects on a broad European scale [12].

In Lithuania, it has been declared for several years that children's nutrition needs to be supplied with more fresh products - vegetables, fruits or fish from local growers and producers. Until now, most of educational institutions are fed by a few large companies. This happens due to the fact that municipalities and other organizations purchasing catering services choose suppliers offering according to the lowest prices and large quantities. In order for the product grown or produced on the farmer's farm to reach consumers in the shortest or "straightest" way, and for them to consume fresh, local, organic produce, to raise awareness of sustainable food use and at the same time contribute to the creation of a sustainable economy and environment Ministry of Agriculture of the Republic of Lithuania strives to create all conditions so that only natural, fresh and nutritious food products reach children through institutions providing public services. The Public Procurement Service proposes to divide purchases into smaller values so that local producers and farmers could also participate in the tenders [13]. However, according to municipalities and farmers, the biggest problem today in Lithuania is still rather complicated public procurement procedures. Small farmers who cannot ensure the diversity of the assortment face competition - it is easier for municipalities to choose one large supplier that will deliver all the necessary products [14].

Klaipeda Region has a regional specialisation strategy for 2030 where different measures are dedicated to food topics under the „Bioeconomy" priority [15]. One of them is the promotion of an application of green public procurement criteria on the municipal level, also, district municipalities are working actively on the creation of short food supply chains, organizing catering services in the Klaipeda region in public institutions (schools, hospitals, etc.). Also, on the regional level, the importance of educating society and informing about local food value, is being emphasized. Small farms still predominate in Klaipeda region, but it is becoming more and more difficult for them to operate in market conditions, especially during the coronavirus pandemic. The biggest problem is the lack of the necessary infrastructure in Klaipeda region for the successful cooperation of schools and local farms [16]. Moreover, some other problems have been identified. Neither the heads of educational institutions nor the farmers have the time and ability to

devote all their time to the paperwork and documents of public procurement, then to the inspection of goods, logistics, etc. It's just that the system is not developed and does not work smoothly. It is difficult for small farmers to provide purchases and ensure large quantities of products needed [16]. This requires to further improve the cooperation of regional food chains and farmers. Today, there are legal options to buy food products from farmers, but that path is quite complicated, which is why few choose it. Anyway, Klaipeda region sees its task to promote information and education of the population, why local products and locally produced food are more useful, healthier and better for people.

The present article has been prepared within the framework of the BSR Food Coalition project funded by Interreg Baltic Sea Region Program (contract #S002), the aim of which is to create the conditions for the emergence of the "From farm to school" model in the Baltic States. The study presented in the article is a part of a wider research which has been sought to disclose the conditions and opportunities for the promotion and use of foods produced by local farmers in general education schools in Klaipeda region, Lithuania as well as at defining necessary educational efforts to increase healthy nutrition, develop general health habits, and agricultural and food system literacy within general education schools and their communities. To achieve the aim the surveys with project target groups (school administration, students and their parents) have been carried out in Klaipeda region. The present article will highlight the main findings of the survey thus helping to raise the awareness among all interested groups and promote collaboration. In addition, the study is also related to the global and Lithuanian sustainability goals [2] and other goals of sustainability and food strategies.

II. MATERIALS AND METHODS

The aim of the survey was to gather data on project target groups' perceptions of local school food procurement in Klaipeda region and to collect operational information such as purchasing practices and preferences. The instrument (the questionnaire) for data collection was developed containing the following blocks of questions:

1. Questions about the quality of school meals;
2. Possible contribution of local farms to the quality of meals;
3. Participation and support from parents and students regarding healthier food;
4. Possibilities of educational activities in collaboration with farms;
5. Contribution to healthy nutrition, health habits, and agricultural and food system literacy.

Data was collected by means of a survey involving project target groups. Three target groups were chosen for the survey: 1. Representatives of schools' administration (who deal with food, catering, procurement etc. issues); 2. Students; 3. Parents.

The survey was organized in schools of Klaipeda region (Klaipeda, Gargždai, Skuodas, Kretinga, Šilutė). 8 general education schools (6 gymnasia and 2 secondary schools) were selected with the aim to reflect the whole district. 3 schools were urban and 5 were from rural areas. All selected schools are rather big – the number of students exceeds 300: 5 schools – 300-500 students; 3 schools – with 500 and more students.

Survey was carried out using Google survey tool. 391 responses were received from students and parents and 12 responses from school administration. When analysing quantitative survey data, statistical analysis methods were applied: descriptive statistics (calculated percentage expression).

The analysis of the qualitative data (open question responses) from the survey was carried out using the content analysis method. The informants' answers were first processed by means of content analysis, when semantically similar phrases and statements are combined into so-called categories. In other words, individual opinions that are separate but similar to each other have been given a generalizing label. This analysis includes several [17]: 1) repeated reading of the text; 2) separation of manifest categories based on meaningful words; 3) interpretation and justification of categories with evidence extracted from the text. After this qualitative research procedure, it became possible to calculate the frequencies of categories that showed the prevalence of individual opinions and their combinations in the studied population, i.e. - made it possible to identify both prevailing and rare, atypical opinions. It should be noted that in the so-called open questions, the specific content of the answers is NOT imposed on the subjects. In principle, the subjects have the opportunity to see, raise and emphasize the most diverse aspects of the question and the problems behind it in their answers. We were guided by the theoretical assumption that the text provided by the informant is the material for content analysis as an educational diagnostic study, reflecting the process of personal reflection as an essential aspect of experiential learning [18].

The analysis of school administrators' responses was done using the interpretative analysis of qualitative data [18]. This kind of analysis was selected because of the number of respondents (12) whose answers were more of a descriptive nature. All the information provided was very valuable for research results.

III. RESULTS AND DISCUSSION

School administrators

Study participants school administrators responsible for food, catering, procurement etc. issues provided their opinion about legislative acts regulating school meals and suppliers of raw materials. In the words of the informants "it is the owner of the school, i.e. the local government who decides how the organisation of catering in educational institutions will take place. The head of the school will act in accordance with this decision". According to study participants, in general, three main

models of catering in Klaipeda region schools may be distinguished:

1) "Smaller schools, where the institution has its own kitchen and cooks, or the designated employees acquire raw materials from freely selected providers, but mostly all raw materials are purchased through bulk warehouses". Only a few schools that answered the questions have direct links with farms. In the survey four schools' administrators answered that they have not procured. It was pointed, that "in rural schools without procurement, there are several suppliers, as well as producers and farms in addition to the bulk warehouse". At the same time, according to respondents, "small schools far from the city have limited options in the choice of suppliers, especially if there are no producers in the area, then a wholesale warehouse usually supplies".

2) "Institutions with the obligation to procure raw materials, where the procurement of raw materials by the institution is organised for their kitchen". Three of the respondent schools have procurement of raw materials. In the survey, it was pointed out that "schools receive goods from local organic producers from a bulk warehouse or a catering company, with whom farms can cooperate in the field of logistics".

3) "Larger schools, where the school together with the local government organises a procurement for the provision of catering services; the raw materials are organised by the kitchen service provider". The respondents pointed, that "there is generally no system for sourcing directly from farms". One school replied that "the local government procures their catering services together for several schools".

According to the survey participants, there is no system of food procurement directly from local farmers in Klaipeda region. In the opinion of one of the responding schools, "the catering service provider has direct relations with small producers, and organic products reach the school's kitchen through the service provider. The goods of the local small producer can reach other schools through a wholesaler who has a price list of organic products for this purpose". The responses revealed that currently "the goal in smaller schools is to get as much local raw materials as possible and to restore the network of farms". Larger schools with a procurement obligation cannot include the requirement of local food in the procurement, as this would be against the principles of the EU common market. Organic production requirements can be included in the tender, as this is the EU production quality standard.

According to study participants, as local small producers mostly lack the capacity to provide year-round supplies, six out of twelve responses cited this as "a key issue why schools find it difficult to use their products".

Obstacles to buying products from local producers were pointed out by survey respondents: cost (3 respondents), delivery (2 respondents), storage (2 respondents), school labour concerns (3 respondents), threat to current vendor relations (2 respondents). In addition, it was pointed out that local producers do not participate in procurements if the school has to use a vendor selected through procurement (4 respondents) and the school itself does not know small producers (2 respondents). The responses also revealed that currently, "local farms have also brought apples for free if it's a good apple year, depending on the situation". According to school administrators, "the price of local products is mostly negotiable, and considering the market price, the price has remained within reasonable limits, so that there is enough money in the budget and schools can afford to buy until the end of the school year".

Three respondents indicated that cooperation with local farmers "contribute to more healthier meals". The effect of cooperation with local farms is highlighted in the responses of school representatives – "smaller ecological footprint, faster delivery, fresher, more reliable raw materials". One respondent thought that "it did not affect the healthiness of the food".

Six respondents thought that "there would be no need for a separate farm under the school". Four respondents felt that "it needed a lot of changes and resources, but could introduce students to where the food on their table comes from and what kind of effort it takes to do so". According to respondents, this would also help to change the consumption habits of young people. Two study participants answered that "this farm would be needed".

Regarding cooperation with organic farms, eight respondents thought that "it could be tried or that they have already cooperated in this way". Four respondents found that "it is not a priority at the moment or maybe in the future". Most of the respondents thought that cooperation with local farmers "is definitely needed, which will contribute to the curricula".

All respondents agreed that "the cooperation with local farms contribute to healthy nutrition, develop general health habits, and agricultural and food system literacy within our school community". In the responses of school administrators, it was pointed out that "cooperation with farms could work in different forms, depending on the farm and time - for a shorter or longer period". In addition to ordering local products for the kitchen, "the children could go to farms to learn how to do different jobs, visit open farm days, the local farmers themselves could come to the school to offer their products".

Students and parents

To the question "Are you satisfied with the quality of food in your school?" all 100 percent of respondents provided their answers. 37 percent of respondents stated that they are satisfied with the quality of school meals. However, 63 percent were only partly satisfied or dissatisfied. As the question was open-ended, respondents were asked to provide their comments. The comments were analysed applying the method of content analysis. The analysis of answers of the respondents, who were satisfied with the quality of school food, allowed to extract 3 categories as shown in the Table 1.

TABLE 1 REASONS FOR RESPONDENTS' SATISFACTION WITH THE QUALITY OF SCHOOL FOOD (N=34)

Category		**Illustrative statement**
The relation between the price and the quality	56%	This is a good value for money. The food is good and the prices are satisfactory. The quality of food and the prices for food are acceptable for me.
The assortment of dishes	44%	Yes, everything is great. Plenty of dishes. The child likes the food, always eats in the school canteen in the morning and after school.
Tasty food	28%	Yes, very tasty food. The son says that the meal is both tasty and filling.

The analysis of answers showed that those study participants, who were in general satisfied with the quality of school meals, positively assed the relation of price and food quality, the choice of various dishes in schools as well as the good taste of food itself.

The analysis of answers provided by the respondents, who were partly satisfied or dissatisfied with the quality of school food, allowed to extract 5 categories (table 2).

TABLE 2 REASONS FOR RESPONDENTS' DISSATISFACTION WITH THE QUALITY OF SCHOOL FOOD (N=97)

Category		**Illustrative statement**
Taste of food	79%	The food is not tasty, a lot of sauces. My daughter complains that it doesn't taste good, so she doesn't eat it. The quality is not good, my son complains. My son has stomach aches after the meals.
Too much sugar containing food	67%	There could be no buns, unnatural juices (packs), just normal food, no chocolates or anything like that. Sweets are distributed to the children every day. Instead, it is better to give a fruit or vegetable every day. There should not be a possibility to buy juice and muffins.
Availability of healthy food	61%	The selection of healthy food is small. There are no truly delicious and healthy choices. There could be a larger selection of vegetables and fruit.
Limited selection of dishes	54%	Dishes are repetitive, little choice Some days, it seems, there is no choice about what to eat. I would like the menu to be more interesting, maybe even some healthier dishes. There is no choice of fruit at all. Vegetables are barely added. The child complains that there is only mashed potatoes in the canteen (there could be just plain boiled potatoes). No choice for vegetarians.
Matters of meal organization	38%	Long queues in a canteen. Cold food. Too many students need to eat and the break is too short.

Having generalized the respondents' answers it is possible to say that even though some part of survey participants is satisfied with the quality of school food and the main reason for that is the relation between the price and the quality, the majority have some claims to the quality: first, the issue of taste, second – too much added sugar, third – big choice of a junk food instead of healthier one.

To the question "Are there enough vegetables and fruit in the school meals service?" all 100 percent of answers were received. Only about one fourth of respondents (23%) stated that there are enough of vegetables and fruit, at the same time, more than two thirds (60%) of respondents emphasized that the quantity of vegetables and fruit in school menu, in their opinion, is not really sufficient.

All 100 percent of research participants provided their answers to the question "Are you involved in making meal menus?". Regretfully, but the majority of respondents (86%) pointed that they are not able to participate in the creation of menus and they do not have information about how they could join this activity (11%). Some of the respondents (3%) pointed that they sometimes participate in the selection of school meals (but that was the case of the school that orders meals from the external providers).

All respondents participating in the survey provided their answers to the question "Would you like to have more organic products (vegetables, fruit etc.) in your school meals?". Almost four fifths (79%) of the respondents claimed that they would be eager to have more organic products in school menus. The analysis of the comments provided by the respondents allowed to extract the following categories (table 3).

TABLE 3 THE REASONS WHY RESPONDENTS WOULD LIKE TO HAVE MORE ORGANIC PRODUCTS IN SCHOOL MENU (N=56)

Category		**Illustrative statement**
More organic products from local farmers	69%	I would like more seasonality, local production. We would like to have organic products in menus. I would like my son to eat more vegetables.
Healthier food	52%	Vitamins and useful nutrients. I would like more fruits and vegetables, healthier products. I am all for healthier food, but healthy food must also be tasty food.
Ecological food and packages	49%	Ecology is a very important topic these days and I think it would benefit everyone. I also think that it could be a less polluting packaging option, because everyone takes a plastic bag to put one bun in, but if the bags were minimally taxed - we would reduce pollution. You can also use paper bags as an alternative.
Food for vegetarians and vegans	24%	There are few vegetarian and vegan options, so people on those diets are at a disadvantage compared to other people's food choices

The analysis of the data allows stating that the majority of survey participants would like to have more organic products in school meals. The reason is the following: local foods are considered as healthier and ecological.

To the question "Are you aware of local farmers that could provide your school with organic products?" all 100 percent of answers were received. The majority of the respondents (78%) stated that they are not aware of such products. Anyway, the study participants emphasized that they would be eager to find and establish connections with local farmers, because, in their opinion, "both children's health would benefit, and we would support small farmers".

All the 100 percent of the respondents answered to the question "Would you support the idea of buying food from local farmers even though this could require additional money?". About one third of the respondents (33%) stated that they would be eager to buy form local farmers even though this could require more money. However, another one third of respondents (38%) would only partly agree to buy. The other part of the respondents (29%) would hardly agree to buy if it requires additional expenses. To sum up, the study participants would estimate the costs and the benefits of eating healthier.

All the study participants (100%) provided their answers to the question "Would there be a need to create/have a farm at the disposal of the school, the production of which would supplement the school's meals?". About one third of the respondents (33%) would support the idea of the farm at the disposal of their school. However, other part of the respondents has some doubts about the idea. Two fifths of the respondents (38%) would partly support it. And 29 percent would not agree.

TABLE 4 THE OPINION OF THE RESPONDENTS ON THE IDEA TO HAVE A FARM AT THE DISPOSAL OF THE SCHOOL (N=94)

Category		**Illustrative statement**
Not very important for school	71%	Because these are additional worries, who would take care of them. A nice wish, but first there are no free plots of land. The second fastest growth of vegetables is in the summer, when the school community is on vacation. Our school doesn't have a lot of funds anyway, so I don't think we can even take on such a thing. This would be a loss-making "business" for the school.
Difficult to adjust to seasons	58%	No. Because there are four seasons in Lithuania, it would be difficult to produce various products in different seasons. That would require a lot of money.
Better to support local farmers	44%	Maybe it would be a really cool idea. but of course labor and financial costs would increase. I think it would be cheaper to buy from farmers. No, because it would require separate working people and it would not be cheaper than buying from the farmers as long as there is someone who takes care of it. It is not enough just to sow. It depends on whether it pays off for the school to invest in agriculture, production and exploitation. If the produce of a local farmer is cheaper, I would choose a contract with farmers. Everyone has to do what they do best. School to teach, farmers to farm.

Respondents were also asked to provide their comments on the question „Would you like to have cooperation with local farmers as a training base for students through direct work skills lessons and/or extracurricular activities?". The analysis of the comments allowed to extract the following categories.

TABLE 5 THE OPINION OF THE RESPONDENTS ON COOPERATION WITH LOCAL FARMERS AS A TRAINING BASE FOR STUDENTS (N=87)

Category		**Illustrative statement**
Interesting experience for students	65%	It would be a rewarding experience for children. Maybe the problem of food waste would decrease, because they would become familiar with the processes of food production. Also, the knowledge of protecting the planet and ecology would expand. Yes, educational and extracurricular activities on such farms are very suitable for children. If it was presented in an interesting way, instead of putting just + on, it sounds cool. It is possible to organize educations about ecology. I think that the school should cooperate with local farmers, because their cooperation would help children to be curious and interested in similar activities and children would want to go on such educational excursions.
Returning to soviet times	59%	It reminds us of the Soviet times, when schoolchildren were taken to Soviet farms, the conditions were really poor in terms of legality and hygiene. I think modern farms should be mechanized, unless it is a cognitive activity. I'm going back to the Soviet era, when it was worth going to the kolkhoz fields to work, I don't think that modern youth would like it...but if it would interest,, maybe it's a good idea to attract children.
School is responsible for education	49%	No need. Students already have huge workloads in their studies, let's leave the farming to the farmers. Our high school students are not kindergartners who need to be told, shown (maybe even taken to "practically" help farmers...) about farming. I think these extracurricular activities would be "very unpopular". I do not think that farmers are able to participate in the activities in a qualitative way.

Even though the study participant have positively evaluated the idea of having farms as a training bases for students, they also have mentioned some doubts regarding its economic value as well as its value for educational process.

All the respondents (100%) provided their answers to the question „ What do you think - could the cooperation with local farmers contribute to health education and more sustainable consumption?". However only two fifths (42%) of the respondents would support such an idea of cooperation. The majority of the respondents would only partly support (34%) or reject it (24%).

The analysis of the comments of the respondents to the question "Would the cooperation with local farmers contribute to healthy nutrition, develop general health habits, and agricultural and food system literacy?" is provided in the table 6.

TABLE 6 RESPONDENTS' OPINION ON THE COOPERATION WITH FARMERS WITH THE AIM TO CONTRIBUTE TO HEALTHY NUTRITION, DEVELOP GENERAL HEALTH HABITS, AND AGRICULTURAL AND FOOD SYSTEM LITERACY (N=68)

Category		**Illustrative statement**
Students need more knowledge on ecology and farming	78%	I think so, nowadays, children's knowledge about the concept of agriculture and food system is very narrow. I don't know if cooperation with farmers would change the students' attitude towards food, but I agree that we should at least try to change it. There is a lack of enlightenment about healthy food, lifestyle, cooking healthy meals, how to replace some products with other - healthier ones.
The role of the school and the family is the most important	68%	Children get all the information from the teachers, so if the farmers cooperated with the school, they would still get the information from the teachers and not from the farmers. I think that with the help of parents and teachers, we can tell what good and healthy food is.
Farmers could contribute to education	54%	I think that the appearance of food on the table is taught by the natural sciences. Also educational tours. If the farmers have something more extensive and interesting to say about healthy eating and health-enhancing habits, I agree.

All respondents were positive towards the possible collaboration with farmers and its contribution to healthy nutrition, health habits, and agricultural and food system literacy. According to respondents, food products would come directly from the farm to the school - and healthier and more sustainable relationships locally, and cheaper, etc.". Through direct participation, students would better understand the benefits of food products, feel the difference between taste, appearance, etc. By participating, they would learn more about agriculture, the advantages of its production, etc., maybe even become interested in agricultural profession

CONCLUSIONS

Within the framework of the project "BSR Food Coalition" (no. #S002, 2021-2024) financed by Interreg Baltic Sea Region program, it has been specifically sought to create conditions for the "From farm to school" model to appear in the Baltic countries, including Lithuania. The study presented in the article aims at disclosing the conditions and opportunities for the promotion and use of foods produced by local farmers in general education schools in Klaipeda region, Lithuania as well as at defining necessary educational efforts to increase healthy nutrition, develop general health habits, and agricultural and food system literacy within general education schools and their communities. To achieve the aim the surveys with project target groups (school administration, students and their parents) have been carried out in Klaipeda region. The objectives of the study were to gather data on target groups' perceptions of local school food procurement and to disclose their opinion, needs and expectations related to model development. The findings of the study would be helpful for designing the further steps of collaboration between schools and local farmers in Klaipeda region.

In recent years, the possibility of improving school meals by including locally grown products has been increasingly emphasized, thus contributing to the development of local economic systems. This model has acquired the name "From farm to school" in the practice of some countries. The "From farm to school" model would enrich the relations of educational institutions with local small farms, which are the main producers of organic and local food in the Klaipeda region. The model emphasizes public procurement of locally grown food as a key market opportunity for farmers. In addition, small and medium-sized farms play an important role in providing food to local communities, and their owners contribute significantly to community vitality by developing ecosystem services, economic health and social well-being.

Main findings from the survey including project targets groups (school administrators, students and parents) in Klaipeda region show that there is no coherent system of food procurement directly from local farmers and no effective logistic system. The existing food quality in schools is not satisfactory, but students and their parents are not involved in menu design. Also, they lack in knowledge on local ecological production. School communities would vote for change in school meals including more organic, ecologic, healthy products and provide support for this change. Cooperation with farmers would be a good solution for this change. However, public procurement system is rather complicated and unclear. The lack of knowledge of local farmers in the region for the administration of school food purchase is the key issue. On the other hand, larger schools with a procurement obligation cannot include the requirement of local food in the procurement, as this would be against the principles of the EU common market. Speaking about the cooperation between schools and farmers, the common opinion was that the economic side is important, but the social and community side are also very important when offering

local organic products. Moreover, educational activities in collaboration with farmers could add value to developing of healthy nutrition, health habits, and agricultural and food system literacy.

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Assessment of Rare Epiphytic Liverwort Transplantation Method in Populus Tremula Forest

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Abstract. **Epiphytic bryophytes are important biodiversity elements in forest ecosystems globally. In addition, bryophytes take part in ecosystem functioning and are excellent environmental indicators. Almost half of the red-listed bryophyte distribution in Latvia is related to forest habitats. However, despite the increasing knowledge about epiphyte ecology, we are lacking information about individual rare species environmental demands. The present study aimed to evaluate the transplant disc method in rare liverwort transplantation success in aspen forest. As a result, we found that the transplant disc method can be used in epiphytic liverwort studies, but improvements are recommended in sealant selection for transplantation. Liverwort transplants were sensitive to changed substrate quality. Although transplant physiological stress during the transplantation experiment could be important. Epiphyte transplantation studies could help to test epiphyte sensitivity to global climate change in the future.**

Keywords*: *transplantation, liverworts, epiphytes, Populus tremula.

I. Introduction

Bryophytes are important biodiversity elements in forest ecosystems worldwide [1]. They have significant role in ecosystem functioning, providing shelter for other organisms and their role in human life (for instance, peat-forming) is huge [2]. Bryophytes are also much better environmental indicators than vascular plants [3]. Due to their indicator ability, bryophytes were used as excellent indicators in studies of air pollution and ecology [4].

Epiphytic bryophytes and lichens have been used in transplantation experiments using different methods for several decades [5], [6], [7], [8]. Pioneering work by Brodo [9] showed the practical use of epiphytic lichen transplants as indicators of air pollution. Similar method could be applicable also to epiphytic bryophytes. The results of transplantation experiments can reveal new knowledge about a wide range of ecological questions from local to worldwide scale [8].

Despite of many epiphyte transplantation studies around the world, epiphytic liverworts (one of three bryophyte groups) were rarely used as a model organism. A recent review indicated that only 4% of bryophyte and lichen transplantation studies until 2020 around the world used liverworts as model species [8]. However, liverworts are important biodiversity elements and are sensitive to changed environmental conditions. This shows that they could be important indicators of the changed environment. The last compilation counted 7486 liverwort species globally [10] contributing significant part of global biodiversity.

Almost half of red-listed bryophyte species distribution in Latvia is related to forest habitats [11]. The studies about ecology of most of these species are missing, especially about red-listed liverworts. The transplantation approach could contribute to knowledge about liverwort ecology.

The aim of this study was to evaluate the transplantation method potential of red-listed epiphytic liverwort *Lejeunea cavifolia* for ecological studies in aspen *Populus tremula* forest.

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II. Material and Methods

We studied *Lejeunea cavifolia* transplant vitality in aspen *Populus tremula* dominating forest stand in Ābeļi Nature Reserve in the south-eastern part of Latvia (Fig. 1). This study was conducted with the permission of Nature Conservation Agency Republic of Latvia.

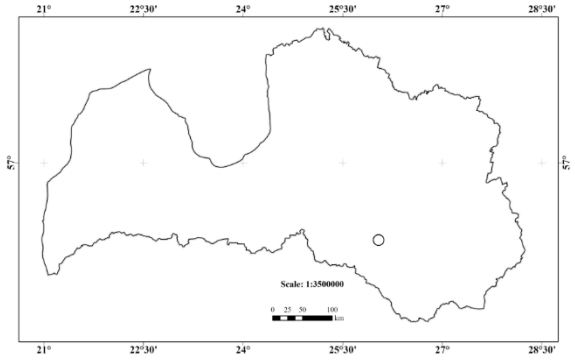

Fig. 1. Study site (circle) in Latvia. Base map author: Māris Nitcis.

Lejeunea cavifolia is red-listed liverwort species and is protected by Latvian government regulations [12], [13], [14]. This species is growing on deciduous trees in old-growth slope, deciduous and boreal forests [15] and is distributed in Europe, Asia, North America, South America and Macaronesian Islands [16]. *Lejeunea cavifolia* has a scattered distribution in Latvia [17] and reproduces sexually by spores [18].

We conducted transplantation experiment in aspen forest stand that was 92 years old with area of 4.6 ha (Latvian Forest Resource Database). We transplanted *L. cavifolia* transplants to a good substrate (control treatment) and a bad substrate treatment. As a good substrate we defined living aspen individuals with stems larger than 0.20 m at the diameter of breast height (DBH). Bad substrate aspen stem DBH was less than 0.20 m. Transplant consisted of a piece of the tree bark disc with living *L. cavifolia* plants. We took *L. cavifolia* transplants from several good substrate trees (donor trees) which we attached to recipient trees. One tree could serve as a donor for several transplants. In total, we selected 20 good substrate recipient trees and 20 bad substrate recipient trees. We applied the bark disc transplantation method [9]. Initially, transplants were removed from the donor tree bark (bark discs 4.5 cm in diameter) with a knife and electric drill. Each transplant was affixed to the recipient tree by silicon sealant (water-resistant, for outdoors) in a pre-prepared bark hole (part of the bark was removed before). We took digital photographs on a transplantation day: in the summer of 2020 and after a year in 2021. Each transplant photograph was analyzed and transplant vitality was evaluated based on four vitality classes: 1) high vitality: moist transplant is green or without damaged patches or spots; 2) medium vitality: transplant is green, but some damaged or dead patches or points occur (<50% damaged); 3) low vitality: more than half of the transplant area is dead, some remnant green patches left; >50% damaged; 4) transplant died; transplant is brown without living tissues.

To compare the transplant vitality within vitality classes between 2020 and 2021 we applied Chi-square test. Data analyses were performed in R programme [19].

III. Results and Discussion

Most of *Lejeunea cavifolia* transplants were still in place after a year. However, one transplant in good substrate treatment and one transplant in bad substrate treatment were fallen. Several transplants were partly detached from the recipient tree bark. This could be related to insufficient silicon sealant supply during the initial transplantation in 2020. Transplantation was done in dry weather, however, rainy weather could follow after transplantation causing some transplant partial detachment and contamination. Some transplants were partly damaged by silicone sealant. Probably other silicon sealant or glue substance could be more successful in the future. Also, stochastic reasons may cause the falling of transplants.

Transplants of *Lejeunea cavifolia* showed significant differences in vitality between 2020 and 2021 in good substrate and bad substrate treatments (Fig. 2).

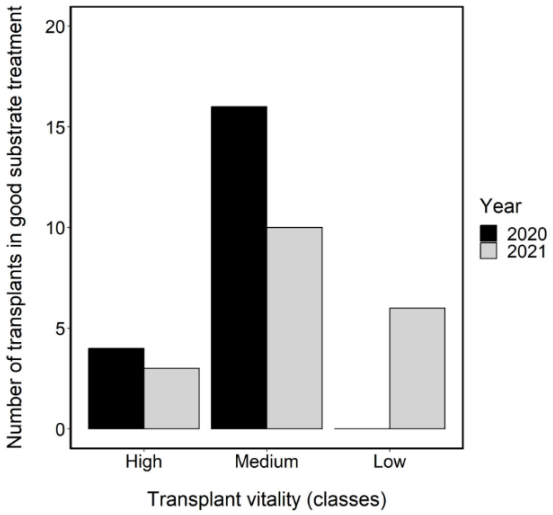

Fig. 2. Transplant vitality class (high, medium, low) in good substrate treatment within the study period. Significantly higher number of low vitality transplants (p=0.01) was found in 2021.

The number of transplants with high and medium vitality did not differ significantly, but the number of transplants with low vitality differed significantly between 2020 and 2021 in good substrate treatment (Fig. 2). This could be related to transplant physiological stress that could be caused by the microenvironmental differences between donor and recipient trees shortly after transplantation.

The number of *L. cavifolia* transplants with medium vitality decreased significantly in bad substrate treatment between 2020 and 2021 (Fig. 3). In addition, the number of low vitality transplants increased significantly in bad substrate treatment. Other transplantation studies showed that bryophytes are sensitive to microclimatic changes in transplantation experiments [8].

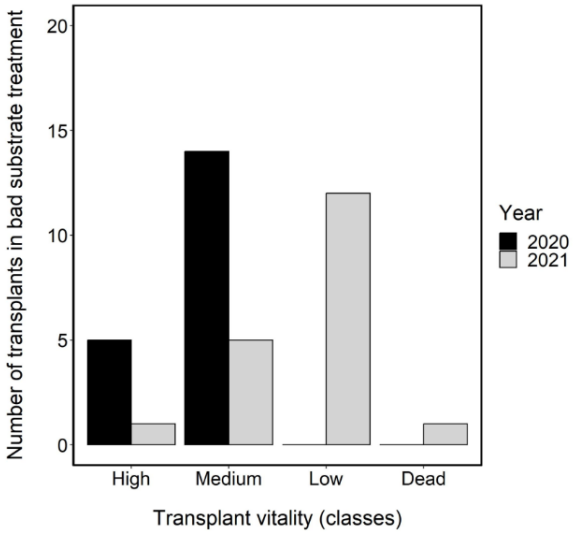

Fig. 3. Transplant vitality class (high, medium, low, dead) in bad substrate treatment within the study period. Significantly lower number of medium ($p=0.04$) and significantly higher number of low ($p<0.01$) vitality transplants were found in 2021.

The substrate is one of the most important variables in epiphytic bryophyte distribution. It is also known that tree bark pH differs among tree species [20]. Living aspen tree bark pH was around 4 in Sweden [21]. Mežaka and Znotiņa [22] found that average pH value of aspen is 5.2 in slope forests of Latvia. However, bark pH can change with age, when bark physical properties are changing and amount of environmental dust is increasing on a bark. Older bark obtains more crevices than younger and this could be suitable for epiphyte establishment.

Alexander et al. [23] highlighted the importance of transplantation experiments in ecological studies of community interactions in global change perspective. This could be useful approach also in epiphytic bryophyte community studies in a future.

IV. Conclusions

In general, the bark disc method was suitable for *Lejeunea cavifolia* transplantation in aspen forest. However, the method could be improved with different sealant or other gluing substances that would ensure bark disc attachment in a long-term, preferably several years. This method could be used in further ecological studies with careful selection of silicone sealant. *Lejeunea cavifolia* is dependent on substrate quality and this should be taken into account in forest conservation planning in aspen-dominating forest landscape.

Acknowledgments

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The Impact of the Weather Conditions on the Quality of Birch Veneer Logs During Winter Harvesting

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Abstract. The external characteristics of a tree give the only clue to the quality of veneer log obtained in harvesting. When the tree is bucked into veneer logs, the cross sections at the butt and top ends of these assortments may provide additional indicators of the quality. Thus, it becomes important to study the abnormalities that can be seen on the end surface of the veneer logs such as heart shakes, and to correlate the occurrence of these imperfections with the quality of veneer that is produced from the veneer log.
Therefore, the purpose of this study was to: (1) identify and measure heart shakes length, width and depth in wood in all investigated veneer logs diameter groups: 180-249mm; 250-299mm, 300<mm in the period of storage, (2) identify the factors that could initiate heart shakes in veneer logs in the period of storage (number of storage days, weather temperature, moon phases, relative humidity) in all diameter ranges, (3) by analysing the results to work out the recommendations to improve the forest management in forest stands when veneer logs are manufactured.

Keywords: Bertula pendula, Bertula pubescens, veneer logs, heart shake.

1. INTRODUCTION

There has been an increasing demand from industry for suitable veneer grade rules for *Bertula pendula Roth*. and *Bertula pubescens Ehrh.* specie used in the manufacture of veneer. *Bertula pendula Roth*. and *Bertula pubescens Ehrh.* are short lived, relatively small broadleaved trees that occur throughout most of Europe, particularly in northern regions. Birch trees provide the predominant hard wood source in northern Europe, and some varieties of *Bertula pendula Roth* peroduce highly priced veneers, while *Bertula pubescens Ehrh.* is mostly used for pulp and fire wood.

Bertula pendula Roth. is medium-sized tree, growing up to 30m, while *Bertula pubescens Ehrh.* is relatively shorter, rarely growing beyond 20m and less towards its northern range limits [3], [4]. *Bertula pendula Roth*. and *Bertula pubescens Ehrh.* occur naturallty throughout most of Europe up to central Siberia. Given their wide distribution, these two birches (Figure 1) show a high morphological variability and different subspecies and varietals have been described [6]. Birches are most abundant in the boreal zone of northern Europe, where thay can co-dominate or dominate in late-successional vegetation.[10]. Species are not wind resistant. Birch provides the commercially most important source of hardwood in northern Europe and is often an important component in conifer plantations, such as those of *Pinus sylvestris* and *Picea abies.* The value and yield of these veneer logs stands with large stump diameter dimensions have been adversly affected by the presence of *heart shakes* in many of trees.

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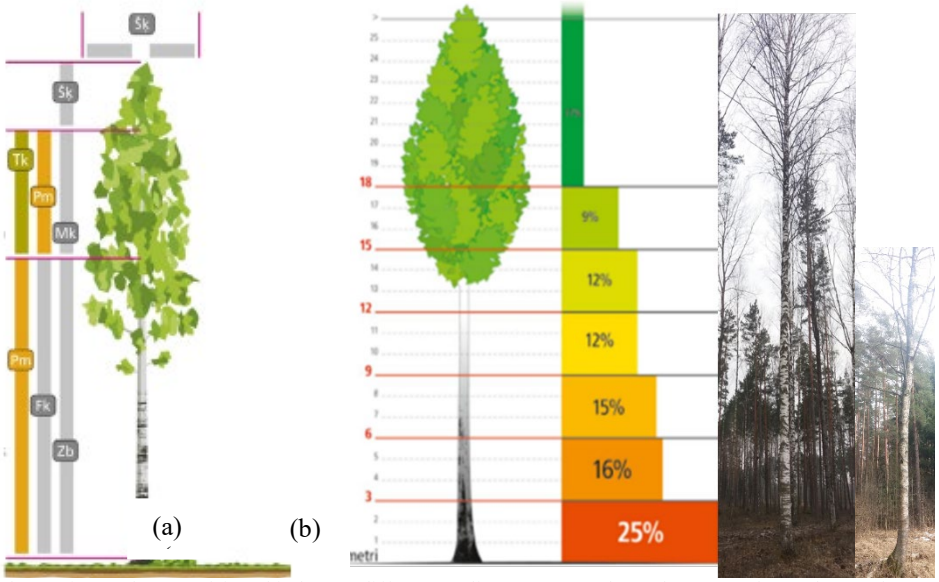


Fig.1. Roundwood assortiments harvested from birch stem different quality zones (a), where Fk – veneer logs, Zb – sawlogs, Mk – fire place firewood, Pm, – pulpwood, Tk – technological wood/ firewood, Šķ - wood residuals for chips manufacturing. Distribution of *Bertula pendula Roth*. and *Bertula pubescens Ehrh.* trunk by volume (b).

Heart shake are found in all veneer logs. Most of the heart shakes are located in the butt assortments, extending downward into the stump

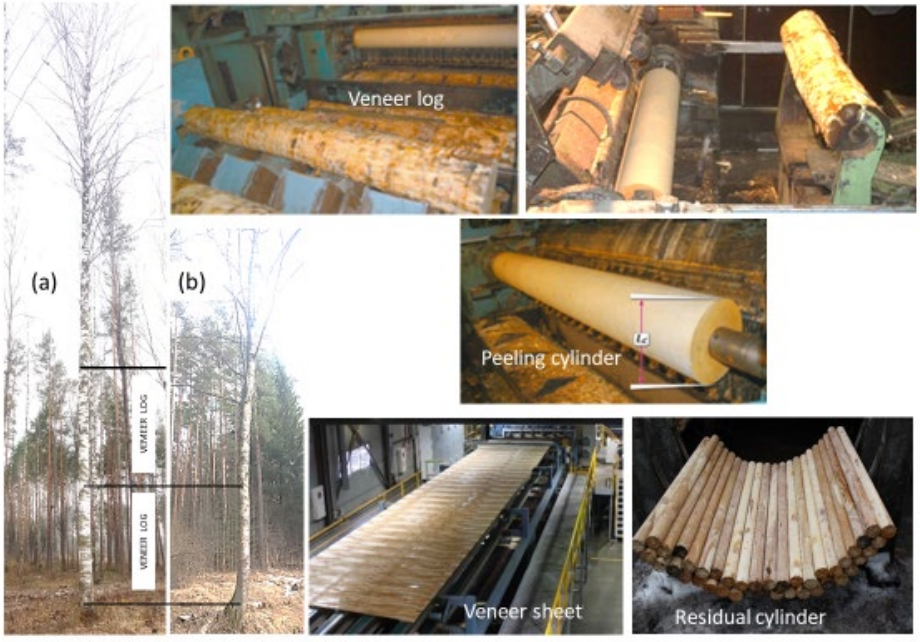


Fig.2. Harvested veneer logs and veneer peeling technological process, where: (a)- *Bertula pendula Roth* stem, (b) - *Bertula pubescens Ehrh.* stem.

Heart shake: A group of splits or split radiating from the pith or centre of the tree in the form of star or as a single spit perpendicular to the growth rings. Star shakes are usually formed due to extreme heat or severe frost during the tree's growth. In some instances it is restricted to the heart center of a tree, in others it appears to enlarge progressively with heartwood formation and then extends across the heartwood zone. Heart shake may be disregarded as a defect in veneer logs when contained within the flange area of the lathe chuks which diameter is 70mm. When the split extends beyong the rim of the chucks, due allowance should be made for cull, since shorts only can be produced from the residual cylider. Althought this is a naturally occuring defect possibly caused by frost or wind stress, shakes can also occur on impactat the time of felling and because of shrinkage in the log before the technological process of converting veneer logs to veneer sheets.

Bertula is the third most commercially important tree species in Latvia (27.9% from the area) [8]. The statistics [6], [7], [9] show that the form of the birch stem between 1.5m above the stump cut and the height of 4m is close to cylinder- the taper of 2.5 m long log is only slighty above 3cm and the differences between the forests on dry mineral soils and other forests are not significant.

Most veneer and plywood plants have some method of classifying logs by grade to control the purchase price paid for logs bought on the open market. Such log-grading systems have been developed by experience and are dependent to a large extent upon the ability of the grader and his knowledge of veneer grades and yields required for the specific product produced by his company. These rule-of-thumb grading systems are often very inaccurate and inconsistent. Manufactures of both high and low grade veneer recognize the need for a veneer log grading system that can be easily and uniformly applied. Therefore, the new actualized and systematizated, scientifically approved findings related to birch physical characteristics are needed to improve the technological process of converting veneer logs to veneer sheets.

The goal of this study was to synthesize the existing experience and knowledge about birch veneer logs quality requirements and to work out the recommendations to improve the forest managment in forest stands, where *Bertula pendula Roth*. and *Bertula pubescens Ehrh.* stands are growing.

The following objectives were set to achieve the study goal:

To determine the distribution of heart shakes within and among trees, where the physical characteristics of the trees or any environmental factors were associated with heart shakes,

To identify and measure heart shakes lenght, width and depth in wood in all investigated veneer logs according to diameter groups: 180-249mm; 250-299mm, 300<mm.

To identify the factors that initiate heart shake in veneer logs at the period of storage (number of storage days, weather temperature, moon phases, relative humidity) in all diameter groups,

To measure heart shakes extending downward into veneer log depth, where the width in the widest place is greater than 2mm.

By analysing the results to work out the recommendations to improve the forest managment in forest stands when veneer logs are manufactured.

II. MATERIALS AND METHODS

2.1. Field Measurements

Sampling stumps of *Bertula pendula Roth*. in different forest types and age class felling areas to harvest birch roundwood assortiments according to the specification (Table 1.)

Measuring the end surface diameters, the heart shakes width,, length and depth of stocked veneer logs according to the scheme (Figure 3; 4) [5].

Checking moon phase, relative humidity, weather temperature, storage days after harvesting on the day of measurement.

Checking the actual heart shakes distribution extending downward into the veneer log according to the scheme (Figure 2; 4) to verify the adequacy of the heart shakes depth measurement methodology

2.2. Statistical Analyses

The sequental data were collected and analysed:

Block area-Forest block-Forest compartment; Area (ha); Stock nr; Average tree volume (m^3); Stock (m^3); County; Coordinates X/Y; Forest type; Age class; Age decade; Species composition; Sampled Birch trees (pcs.); Mean height (m); Mean diameter (cm); Harvested volume (m^3/o.b.); Harvested volume (m^3/u.b.); Harvested assortiments ((pcs.// m^3/u.b. //total lenght (m)); Mean heart shake length/ Stdev (mm); Mean heart shake width/ Stdev (mm)

III. RESULTS AND DISCUSIONS

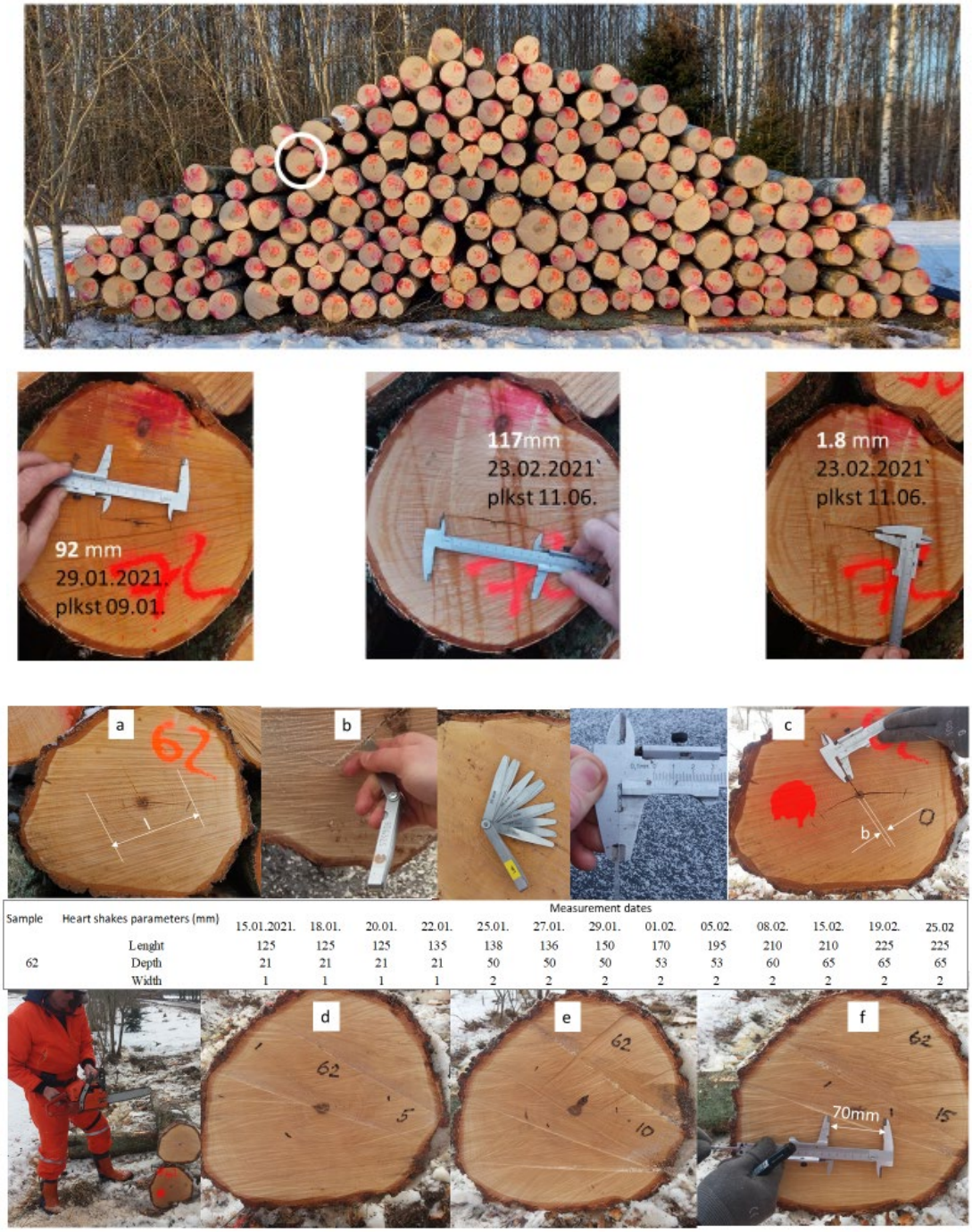
In the Vidusdaugava Logging Region, a felling area (502-247-20) was selected, where 247 birch veneer logs were prepared and stacked in the stock JD1134_01 (Table1).

TABLE 1. CHARACTERISTICS OF INVESTIGATED FOREST SITE TYPES AND HARVESTED BIRCH ASSORTMENTS

Parameter	**Data**	
Block area-Forest block-Forest compartment	502-247-20	309-238-30
Area (ha)	1.85	3.01
Stock identification	JD1134_01	DE2073_01
Average tree (m^3)	0.73	0.94
Stock (m^3)	527.81	642.96
Country	Koknese	Daugavpils
Parish	Nītaure	Nīcgale
Coordinates X/Y	586300/293224	652495/213459
Forest type	Mercurialiosa mel.	Oxalidosa
Age class	Mature stand	
Age decade	80	
Species composition	8 *Bertula* 1 *P.Abies* 1 *P.tremula* 72	5 *Bertula* 4 *P.tremula* 1 *P.Abies* 76
Specie	04-*Bertula*	
Age (years)	72	76
Trees(pcs.)	489	782
Mean height (m)	24	26
Mean diameter (cm)	33	29
Volume (m^3/o.b.)	203.473	372.62
Volume (m^3/u.b.)	180.652	332.25
Assortiment specification ((top diam.(mm)/ butt diam. (mm)/ nominal lenght (cm)/ oversize (mm))		
Veneer logs	185/700/270/5	
Packing case timber	120/500/240/10	
Fire place firewood	100/400/300	
Pulpwood	60/700/270;300	
Firewood	50/800/270;300	
Harvested assortiments((pcs.//m^3/u.b.// total lenght (m))		
Veneer logs	491/64.248/1358.18	785/115.96/2165.55
Packing case timber	983/61.738/2473.59	1132/84.81/2842.09
Fire place firewood	7132/36.803/2149.71	824/47.34/2480.07
Pulpwood	374/17.371/1127.54	984/66.50/2940.24
Firewood	27/0.492/81.44	983/17.70/277.73
Average tree diameter DBH (cm)	219	
Average tree volume (m^3/o.b.)	0.416	
Average tree volume (m^3/u.b.)	0.369	

In the South Latgale logging region, a felling area (309-238-30) was selected, where 223 birch veneer logs were prepared and stacked in the stock DE2073_01 (Table 1).

Measuring of the heart shakes distribution on the end surfaces of the veneer log sample according to the storage days after harvesting and the actual depth distribution were done according to the scheme (Figure 3).



Sample	Heart shakes parameters (mm)	Measurement dates												
		15.01.2021.	18.01.	20.01.	22.01.	25.01.	27.01.	29.01.	01.02.	05.02.	08.02.	15.02.	19.02.	25.02
62	Lenght	125	125	125	135	138	136	150	170	195	210	210	225	225
	Depth	21	21	21	21	50	50	50	53	53	60	65	65	65
	Width	1	1	1	1	2	2	2	2	2	2	2	2	2

Fig. 3. Measuring of the heart shakes distribution on the end surfaces of the veneer log sample according to the storage days after harvesting, where a – heart shake length (using caliper), b- heart shake depth (using 0.1mm thick caliber), c-heart shake width (using caliper), d/ e/f - heart shake length and the actual depth distribution 50 mm /100mm/150mm from the end surface.

Checking the actual heart shakes distribution extending downward into the veneer log were done according to the scheme (Figure 4).

Fig. 4. Heart shakes distribution extending downward into the veneer log, where:
(I-I); (II-II); (III-III); (IV-IV); (V-V) – end surface of veneer log; h- deep of the heart shake; b- width of the heart shake; l- actual length of the heart shake; d-diameter (70mm) of the residual cylinder; a- end point of the heart shake.

Characteristics of measured heart shakes depend on veneer diameters are given (Table 3; 4)

TABLE 3. CHARACTERISTICS OF MEASURED HEART SHAKES DEPENDING ON VENEEER DIAMETERAS IN THE STOCK JD 1134_01

Parameters	Results							
Measurement dates/ storage days after harvesting	26.01.2021./3	29.01./6	01.02./9	04.02./12	09.02./17	15.02./23	20.02./28	24.02./32
Moon phase	Growing moon	Full moon	Descending moon	Descending moon	Descending moon	Growing moon	Growing moon	Growing moon
Relative Humidity (%)	87	75	71	80	86	63	81	90
Weather temperature (^{0}C)	1	-3.5	-1	-9	-12	-7	-8	3
Diameter group (mm) 180-249 (215pcs.)								
Mean heart shake lenght/Stdev (mm)	56/37	62.8/39.1	63/39.7	56/37	56/37	56/37	56/37	56/37
Mean heart shake widtht/Stdev (mm)	0.7/0.4	0.7/0.4	0.7/0.4	0.7/0.4	0.8/0.6	0.8/0.6	0.8/0.6	0.8/0.6
Diameter group (mm) 250-299 (22pcs.)								
Mean heart shake lenght/Stdev (mm)	56.1/38.5	62.9/40.2	63.1/40.6	56.1/38.5	56.1/38.5	56.1/38.5	56.1/38.5	56.1/38.5
Mean heart shake widtht/Stdev (mm)	0.7/0.4	0.7/0.4	0.7/0.4	0.7/0.4	0.8/0.6	0.8/0.6	0.8/0.6	0.8/0.6
Diameter group (mm) 300< (10 pcs.)								
Mean heart shake lenght/Stdev (mm)	56.6/37.7	63.4/39.1	63.6/39.5	56.6/37.7	56.6/37.7	56.6/37.7	56.1/37.7	56.6/37.7
Mean heart shake widtht/Stdev (mm)	0.7/0.4	0.7/0.4	0.7/0.4	0.7/0.4	0.7/0.5	0.7/0.5	0.8/0.6	0.8/0.6

TABLE 4. CHARACTERISTICS OF MEASURED HEART SHAKES DEPENDING ON VENEEER DIAMETERAS IN THE STOCK DE 2073_01

Parameters	Results												
Measurement dates/storage days after harvesting	15.01.2021./1	18.01./4	20.01./6	22.01./8	25.01./11	27.01./13	29.01./15	01.02./18	05.02./22	08.02./25	15.02./33	19.02./37	25.02./43
Moon phase	Growing moon	Growing moon	Growing moon	Full moon	Full moon	Full moon	Full moon	Descending moon	Descending moon	Descending moon	Growing moon	Growing moon	Growing moon
Relative Humidity (%)	78	86	86	88	92	97	93	89	89	78	84	73	85
Weather temperature (^{0}C)	-17	-13	-12	1	1	1	-3	-3	-9	-10	-9	-13	8
Diameter group (mm) 180-249 (148 pcs.)													
Mean heart shake lenght/Stdev (mm)				20/62.5	35/38.47	45/38.68	45/39	50/40.83	80/45.12	120/50.40	120/51.38	120/52.46	101.5/52.77
Mean heart shake widtht/Stdev (mm)				0.5/0.45	0.5/0.45	0.5/0.44	0.5/0.44	0.5/0.47	0.5/0.47	0.5/0.58	0.5/0.63	09.5/0.63	0.75/0.63
Diameter group (mm) 250-299 (68 pcs.)													
Mean heart shake lenght/Stdev (mm)			29.3/44.1	73.8/40.8	74.7/39.3	81.5/39.1	94.2/41.1	103.0/46.3	103/54.6	103/56.1	103/56.1	103/58.2	100.6/57.1`
Mean heart shake widtht/Stdev (mm)			0.5/0.3	0.7/0.3	0.7/0.3	0.7/0.5	0.7/0.5	0.7/0.5	0.7/0.5	0.7/0.5	0.7/0.5	0.7/0.6	0.7/0.6
Diameter group (mm) 300< (7 pcs.)													
Mean heart shake lenght/Stdev (mm)	147/101.5	152/100.3	152/100.3	152/100.3	115/82.4	117/81.2	116/81.2	123/78.3	135/76.1	149/94.3	153/99.7	157/105.1	156/105.3
Mean heart shake widtht/Stdev (mm)	1/0.6	1/0.6	1/0.6	1/0.6	1/0.7	1/0.7	1/0.7	1/0.7	1/0.7	1/0.7	1/0.9	1/0.9	1/0.9

IV. CONCLUSIONS AND RECOMENDATIONS

According to the investigation results and the statistical analyses of the occurrance of heart shake [1], [2] in *Pinus elliotti* trees revealed that there were no important differences among geographic locations in the occurance of heart shakes. No important relationships existed between any of the location or soil variables studied and the measures of the occurance of heart shakes or of their linear guantities. Therefore, on this basis such conclusions would also be plausible for *Betula pendula Roth*. and *Bertula pubescens Ehrh.* species.

The heart shakes distribution process depends on diameter of veneer logs and weather temperature at the period of storage. Heart shakes appear in veneer logs (diameter group 300<mm) in the first day after harvesting, in veneer logs (diameter group 250-299mm) in period of 3rd-6th day aftter harvesting, in veneer logs (diameter group 180-249mm) in period 3rd-8th day after harvesting.

Heart shakes length decreases till 2.33 % in case where is a rappid weather temperature change from (-)13 to (+)8°C in diameter group 250-299mm, 15.83 % in the case when there is a rappid weather temperature change from (-)13 to (+)8°C in diameter group 180-249mm.

Heart shakes length decreases till 11 % in the case if there is a rappid weather temperature change from (-)1 to (-)9°C in all diameter groups.

The study obtained a finding that indicates the inconsistency of the applied method in measuring the depth of cracks. The actual depth of the cracks cannot be determined with a feeler gauge. This can only be determined by cross-cutting.

The presence of a heart shake in veneer logs affects not only the quality of the veneer sheet, but also the safety of the peeling technological process if the width in the widest place is greater than 2mm and heart shake splits the veneer log side surface.

Based on the results of the study it is proposed to harvest veneer logs in length 35 cm longer compared to manufactured veneer sheets width. In this case heart shakes should not be evaluated.

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Identified Resilient Flax Genotypes with Improved Agronomic Characteristics for Pre-Breeding

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***Abstract*. Genetic diversity evaluation in a breeding program is essential produce robust, resilient crop varieties with improved agronomic characteristics under environmental challenges in the sustainable agro-ecosystems. Knowledge and full potential on the impact of genotypes and growing conditions on flax yield traits still incomplete. The aim of this study was to evaluated the influence of hydrothermal conditions on the development of agronomic important traits of flax, analysed agronomic characteristics and identified perspective genotypes for pre-breeding. Field investigations were carried out from 2014 to 2017 for agronomically important traits of flax. In the study was evaluated flax population with Latvian origin in 24 fibre flax genotypes and 'Vega 2' (ST) as the standard variety of Lithuanian origin under Latvian meteorological conditions. Correlation between flax genotypes of the agronomically important yield traits and years of the hydrothermal coefficients during the growth period were analysed. According to the results obtained that most of genotypes the significant higher plants stem yield, total plant height, technical plant height, number of seed vessels per plant were measured in the growing seasons with high humidity. However, the higher seed yield and 1000 seed weight were measured in the driest year. The correlation between flax fibre content, seed number per seed-vessel, oil content and humidity level differed in dependence on genotype. The coefficient of variability between years was higher for of stem yield when compared with seed yield. The flax genotypes 'S13/5-7/5-93' exhibited more stable, highest stem yield (840.0 g $m^{-2)}$ and high seed yield (162.2 g m^{-2}). The flax was identified 80% samples the short and 20% the medium vegetation period.**

Keywords: fibre flax, hydrothermal conditions, yield.

I. INTRODUCTION

Flax (*Linum usitatissimum* L.) was known mainly as a textile crop in temperate region. The importance of flax grows up, as an environmentally friendly and potential natural resource, oriented to multilateral use also in nontextile industries - for use in building, paper, furniture industries and in composite (construction or automobile industries) production etc. [1], [2]. In Europe flax is the most general fibre crop.

Divergent breeding for fibre flax and linseed flax in connection with the early dispersion of this crop resulted in a wide range of intraspecific variation [3], [4]. The availability of diverse germplasm, characterization and evaluation data is of the greatest importance to realize the

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full potential of flax in agriculture [5] – [7]. Furthermore, plant breeders are continuously challenged to develop flax cultivars adapted to changing market needs and environments [8], [9].

According to the climate classification, the territory of Latvia is located in the wet climatic zone with warm summers. Currently, flax varieties which are grown in Latvia are from foreign a country, which does not always ensure stable and high quality of stem and seed yield in local climatic conditions. Similar like in the Latvia, in the Europe the aims of new flax varieties are: resistance to lodging reaching 9 points of the grade, middle early vegetation period, yield potential of stem reaching 7 – 8 t ha^{-1}, yielding potential of the seeds reaching 1.10 – 1.30 t ha^{-1} in the trials [10]. Commercial fibre yields depend not only on bred genotype but also on resistance to biotic and abiotic stress during the growing season.

In Europe, the limiting factor that affects flax yield very often is weather conditions (precipitation) [11]. To receive high quality fibre the smooth, wet climate without sudden changes in temperature and humidity and in the soil condition is required [12]. The optimum growing conditions for fibre flax could be when annual precipitation is at least 600 – 650 mm, of which at least 110 – 150 mm rainfalls perform during flax vegetation period [13]. The moisture for the fibre flax in the first period of development from germination to flowering is especially important [14]. Periods of insufficient moisture have a negative effect on the quality and quantity of yield as well significantly reduced the size of the main root and the number of side roots [15]. The insufficient moisture during the intensive growth of the stems has the most negative effect on the length of the technical part of the stem, so this period in the ontogenesis of flax is critical from the point of view of fibre yield formation. Excess moisture, especially when sowing densities and nitrogen content in the soil are high, can result in lodging [16]. However, flax is characterized by wide ecological differentiation including significant polymorphism in response to moisture deficiency [15].

In recent years, it has become more difficult to breed new fibre flax varieties with a better fibre quality, increased fibre yield, and the required resistance, due to repeated use of modern cultivars as crossing parents [10]. Knowledge on the impact of genotypes and growing conditions on flax yield traits as well resistance of disease of flax are still incomplete under the impact of the environments. The aim of this study was to evaluated the influence of hydrothermal conditions on the development of agronomic important traits of flax, analysed agronomic characteristics and identified perspective genotypes for pre-breeding.

II. MATERIALS AND METHODS

The research was conducted at the Institute of Agricultural Resources and Economics, Priekuli Research Centre, Department of Plant Breeding and Agroecology at Vilani during 2014 to 2017 for agronomically important traits of flax. Experimental material for the study consisted of 24 fiber flax genotypes of the Latvian origin (Table 1) and 'Vega 2' (ST) as the standard variety of Lithuanian origin.

TABLE 1. ESTIMATED FIBRE FLAX GENOTYPES

Nr.	Genotype	Nr.	Genotype
P1	Altgauzen	**P13**	T29-36/10-5-94
P2	Rota 1	**P14**	T29-36/7-1-94
P3	Rota 2	**P15**	T31-40-94
P4	Rezeknes	**P16**	T36-26/4-8-94
P5	Ruda 1	**P17**	K47-17/11-1-95
P6	S13/5-7/5-93	**P18**	K47-17/11-6-95
P7	S32/4-8-93	**P19**	L2-14/6-97
P8	S53/8-3-93	**P20**	L11-11/10-97
P9	S64-17-93	**P21**	L11-11/11-97
P10	T11-6/2-15-94	**P22**	L19-6/15-97
P11	T11-13/3-1-94	**P23**	L23-26/3-97
P12	T25/5-33/12-8-94	**P24**	L26-47/1-97

Field traits. Plants were grown in standard block plots of 1 m^2 with a distance between rows 10 cm, 1700 flax seeds per 1 m^2 were sown by hand with sowing depth 1.5–2 cm at the field trial. Prior to sowing, germination tests were performed for all used genotypes. Seeds were sown during the first 10 days of May. Flax was grown in humi-podzolic gley soil. The main agrochemical parameters of the arable soil layer were following: humus content – 6.5%, pHK_{Cl} – 6.4–7.0, available P_2O_5 – 130–145 mg kg^{-1} and available K_2O – 118–124 mg kg^{-1} soil (by results of The Latvian State Plant Protection Service). Complex fertilizer NPK 16:16:16 – 300 kg ha^{-1} was applied after first soil cultivation. For plants' further development a surface fertilizer - ammonium nitrate 30 kg ha^{-1} N in fir-tree like phase was applied. Insecticide ('Fastac 50' 0.4 L ha^{-1}, active substance: 50.0 g L^{-1} alpha-cypermethrin) was sprayed against flax flea beetles (Aphthona euphorbiae) as required by the instructions. The tractor-drawn sprayer 'Pilmet 412' was used for insecticide application. Fungicides for flax diseases were not used at all. Plants were pulled manually at the stage of early yellow ripeness and then left on ground for air-drying for 5–8 days. The seed-vessels were removed by "Eddi" device. Seeds were cleaned with "MLN" sample cleaner. The yield of seeds was weighed and then re-calculated to weight by 100% purity and 12% humidity. The total and technical plant heights, fibre content was determined using randomly selected most typical 20 plants in each parcel area before the harvest. The length of the vegetation period from seeding to early yellow ripening stage was evaluated [2].

Meteorological conditions. Agro-meteorological conditions were determined by ADCON installed meteorological stations connected to the computer program Dacom Plant Plus. Facility provides information directly to the nearby field trials. In this study hydrothermal coefficient (HTC) of each month was calculated during the growing season (Table 2). The calculations were performed by applying formula [17]:

$$HTC = \Sigma x / \Sigma t \times 10, \quad (1)$$

where Σ x and Σ t – sum of precipitations and temperatures in the period, when the temperature has not been lower than 10°C (1).

Ranges of values [18]: HTC ≤ 0.4 extremely dry; 0.4 < HTC ≤ 0.7 very dry; 0.7 < HTC ≤ 1.0 dry; 1.0 < HTC ≤ 1.3 relatively dry; 1.3 < HTC ≤ 1.6 optimal; 1.6 < HTC ≤ 2.0 relatively humid; 2.0 < HTC ≤ 2.5 humid; 2.5 < HTC ≤ 3.0 very humid; HTC > 3.0 extremely humid.

Statistical analysis. MS-Excel software was used for data statistical analysis. Significant differences among the measured characteristics of flax were compared by Fisher's protected least significant difference (LSD) tests ($p \leq 0.05$). The correlation coefficient was used to analyse relationship between hydrothermal coefficient (HTC) and agronomically important traits for each genotype. We used the coefficient of variability (CV) used by [19], [20] to describe of stability for each genotype as a stability parameter for stem yield and seed yield.

TABLE 2 TOTAL RAINFALL, AVERAGE OF AIR TEMPERATURE AND HYDROTHERMAL COEFFICIENTS (HTC) DURING 2014 TO 2017

Year	Month	Rainfall, mm	Temperature °C	HTC	Classifications
2014	May	99.5	7.6	2.9	very humid
	June	75.6	13.2	1.7	relatively humid
	July	25.2	13.7	0.5	very dry
	August	124.8	19.9	2.6	very humid
	May - August			**1.8**	relatively humid
2015	April	71.5	16.9	2.1	humid
	May	38.0	15.3	0.8	relatively dry
	June	89.5	16.2	1.8	relatively humid
	July	19.5	17.7	0.4	very dry
	May - August			**1.2**	relatively dry
2016	May	38.0	14.1	0.9	dry
	June	102.5	16.4	2.1	humid
	July	165.3	18.0	3.0	very humid
	August	70.7	16.2	1.4	optimal
	May - August			**1.9**	relatively humid
2017	May	15.1	10.7	0.5	very dry
	June	77.3	13.7	1.9	relatively humid
	July	129.5	15.4	2.7	very humid
	August	239.4	16.4	4.7	extremely humid
	May - August			**2.7**	very humid
Long term average	May	52.0	11.1	1.5	optimal
	June	75.0	14.8	1.8	relatively humid
	July	81.0	16.9	1.6	optimal
	August	71.0	15.5	1.5	optimal
	May - August			**1.6**	optimal

III. RESULTS AND DISCUSSION

The hydrothermal conditions during the growing stages of flax differed (Table 2). In 2014 HTC was 1.8 and in 2016 was 1.9, where it is characterized as relatively humid, in 2015 it was 1.2 what means as relatively dry. But 2017, when it was 2.7, it was very humid, when HTC in August was 317%, what is extremely higher than the long-term average.

The genotype effect on the overall statistically different stem, seed yield and yield components in different humidity conditions was quite variable during 2014 to 2017 (Table 3 and 4). The correlation confirmed significant positive relationship to the most of genotypes between stem yield, total plant height, technical plant height and level of humidity. The correlation coefficient shows that genotypes 'Altgauzen' (P1) and 'Vega 2' (ST) have been highest total plant height and technical pant height in the high humidity condition. The significant impact of the hydrothermal conditions on the fibre content between genotypes was not observed. This fact suggests that flax fibre content more dependence on genotype. According to [10], [21], is known that both additive and dominant effects of genes are involved in the heredity of fibre content and both effects are influenced by environmental conditions but it is still uncertain how many genes are involved in the heredity of fibre content and stem yield at the same time the heritability was lower. It was proved earlier [22], that the low heritability found for stem yield suggests a considerable environmental influence.

The current study showed that from all accessions, 80% of genotypes were with short (3) and 20% of genotypes with medium (5) vegetation period (Table 3). The resistance to abiotic factors as lodging of the tested accessions ranged from 3 (low) to 9 (very high). The highest resistance to lodging reached 9 of the genotypes 'Rota 1' (P2), 'T31-40-94' (P15) and 'K47-17/11-6-95' (P18) during 2014 to 2017. According to the data, between all flax accessions were identified genotypes 'L11-11/11-97' (P21), 'S13/5-7/5-93' (P6), 'T11-13/3-1-94' (P11) and 'S64-17-93' (P9) with significant ($p \leq 0.05$) higher the stem yield with the range from 755 to 840 g m^{-2}. The significant ($p \leq 0.05$) highest total plant height was observed in 13 genotypes with the range from 75.8 to 81.4 cm, the technical plant height - in 14 genotypes with the range from 61.8 to 67.1 cm and the fibre content - in 8

genotypes with the range from 29.6 to 32.0% compared with the standard 'Vega 2'(ST). According to [23], important agronomic traits such as vegetation period length, plant height, and lodging resistance may also indirectly affect yield through various physiological mechanisms, allowing crop phenology and plant architecture to be adapted to regional growing conditions, thus avoiding yield and quality losses.

TABLE 3 AGRONOMICALLY IMPORTANT STEM YIELD TRAITS OF FLAX GENOTYPES AND CORRELATION COEFFICIENT BETWEEN TRAITS AND HYDROTHERMAL COEFFICIENT (HTC)

Nr.	VP	L (range)	STY, g m^{-2}	r_{STY} /HTC	ToPH, cm	r_{ToPH} /HTC	TePH, cm	r_{TePH} /HTC	FC, %	r_{FC} /HTC
P1	3	3-9	362.5	0.14	59.4	**0.95***	43.1	0.09	24.2	-0.71
P2	3	9	650.0	0.57	**75.8**	0.83	59.1	0.42	27.2	0.29
P3	3	3-9	470.0	0.41	58.1	0.47	45.1	-0.03	27.9	-0.43
P4	3	5-9	262.5	-0.15	51.9	0.00	37.9	-0.82	25.1	0.37
P5	3	7-9	427.5	0.08	60.9	0.77	48.4	0.29	25.8	0.49
P6	3	7-9	**840.0**	0.51	**79.5**	0.90	**64.7**	0.64	26.2	0.23
P7	3	7-9	597.5	0.40	69.1	0.74	54.5	0.23	**30.1**	0.01
P8	3	7-9	665.0	0.44	77.3	0.76	**62.4**	0.48	**31.7**	-0.37
P9	5	5-9	**755.0**	0.62	77.0	0.67	**61.8**	0.53	26.9	-0.58
P10	3	3-9	665.0	0.76	72.3	0.68	58.4	0.44	**30.0**	0.31
P11	3	5-9	**815.0**	0.70	**79.2**	0.85	**64.8**	0.67	28.9	-0.22
P12	3	5-9	675.0	0.27	**80.1**	0.70	**65.2**	0.32	28.7	0.30
P13	3	5-9	660.0	0.36	**78.8**	0.47	**65.5**	0.29	**29.9**	0.61
P14	3	5-9	667.5	0.41	**78.8**	0.69	**64.2**	0.17	**29.6**	0.13
P15	3	9	617.5	0.14	**78.3**	0.87	**63.0**	0.24	25.6	-0.54
P16	3	7-9	660.0	0.33	**79.3**	0.72	**64.4**	0.27	**32.0**	-0.01
P17	5	5-9	660.0	0.19	**79.4**	0.43	**64.0**	0.00	28.7	-0.64
P18	5	9	622.5	0.30	**78.0**	0.63	**63.2**	0.26	28.1	-0.41
P19	3	5-9	542.5	0.22	73.4	0.40	59.4	0.00	27.1	-0.11
P20	3	5-9	687.5	0.36	73.3	0.44	58.2	-0.01	26.5	-0.03
P21	5	7-9	**840.0**	0.76	**80.8**	0.68	**64.2**	0.08	29.4	0.72
P22	3	5-9	664.3	0.69	74.1	0.87	60.6	-0.08	26.5	0.37
P23	3	5-9	642.5	0.66	**78.5**	0.43	**63.5**	0.03	**30.8**	-0.88
P24	5	5-9	672.5	0.55	**81.4**	0.84	**67.1**	0.60	**29.9**	0.22
ST	3	7-9	562.5	0.54	73.4	**0.98***	58.5	**0.95***	27.1	-0.28
LSD$_{0.05}$			*174.4*		*4.2*		*3.1*		*2.3*	

VP – vegetation period; L – lodging; STY - stem yield; ToPH - total plant height; TePH - technical plant height; FC - fibre content; LSD values significant at $p \leq 0.05$ are marked in bold comparing with 'Vega 2' (ST); *r* - correlation coefficient * − correlation significant at $p \leq 0.05$; ** − at $p \leq 0.01$

The correlation confirmed significant negative relationships between seed yield, seed number per seed-vessel, 1000 seed weight and level of humidity to the most genotypes (Table 4). The correlation coefficient shows that the seed yield for genotypes 'Ruda 1' (P5), 'S13/5-7/5-93' (P6), 'S32/4-8-93'(P7), 'L26-47/1-97' (P24), 'Vega 2' (ST) and seed number per seed-vessel for genotype 'T29-36/7-1-94' (P14) have been highest in the dry condition. A significant influence of the hydrothermal conditions on the 1000 seed weight for 12 genotypes was found. This fact suggests that the 1000 seed weight of identified genotypes is the highest in the dry conditions. The correlation confirmed significant positive relationships between number of seed-vessel per plant, oil contents and level of humidity to the most genotypes. The correlation coefficient shows that the number of seed-vessel per plant for genotypes 'S13/5-7/5-93' (P6), 'T36-26/4-8-94' (P16), 'K47-17/11-1-95' (P17), 'K47-17/11-6-95' (P18) have been highest in the high humidity condition. The correlation equation shows that the highest oil content was found for genotypes 'Rota 1' (P2), 'T29-36/10-5-94' (P13), 'L19-6/15-97' (P22), 'L23-26/3-97' (P23), 'Vega2'(ST) in the high humidity condition but for genotypes 'Rezeknes' (P4) and 'S13/5-7/5-93' (P6) - in the driest conditions.

Some study [24] proved that in flax yield and its components such as 1000 seed weight, seed number per seed-vessel and number of seed-vessel per plant are quantitatively inherited and controlled by many genes affected by multiple interactions with other genes and the environment.

The study [25] note, that the change in oil content depends on the genotypic differences. However, some [26], [27] note, that the range of variation not only within the genotype but also with regard to the climatic conditions of cultivation including water availability influence the oil content of flax seed. In general, similar results could find in our study.

TABLE 4 AGRONOMICALLY IMPORTANT SEED YIELD TRAITS OF FLAX GENOTYPES AND CORRELATION COEFFICIENT BETWEEN TRAITS AND HYDROTHERMAL COEFFICIENT (HTC)

	SY, g m^{-2}	$r_{SY/HTC}$	NSVP	$r_{NSVP/HTC}$	SNSV	$r_{SNSV/HTC}$	SW, g	$r_{SW/HTC}$	OC, %	$r_{OC/HTC}$
P1	100.2	-0.87	9.7	0.81	**8.4**	0.80	4.0	**-0.98***	**43.3**	0.68
P2	**163.8**	-0.34	9.8	0.79	**8.7**	0.37	5.0	-0.94	42.2	**0.96***
P3	**159.9**	-0.81	8.3	0.26	**8.5**	-0.76	5.7	**-0.97***	**43.6**	0.26
P4	121.2	-0.84	**10.0**	0.70	**8.7**	-0.50	4.4	-0.92	**43.6**	**-0.96***
P5	**165.0**	**-0.99***	9.7	0.71	**8.6**	-0.60	5.0	**-0.99****	**43.0**	0.50
P6	**162.2**	**-0.96***	8.1	**0.97***	**9.4**	-0.20	4.6	**-0.99****	42.2	**-0.99****
P7	**162.0**	**-0.98***	**10.4**	0.75	**8.6**	0.18	4.5	**-0.99****	41.9	0.03
P8	145.1	-0.84	9.9	0.67	**8.8**	-0.45	4.7	**-0.95***	43.0	0.90
P9	**158.4**	-0.84	9.6	0.92	**9.1**	0.42	4.5	**-0.96***	42.5	0.90
P10	**153.2**	-0.98	8.9	0.61	**8.8**	-0.35	**5.1**	**-0.99****	42.0	0.02
P11	**158.9**	-0.83	8.8	0.59	**8.7**	0.65	4.8	-0.78	42.2	0.20
P12	110.4	0.02	7.6	0.63	**8.5**	0.69	4.7	-0.94	**43.6**	0.84
P13	137.4	0.08	6.9	0.82	**8.8**	0.10	5.0	-0.93	42.1	**0.97***
P14	133.4	0.15	7.7	0.73	**9.0**	**-0.95***	5.0	-0.85	41.9	0.94
P15	112.2	0.13	8.6	0.90	**8.4**	-0.70	4.6	**-0.96***	**43.6**	0.59
P16	117.5	-0.31	8.8	**0.99****	**8.9**	-0.68	5.0	-0.83	**43.7**	0.76
P17	134.9	-0.60	9.1	**0.98***	**8.9**	0.68	4.8	-0.92	**43.6**	0.90
P18	135.3	-0.63	9.8	**0.95***	**8.8**	-0.63	4.6	-0.94	42.6	-0.16
P19	139.0	-0.62	9.3	0.93	**8.9**	0.50	4.5	-0.90	41.9	0.50
P20	**163.5**	-0.82	**10.4**	0.49	**8.6**	-0.56	**5.3**	**-0.99****	**43.5**	0.82
P21	**168.7**	-0.53	**10.6**	0.78	**8.9**	-0.09	4.9	**-0.95***	42.9	0.76
P22	140.1	-0.16	9.7	0.72	**9.0**	-0.82	**5.4**	-0.87	**43.7**	**0.99****
P23	108.5	0.83	8.7	0.92	**8.7**	0.41	4.6	-0.84	42.5	**0.99****
P24	141.1	**-0.98***	8.3	0.93	**9.2**	-0.34	4.6	**-0.96***	42.7	0.54
ST	126.9	**-0.97***	8.5	0.87	8.1	-0.24	4.7	-0,94	42.7	**0.99****
LSD$_{0.05}$	*19.5*		*1.4*		*0.3*		*0.4*		*0.3*	

SY - seed yield; NSVP - number of seed-vessel per plant; SNSV - seed number per seed-vessel; SW - 1000 seed weight; OC - oil contents; LSD values significant at $p \leq 0.05$ are marked in bold comparing with 'Vega 2' (ST); r - correlation coefficient * − correlation significant at $p \leq 0.05$, ** − at $p \leq 0.01$

The current study identified 10 genotypes with the significantly ($p \leqslant 0.05$) highest seed yield (the range from 153.2 to 168.7 g m^{-2}) and 4 genotypes with the number of seed-vessel per plant (the range from 10.0 to 10.6) (Table 4). The seed number per seed-vessel (in range from 8.1 to 9.4) for all accessions was significantly higher than that of the standard variety 'Vega 2'. The significantly highest 1000 seed weight was observed in 4 genotypes: 'Rota 2' (P3), 'T11-6/2-15-94' (P10), 'L11-11/10-97' (P20) and 'L19-6/15-97' (P22) with the range from 5.1 to 5.7g. The significantly highest oil content was observed in 10 genotypes with the range from 43.0 to 43.7% compared with the standard 'Vega 2' (ST).

The flax genotype 'L11-11/11-97'(P21) exhibited the highest average stem yield (840.0 g m^{-2}), seed yield (168.7 g m^{-2}) and high total plant height, technical plant height, number of seed-vessel per plant, seed number per seed-vessel than the standard variety 'Vega 2'. However, there was identified most promising genotype 'S13/5-7/5-93' (P6) with high stem yield (840.0 g m^{-2}) and lower correlation between HTC (r = 0.51) and stem yield (Table 3). This fact suggests that the identified genotype 'S13/5-7/5-93' (P6) was more resistant to dry and humidity conditions during the growing periods.

The current study according to soil analysis, agrochemical indicators have not significantly differed by years which suggested complex (genetic, environment) factors influencing the growth and development of flax. At same time finding current study showed that most of the agronomically important traits of flax are subject to productivity variation depending on the effect of various humidity conditions between years and genotypes. Furthermore, identified that each genotypes have different response at the same conditions. The results allow selecting the environment which genotype is more adapted at different hydrothermal conditions in comparison with other genotypes evaluated simultaneously in the same environments. The research needs to be continued in order to understand the specific needs of each genotype and to identify which ones are more suitable to local conditions.

The coefficient of variability (CV) between years was higher for of stem yield when compared with seed yield (Fig.1, 2). The 'S53/8-3-93' (P8) had lowest coefficient for seed yield (CV =8%) and the 'Rota 1' (P3) had the highest (CV =51%). Potential promising genotypes with highest seed yield and higher stability were identified 'L11-11/11-97' (P21), 'Rota 1' (P2), 'L11-11/10-97' (P20) and 'S13/5-7/5-93' (P6).

Between genotypes, the 'L26-47/1-97' (P24) had the lowest variability coefficient for stem yield (32%), and the 'L11-11/11-97' (P21) had the highest (CV = 60%). However, the most promising genotype with the highest

seed and stem yield and lowest coefficient of variability was 'S13/5-7/5-93' (P6) was observed.

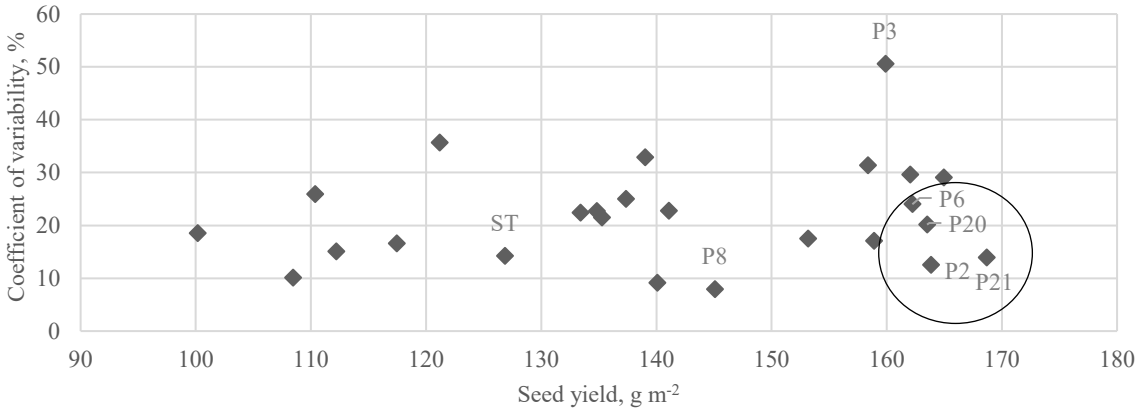

Fig. 1. The relationships between coefficient of variability (CV) of seed yield and average seed yield for each flax genotype from 2014 to 2017.

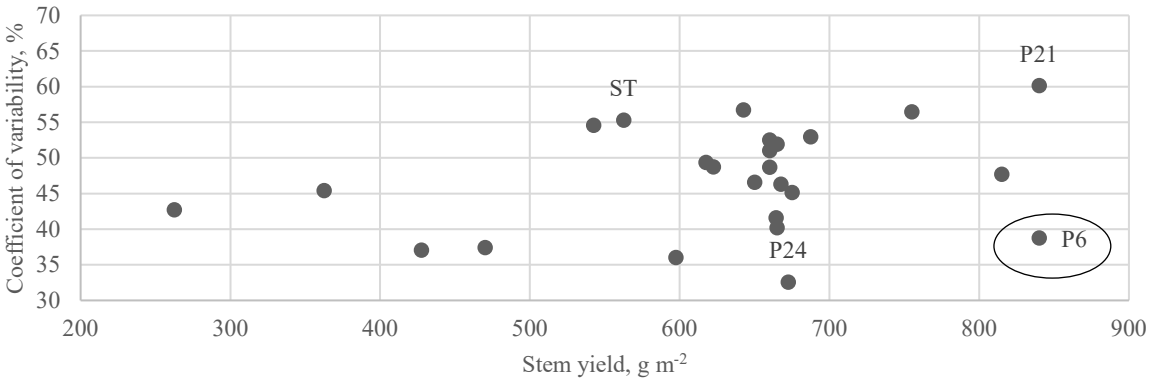

Fig. 2. The relationships between coefficient of variability (CV) of stem yield and average stem yield for each flax genotype from 2014 to 2017.

IV. CONCLUSIONS

Overall, based on the analyses of correlation, a variable influence of hydrothermal conditions on the trait of flax between years and genotypes was found. The most flax genotypes had highest total plant height, technical plant height, stem yield, a number of seed-vessel per plant and oil contents in high humidity conditions and seed yield, seed number per seed-vessel, 1000 seed weight highest in dry conditions. Furthermore, identified that each genotypes have different response at the same conditions. The flax fibre content was identified as the more heritable.

The promising genotype 'S13/5-7/5-93' (P6) with high stem (840.0 g m^{-2}), seed yield (162.2 g m^{-2}) and more stable stem yield performance between variable hydrothermal conditions were identified for pre-breeding.

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Physical Properties of Geopolymers Made from Mineral Waste

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***Abstrac*t. Geopolymer is an alumino-silicon gel consisting of tetrahedral SiO 4 and AlO 4 sections, polycondensed in a spatial structure as a result of the reaction between aluminosilicates and an alkaline activator.The report is a part of the complex research plan for geopolymers, in which information is given about the experimental results in the preparation of geopolymers from natural and man-made mineral components characteristic of Latvia (clay, sand, wood ash, brick waste).**
The aim of the study was to find out the dependence of the geopolymer formation process on the composition of the reacting components at constant exposure factors. Sodium alkali solution and sodium silicate was used in the experiments. The raw materials used are red and gray clay, sand, wood ash.
The composition of the clay, ash and sand composition was changed with an interval of twenty percent. The obtained geopolymer samples were subjected to physical and technical tests. The compositions that are perspective in terms of properties in the studied modes of exposure have been determined.

Keywords: Geopolymer, mineral waste, alkaly activators, mechanical properties of minerals.

I. INTRODUCTION

Geopolymers according to J. Davidovits [1] are synthetic alkali aluminosilicates - or inorganic polymers , which are formed as a result of the reaction between aluminum and silicon-containing hard minerals and high-concentration alkalis (NaOH, KOH) or acids (H_3PO_4) [2] .The spatial structure of geopolymers consists of SiO_4^{4-} and AlO_4^{5-} tetrahedra, which are mutually combined with oxygen molecules. Thanks to such a structure, they acquire many positive mechanical properties - strength, water resistance, heat resistance..., as a result of which they have become a perspective material in construction and have potential successfully compete with cement [3]. The original geopolymers were made of metakaolin[4], but the researches carried out later, proved that a very wide range of different minerals can serve as raw materials for the geopolymer, including a whole series of man-made mineral waste. Studies have been conducted in which were proved that mineral waste such as fly ash of coal, blast furnace slug and sludge, silica fume, mining waste , ore enrichment tailings and others may be used in the production of geopolymers[5,6,7,8].

If also to take into account the fact that the production of geopolymers does not require firing at high temperatures, which is typical in the cement production process and thus drastically reduces the impact on the environment (including carbon dioxide emissions in the atmosphere) [9], it is understandable that there is a great interest in in exploring possibilities of the efficient production of this product. In perspective, geopolymer can replace the use of cement in various spheres.

Studies have been conducted for their use in road surfaces, water tanks, building construction elements, tile production, 3D printing, etc.[10,11,12].

However, the competitiveness of geopolymers with Portland cement has not yet been ensured. Its use is episodic but impressive and promising(Brisbane West Wellcamp Airport in Toowoomba,in Australia,the Global Change Institute at the University of Queensland)[13,14].

Circumstances that do not allow to expand the use of geopolymers are related, first of all, to raw materials. It can not rely only on metakaolin. It is necessary to use a wider range of raw materials. Emphasis is placed on the use of mineral waste, but their composition is diverse and it requires optimizing the parameters of the production process every time. The mechanisms of the polymerization process are explained in different ways, but nevertheless they are generalized to a wide range of

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minerals. [15,16] . There are problems with efflorescence also [17] .
That is why most researches are now conducted using the trial-and-error approach in their investigations. It is necessary to develop the relevant standards for the relevant compositions of raw materials.
Studies have shown that the best results are achieved when the raw materials are fine milled.[18] But the grinding of hard mineral materials is a very energy-intensive process - the specific energies can be as high as 60 kWh/t. [19], which immediately makes the final product more expensive.
The use of activators – alkali and silicates in the process also makes a big contribution to the increase in the price of the final product.The cost of activators often exceed 50%of total expenses [20].
In addition, sodium silicate is a material in high demand in other industrial sectors as well, and this limits the possibilities of using it in large-scale geopolymer production.
The properties and structure of the manufactured geopolymer also depend on the conditions under which the material is compacted and hardened.
Until now, it is not clear what geopolymer curing regimes are optimal - curing temperature and time, atmospheric humidity, etc., because different authors give different information about them.[21]
In our research, as the first task, we decided to investigate the possibilities of geopolymer formation under the same process conditions from charachateristic for Latvia raw materials - technogenic and natural mineral resources - wood ash, clay and sand taken in different proportions. In order to evaluate the principial possibilities of creating a geopolymer with lower energy consumption, the process conditions were those selected when the primary treatment of substances has been reduced to a minimum (there is no crushing,milling, only sieving, grain sizes 0.25, 0.1 mm, curing takes place at normal atmospheric temperature without heating.

II. MATERIALS AND METHODS.

In accordance with the stated goals of geopolymer research, mineral resources widely represented in Latvia were used as raw materials for the preparation of samples, such as natural ones - clay and sand, as well as a technogenic mineral waste - wood ash.
Clay was obtained from the largest Kuprava clay deposit in Latvia, Katlešu suite. The Kuprava clay reserves are significant - 16 million m^3, and the forecasted reserves exceed several billion m^3. At the same time, mining of this clay is currently not taking place. Therefore, it is useful to consider all possible options for the inclusion of this clay in the Latvian economy. One of them is to analyze the possibilities of using them in the production of geopolymers.
The clay of the Katlesi suite in the Kuprava deposit consists mainly of clay minerals illite and kaolin. The content of illite is predominant. The other minerals are quartz, dolomite, calcite and minerals of the feldspar [22](Fig. 1).

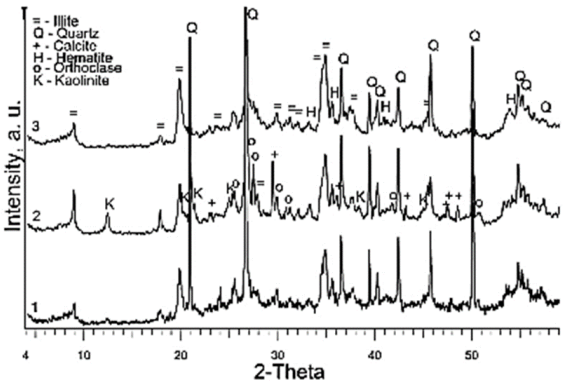

Fig.1. Kuprava clay deposit clay mineral composition X-ray diagram . 1- Kuprava district clay , 2- Mednieki deposit clay , 3- South section of quarry clay.

The chemical composition of Kuprava clay is characterized by a high content of silicon oxides SiO_2 (50-43%) and aluminum oxides Al_2O_3 (14-17%). The content of calcium oxide in clay is quite low and does not exceed 5% [22](table 1).

TABLE1 Chemical composition of Kuprava clay

Clay	*SiO_2*	*Al_2O_3*	*Fe_2O_3*	*K_2O*	*CaO*	*MgO*	*TiO_2*
White	46,8-50,0	14,6-16,4	5,1-5,6	3,6-5,6	2,2-3,0	2,2	NA
Brown	43,8-45,4	8,3-10,0	8,3-9,9	4,5-5,5	0,8-4,8	1,6-2,4	0,98

Sand is also one of the most common useful mineral resources in Latvia.[23]
Sand with a quartz content of 60-70% was used in the study. The fraction with a grain size < 0.25 mm was sieved for the preparation of geopolymer samples. Some samples were prepared of sands witn a grain size less than 0.1. In the studies related to the production of geopolymers, mostly coal ash and the finest part of it - fly-ash was used as one of the mineral waste components. This kind of ash is not decisive in Latvia, due to the very low share of the use of hard coal in the energy sector. The main amounts of ash are the bottom ash of furnaces formed as a result of burning wood and, to a lesser extent, other types of biomass. The wood ash amounts will increase gradually in nearest years due to using pellets and chipped firewood in the state energy production sector.
Therefore, wood ash (a mixture of coniferous and deciduous trees) was used in our experiments. Ash density is determined to be 1.74-1.82 g/cm^3, porosity in the embankment is 68-72.5%, loss on ignition is 6.9-7.8%.The analysis of wood ash showed that their chemical composition varies within quite wide limits and is different from the composition of coal ash [24] (table 2). Wood ash has a much lower content of silicon and aluminum oxides compared to coal ash, but the content and the ratio of these components are determinants, as

found in many studies [25,26,27,28] for the successful development of the geopolymerization process.

TABLE 2 Chemical composition of ash in terms of oxides

Oxide	*Wood ash content, wt %*	*Coal ash content, wt %*	*Sewage sludge ash, wt%*
SiO_2	20-60	40-70	27
Al_2O_3	0,1-12	14-35	14,4
Fe_2O_3	1,5-5,3	2-20	8,2
Fe_3O_4	-	2-14	-
MgO	0,3-5	1-10	3,2
Na_2O	0, 1-0,8	0,1-5	0,5
CaO	0,8-43	0,5-30	21

NaOH solution with a concentration of 12M and industrially produced sodium silicate with a density of 1.39g/cm^3 and a ratio of SiO_2:Na_2O=3:1 (SiO_2- 28.1%, Na_2O- 9.6%) were used as process activators. Based on literature data [29] and our test measurements, the mixture of activators was taken as the closest to the optimum in the ratio Na_2SiO_3:NaOH=3:1. This relationship remained constant throughout the experiments.

In the previous test experiments, the ratio of solid components GS to the total amount of activators GA of the activator solution was also evaluated as the most optimal. For further experiments, this ratio was assumed as GS:GA = 3:1. Water from 2 to 8% of the total mass of the mixture was added only to some samples.

Mixtures of solid components were made in three groups of experiments : 1)only one component (sand, ash, clay); 2) a mixture of two components; 3) different proportions of all three components.

The process of making the samples was as follows.

At least one day in advance, the activator was prepared - a solution of a mixture of sodium silicate and sodium alkali. The solid components were weighed and thoroughly mixed in the appropriate proportions. An activator (Na_2SiO_3 +NaOH) was added to the mixture and the whole mass was intensively stirred for 5-7 minutes. In the next stage, the dissolved material was placed in plastic cylindrical forms (d=28mm, h=28mm), compacted with vibration and left to harden at ambient temperature for 5 days. After that, they were removed from the containers and left for further curing for 10 days. After this period, the samples were subjected to measurements. Their density was measured by hydrostatic weighing method according to standard ASTM D7263 – 21[30], moisture capacity and water resistance were determined by immersing them in water for 5 days according to standard methods[31]. Dry samples were subjected to strength determination according to standard test methods [32].

III. RESULTS AND DISCUSSION

The testing results of the obtained geopolymer samples are summarized in the table 3 and figure 2.

TABLE 3 Mechanical properties of produced geopolymer samples

Sample Nr	*Composition Sand:Clay: Ash (%)*	*Density,ρ, g/cm^3*	*Moisture capacity ,w,%, water resistance*	*Compressive strength,σ, MPa*
1	100:0:0	1.98	Disintegrate	0.10
2	60:40:0	2.30	Disintegrate	7,8
3	33:33:34	1.72	12,8	4.17
5	80:20:0	2.18	Disintegrate	
6	0:50:50	1.88	13.7	
7	50:0:50	2.00	Disintegrate	
8	20:50:30	1.99	Disintegrate	4.54
9	60:20:20	1.62	Disintegrate	
10	25:25:50	1.84	5,6	5.70
11	40:40:20	1.87	Disintegrate	1.70
12	40:30:30	1.84	Disintegrate	2.30
13	0:50:50	2.08	20.8	2.60
14	0:0:100	1.59	16.5	2,20
15	0:100:0	2.97	Disintegrate	7,15
17	75:10:15	1.80	Disintegrate	2.35
18	10:10:80	1.65	13.6	2.30
X	0:31:36+b1+b2	1.97	16.3	7.53

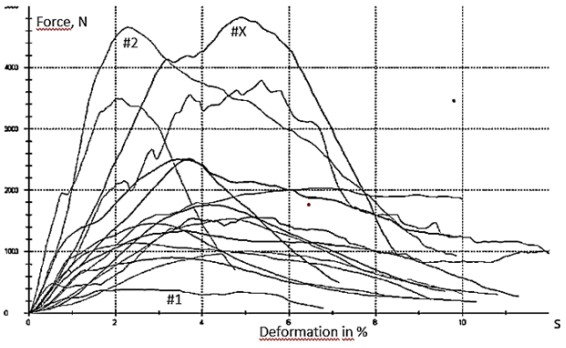

Fig.2. Stress-deformation curves for studyed samples.

The analysis of the produced geopolymer samples showed that the polymerization process strongly depends on the composition of the components.

Water resistance tests showed that many samples after 5 days curing did not obtain water resistance – they disintegrate in water partly or completely.

Compression tests after 20 days curing showed that strength of obtained samples did not achieve sufficient strength – in the most cases it was between 2- 4 MPa.

Thus, comparing single-component samples, it was found that samples made from wood ash are best subjected to polymerization.

Ash-based geopolymers are characterized by a mostly amorphous structure, which means a full-fledged polymerization process, they have water resistance - no changes in properties were observed after 10 days in water, the average moisture content is in the range of 15-16%, volumetric weight 1.55-1.6 g.cm $^{-3}$,conpressive strength 2 MPa and more (Fig.3,sample14)

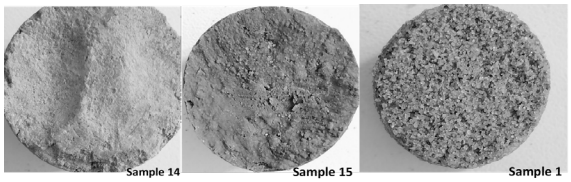

Fig.3. Single-component samples.

Samples made of 100% clay, judging by the structure, are only partially amorphized, water resistance is not sufficient - 10 days of exposure to water led to partial collapse - mass loss is more than 50% , but tests on compressive strength showed relatively higher values - more than 7MPa (Fig.3, sample15).

Samples made only from sand are the least susceptible to the polymerization process - the produced samples practically consist of quartz grains, the bonds between which are weak and as a result of exposure to water they disintegrate after only one day. Their density is 1.98 g.cm^{-3} , compressive strength very low – does not exceed 1 MPa. (Fig.3 ,sample1).

Two-component composition samples with a 1:1 ratio of components by mass (Fig.4) show that their degree of polymerization is also related to the presence of sand in the composition.

Geopolymer from sand and ash is crystalline in structure, density is 2g/cm $^{-3}$, disintegrates in water. (Fig.4, sample 7).

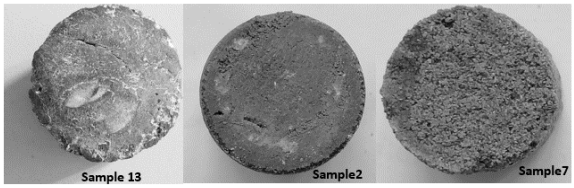

Fig.4 . Two- component samples.

Contrary, the samples whose raw material was clay and ash (fig.4, sample13) showed full polymerization, characterized by a homogeneous dense structure and water resistance. Moisture content from 14 to 20%wt depending on the geopolymer curing conditions. Density 1.9-2.1 g.cm-3,compressive strength – 2.6 MPa.

A composite of equal amounts of clay and sand (Fig.4, sample 2) shows that the structure is denser and more uniform, but the samples are not water resistant. An at the same time their compressive strength turned out to be larger if compared with other samples.(see table3).

Samples made from a mixture of all three components in different proportions showed that the presence of sand more than 25% by mass has a negative effect on the polymerization process, does not ensure water resistance of the geopolymer. However, the presence of ash in the mixture has a beneficial effect on the polymerization process, especially if its content is more than 40%.(Fig.5,samples10 ,18)

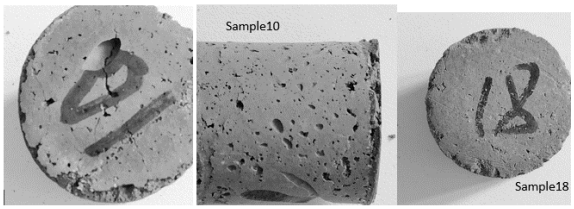

Fig.5. Three- component samples.

The samples obtained under these conditions are characterized by maximum water resistance, the moisture content is within 13-17%.

By summarizing all the experimental data, the optimal area of the composition of these three components (sand + ash + clay) can be determined in a triangle diagram with limits - the amount of sand does not exceed 30%, the amount of ash is greater than 40%, the clay content is up to 50%. (Fig.6). The results which correlate with our experiments were obtained in other works [6,7].

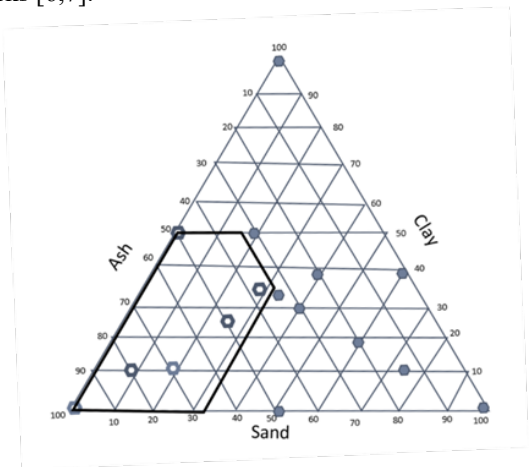

Fig.6. Triangle phase diagram: sand - clay - ash. The perspective area of the composite content is marked by the thick line.

Data from the literature [33]show that the water resistance at the normal curing temperature of the geopolymer mass is determined by the use of blast furnace slag as one of the components. In other cases, the increased curing temperature regime is required. Since in Latvia these slags are not available optimization of the composition and its curing conditions is required.

In addition to the examined series of geopolymer samples, consisting of three components - clay, ash and sand, samples were made that also included waste from the construction process - ground fragments of clay bricks and silicate bricks (Fig.7.sample X , Table3).

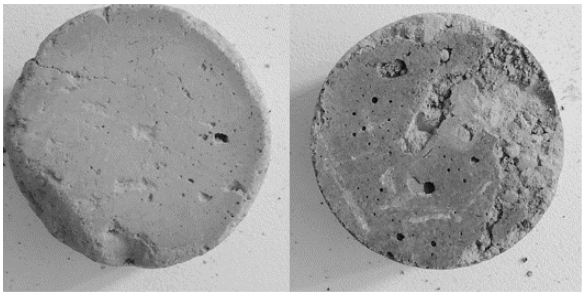

Fig.7. Sample X, prepared from clay, ash, sand and waste silicate and clay bricks.

These samples showed the highest strength and water resistance in this study. This indicates that supplementing the composition with recycled construction materials is a promising direction in the production of geopolymers and, therefore, in the inclusion of man-made waste in the economic cycle.

IV. CONCLUSIONS

The studies showed the principle possibility of obtaining geopolymers from man-made and natural mineral resources available in Latvia. Since the experiments were performed based on the minimum pretreatment of the raw materials, the desired strength of the geopolymer was not achieved, but the proportions of the composition of the geopolymer raw materials were determined, which are promising for further research. These proportions shown on the graph (Fig.6) is as follows: sand does not exceed 30%, the amount of ash is greater than 40%, the clay content is up to 50%.

Increasing the mechanical properties of geopolymers is possible:

- Expanding the composition of raw materials to include construction and demolition mineral waste;
- By increasing the reactivity of the components (chemical activity) by grinding them to particles of about 20-60 μm;
- Specifying the amount and concentration of activators corresponding to each composition of the composite;
- By carrying out the curing process at elevated temperature and humidity.

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Genetic Diversity and Population Structure of the European Eel (Anguilla anguilla) in Baltic Lakeland

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***Abstract. Anguilla anguilla* (Linnaeus, 1758) is the unique catadromous fish species in the Latvian fauna. The Baltic Lakeland area representing naturally recruited and introduced eels. In recent decades, its population has decreased not only in Latvia, but also in Europe. European eel critically endangered due to overfishing of glass eels, blocking of migratory paths, deaths in HPS turbines, water pollution and diseases and parasites. Only some bodies of water are freely accessible to natural migration of eels in Latvia.**

Currently, its position has been recognized as being critical, and a range of normative acts have been adopted for its restoration, such as the Regulation EC 1100/2007. The restocking programs of the European eel *Anguilla anguilla* have been conducted for nearly one century in Latvia.

This study provides the first data on population structure of freshwater eels in Baltic Lakeland, for use in eel conservation and management of aquaculture on a regional and/or global scale. By analysing the sequences of the Cyt *b* gene of mtDNA for individuals caught in locations throughout in Baltic Lakeland, we determined the population genetic structure of *A. anguilla* in the area. The diversity of haplotypes was studied in ten waterbodies from part of Baltic Lakeland, namely Lake Sīvers, Lake Usmas, Lake Ķišezers, Lake Liepājas, Lake Alūksnes, Lake Rāznas, Lake Vialikija Švakšty, Lake Svir, Lake Myadzyel, Myadzelka river. Additionally, this study investigated the affinity of the Latvian populations to other *A. anguilla* populations around the world.

This is the first report about eel's population genetic diversity in Baltic Lakeland. Haplotype variation was different in all investigated waterbodies. In current studies seven new unique haplotypes were detected. Eel population in Baltic Lakeland shows quite high genetic diversity and rapid population expansions, which possibly is results of intensive restocking program. Sequences characterized *Anguilla rostrata* in Lake Alūksnes were detected.

Keywords: Anguilla anguilla, cyt b, genetic diversity, haplotype.

I. Introduction

European eel (*Anguilla anguilla* (L.)) is a catadromous euryhaline fish characterized by a complex biological cycle involving marine, brackish, and freshwater habitats [1]. The Baltic Lakeland area representing naturally recruited and introduced eels. In recent decades, its population has decreased not only in Latvia, but also in Europe. To increase the local eel production in Latvia, the restocking plan has been conduct since 1927. During 1960 to 1988 by the government, almost 30 million of glass eels imported from France were regularly released in 51 Latvian lakes [2]. After 1990, eel was mentioned in the fishing haul statistics in 16 lakes, but only four of these water bodies are freely accessible to natural migration of eel, and in the others eels which were released in the 1960s-1990s were caught [3]. The restocking programs of the

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European eel have been conducted for nearly one century in Latvia [2]. European eel critically endangered due to overfishing of glass eels, blocking of migratory paths, deaths in HPS turbines, water pollution and diseases and parasites. In Latvia, *A. anguilla* was one of the most expensive fish that fishermen were most interested in. Currently, its position has been recognized as being critical, and a range of normative acts have been adopted for its restoration, such as the Regulation EC 1100/2007 [2]. Although the restocking plans were conducted for a long time in Latvia, the following restocking efficiency was seldom evaluated, nor was the contribution of restocked eels to the local population examined. In Latvia, information on the genetic diversity and population structure of this species is necessary for resource management.

The aim of present research is to evaluate the genetic diversity of *Anguilla anguilla* population in Baltic Lakeland.

In order to address this paucity of information, sequencing of the entire mitochondrial control region (mtDNA) was carried out for *Anguilla anguilla* from Baltic Lakeland. By analysing the sequences of the Cyt *b* gene region of mitochondrial DNA for individuals caught in locations throughout in Baltic Lakeland, was determined the population structure of *A. anguilla* in the area. Additionally, this study investigated the affinity of the Latvian population to other *A. anguilla* populations around the world.

II. Materials and Methods

A. Sample Collection

To evaluate the efficiency of the eel restocking program and reveal the migratory life histories of European eels in Baltic Lakeland waters, a total of 34 individuals were collected. Eel samples were collected in 2014 - 2020 from seven lakes, namely Lake (further L.) Usmas, L. Liepajas, L. Kisezers, L. Aluksnes, L. Vaidavas, L. Raznas, L. Sivers in Latvia and from four waterbodies, namely L. Myadzyel, L. Svir, Myadzyelka river, L.Vialikija Svaksty in Belarus (Fig. 1), in accordance with the monitoring plan of fish resources.

Fig. 1. Sampling sites of studied European eel.

B. DNA Extraction and Mitochondrial DNA Sequencing

Genomic DNA was extracted from muscle tissue or fins according to the salt-extraction method of Aljanabi and Martinez [4], which earlier was used in genetic researches of water animals [5], [6]. The quality and quantity of DNA samples were determined using spectrophotometer BioSpec-Nano. The extracted DNA was stored at -20ºC until analysis. For the analysis, the DNA was diluted to a concentration of 10 ng/µL. The primers for the Cyt *b* gene (forward primer: 5`CCTCCTTCTTCTTTATCTGCCT 3`; reverse primer: 5`GTTTTCTAGTCAACCTGCTAATGG 3`) were used [7], [8]. Polymerase chain reaction (PCR) was performed using ABI 9700 thermocycler with a total reaction volume of 10 µL, containing ddH2O, 10xPCR buffer, 25mM MgCl2, 2mM dNTP Mix, 3pmol of each primer, 0.1U Taq DNA polymerase and 100 ng template DNA. Amplification started with an initial denaturation step for 5 min at 95 °C, followed by 35 cycles (denaturation for 45 s at 94 °C, annealing for 45 s at 56 °C, elongation for 1 min at 72 °C), and ended with a final elongation step for 5 min at 72 °C. The length of the amplified fragment was approximately 550bp. The amplified product was evaluated electrophoretically for quality using agarose gels and was purified using EXS-500 ExS-Pure™ Enzymatic PCR purification kit (NimaGen). Samples were sequenced in both directions using Big-Dye Terminator v1.1 Cycle Sequencing Kit (Thermofisher) on ABI 310 automated sequencer.

C. Data Analysis

The sequences were assembled and aligned using the ClustalW algorithm [9] in MEGA 11 [10]. The haplotype number (*Nh*), haplotype diversity (*h*), nucleotide diversity (π), number of polymorphic sites (*S*), number of mutations (η), average number of nucleotides differences (*k*), Tajima's D and Fu's Fs were calculated using DnaSP v6.12 [11]. The haplotype network was constructed using the Median Joining (MJ) [12] algorithm, implemented in NETWORK 10.2.0.0 software [13].

III. Results and Discussion

A total of 34 individuals were sequenced, total number of aligned sites was 394, number of polymorphic sites 26 and conserved sites 368. A total of 18 different haplotypes were identified (TABLE 1). Haplotype diversity (*Hd*) for all the 394 sequences was calculated to be 0.914 +/- 0.032 SD and nucleotide diversity π was 0.0075+/- 0.0017 SD. Average number of nucleotide differences *k*= 2.95. Totally there were noted 27 point mutations and nine parsimony informative sites. In spite of high haplotype diversity, low nucleotide diversity value suggested, that there are small differences between haplotypes. Both Tajima's D and Fu's Fs statistics were negative (- 1.94 and -10.39) and statistically significant ($P < 0.05$). That indicates deviations from neutrality. The combination of high haplotype and low nucleotide diversity in present research can be a signature of a rapid population expansion from a small effective population size as a consequence of intensive restocking program. The rapid eel's population expansion, shown by mtDNA

markers, was also revealed in eel's population from waterbodies in Lithuania [8].

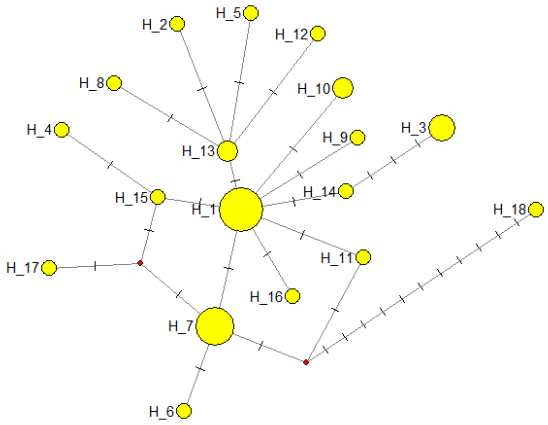

Fig. 2. Haplotype network of *Anguilla anguilla* based on *Cyt b* gene sequences (the dashes between the nodes indicate particular mutations, the size of the circles is proportional to the haplotype frequency).

Detected haplotypes were separated into two haplogroups based on haplotype frequency and by minimum mutational steps (Fig. 2). Network reflects haplotype diversity, variability and relationship between detected haplotypes.

Altogether 18 haplotypes were revealed (TABLE 1). Haplotype H_1 was revealed in eel's samples from five waterbodies, namely L.Usmas, L. Kisezers, L. Vaidavas, L. Liepajas and L. Myadzyel. Haplotype H_1 is widespread across *Anguilla anguilla* distributional range. This haplotype was reported for 26 isolates from eight localities (data from GenBank) [14], [15]. Another haplotype, which was detected in five waterbodies (L. Myadzyel, L. Raznas, L. Usmas, L. Sivers and Myadzyelka river) is haplotype H_7.

TABLE 1 HAPLOTYPE VARIATION DETECTED AMONG 34 *ANGUILLA ANGUILLA* SAMPLES FROM 11 WATERBODIES IN BALTIC LAKELAND (ONLY VARIABLE SITES WITH SEQUENCE POSITION GIVEN IN FIRST ROW ARE SHOWN. IDENTTITY WITH THE FIRST SEQUENCE IS MARKED BY THE DOT, SUBSTITUTION IS MARKED BY A DIFFERENT BASE LETTER (A, T, G OR C))

Position / **Haplotypes**	**38**	**47**	**89**	**122**	**140**	**153**	**176**	**179**	**203**	**209**	**224**	**242**	**250**	**254**	**272**	**281**	**284**	**308**	**311**	**317**	**362**	**377**	**380**	**386**	**389**	**392**	**Frequency**
H_1	A	T	A	T	C	C	T	G	A	C	G	C	T	A	T	C	A	A	A	G	C	C	C	T	G	G	8
H_2	.	.	G	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	A	.	1
H_3	.	.	.	C	.	.	.	.	G	.	.	.	.	.	.	T	.	.	.	A	.	.	.	.	.	.	3
H_4	.	.	.	.	.	.	C	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
H_5	.	C	G	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
H_6	.	.	.	.	.	.	.	.	.	.	A	.	.	.	.	.	.	.	.	.	.	T	.	.	.	.	1
H_7	.	.	.	.	.	.	.	.	.	.	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
H_8	.	.	G	.	.	.	.	.	.	.	.	.	.	.	.	.	G	.	.	.	.	.	.	.	.	.	1
H_9	.	.	.	.	.	.	.	.	.	.	.	.	.	G	.	.	.	.	.	.	.	.	.	.	.	.	1
H_10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	T	.	.	.	.	.	.	2
H_11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	A	1
H_12	.	.	G	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	A	.	.	.	.	.	1
H_13	.	.	G	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
H_14	.	.	.	.	.	.	.	.	G	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
H_15	.	.	.	.	.	.	.	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
H_16	G	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
H_17	.	.	.	.	T	.	.	A	.	.	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
H_18	.	.	.	.	.	T	.	.	.	T	A	T	A	.	C	.	.	G	G	A	.	.	T	C	A	A	1

H_7 haplotype is also widespread across *Anguilla anguilla* distributional range. Identical sequences were reported for ten *Anguilla anguilla* isolates and for one *Anguilla rostrata* isolate (data from GenBank) [15], [17]. In current studies three haplotypes were revealed, which occur each in two waterbodies. That were H_3 in L. Kisezers and L. Sviras, H_10 in L. Sivers and L. Vialikija Svaksty, H_13 in L. Sviras and L. Vialikija Svaksty. The sequence similar to H_3 haplotype has been reported in GenBank for only one isolate of *Anguilla anguilla* x *Anguilla rostrata* hybrid from Greenland [17]. The sequence of haplotype H_10 was quite rare. Identical sequences have been reported in GenBank only for two *Anguilla anguilla* isolates from Cantabrian Sea in Spain and from Ireland's waters [15], [17]. Sequences similar to haplotype H_13 in present study have been reported in GenBank for two *Anguilla anguilla* x *Anguilla rostrata* hybrid's isolates from Greenland [20] and for three *Anguilla anguilla* isolates from other waterbodies [2], [15].

The sequences of five haplotypes (namely, H_11, H_14, H_15, H_16 and H_17) are quite rare in present research. That were revealed each in one waterbody only.

But identical sequences in GenBank have been reported as widespread. For instance, sequences of haplotype H_11 has been reported for 27 *Anguilla anguilla* isolates from waterbodies in Spain, Ireland, France and Sweden [14], [16], [21]. Whereas sequence of haplotype H_14, which was detected in L. Sviras, has been reported for one *Anguilla anguilla* isolate only [22]. Sequences of haplotype H_15, which was revealed in L. Sviras also, has been reported for two *Anguilla anguilla* isolates from France and Ireland waterbodies and two *Anguilla anguilla* x *Anguilla rostrata* hybrid's isolates from Iceland waterbodies [18], [16]. Sequence of haplotype H_16, which was detected in L. Usmas only, in GenBank has been reported for *Anguilla anguilla* x *Anguilla rostrata* hybrid's isolates from Iceland [18]. Finally, very rare sequence of haplotype H_17, which was detected in Myadzyelka river, has been reported for only one *Anguilla anguilla* isolate in France waterbodies [23].

In current studies new unique haplotypes were detected, namely H_8 in L. Myadzyel, H_9 in L. Sivers, H_12 in L. Sviras, H_2 and H_4 in L. Kisezers, H_5 and H_6 in L. Liepajas. New revealed haplotypes have not been deposited to GenBank yet.

The last haplotype H_18 was detected in L. Aluksnes only, but that sequence has been reported in GenBank for 20 isolates as *Anguilla rostrata* (American eel) from different waterbodies in USA. Lake Aluksne is a waterbody which is not freely accessible to natural migrations.

So, definitely, we have *Anguilla rostrata* individuals or *Anguilla anguilla* x *Anguilla rostrata* hybrids in L. Aluksnes and can speak about anthropogenic invasion as a result of incorrect resource for restocking.

These two species (European eel and American eel) spawn in Sargasso Sea (Atlantic Ocean) and therefore American eel or its hybrids could not be as a potential threat to biodiversity of European eel. However, these two species have similar biology and, therefore, could enter trophic interactions and compete. In addition, translocated species, may promote pathogen pollution in the invaded area leading to the emergence of diseases.

IV. Conclusions

This is the first report about eel's population genetic diversity in Baltic Lakeland. Eel population in Baltic Lakeland shows quite high genetic diversity and rapid population expansions, which possibly is results of intensive restocking program. American eel's haplotype detected in sample from Lake Aluksnes, indicate possible anthropogenic invasion, which may be a result of incorrect resource for restocking.

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The Influence of Temperature Conditions on The Yield of Biogas and Methane, which is Obtained from Aquaculture Waste

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***Abstract*. The research looks into the potential of generating biogas from waste generated by aquaculture. The EDF-5.4_2 bioreactor, produced by "Biotehniskais centrs" (Latvia), was utilized for the experimental study. Samples of sludge from a fish farm located in Nagļu parish, Rēzekne district were collected and analysed for their moisture and organic matter content before being mixed with crushed reeds to increase the organic matter available for fermentation and biogas extraction.**

In this study, biogas was produced by mixing different ratios of sludge and reed residue. The yield of biogas varied based on the temperature, with the best results being achieved at 40°C. During the experiment, 2.75 L of biogas containing 37.3% methane was produced from the mixture of 1,200 g of fish farming sludge and 100 g of crushed reeds. Although the highest methane content of 40.16% was recorded at 43°C, the total amount of biogas produced was lower by 15% at this temperature.

The least favourable results were recorded at 37°C, in terms of both the amount of biogas produced and the methane content. The experimental studies demonstrate that residues from aquaculture can be used for biogas production.

Keywords: Aquaculture, waste, biogas.

I. Introduction

Aquaculture waste, in both solid and water form, is one of the main challenges for any aquaculture production system (such as fish and shrimp crops) and often enters the ecosystem, causing environmental pollution. Feed wastage has been identified as a major cause of high pollution loads in aquaculture effluents. In semi-intensive and intensive aquaculture systems, moderate to high fish population densities depend mainly or exclusively on the supplemented feed [1]. Despite their higher costs (around 50% of total production costs), from 8.6% to 52.2% of fish feed is consumed, and the remain is discharged into farming waters. It is estimated that more than half of the nitrogen (N) and phosphorus (P) elements in culture ponds are derived from fish feed, for example, 57–71% N and 44– 58% P are found in water in the common carp farm of Cyprinus carp [2]. The amount of feed wasted depends to a large extent on feeding methods (such as conventional feeding or chamber monitoring during feeding to reduce feed wastage) and the feeding behaviour of the cultivated species. In addition, feed quality determines the concentration of nutrients released into water bodies and is thus a contributing factor to water quality in aquaculture. The intensity of aquaculture production systems (i.e., either extensive, semi-intensive or intensive aquaculture systems) is also directly related to the potential adverse effects on the environment [3]. In addition to feed, the release of fish is an important source of elements found in aquaculture effluents. As a result of excretion, macronutrients, including P and N, in particular in the form of ammonia resulting from the amino acid catabolism of cultured species, are introduced into the aquatic environment. In addition to feed and excretion, aquaculture effluents may contain chemicals used for a different purpose in fish farms, such as medicines, fertilizers, disinfectants and antifoulants [4]. For example, although the antibiotic chloramphenicol is banned in many countries because of its negative effects on human health, it is still used to control diseases in fish or shellfish in aquaculture. Chloramphenicol does not decompose easily at ambient temperature even after hydrolysis [5], and its residues can often be found in nearby aquatic environments and organisms.

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The "Sustainable Development Strategy of Latvia until 2030" discusses the utilization of biological waste as a potential resource for biogas production, which can be applied in various sectors such as public transport, agriculture, and heat production. According to paragraph 224, this can be achieved. In Latvia, the aquaculture industry produced 788 tons in 2018. "Nagļi" is currently the biggest aquaculture company in Latvia as well as the entire Baltics. It is a full-cycle aquaculture farm with its own carp and pike farming material, which incubates spawning fish, rears juveniles and then sends the fish products to the market. The aquaculture facilities cover an area of about 2000 ha, including ponds, dams, land under the incubator and workshops, as well as the Malta river reservoir, from which all fishing ponds are filled [7].

Potentially, the "Nagļi" fishery can produce up to 1,500 tonnes of aquaculture production per year. At the same time, the amount of waste generated during the life cycle of fish also will be 1,500 tonnes per year. On the one hand, it is a very big problem to dispose and treat such amount of waste, but on the other hand, waste from fish farming processes is a good raw material for biogas plants. For example, a biogas plant with an electrical capacity of 100 kW_{el} requires about 6 tonnes of raw materials per day. Although biogas production from aquaculture waste is generally less effective than from other raw materials (e.g., from fish processing waste it is possible to produce 20 mL g^{-1} of biogas per day, but from corn stover – 40 mL g^{-1} of biogas per day), nevertheless, the aquaculture farm called "Nagļi" has the ability to supply enough raw materials to power a 100 kW electric biogas plant, which would address the issue of waste disposal while also generating electricity and heat for the farm's use. [8]-[10].

Likewise, waste management and energy scarcity are challenges encountered by companies involved in fish processing. As of 2018, Latvia had over 100 fish processing companies that generated almost 100 tons of fish products. The waste produced by these plants can serve as valuable input material for biogas facilities [11].

Biogas production can utilize various types of organic matter as feedstock, including readily available biomass such as manure, by-products of food production, forest and wood processing waste, sewage sludge, household organic waste, straw, and more. However, the quantity of biogas generated from each source can differ and is not constant [12].

The materials utilized for producing biogas can be categorized based on their source, dry matter percentage, methane production potential, and other characteristics [13].

The wet fermentation method involves using substrates that contain less than 20% dry matter, which encompasses materials such as animal slurry, sewage sludge, manure, and wet organic waste from the food industry (such as whey from dairy processing). On the other hand, dry fermentation is employed for substrates with a dry matter content of at least 35%, which is typically found in energy crops and silage [14]. Energy crops consist of grasses like grass, maize, and oilseed rape, as well as trees like willow, poplar, and oak, although the latter requires special pre-treatment to remove lignin [15].

The strict separation of wet and dry fermentation technologies is biologically misleading, as the microorganisms involved in the fermentation process need a liquid medium to grow and multiply [16]. The classification of technologies does not depend on the dry matter content of the individual substrates used, but on the dry matter content of the bioreactor. In wet fermentation technology, the dry matter content of the reactor is about 12%, and the reactor content can usually be pumped because it is liquid. If the dry matter content of the reactor is increased to 15-16%, the reactor content can no longer be pumped and this technology is called dry fermentation [17].

Obtaining biogas from organic fractions of municipal solid waste, various manure, fish waste, and agricultural waste has been described by different researchers. However, fewer studies have been reported on the use of aquaculture waste. McDermott et al. [18] reported the production of biogas while investigating the effect of sonication as a pre-treatment of aquaculture waste for anaerobic digestion. Lanari and Franci [19] produced biogas from rainbow trout faecal sludge biomass using an anaerobic recirculating upflow digester. Marheim et al. [20] described the treatment of solid waste from the fish processing plant by a combined digestion method with thermophilic anaerobic bacteria and blowflies to produce biogas. Batch fermentation of fish waste and sisal pulp was studied by Mshandete et al. [21] in bioreactors constructed using conical glass flasks. Gebaur [22] reported that anaerobic treatment is the preferred method for stabilizing and hygienizing sludge from saline sewage from fish farms due to its biogas production.

The initial attempts to obtain biogas from aquaculture waste under local conditions, as well as the influence of certain physical factors on biogas yield, were investigated in the authors' previous articles [23]- [24].

The scope of this present work was to conduct research work on laboratory scale in order to estimate the biogas producing from anaerobic digestion of aquaculture waste and crushed reeds.

II. Materials and Methods

A. Biomass

Aquaculture residues (sludge) from a fish farm located in the Rēzekne district, Nagļu parish were selected as raw material for biogas production and research. The reeds from Daugavpils Esplanāde pond were used for increasing organic matter content. The reeds were dried 24 h in the drying oven Binder FD 23 at 70°C and 0% air recirculation and then crushed manually.

Digestate from the biogas plant "Skaista" located in Skrudaliena parish of Daugavpils district was utilized to effectively carry out anaerobic fermentation processes.

B. Laboratory scale bioreactor

The bioreactor *EDF-5.4_2* produced by "Biotehniskais centrs" in Latvia was utilized to conduct experimental research. This bioreactor is specifically designed for studying biomethane production, with a sturdy, ergonomic and compact build. Its design includes a glass cylinder vessel positioned between the metallic jacketed bottom and the upper lid. The bioreactor is easy to maintain and carry out basic operations, such as washing and autoclaving.

Mass flow controllers from Hamilton ARC and pH and dissolved oxygen sensors were used for gas mixing. These sensors send signals directly to the process control system (PCS) and also facilitate data management via Bluetooth through a program that can be accessed through a smartphone or PC. The program generates a report detailing calibration procedures, sterilization numbers, and predicted service life. The sensors are also connected to the PCS for off-gas analysis to identify and estimate the volume of O_2, CO_2, and CH_4.

The PC implemented program algorithms, such as Matlab and Python, were utilized to perform on-line/off-line data analysis and advanced process control. These algorithms communicate with the PCS and the Supervisory Control and Data Acquisition (SCADA) system.

C. Determination of slugde and reed moisture

To determine the organic matter content of the sample, the crucibles were first heated to 800±10°C for at least 60 minutes in a muffle furnace *Nabertherm LE 6/11*. After being removed from the furnace, the crucibles were allowed to cool for 5-10 minutes on a heat-resistant surface before being placed in a desiccator to cool completely. Each cooled crucible was then weighed to the nearest 0.1 mg using an analytical balance, and 1 to 2 g of the test sample was added to the crucible. The test sample was then heated for two hours at 800±10°C in a muffle furnace, and placed back in the desiccator to cool. This heating and weighing process was repeated until a constant weight was achieved. The organic matter content was calculated as a percentage of the dry residue. This same procedure was carried out for the reed sample. Both procedures were performed according to the ISO 18122:2015 – Solid biofuels – Determination of ash content.

D. Preparation of the mixture for biogas production

The experiment was conducted three times. First, 100 grams of crushed reed powder was added to 1,200 grams of aquaculture sludge, and the mixture was thoroughly mixed. The prepared mixture was then immersed in the reactor vessel, and 300 mL of bog water was added and mixed thoroughly using a metal spatula. Finally, 1,000 grams of digestate was added, and the bioreactor lid was firmly sealed. The appropriate temperature mode and agitator rotation speed were selected and connected to the bioprocess controller.

E. Selected parametrs of the bioprocess controller

The following parameters were used in the bioprocess controller to perform the research:

- 37°C, 40°C, and 43°C temperature mode;
- Agitator rotation speed interval 50 RPM;
- Foam level sensors.

A computer equipped with SCADA software was connected to the bioreactor in order to monitor and record the volume and composition analysis of the biogas that was released.

III. RESULTS AND DISCUSSION

A. Determination of slugde and reed moisture and organic matter content

The moisture results acquired from the sludge samples are appropriate for generating biogas because the substrate samples contain roughly 15% dry matter (as seen in Table 1). These outcomes are consistent with the wet fermentation process used, which resembles other feasible biogas technologies [13].

TABLE 1 MOISTURE LEVELS AND ORGANIC MATERIAL COMPOSITION OF BOTH SLUDGE AND REED. AVERAGE VALUES AND RELATIVE STANDARD DEVIATIONS ARE GIVEN FOR THREE REPLICATE RUNS

Biomass	Moisture [%]	Organic matter content (from dry matter) [%]
Sludge	83.47±0.55	26.91±0.68
Reed	1.18±0.19	96.14±0093

The sludge samples contain roughly 27% organic matter, indicating a substantial amount of inorganic substances in the substrate. To increase biogas production in the study, a larger quantity of aquaculture sludge needs to be added to the bioreactor, along with another type of substrate that consists of 95% or more organic matter.

The reed samples contain roughly 96% organic matter, signifying a substantial amount of organic material. Thus, it would be beneficial to incorporate the reed samples with the fish-farming pool sludge in a specific proportion.

B. Biogas production

During the experiment, the amount of released biogas and its gas composition were studied with the software SCADA. The biogas release trend over 60 days at 40°C is shown in Figure 1.

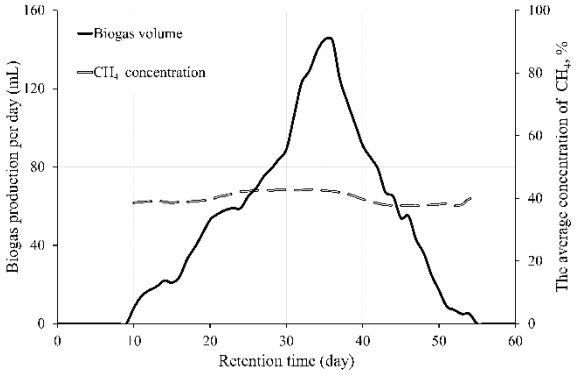

Fig. 1. Trend in biogas volume and proportion of methane in biogas release over 60 days at 40°C.

95% of the total biogas produced during the fermentation period (60 days) was produced between days 10 and 55. The optimal retention times are approximately 36 days. The total volume of biogas produced during the fermentation period is approximately 2.75 liters – it corresponds to 2,155 mL kg^{-1} waste. Similar results were obtained by Salam and Sarker [25], who investigated the anaerobic digestion of fish waste and co-digestion of fish waste and cow dung. The maximum ultimate gas yield was obtained from 1:1.2 fish waste and cow dung ratio and amounted to 1,955 mL kg^{-1} waste.

The average methane concentration in the biogas is 37.3%, the carbon dioxide is 61.8%, and the other gases are 0.9% of the sample.

Figure 2 shows the evolution of biogas volume over 60 days at 37°C, 40°C and 43°C. The optimal storage time is approximately 35 days at 40°C, 38 days at 37°C and 33 days at 43°C. The feed mixing mode during the experiment prevents the formation of dry and inactive flotation layers and can affect the optimal retention time. In this study, more than 95% of biogas can be produced in less than two months.

For three temperatures, the average cumulative biogas production in litres was measured and recorded daily, as shown in Figure 3. As can be seen from Figure 3, the influence of the temperature on cumulative biogas production is substantial. The temperature affects bacterial and archaeal community structure, diversity of microbiota and the high complexity of their interactions that mediate biogas production. Hence a detailed understanding of the temperature impact on microbiota is essential for the overall stability and performance of the anaerobic digestion process.

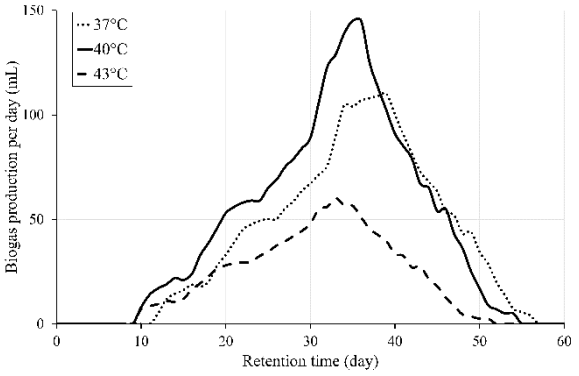

Fig. 2. Trend in biogas volume release over 60 days at different temperatures.

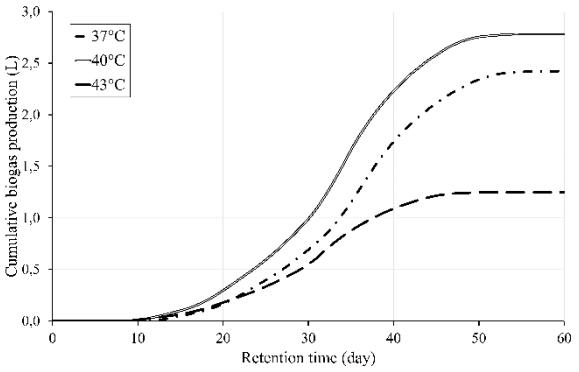

Fig. 3. Trend in cumulative biogas production over 60 days at different temperatures.

IV. CONCLUSIONS

The amount of biogas produced during the bioprocess is influenced by temperature, and our research found that the optimal temperature was 40°C. In our experiment, a combination of bog sludge and crushed reeds yielded 2.75 liters of biogas with an average methane content of 37.3% at 40°C. Although the highest proportion of methane (40.16%) was obtained at 43°C, the total amount of biogas produced at this temperature was approximately 15% lower. The worst results were obtained at 37°C – both in terms of biogas volume and methane content.

ACKNOWLEGMENTS

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Mechanical System for Wire Arc Additive Manufacturing

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Abstract. **This article discusses the reassembly of a mechanical system for 3D printing plastic parts to be used for plasma arc additive manufacturing. The main issues in converting an existing 3D printer designed for plastic additive to used for producing metal parts are: control of the welding power source; installation and realization of the movement with the welding torch; set the height of the zero layer; setting up the program software to generate the control file.**

Keywords: plasma arc, additive manufacturing, 3D printer, mechanical system.

I. INTRODUCTION

Additive manufacturing is the process of creating an object by building it up one layer at a time. This is the opposite of subactive manufacturing, where it is created by cutting a solid object out of material until the finished product is complete. Technically, additive manufacturing can refer to any process where a product is created by building something, such as molding, but it always applies to 3-D printing [1], [2], [3], [4].

Additive manufacturing was first used to develop prototypes in the 1980s - these objects are not functional. This process was known as rapid prototyping because it allowed people to create a scale model of the final object quickly, without the typical setup process and costs associated with creating a prototype. As additive manufacturing improves, its use extends to rapid tooling that is used to create molds for finished products. Additive manufacturing (AM) — has formidable potential across the manufacturing [1]. It enables products to be made on demand, at point-of-use, and with very efficient material usage. AM's primary use to date is in rapid prototyping, tooling, and production of replacement parts. 3D printing, or additive manufacturing (AM), is highly suited to high precision manufacturing in a wide range of details [5], [6], [7], [8].

3D printing is a technique that "prints" an object, thus displacing traditional technologies for the production of details. This method uses a wide range of materials such as photopolymers, thermoplastics, paper and others [9], [10], [11]. Since these materials in most cases do not have good mechanical and technological characteristics, they are not suitable for direct installation and loading in industry.

In this paper we present "printing" process that uses metal as a raw material. The process involves the use of selective metal fusion plasma remelting and an adapted torch drive from a commercially available 3D polymer printer modified by us, which deposits successive layers of metal in such a way as to form a 3D solid. This process can also be considered a low volume production process.

II. MATERIALS AND METHODS

In order to reduce the cost and time of making our 3D printing system by selective plasma remelting, we decided to use a ready-made 3D polymer printer Wanhao brand model Duplicator 12 D12/500 D12-500 Double Extruder the following technical fig.1 with features:

500mm X 500mm X 500mm Build Area, Product Name: D12/500, Max Printing Area :500*500*500mm, Max Print Speed: 150mm/s, Software: CURA, Filament Diameter: 1.75mm, Material Support: PLA, PETG, any filament melt =<260 C , Machine Size: 67*81*78cm, Extruder System : MK14 Single / Double together;

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Fig. 1. Wanhao Duplicator 12 D12/500 D12-500 Double Extruder.

The main goal we set ourselves is:

To modify and adapt the mechanical drive of the printer to work with different types of plasma (welding) torches.

In order to achieve the set goal, we had to solve the following tasks:

- Build a 3D CAD model of the printer so we can experiment with different drive modifications.
- To move the height sensor "3D Touch" mounted on the print head so that it works normally without being in danger of damage due to the effect of the plasma arc.
- To ensure reliable grip of various plasma torches.

III. Results and Discussion

1. Building a 3D CAD model of the printer.

After a detailed dimensional capture of the existing printer, in a SolidWorks environment we built a 3D CAD model of the printer, which allowed us to test different drive modifications and choose the most suitable combination to implement in practice. Fig.2 a and b shows the 3D model of the printer.

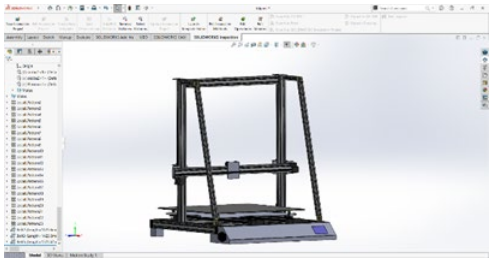

Fig. 2a. 3D model of the printer.

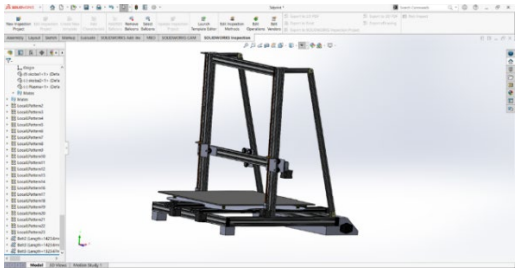

Fig. 2b. 3D model of the printer.

2. Moving the “3D Touch” height sensor.

In order to drive the plasma torch from the 3D printer, we first had to move the "3D Touch" height sensor, which is mounted on the printing head fig.3. This was necessary for the following reasons:

- "Fooling" the electronic unit, that the sensor moves together with the original print head, to ensure normal operation of the drive;
- Protection of the sensor from the effects of high temperature and metal splashes during the operation of the plasma torch.

Fig.3. Printhead with “3D Touch.

After trying several combinations, which we checked on the 3D CAD model of the printer we made, we chose to mount an angle plate on a vertical fixed beam from the printer frame fig. 4.a and b. The angle plate plays the role of the printer's work table. In this way, we "fool" the sensor that it is in contact with the mass and it gives information to the control unit that everything in the system is fine. Thus we ensure smooth and reliable operation of the drive.

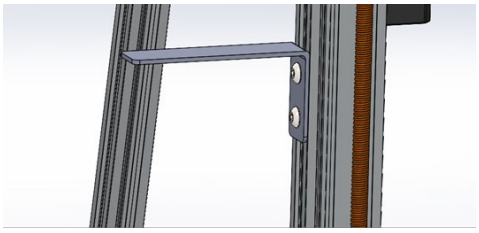

Fig. 4.a.” Angled Plank 3D Model”.

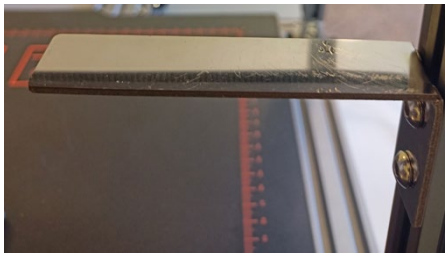

Fig. 4. b.” Angled Plank”.

We mounted the "3D Touch" itself on the horizontal movable beam of the printer so that the sensor is located above the corner plate fig. 5 a and b. For the installation of the sensor, we used an intermediate plate made by us fig. 5. b.

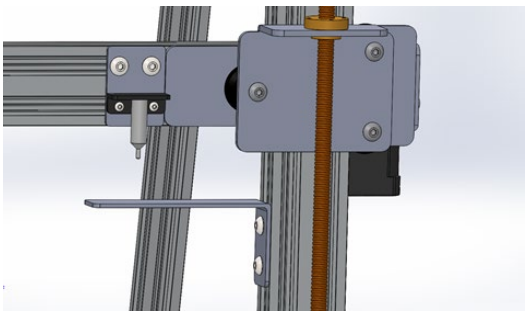

Fig. 5. a. 3D model "3D Touch".

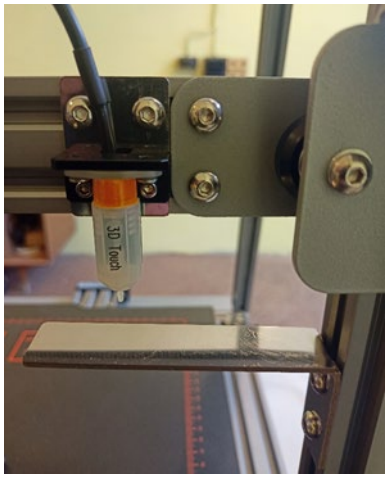

Fig. 5. b. "3D Touch".

3. Grip the various plasma torches.

To hold the plasma torches, we designed and manufactured a special bracket that we installed in place of the original print head. Thanks to the samples we made in advance with the 3D CAD model of the printer, the bracket was designed so that during installation there would be no changes to the original construction of the printer fig. 6 a and b.

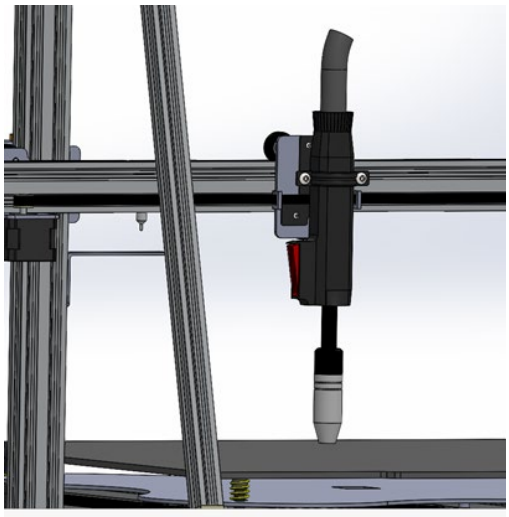

Fig. 6. a. Bracket for holding the torch 3D.

Fig. 6. b. Bracket for holding the torch.

Figure 7.a and b shows the modified printer based on the 3D CAD model.

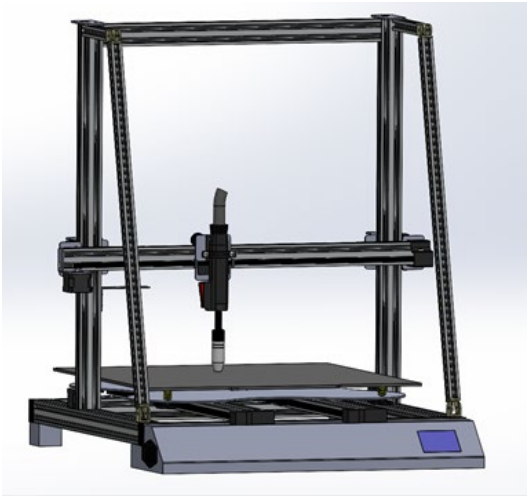

Fig. 7.a. 3D CAD model.

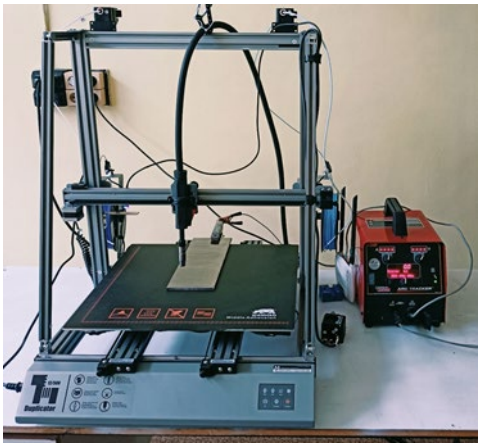

Fig. 7. b. 3D selective plasma remelting.

IV. CONCLUSIONS

Based on 3D model of printer end the parts we designed and built, we successfully converted an existing 3D printer designed for plastic additive hu be used of produce metal parts. We realized a stable grip on the welding torch. We ensured a smooth and steady movement of the welding torch. We have achieved full synchronization between the 3D printer and the welding power source. We have adjusted the software to generate the control file so as to obtain a sustainable 3D printing process of metal products with selective metal fusion plasma remelting.

This is the work that we did in the first stage of the contract. At the next stage, we envisage the creation of details with different geometries, which will be thoroughly investigated by performing mechanical tests, flaw detection, microstructure research, etc.

V. ACKNOWLEDGMENTS

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An Approach to Modeling Innovation Obsolescence

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Abstract. **Currently, the Fourth Industrial Revolution (FIR) has a very strong impact on innovation activity and innovation obsolescence. In order to formulate a methodology for the selection of alternative solutions, it is necessary not only to take into account the impacts of FIR, but also to choose an approach for modeling innovation obsolescence. The aim is to propose a new approach for modeling innovation obsolescence, in which the influencing factors will already be present in the innovation development methodology.**

Keywords: alternative solutions, approach to modelling, innovation obsolescence.

I. INTRODUCTION

The rapid development of information technologies (IT) reduces risk, has a positive impact on the competitiveness of the enterprise, contributes to the faster and more targeted development of innovations in the industry [2]. The widespread implementation of such systems in the Republic of Bulgaria and the world, as well as the opening of European and global markets, created a dynamic and difficult to predict environment in which industrial companies and their competitors are forced to constantly develop and change their products and services. and thereby transform the accompanying business technology model [1]. In response to this need, a number of studies have been conducted. To establish control, organizations introduce formal methods for iterating technological and business processes and changing business models [15]. There are many tools and models for strategic innovation development. But most of them describe the problem statically, i.e. at a certain point in the development of the company, and the time factor is not taken into account, and it is the decisive one for any start-up business company [10].

This is precisely the reason to look for a new, integrated approach of methods and tools for the implementation of an information system related to the innovative development and obsolescence of industrial technologies [3].

The aim of the article is to propose a new approach to modeling innovation obsolescence, in which the influencing factors will already be present in the innovation development methodology.

II. EXHEBITION

The integrated approach to modelling obsolescence (innovative and planned) defines the following sequence, virtuality and solution scope, namely:

- A virtual server provides access to its own or licensed applications in the cloud for its own or licensed applications, without providing it with the ability to control or manage the infrastructure resources themselves.
- This provides the ability for the user to design, deliver and store networks and other computing resources, while retaining the right to add and run any other software.
- Load and run multiple applications and operating systems on a single machine, simulating an individual virtual environment. It is usually used for the installation of hardware devices in a customer base and that too as network devices [7].

Before starting the development of the technology solution, the modelling of the innovation is subject to a number of studies and validation of the marketing product idea as well as that of the sales channel. This reduces the risk of failure of volume developments in the market [12].

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The rapid development of communication and information technologies not only reduces risk, but also has a strong impact on the ability of industrial companies to develop innovative activities faster and more purposefully [6]. A dynamic and hard-to-predict environment is being created in which companies are forced to flexibly search for alternative solutions to the factors negatively impacting their activities. There are many tools and models for strategic innovation development and evaluation. Most of them describe the problem statically, i.e. at a certain point in the firm's development, while the components of time and innovation obsolescence are not taken into account [11].

2.1. Significance of the Innovation Development component

The influence of innovative development on technology arises from the improvement of existing and the construction of fundamentally new machines, devices and equipment [13]. According to their purpose and productivity growth rates, they can be divided into two main groups:

- machines and equipment with special requirements, intended to produce uniform production on a mass scale and

- machines and equipment intended for performing a variety of activities, i.e. with universal purpose.

In recent years, a trend of strong unification and standardization of the elements in machine assemblies based on the modular principle has been noticed. The goal here is to create conditions for the rapid assembly of machines with different technological purposes, but with a universal purpose, for the needs of the new cyber requirements [2].

The study of the regularities of the development and improvement of the technique with special and universal purpose makes it possible to determine the period in which the greatest effect can be obtained from a given generation of machines intended for a specific production process, and at the same time the period of transition to the production of new types of machines, for the new intelligent production systems [8].

In the modern conditions of accelerated scientific and technical progress, the importance of this direction and its manifestation on the rates and scales of the innovative obsolescence of the technique has significantly increased. The real consequence of this impact is expressed in increasing the scope and terms of innovative obsolescence of the machines and equipment in operation and the rapid change of their structural composition.

Innovative development is expressed in the creation of new materials [9]. They, in turn, have an active impact on accelerating the innovative obsolescence of the technology used in production. This influence is determined by the wide application of new materials, alloys, plastics and others with specific characteristics and suitability for processing a specific type of machine [4]. The extent of their use in production depends on the proportion of unnecessary equipment that is adapted to processing the old materials. This is precisely the impact of innovative development on technological processes.

The changes occurring from the application of new technologies in all cases play an active role in the production process, as a result of which the relative share of the old technological processes is constantly reduced, and together with them, the machines and equipment used for this purpose. On the other hand, it is related to the professional training, the improvement of the methods of increasing the qualification and the training of the personnel in the enterprise [14]. Substantial changes occur in the qualification composition of the personnel, as a result of which a large number of new professions appear, old ones disappear, changing the ratio between individual groups of professions, which is the subject of Industry 5.0. Different human resources management practices in competitive environment are described. Organizational learning is a basic component of organizational intelligence. Also, it is a strategic organization re-source that appears in all organizational levels. Organizational learning is based on the integration of individual and group level of learning. Transformation into a learning organization will assure advantage in knowledge-based economy trough creativity and intelligence of organization’s personnel and its ability for learning and development [16]. The methodology and the aim of the research, the concrete tasks and results of implemented research in factories from machine-building and human resources are object in Industry 5.0 [17].

The development of the technique leads to significant changes in the methods of its exploitation on the one hand, and on the other hand to the improvement of the methods for changing the nature of the work and increasing the qualification of the personnel.

2.2. Significance of the Innovative Obsolescence component

At the current stage of technical development worldwide, innovative obsolescence takes precedence over physical obsolescence. Therefore, a particularly important point in this direction is the correct determination of the degree of innovative obsolescence. The goal is to establish the impact of innovations on the technical, economic and social results of industrial activity. Correct assessment of their impact on the scale and timing of innovative obsolescence is of utmost importance for timely elimination of the negative consequences of their impact. This process is influenced by the two directions of innovative obsolescence.

The first direction of innovation obsolescence is an inevitable consequence of innovation development in the field of technique and technology in industries producing industrial products [5].

Cost growth in industries that produce industrial products is relatively decreasing. The rate of decline depends on the rate of labor productivity growth already on a global scale. The rate of real product cost decline will be lower than the rate of productivity growth. This rate is determined by the ratio between the "growth of labor productivity" index and the "growth of real wages"

index. Given that the growth of real wages is lower than the newly created value of the public product, it can be said that the rate of real decline in the price of products equals n% per year.

In this way, the social cost of engineering products will be determined by the expression:

$$K_i = \frac{K_0}{(1+0{,}01b)^{t-1}} \quad (1)$$

where K_i is the value of the article; K_0 is the value of the product in the first year; b – relative decrease in the cost of the product compared to the increase in labor productivity; t – final year.

The deprecation of the same products as a results of innovation obsolescence in the first direction is determined by the expression

$$K_n = K_0 - K_t = \left[1 - \frac{1}{(1+0{,}01b)^{t-1}}\right] \quad (2)$$

where K_n is the innovation obsolescence in the first direction.

The second direction of innovative obsolescence arises under the influence of innovative solutions, expressed in the designed and implemented in production new, more modern, more productive and with better technical and economic indicators machines, devices and equipment compared to those produced before them. In these cases, the efficiency of using the old machines and equipment will be significantly lower, and they themselves will depreciate to a certain extent. The effect of using such machines and technologies will be reduced, and the amount of this reduction will depend on the strength of the manifestation of the factors characterizing their innovation obsolescence. The second direction of innovation obsolescence contains some features that most fully reveal its essence and the economic consequences of its influence on the elements of production. The main feature is that it gives rise to a partial or complete devaluation of machines and technologies and their use value, as a result of which there is a need to replace technically obsolete machines before the period of their physical wear and tear has expired. The economic expediency of such a replacement is not determined by the very fact of the appearance of new machines with a similar technological purpose, but above all by the degree of innovation obsolescence of the existing machines and the level of reduction in economic efficiency from their continued use. It should be borne in mind that the loss of consumer value and the need to replace machines and technologies with new ones is determined by a number of factors reflecting the specific directions of the influence of innovative development.

Taking into account these factors characterizing the qualitative side of innovation development and obsolescence allows to reveal not only the mechanism of its impact on production efficiency indicators, but also its impact on different sides of the production process.

2.3. An integrated modelling approach

For a more accurate and correct accounting of the benefits and effects of innovation development and innovation obsolescence, the development of the problem should be considered comprehensively. This means that the problem characterizing the qualitative nature of indicators such as the ***degree of innovativeness*** and ***innovation activity***, which are inherent in innovation development and the indicators of innovation obsolescence, are part of the alternative solutions inherent in rapid innovation obsolescence. Therefore, both components should be considered as a complex integrated solution model. The integrative nature of this approach is based on the fact that it involves more influencing factors influencing the efficiency of the innovation activity of industrial firms. The solution structure includes several methods defined as an integration model [4]:

- ***Method for determining the degree of innovation (J_{ino});***

Mathematical methods and models can be applied to determine the degree of innovativeness of products and processes, and specific indicators are used to solve them:

- Technical indicators (new);
- Indicators determining user essence (applicability);
- Commercial implementation (market).

Technical (J_{teh}), consumer (J_{pot}), investment (J_{inv}) and other indicators (J_{kk}, J_{eko}) are used at the idea screening stage when developing new products

$$J_{ino} = J_{teh} + J_{pot} + J_{mt} = J_{teh} + J_{pot} + J_{inv} + J_{kk} + J_{eko} \quad (3)$$

The degree of J_{ino} innovation is defined as the sum of the results of the separate indicators, taken as relative weights, subject to the condition:

$$J_{teh} \leq 1;\ J_{pot} \leq 1;\ J_{mt} \leq 1;\ J_{ino} \leq 3.$$

$J_{mt} = J_{inv} + J_{kk} + J_{eko}$– market indicators.

When using the condition:

$$J_{mt} \leq 1, J_{inv} \leq 0{,}33, J_{kk} \leq 0{,}33, J_{eko} \leq 0{,}33.$$

Technical indicators (J_{teh}) are the most important because the main thing about them is the higher productivity, as well as the economy of materials, labor, energy, quality improvements and others of the new product compared to the old one or similar to it. The technical indicator (newness) has 100% significance in the study. The remaining indicators can take zero values (0%).

Hence $J_{ino} = J_{teh}$.

- ***Method for innovation activity ($S_{(t)}$);***

The determination of innovation activity over a given period of time, under predefined parameters, can also be modelled. Through the innovation activity model, it is revealed how products are perceived as attractive among real and potential users. The innovation activity model

can be widely used in product and technology forecasting.

$$S(t) = m.f(t)\,, \qquad (4)$$

$$S(t) = m.\frac{(p+q)^2}{p}.\frac{e^{-(p+q)t}}{\left(1+\frac{q}{p}.e^{-(p+q)t}\right)^2}\,, \qquad (5)$$

where **m** is final marketing potential.

The model is suitable for use in a wider range of innovative products, although solutions vary widely.

- ***Innovative aging method (M);***

Innovative obsolescence is measured by the degree of depreciation of any of the functions of old machine designs compared to those of newly manufactured innovative ones. They are determined using the formula:

$$M=W.K \quad (6)$$

where M is innovation obsolescence, (depreciation of the functions of old machines in BGN); W - initial value of the old machine in BGN; K - coefficient accounting for the percentage level of innovation obsolescence, changes in the limits -1≤K≤1, as:

- at K=1,0 there is no innovation obsolescence (the machine is 100% innovative);
- at K=0,5 the machine is half innovatively obsolete or 50%;
- at K≤0 the machine is completely innovatively obsolete or with 0% innovativeness.
- ***Method for alternative solutions (AR).***

The rapid innovation obsolescence of products and services presents humanity with the solution of the problem of removing the harmful consequences of its impact. Alternative solutions against rapid innovation obsolescence AR depend on

$$AR=F(J, S, M) \quad (7)$$

where J is the degree of innovation; S - innovation activity; M – innovative obsolescence.

The relationships between these components define a system dependency, or the entire functional structure has a systemic character. Therefore, it can also be represented as an integrated model based on system dependence or an integrated model.

The model is based on the following mathematical relationship:

$$(J_n.\left(\frac{1}{n}\right)).S_n - (J_m.\left(\frac{1}{m}\right)).M_m = (J_n.\left(\frac{1}{n}\right)).S_n - AR \quad (8)$$

where: J_n is the value of the base (innovation) product, at a certain degree of innovation; S_n - the investment return time for the innovation (base) product, or the time when the product is in operation (it is customary to call it the "period of innovation activity"); n – number of periods (months, years), before and after the occurrence of innovation obsolescence; M_m – the time since the occurrence of innovation obsolescence of the base product; m - number of periods (months, years) after the occurrence of innovation obsolescence.

III. CONCLUSONS

Based on the above, the following conclusions can be drawn:

- The methodology for choosing alternative solutions against rapid innovation obsolescence has been formulated.
- The interrelationship (constellation) between innovation development, innovation obsolescence, innovation activity and programmed obsolescence was investigated.
- An integrated model was developed and pro-posed for the selection of alternative solutions against rapid innovation obsolescence based on the methods for: determining the degree of innovation; innovation activity; innovative obsolescence and for alternative solutions.

The development of innovation technology is closely related to the operational life of machines and their physical and innovation obsolescence. This aging can be predicted and partially controlled.

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Improvement of Constructive-Technological Approaches Reducing Innovative Obsolescence of Industrial Technologies in the Context of Industry 4.0

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Abstract. **The article is dedicated to the improvement of constructive-technological approaches in the design and manufacture of engineering products, innovations, their management and implementation in enterprises, innovation strategy and policies for its achievement, as well as methods for alternative solutions against the rapid obsolescence of innovations in the field of technology in the conditions of the Fourth Industrial Revolution (FIR) and globalization. Emphasis is on the stages in the design of the technological process for mechanical processing of engineering products, as well as the optimization of dimensional-accuracy connections. Schemes describing the optimization have been developed, and the approach will be programmatically implemented in subsequent development.**

Keywords: Constructive-technological approaches, Industry 4.0, Innovative obsolescence, Technological process.

I. INTRODUCTION

The development of a new product is a complex task for the solution of which it is necessary both to reach the necessary technical level of the finished product and to reduce as much as possible the costs of materials and the time for development, production, maintenance, repair. This is possible by creating a new technology for construction and dimensioning at the stage of development of the structures of the products. A primary role in ensuring the technological feasibility of the product structures belongs to the designer. He is the one who provides the necessary quality indicators of the constructed product and constructive properties that predetermine the level of resource costs in the creation, production, maintenance, and repair of the product. The set of all these properties of the product determine its technology [9].

Achieving the necessary manufacturability of the structure is a complex problem that has long been the subject of attention of many scientists and practitioners.

The general rules for analyzing the manufacturability of the construction of the products, as well as rules for ensuring this manufacturability, are considered in several standards [8].

However, currently there are great difficulties in the technological control of the construction documentation,

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i.e. specific practical requirements for the technologist for its implementation have not been developed. First of all, this is related to the fact that at the stage of development of the construction documentation, the functional requirements for the pro-duct are mainly fulfilled: the dimensional chains are determined and fixed, based on the purpose of the product and its necessary performance, and at the stage of technological analysis, they are also determined the relationship between all dimensional parameters in the production process of the product is fixed.

The functional connections in the product are primary in terms of technological and metrology. This means that the dimensions included in the dimensional chains when performing a functional analysis are mandatory for the remaining dimensional relationships.

In many cases, individual dimensions such as functional dimensional relationships are applied to drawings in such a way that they become technologically difficult or impossible to implement. Unfortunately, this often happens only at the technological design stage. Therefore, the main task of the techno-logical control of the construction documentation is the determination of such dimensions. It should be borne in mind that the technological control does not appear only in the recalculation of the dimensional chains.

The inspection of a new development is a complex study of the new construction by specialists from all divisions of the production system. This accelerates the finishing works of all elements of the structure from the point of view of purpose, reliability, cost and appearance [3].

The final check of the product's manufacturability is done at the completion of the design work, testing and analysis of the test samples of the product. This is the last opportunity to change the construction without seriously interfering with the master plan. The costs of the project at this stage are much smaller than the changes introduced later - during the pro-duction or operation of the product.

The work on the compilation and analysis of the dimensional chains must be done until the work on the construction documentation is completed. The designer must consider the influence of the functional dimensional chains and the related technologies, and the specialist must implement the technological control [2].

There are often cases when the constructor, based on the remarks of the technologist, must not only refine, but also redo the construction. As a rule, the technologist's attempt to make changes to the structure is met with objections from the designer. They are justified by the fact that the reconstruction of individual details leads to limitations in already developed mechanisms, and the subject of the given product is already finished. But in the practice of enterprises, there are often cases when the requirements of the technologist, made to the manufacturability of the detail at the stage of techno-logical control of the design documentation, are not initially accepted by the designer, which must be corrected in the drawings after the product has already been released into production. Therefore, the construction can be considered complete only after careful consideration and agreement with the technologist.

The product, first, is an object of exploitation and is evaluated by users mainly according to the relevant purpose. But before it becomes an object of exploitation, the product is considered as an object of production, which is subject to completely different requirements, called in general - processability. Therefore, the designer must proceed to the final design of the drawing after making sure not only of the operational qualities of the product, but also of its technology, i.e. in its possibilities for production in the specific production conditions [4].

The task of the specialist carrying out technological control is to demand timely help from the designer to improve the technology of the product. He is obliged, together with the designer, to deal with the construction and determination of the dimensional chains. For each structure, several functionally equivalent dimensional chains can be formed in the development process. From these, the designer must select that dimension chain for which the constituent units of the dimension chain have the largest deviations. It is expedient to solve such a task by means of optimization methods, where it is best to take the value of the product during production as optimality criteria. If in technological design it is necessary to change the dimensional chain, this task can be solved by converting the required dimensions by applying the theory of dimensional chains [7]. Considering the complexity of finding the optimal functional relationship and the search for a compromise solution in practical development, it is expedient to solve such a task using modern computer technologies.

No matter how experienced the technologist is, he cannot always determine the most expedient techno-logical solution. Therefore, the collective discussion is the most essential and principled moment of the technology. This requires the selection of the optimal design option to be carried out during the development of the TA, especially in its initial stage [4].

An important moment in the construction of the products is the choice of the construction bases. The design bases, determining the mutual arrangement of the details of the product, must relate to the technological bases. The production of products with the smallest error occurs only in this case, when the dimensions set by the designer, determined by the design bases, coincide with the technological ones. Thus, there is no need to introduce intermediate dimensions, which always reduce the accuracy of the closing units. Therefore, when constructing new products, we must strive to eliminate the design and assembly bases with the technological ones, which is feasible with the corresponding configuration and dimensional relationships in the constructed product. Therefore, the designer, when choosing construction bases, is obliged to match them with the technological bases, and to analyze their features and their influence on the accuracy of the dimensions of the finished products.

In practice, this means that already during the development of the construction of the part, the designer is obliged to mentally outline the technology to produce the designed part, to foresee the establishment of the calculated dimensions directly from the main technological bases [6].

The analysis of the existing systems for manufacturability to date is carried out in accordance with the existing standards.

The processing of manufacturability takes place in accordance with the Unified Standard for Design Documentation (USDD) "General rules for ensuring the manufacturability of the design of the products" and the Bulgarian State Standard (BSS) "Technological control of the design documentation".

Working out the feasibility of certain details of a product must be done by a technologist with sufficient experience and practice through a general analysis of the drawings presented by the designer.

This analysis is accompanied by certain difficulties caused by the following:

- For the technologist's analysis, no information about the features of the new product is presented. On what equipment will a certain part be produced - existing or new? What methods of reducing the labor intensity (for example by 20%) compared to a previous product (if it is a question of improving a product) does not appear to her. There are no promising technologies, there is no collective discussion of these issues.

- The analysis begins with an assembly drawing, in which the technologist meets with the designer, and the preparation of the product is studied. The drawings of the parts are distributed by groups by type of blanks. For details where at a given stage the method of obtaining the workpiece is unknown, the workpiece is mentally represented by similitude.

The analysis of dimensioning of the detail drawings is not done, that is, this question does not arise due to the insufficient experience of the technologist. The collective discussion of any questions on the analysis of the construction of the details and the technology of their processing is not done.

Often the designer is not given to realize his idea, i.e. the available equipment cannot provide the required accuracy of the manufactured part. The method of obtaining the blank of the part and the planned labor intensity are determined by analogy with previously produced products.

At the stage of scientific and research work, the product is technologically analyzed by an experienced technologist, designers of devices and calibers, but this activity is superficial. Serious processing begins only at the stage of technology development when the order is signed according to the relevant order.

In the casting department, the drawings of the details are analyzed to determine the possibilities of obtaining the castings, the thickness of the wall and the possibilities of filling the casting with metal are analyzed, and the issue of the placement of the pouring system is resolved. The analysis of the dimensioning of the part is done only by eye on the dimensions of the workpiece. Guidelines for the analysis of materials in the sizing of details are not made.

The analysis of the existing system for processing manufacturability shows that many specialists in the enterprise - designers, technologists are distracted from the main work for various changes and corrections, and are engaged in secondary work, for example, forming remarks.

For the assessment of the level of quality in preparation for production and the corresponding design and technological documentation of the production technology, a statistical analysis of the observations as quantitative and cause-and-effect structure in several productions is made, and it starts from the moment of mastering the new product.

A sufficiently large number of remarks on the considered products are technological and prevail over all other remarks accepted by the standard for enterprises. In reality, they are the most numerous, i.e. remarks on reduction of material intensity, processing of the technological process, expanded production capabilities, improvement of control and collection, alignment with current pro-duction, reduction of labour intensity, etc., referred in a number of cases to "miscellaneous", can be attributed to "technological".

Thus, when analyzing the existing systems for mechanical processing from the point of view of the technological nature of the product, during the design in the enterprise, they show that the study of the construction documentation, the sequence of the processing, are methodologically poorly developed. At the stage of scientific and research work (R&D) the processing of surfaces in relation to manufacturability. The main burden in mechanical processing is the technological preparation, which takes up a limited amount of time, during which the technologists manage to develop and shape only one techno-logical option. This leads to a decrease in the quality of technological solutions, and the entire burden of the final processing of the technological processes is placed on the last stage - the assimilation of the product in the workshop when the technological equipment is also prepared. Any change in the construction-technological documentation at a given stage leads to additional costs associated with corresponding correction, and in many cases also with the design of new technological equipment and their preparation in emergency cases, which is extremely undesirable and affects the time for assimilation of the product.

The purpose of this article is to improve the constructive-technological approaches, leading to the reduction of the innovation obsolescence of industrial technologies, by redesigning the technological process for mechanical processing based on the optimization of dimensional-accuracy relationships. To develop logical

schemes, which at the next stage will be further developed into software.

II. MATERIALS AND METHODS

2.1. Design and dimensional analysis of technological processes, approaches, and methods

Determining the required number of operations and their implementation in the development of a new technological process (TP) - is solved with the help of the use of complex interrelated tasks, the solution of which is possible only with the use of highly experienced scientific workers.

The following factors influence the structure of the TP for the processing of machine-building products:

- The design of the products and the technical conditions for their production.
- The method of obtaining and the technological characteristics of the starting blanks - (overall dimensions, wall thickness, material and hardness, etc.).
- Organizational-production factors (period of assimilation and implementation, etc.).
- Factors related to the work of the workshops (thermal, galvanic, assembly, etc.).

When choosing the structure of the TP, it is necessary to ensure minimum costs for means and materials and for transportation, as well as to consider various possibilities for automation and concentration of processing, ensuring synchronicity of operations.

Studying the type and volume of the works performed during the design of a new TP allows to distinguish seven main stages, differing in content and execution methods, fig. 1:

- Study of the drawings of the details and preparation of the source data in the design of the TP.
- Preliminary design of a schematic diagram and options for processing.
- Size analysis of the planned options and their specification.
- Assessment of TP variants according to criteria and selection of the optimal variant.
- Forming the final selected version of the TP.
- Implementation of the most economically expedient technological process.

Of the listed stages, the fourth one is the most complex - the dimensional analysis, where the dimensional calculations are performed, expressing technologically the technical conditions of the manufactured parts, to ensure their prescribed quality during production.

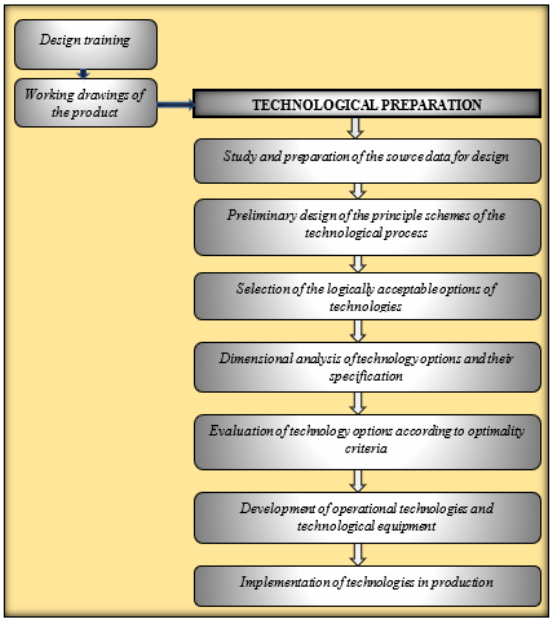

Fig. 1. Stages in the design of a technological process.

The implementation of the fourth stage is started after the three previous stages have been developed, when the logical evaluation of the principle schemes of the several processing options has also been developed.

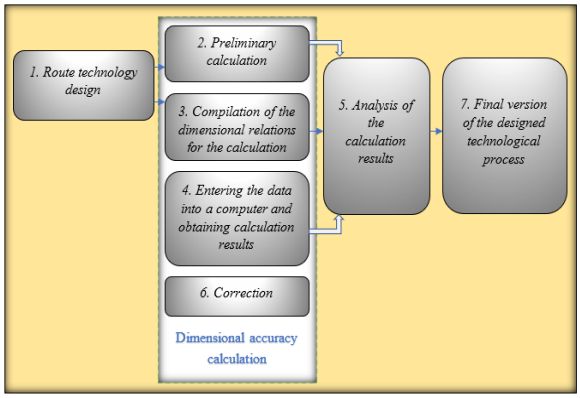

Fig. 2. Stages in the design of a technological process for mechanical processing of engineering products.

Now, the dimensional analysis of the TP is carried out on the basis of existing theories, in which the calculation of the operational tolerances is done by their "overlay" on the size of the finished part. The calculation of operational sizes according to the existing methodology does not allow to cover the entire complex of existing size chains. That is why, at the design stage, it is not possible to ensure all the requirements made to TP to ensure the qualities of the manufactured engineering products. Changing the operating dimensions in many cases requires designing and manufacturing machine-building pro-ducts with additional technological equipment [5].

At the stage of creating a technological route and dimension-accuracy calculation of the dimensional chains when acquiring a new product in one of the technological

departments of a given plant, details of low complexity, mainly rotary details, were selected for the design of a new TP. A group of leading technologists and researchers from TU-Sofia, Plovdiv branch was created to develop a technological route and further control the dimensions of the part.

2.2. Design of the technological routes

The design of the technological routes for the mechanical processing of details and the technological calculations of the dimensional chains are carried out by technologists according to existing methods. The following stages can be distinguished, through which the time for their implementation can be determined:

1. Designing a technological route and performing the necessary calculations of the dimensional chains.

2. Carrying out a dimensional analysis according to the technology of the route.

2.1. Studying the technological process.

2.2. Construction and control of dimensional chains.

2.3. Carrying out dimensional calculations.

3. Duration of the performed works.

4. Analysis and comparison of the loss of time for the design of the technological process according to the methodology existing in the enterprise and with subsequent control of the methods for dimensional analysis.

2.3. Design of the technological process

The design of the TP based on the constructed dimensional schemes and optimization of the dimensional-accuracy relationships allows specifying the final version of the TP and solving the following main tasks:

- Calculation of the dimensions of the blanks with the minimum necessary tolerances, which ensures a reduction of the cost of material.
- Design of TP with a minimum number of operations and transitions, which reduces labour intensity in the production of the product.
- Creation of a new process, during the implementation of which minimal corrections are required during its assimilation.
- Design of TP, stably guaranteeing high quality and economy in production without techno-logical waste.

Solving all tasks without building technological dimensional chains, their analysis and performing the necessary dimensional calculations is practically impossible.

The dimensional analysis of TP is based on a few general rules and propositions of dimensional chain theory [1, 5].

The dimensional analysis of TP has three varieties, which differ in the way of composing and solving the dimensional chains:

- Analysis of the new TP, when only drawings of the details are presented as source documents.
- Analysis of the new TP, when there are not only drawings of the details, but also a known way of obtaining or a drawing of the starting workpiece (mixed task).
- Analysis of the current TP (verification task), when any TP does not provide the necessary indicators in terms of quality, material consumption or other elements. Dimensional analysis establishes the relationship of the dimensional parameters of the various operations, followed by a decision on the dimensional chains and determines the tolerance sizes provided for the operations and determines the possible ways to improve the process.

Carrying out the overall analysis of the dimensional chains is accompanied by the implementation of a series of activities:

- The determination of the basic tolerances of all operating dimensions.
- The determination of the necessary and enough technical requirements of the operations.
- Determination of minimum tolerances.
- The design of the operating schemes of the technological process.
- Detection and fixing of the interrelationship of all parameters of the dimensions along the length of the shape-changing workpiece.
- Revealing the dimensional chain.
- Check calculation of the possibilities to ensure the dimensions of the drawing and the technical requirements.
- Checking and ensuring the optimal methods for determining the sizes of the operations.
- Determining the nominal values of the dimensions of the operations by solving the dimensional chain (manually or by computer).
- Calculation of average and maximum tolerances.
- Determination of the thickness of the layers of wear-resistant coatings (cementation, nitriding, chroming, and other types of saturation) and decorative coatings on surfaces and other tasks.

The complexity of performing all these works is related to the analysis of the dimensions of the TP and optimization of the size-accuracy relationships [10].

The dimensional analysis, the optimization of dimensional-accuracy relationships and the selection of the optimal variant of a technological process, ensuring the prescribed quality and economy of the processed parts, require a large volume of calculations [12].

When creating a design variant of the route and operational technology, all operational dimensions and their tolerances are determined, the accuracy of implementation of all design dimensions is checked. The maximum allowances for machining are also determined. After analyzing the operational pro-cessing technology and the accuracy of the structural dimensions, the search

for ways to increase the accuracy in processing is resorted to [11].

This search can be fulfilled by the application of relevant design methods directed in the following directions:

- Increasing the stability of the technological system. This can be done at the expense of the stability of the machine (choice of another machine), the workpiece (change of the pro-cessing method), the tool (replacement of the tool or change of its attachment) [14].
- Reduction of cutting forces at the expense of changing the size of the feed.
- Reducing the error from static tuning, etc..
- Use of more accurate processing methods.
- Increasing the accuracy of the dimensions of the blanks (changing the methods of obtaining them).
- Reducing the error from establishing the blanks, respectively the error during processing.

After introducing the relevant changes in the processing conditions, it is necessary to specify the tolerances and allowances for mechanical processing and the nominal operating dimensions [15].

At this stage, the main issue is resolved - the technological provision of the technical conditions to produce the part. The following condition must be met:

$$\sum n_i \to 3 \qquad (1)$$

the sum of operations and transitions of each TP must be minimal:

$$\sum m_i \to 3 \qquad (2)$$

the sum of the number of units in the size chain of the missing size - the increment can possibly be equal to 3 (the size of the previous operation, the size of the current operation, an increment between them). The optimal TP will consist of such elementary technological blocks, where the design, technological and measurement bases will coincide:

$$\sum z_i \to min \qquad (3)$$

the amount of operating allowances should be minimal.

$$[\delta_A] \geq \sum \delta_i \qquad (4)$$

The sum of the tolerances of the operating dimensions making up the units of the dimensional chain of the missing structural dimension must not exceed the tolerance of this dimension. In solving the above question, the task "Analysis of calculation results" is used [4, 13].

Therefore, at this stage, the issues of technological assurance are decided (this term is introduced in the practice of design of TP and in the process of processability together with others such as, for example, processability, accuracy, economy, etc.), i.e. a check is introduced to ensure the technical conditions for the production of details according to proposed techno-logical routes and to optimize the dimensional relationships of the drawings of the details, blanks and technological sketches. These calculations are made as many times as possible while adjusting the output data until the technical conditions described in the drawing are satisfied.

If the change of the source data does not lead to positive results, it is necessary to make a route processing technology and prepare a proposal for recommendations for correcting the working drawings.

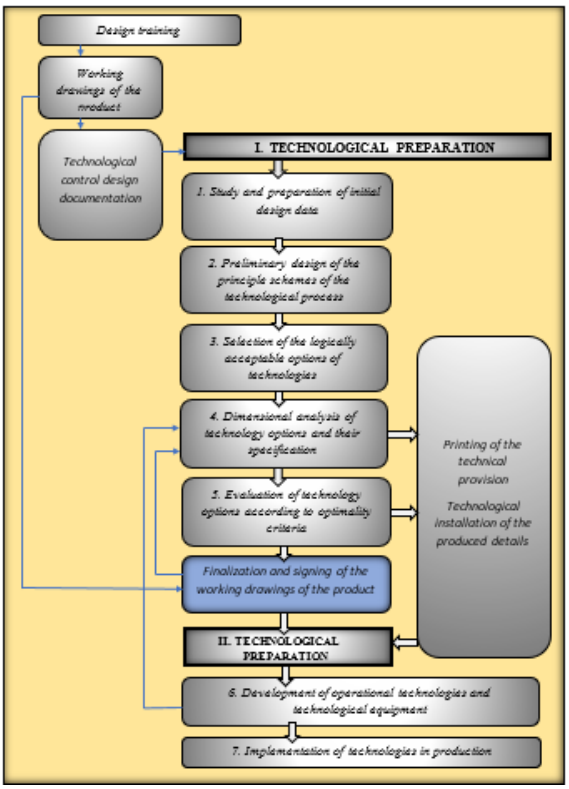

Fig. 3. Stages in the design of TP based on the optimization of dimensional-accuracy relationships.

III. CONCLUSONS

All this gives us reason to conclude that now there are opportunities for analysis and control of design-technological documentation, which is a prerequisite for the creation of an optimal TP with high quality.

The development proposed a methodology for a complex analysis of the construction-technological documentation, and selection of a variant of the technological process. This process must provide the technical conditions for the preparation of the product and its economic justification. This is done at the technology design stage, based on data from the analysis and optimization of dimensional-accuracy relationships.

The results of constructive-technological approaches, leading to the reduction of the innovation obsolescence of industrial technologies, by redesigning the technological process for mechanical processing based on the optimization of dimensional accuracy relationships, are proposed and their logical schemes are presented. On this basis, in a subsequent stage, it is necessary to further develop the idea into a software application for the industry.

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Study of the State of Innovation Development and Obsolescence in the Republic of Bulgaria of Companies from the Mechanical Engineering Sector

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Abstract. **The goal is to make an analytical study of the state of innovation development and innovation obsolescence in 15 machine-building companies in the Republic of Bulgaria. On this basis, the regularity of innovation obsolescence should be established and whether it has priority over physical wear and tear. An alternative approach for choosing solutions to reduce the harmful impact of rapid innovation obsolescence is proposed.**

Keywords: Innovation development, Obsolescence, Solutions.

I. INTRODUCTION

The modern stage of development of economic life is characterized by the globalization of product quality requirements, the need for sustainable growth, the pursuit of highly effective implementation of innovative achievements and high technologies in the field of information and communications [2]. Sustainable trends of globalization of the economy determine the accelerated introduction of innovative solutions, expressed in new technologies and automation of production processes. They solve a wide range of tasks related to:

- increasing productivity;
- with the quality of the manufactured product;
- with the sustainability and flexibility of the production process;
- with the shortening of the period from the birth of the idea to the realization of the product on the market.

Innovative saturation of processes (technological and informational) is aimed not only at eliminating heavy, monotonous, harmful to health and unattractive work, but also at applying specific innovative solutions (artificial intelligence) increasing productivity and efficiency [4]. These solutions have the task of overcoming the permanent tendency of a deficit of labour resources (human capital) determined by demographic factors. On the other hand, at the beginning of the 21st century, the ever-increasing demands of consumers and the increasing competitive pressure on world markets predetermine the need for a radically different approach to the entire innovation process. It is a global trend that manufactured products are beginning to become extremely complex, both in terms of their internal structure and in terms of user and functional

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requirements that must satisfy the need [3]. These new production concepts impose a fundamentally new way of industrial construction. With them, the use of global information networks provides an opportunity to intensify production and significantly improve the quality of manufactured products. The creation of environmentally friendly technological schemes, methods and processes is a priority of the new production concepts. In this direction, social problems and environmental restrictions will impose their predominant importance in the innovative development of production in the future [1]. In doing so, productivity and efficiency will have an integral meaning, determined by the groups of factors generated by the impact of the new concepts. This highly efficient production is a direct consequence of the use of the latest advances in computer engineering and technology, i.e. of innovations [5]. The concepts and solutions for a new type of production are generated by the complex market conditions and the aspiration of the leading companies to produce their new products more and more efficiently, with better quality and more environmentally friendly in order to satisfy the demands of the user on a global scale and communication between them.

II. MATERIALS AND METHODS

Some concepts born of globalization are a direct consequence of the use of innovations, including recent achievements in computer technology and informatics [6].

All this proves that the current state of production is determined by the criteria of globalization, including global competition, the impact of high technologies and the imperatives for sustainable growth. These three criteria actually determine the possibility of effective construction and development of industrial productions (Fig. 1).

In point A we have a relative balance between growth and competition, and the period between T_1 and T_{n-1} is characterized by the need for the investment saturation of the industry with new innovative solutions. In doing so, productivity and efficiency will have an interdependent meaning, determined by factors characterizing the nature of high-performance technologies [6].

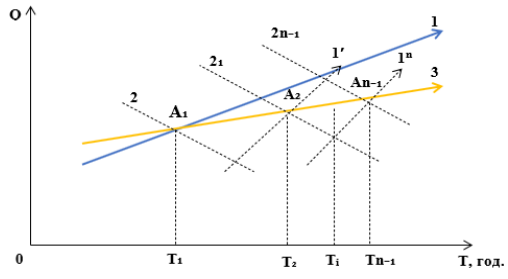

Fig. 1. Dependence between global competition under the influence of high (High) technologies and the imposing assumptions for sustainable growth.
(1 - global competition; 2, 2_1… 2_{n-1} - the efficiency resource of old technologies; A_1, A_2, An- equilibrium points between global competition (1, 1', ... 1^n); sustainable growth (3) and high technologies (2, 2_1,… 2_{n-1}); 3 - sustainable growth; T - time (years); Q - growth)

The relationship between technical levels (W), societal productivity (Q_0) and efficiency (E) is shown in fig. 2.

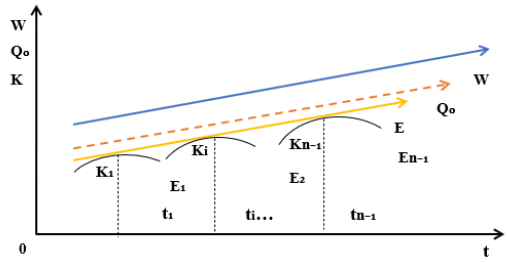

Fig.2. Dependence between technical levels (W), societal productivity (Q_0) and efficiency (E)
(E- efficiency; Q_o - public productivity; K - equilibrium point; t - time (years); W- technical levels).

After point K_1... K_i... K_{n-1}, the productivity starts to approach the limiting line of the reached technological level at time t_i and remains constant, and the efficiency starts to decrease.

Sustainable growth and global competition impose the need to use economic impacts to awaken production growth, effectively balanced between the needs of society and productivity [7]. This means investing in high-performance technologies (pro-duction and information) that provide solutions for global innovation saturation of processes and activities.

Technical regularities in innovation development. Innovative development, intensification, and productivity.

There is a certain relationship between productivity (Q) as a world level reached and technical development. It is expressed in the reached technical degrees of development (W), considering the differences in the corresponding levels (W_n) and the increase in productivity (Q_n). Indicators determining productivity and technical levels are closely related and interdependent, as they are defined by techno-logical development at a given time, which in turn is the result of the reached productivity of technologies as a degree of development of scientific and technical progress [10]. The physical essence of these dependencies is expressed in shortening the periods of creation of new technical solutions, technologies, modern constructions, know-how, etc. and increasing their productivity in absolute and relative terms for each new period (T_1, T_2, T_3..., T_1,..., T_{n-1}). It follows that the periods of innovative obsolescence of technologies become shorter and shorter in time (t_1, t_2, t_3... t_i, t_n), and the technical levels - higher and higher for each subsequent period. These are objective technical regularities, which with technological development mark accelerated steps for each subsequent period (Fig. 3).

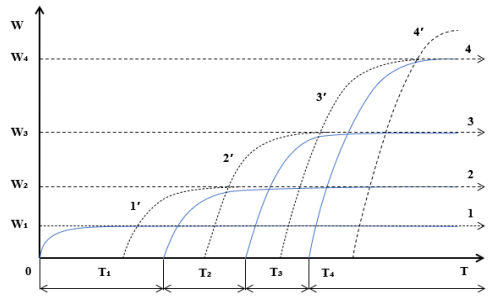

Fig.3 Technical regularities.

Therefore, the future development of industrial activities will be characterized by ever higher technical levels, ever higher productivity, rapid innovative obsolescence and global intensification of processes and activities [11]. At the same time, these dependencies form new spheres, generating a new development environment, flexibly balanced by the impact of internal and external factors.

Now we cannot talk only about individual innovations and innovation processes, but about innovative production, viewed in a complex manner. The impact of the external environment determines the basic requirements for the technological behaviour of companies and creates the prerequisites and conditions for a new attitude to innovation as an integral and necessary part of the global development of industry and society [14].

From the above presented fig. 1.3 it can be seen that:

- in the vertical $W_1 < W_2 < W_3 < \dots W_i \dots < W_{n-1}$, where W_1, W_2, W_3, W_4 is the public productivity defined by the technical levels;

- in the horizontal $T_1 > T_2 > T_3 > \dots T_i > \dots T_{n-1}$, where T_1 is the period of steam engine and mechanization; T_2- period of electricity and automation; T_3- period of computerization and high degree of automation; T_4- period of artificial intelligence and cyber systems.

Innovative obsolescence is a regularity caused by innovative development in all directions of world scientific progress. At the current stage of technical development, innovative obsolescence takes precedence over physical obsolescence. Therefore, a particularly important point in this direction is the correct determination of the degree of innovative obsolescence. The goal is to establish the impact of innovations on the technical, economic and social results of industrial activity. The correct assessment of their impact on the scale and timing of innovative obsolescence is of utmost importance for timely elimination of the negative consequences of their impact [9].

Taking into account the factors that characterize the qualitative side of innovation development allows to reveal not only the mechanism of its impact on the indicators of production efficiency, but also its influence on different sides of the production process. To facilitate the further clarification of the problem, we will group the influence of these factors in several directions [7].

The influence of innovative development on technology is expressed in the improvement of existing ones and the construction of fundamentally new machines, devices and equipment. According to their purpose and rates of productivity growth, they can be divided into two main groups:

- special machines and equipment designed for the production of uniform products on a mass scale; and

- universal machines and equipment designed for the performance of a variety of activities.

In recent years, a trend of strong unification and standardization of the elements in machine assemblies based on the modular principle has been noticed. The goal is to create conditions for the rapid assembly of machines with different technological purposes, but with a universal purpose (the principle of mechatronic machines). The study of the regularities of the development and improvement of the technique with a special and universal purpose makes it possible to determine the period in which the greatest effect can be obtained from the given generation of machines intended for a specific production process, and at the same time the period of transition to the production of new types of machines [12].

In the modern conditions of accelerated scientific and technical progress, the importance of this direction and its manifestation on the rates and scales of the innovative obsolescence of the technique has significantly increased. The real consequence of this impact is expressed in increasing the scope and terms of the innovative obsolescence of the machines and equipment in operation and the rapid change of their structural composition [15].

Innovative development is also expressed in the creation of new materials that have an active impact in accelerating the innovative obsolescence of existing technology. This influence is due to the wide application of new materials adapted for processing on certain types of machines. The extent of their use in production depends on the proportion of unnecessary equipment adapted to processing the old materials.

Innovative development affects technological processes. The changes occurring from the application of these new technologies in all cases play an active role in the production process, because of which the relative share of the old technological pro-cesses is constantly reduced, and together with them, the machines and equipment used for the purpose. It is related to the professional training and improvement of the methods, increasing the qualification and training of the personnel. Substantial changes occur in the qualification composition of the personnel, because of which a large number of new professions appear, old ones disappear, changing the ratio between individual groups of professions. This is the subject of Industry 5.0 [15].

The greatest potential for innovation in the industry is reflected in the application of advanced digital technologies. The era of advanced digital technologies has

been started by the fourth-industrial revolution, better known as Industry 4.0. Many industries expect Industry 4.0 to have a significant impact on their supply chains, manufacturing processes, and business models. Thus, Industry 4.0 is essentially a technological concept offering a promise of enhancement in efficiency through digital connectivity and artificial intelligence. This data-driven digital concept has been initiated by advanced technologies, such as Industrial Internet of Things (IIoT), Cyber Physical Systems (CPS), Industrial Big Data Analytics (IBDA), Artificial Intelligence (AI) and Cloud/Fog/Edge computing. However, the techno-logy-centered approach of Industry 4.0 has proved improper since the lack of a human impact in the application of this concept. Therefore, the wave of change has effects that go far beyond technological transformation [2]. Such as a transformed industry requires new knowledge and skills of both engineers and workers. Hence, the European Commission adopted an official document presenting Industry 5.0 and emphasizing the mean role of the research and innovation sector to support industry in its long-term service to humanity. Therefore, the concept of Industry 5.0 is not based on technologies, but is centered around values, such as human-centricity, ecological or social benefits. This paper represents the shift from Industry 4.0 to Industry 5.0 addressing the issue of how-to bring humans back to the forefront while maintaining the digital agenda and emphasizing sustainability and resilience with the aim to develop human-centric smart manufacturing systems [8].

The development of the technique leads to significant changes in the methods of its exploitation on the one hand, and on the other hand to improvement of the methods for changing the nature of the work and increasing the qualification of the personnel [15].

From what has been stated so far, it can be concluded that: the influence of innovative development is globalizing, because of which innovative obsolescence of technology occurs and the level of technologies put into operation lags behind modern ones. The continued use of innovatively outdated equipment and technological processes leads to certain losses, the amount of which will depend on the degree of this backwardness.

Trends in the relative change in the parameters of products and processes under the influence of innovation obsolescence

Technological development and, more precisely, its consequences, manifested in the form of innovative obsolescence of products and processes, lead to a peculiar attitude of manufacturers to search for ways and means to improve and change their parameters. The tendency to change the parameters of innovative products and processes because of their rapid innovative obsolescence forms a new alternative concept of innovative development. It also sets new requirements, both for the consumer essence of innovative products, and for the methods, approaches, and methods of their production.

The main directions, providing an effective way out of the limitations imposed by rapid innovative obsolescence in the creation of competitive innovative products, are actively applied by many companies in mechanical engineering and electronics. This new approach, quickly adopted by industrial companies, is already showing its advantages in the following directions:

- Application of modular principle of construction and production of innovative products.
- Design and production of modules with differ-rent technological purpose.
- Design and manufacture of innovative pro-ducts with the highest possible reliability and short service life.
- Viewing the design and production cycle as a continuous process and using the methods of competitive engineering, simulation, virtual representation, etc. in order to shorten the cycle as much as possible.
- The shortest possible cycle from an idea to a manufactured innovative product.

Programmed aging is a purposeful and con-trolled human activity with the aim of solving some industrial, economic, and social problems of society's development. The satisfaction of specific individual needs can also be included here. From this point of view and from this point of view, planned obsolescence increasingly begins to play the role of an alternative to the rapid innovation obsolescence of products and processes.

The basic principles of planned obsolescence are shown in fig. 4.

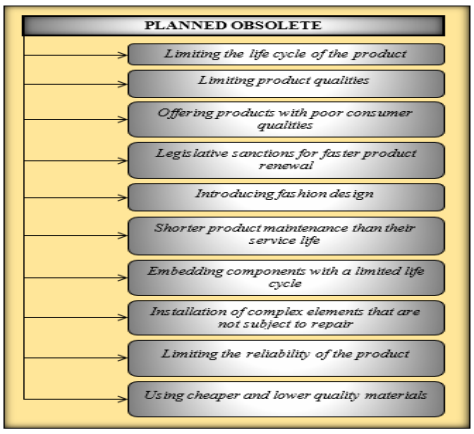

Fig. 4 Principles of programmed aging.

Patterns in innovative obsolescence and the role of programmed early obsolescence.

There are many industrial products on the market that are designed so that they are easier to replace with new ones than to repair, and manufacturers in practice massively use this market approach. In addition, there is also an alternative to innovative obsolescence, which is actively applied by many companies, both in household appliances and electronics, and in automotive and aircraft manufacturing. This new complex alternative approach, adopted quickly by industrial companies, shows its advantages in the following directions:

- It is accepted that innovative aging is an integral part of every stage of our lives. It is the main engine that drives science, technology, and the economy forward.

- Planned obsolescence as an established practice of modern industry has deepened in recent years. Experts together with some of the manufacturers believe that the frequent change of models also leads to waste of resources and damage to the environment. It turns out that the average life of home appliances has decreased by more than 3 years in recent years.

- The goal at the beginning of the 21st century was for industrial companies to produce better while keeping almost the same price. Or that longer product life is possible at the same price. This was the goal in the past, and today with the global economy and competition, everyone wants to sell more and faster. This means that the repair stage of industrial products is lost [13].

- The shortened life of industrial products and machinery is believed to be achieved in part by using lower quality materials.

- Strong impact of environmental factors in the global environment.

The advantages of this new approach are shown in Fig. 5.

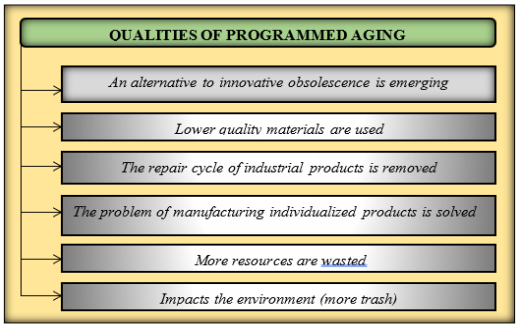

Fig. 5 Qualities of programmed obsolescence.

Technical progress and innovation/program-med obsolescence

Technical progress, innovative development, innovative obsolescence and planned obsolescence are known to be interrelated, but they are not mutually exclusive. They are not the same manifestation, although there is a certain interrelationship between them. This relationship essentially defines the objective interactions and impacts on both world progress and the social relationships of society as a whole.

The relationship between innovation development, innovation obsolescence and planned obsolescence is shown in Fig. 6.

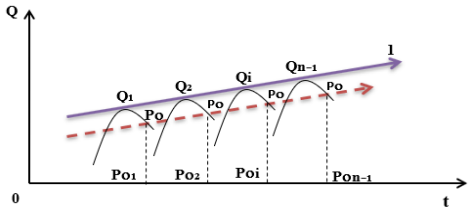

Fig. 6. Interrelationship between innovative development, innovative obsolescence and planned obsolescence.
(1-innovative development; Q_1, Q_2, Q_i… Q_{n-1} - innovative obsolescence (reduction in productivity); P_o- programmed obsolescence; Q- productivity of new innovations).

Manifestation of innovation obsolescence in mechanical engineering

In industrial development, there is a qualitative change based on innovations and high technologies. The development of technologies has the strongest impact on such basic activities as: energy, communications, nanotechnology, etc. There are three factors determining the effect of new technologies in the current stage of industrial development and form the concept of the modern production development of mechanical engineering, namely: technological, social and ecological.

The technological one dictates the tendency to constantly reduce manual, heavy and unattractive labour at the expense of higher productivity, and the object of this activity are all basic and auxiliary technological, production and information processes and activities.

The social presents the requirements for opening new or keeping the old jobs.

Ecological defines the permanent trend of compliance with ecological norms and the parameters of sustainable development of the ecological environment. All this shows that the prerequisites are already in place and conditions and opportunities have been created for a complex solution to the problems of industrial enterprises, and the formation of a new engineering policy based on communications, informatics, the Internet, Intranet, etc.

The innovation process is the most important part of the overall strategy of the enterprise. It is one of the means to achieve the goals of the engineering company, and the goals of every company are related to the sale of the products that it manufactures, trades and from which it derives maximum profit. In this sense, the innovation process is the main way to achieve the company's long-term goals [10]. It is a must for every company. The development and implementation of innovation projects allows the company to be a leader and main competitor on the market. A company that neglects innovation activity is doomed to market failure and takeover by the competition.

The innovation process can be defined and considered as a process of creating and spreading innovations, i.e. it represents a set of consistent and logically connected activities and tasks that must be performed from the moment of the idea of innovation to its market realization and its distribution.

In modern conditions, the interest in innovations is increasing more and more. They are seen as the main means of securing a firm's competitive advantage. Often in practice and theory, as a result of an etymological approach, the term "innovations" is used as a synonym for renewal. Innovation should be associated only with those forms of renewal that lead to progressive, qualitative changes in the technical-economic, technological, social, and environmental parameters of products.

The connection between innovation development and the coming innovation obsolescence in technique and technology has been proven beyond dispute. Research shows that the variant impacts of this interrelationship, both on rapid innovation obsolescence and on the techno-economic indicators determining this development, have not yet been clarified. Therefore, the interrelationship between the different stages of innovation development and innovation obsolescence should be investigated, to look for forms of impact leading to the reduction of the damage from innovation obsolescence.

Interrelationship between technical categories of development

The most important from the point of view of social development are the categories of the reached technical level of world progress and social labour productivity. Productivity in this case is considered as a category of social productivity and it is accepted to be evaluated by comparing the results of productivity and the total costs of labor (material, living) necessary for its implementation. The achieved technical level of world progress is determined by global indicators of technical progress currently expressed through certain categories of indicators, one of which is social productivity. Between it and the technical level there is a certain interrelationship and dependence. This dependence is expressed in degrees of technical level, accounting for differences with a share of productivity increase. The technical level can also be taken as the reached innovation level at the time of development of technical progress [6]. These indica-tors are closely related and dependent on each other because they are defined by the globalization of innovation development at a given time, and the latter is the result of the achieved productivity of the technique, such as the level of scientific developments, or new designs and technologies. The physical essence of this process is expressed in a shortening of the periods of creation of new technical solutions, modern designs and technologies and an increase in productivity in absolute and relative terms of each new period. It follows from this that the innovation obsolescence of the technique occurs in shorter and shorter periods of time. These are economic and technical regularities which, with globalization and innovative development, mark accelerated steps for each subsequent period, creating ever higher social productivity. Therefore, future industrial activities will be of higher technical levels, higher productivity, faster innovation obsolescence and global intensify-cation of processes and activities.

Visually, the interdependence between innovation development, innovation obsolescence and productivity is shown in fig. 7.

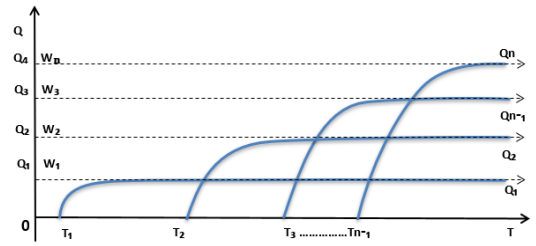

Fig. 7. Interrelationship between innovation development, innovation obsolescence and productivity.
(Q - productivity defined by technical levels; W- periods of emergence of new technical solutions during innovation development ($Q_1 < Q_2 < Q_3 < \dots Q_{n-1}$); T – periods of innovation obsolescence ($T_1 > T_2 > T_3 > \dots T_{n-1}$)).

Innovation development is influenced by several internal and external impacts related to the industrial development of the company shown in fig. 8.

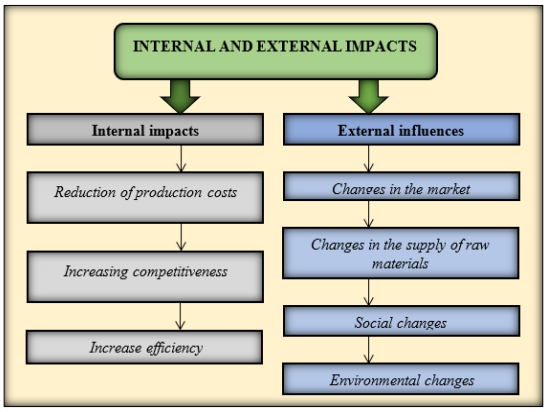

Fig. 8. Impacts influencing innovation obsolescence.

High rates of technical progress require rapid innovation obsolescence of equipment, but this does not mean that the same should be completely replaced with new ones. The successful solution of such tasks requires taking into account the influence or impact of a number of factors forming the requirements for the efficiency of both production and the capacity capabilities of enterprises. Therefore, a balanced ratio between physical wear and tear and innovative and planned obsolescence must be sought. However, practice so far shows that the facts differ significantly from prognostic views. So far, physical wear and tear often exceeds two to three times the innovative obsolescence of the technique. This is particularly characteristic of the so-called universal machines or machines with flexible capabilities. The change in the unit cost of production depending on the operational period is shown in fig. 9.

In practice, various approaches and ways of determining the service life of the equipment are known. These are the method of the total annual costs, the method of reducing the total costs to the sum of the investments, graphic methods, graphoanalytical, analytical, etc.

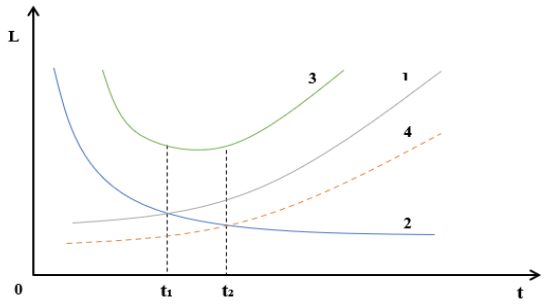

Fig. 9. Change in the cost per unit of production depending on the operational period.
(1–the share of operating costs, growing with an increase in the service life of the equipment; 2–return on capital costs (depreciation deductions); 3–general costs; 4–the share of operating costs that changes during equipment modernization).

III. Results and Discussion

In tabular form (Table 1), a study is presented in 15 Bulgarian machine-building companies, and the following are determined: the degree of innovation (J_{ino}), innovation activity (S), innovation obsolescence (M) and the alternatives for a solution are given (AR).

TABLE 1

Company	J_{ino}, %	$S = m.f(t)$ /бр	M, % $M = W.K = \frac{J}{m}.Mm$		AR
	N_n	S_m	M_m	L	AR
„МОНЕК-ЮГ“ АД	100	1	0,20	20	3
„ДИНАМО СЛИВЕН“ АД	100	1	0,15	15	3
„ЛИБХЕР-ХАУСГЕРЕТЕ МАРИЦА - ЕООД	70/100	2	0,50	50	2
„ВИТТЕ АУТОМОТИВ БЪЛГАРИЯ“ ЕООД	50/80/100	3	0,80	80	1
„ТРАНСВАГОН“ АД	100	1	0,20	20	3
„СКАЙМОНТ“ ООД	100	1	0,30	30	2; 3
„ЗММ–СЛИВЕН“ АД	100	1	0,20	20	3
„ТЕРЕМ–ИВАЙЛО“ ЕООД	100	1	0,40	40	2
„ХЕМ“АД	100	1	0,30	30	2
„МАДАРА АГРО“ЕООД	100	1	0,30	30	2
„ХИДРОПЛАСТФОРМ“ ООД	100	1	0,20	20	3
„ФАБКО“ ООД	100	1	0,10	10	3
„АЛПЕН И СИНОВЕ“ ООД	100	1	0,20	20	3
„ДАРМ“ ООД	100	1	0,40	40	2
„ДИАНЖЕЛИ“ ЕТ	100	1	0,30	30	3

Note: 1 – software obsolescence, 2 – modular constructions, 3 – outsourcing

The experiment proved that there is a functional interrelationship between "programmed" obsolescence and other alternative solutions against rapid innovation obsolescence. It acts as a regulator of the efficiency of the innovation obsolescence process.

The analytical results show that between innovative and "programmed" obsolescence we have both a mutual relationship and a different functional significance. One is a regularity, and the other can be an alternative to rapid innovation obsolescence.

IV. Conclusons

Based on the research, the following conclusions can be drawn:

- The lack of proper technical and economic justification of the developed technologies can lead to the implementation in production of inefficient and competitive variants of manufactured products.
- Innovation obsolescence is a regularity that manifests itself because of the occurring change in the technical levels of innovations with the same technical purpose. Between innovation development and innovation obsolescence there are certain interrelation-ships and interdependencies that essentially characterize the process of innovation obsolescence itself.
- The manifestation of innovation obsolescence is expressed with an impact on engineering structures, processes, and industrial products.
- Innovation obsolescence negatively affects the rapid innovation development and efficiency of industrial products.
- Effective forms of solutions to eliminate negative consequences of rapid innovation obsolescence of products and processes are used by many industrial companies in our country and around the world.
- An effective alternative form of innovation obsolescence is the so-called "programmed obsolescence". It is increasingly being imposed as an approach to remove the consequences of innovation obsolescence and creates conditions for higher competitiveness quickly and effectively.
- In world practice and in our country, many of the forms of programmed obsolescence have taken hold, as one of the means of increasing the competitiveness and efficiency of the production of industrial products.
- Innovative obsolescence is essentially a regularity, and programmed obsolescence is a human-regulated alternative activity aimed at eliminating the harmful effects of innovative obsolescence.

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Evaluation of the Effects of Herbicides on the Weeds and the Productivity of Hybrids Maize

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***Abstract*. In the early stages of maize (*Zea mays* L.) development, it is important to limit weeds that compete with maize for nutrients, moisture, light. Weed control has various methods, for example, agrotechnical, chemical. The aim of the study is to evaluate of the Effects of Weeds and Hybrids on the Productivity of Maize grain in Ukraine. The research was conducted in field conditions in 2019-2021 at the Mykolayiv National Agrarian University, which is located in the southern steppe of Ukraine. The results of the study show that weeds significantly *(P<0.05)* reduced the maize grain yield. During the grain harvesting period, the number of weeds in GS 89 decreased to 137 and 121 weeds m^{-2}. In the experiment, the predominance of early summer weeds (more than 66%) over late summer weeds (about 49%) was found. Effective weed reduction requires the use of several agrotechnical elements. Grain yield of maize hybrids increased significantly in areas where herbicides were applied. The corn hybrid 'Gran 6' was more productive. Maize hybrid *Gran 6* is 1.3 times more productive than maize hybrid *Odesskii 385 MB* in all test variants, which was also influenced by the hybrids' biological differences: maize hybrid *Gran 6* has a shorter vegetation period and is taller (on average 209.1 cm) than maize hybrid *Odesskii 385 MB*, which is 198.0 cm tall on average. Moisture consumption differed in vegetation years (2019-2021), the highest was in 2021 (70.6%), when a higher corn grain yield was also established.**

Keywords: herbicides, hybrid, maize, moisture, precipitation, weed control, yield.

I. Introduction

As the population of the planet increases, it is necessary to increase the amount of food production, i.e. to grow productive food plants, such as maize. In the world, the area of maize and its yield are increasing [1] - [4].

In order to increase the productivity of plants, it is necessary to apply the latest, improved, scientifically based technological elements, such as mineral fertilizers, hybrids, high-quality seed material, etc. [1]- [2], [4] - [9].

Maize (*Zea mays* L., diploid 2n = 20) also name Corn is a grain crop that belongs to the family *Poaceae* [1], [8], [10]. Maize is a no-residue crop that can be used for biogas production after harvesting the grain [11], because it is suitable for biogas production throughout the year [12].

Ukainian researchers A.A. Ivashchenko, S.A. Remenjuk, A.A. Ivashchenko (2018) [13] have pointed out that the problem in Ukraine is crop weediness. The number of unwanted plant seeds and vegetative reproduction organs found in the soil in the 0-30 cm layer ranges from 114 thousand units m^{-2} (in the Steppe area) up to 171 thousand. unit m^{-2} (in the forest steppe). Weed seeds of the *Chenopodioideae* family are the most abundant in the soil - 51.8-62.7%.

If weeds are not limited, maize cannot grow, which can even lead to a complete loss of yield, because, for example, in Latvian conditions, at the beginning of corn growth (in May and June), the air temperature is too low to promote rapid corn growth, whereas it does not slow down the growth of weeds [14]. Crops can be protected from weeds by using appropriate herbicides [15] - [17]. From an environmental protection point of view, it is better to use herbicides after the germination of corn and weeds, when the qualitative and quantitative composition of weeds is visible [14].

The aim of the study is to evaluate of the Effects of Weeds and Hybrids on the Productivity of Maize grain in Ukraine.

II. Materials and Methods

Annual crop – maize (Zea mays L.) from *Poaceae* family – was tested in the locations and under the

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conditions described in Table 1. Trials are set up in the southern steppe of Ukraine.

TABLE 1 TRIAL METHODS OF THE MAIZE (2019-2021)

Parameters	Trial	
	Designation/ units	***Results, size, quantity***
Soil type	Black soil of southern Ukraine, heavy loam	
Soil composition	pH	6.8
	OM, % (deep 0-30 cm)	2.9 (Tyrin's method)
	P, mg kg^{-1}	8.5 (DL method)
	K, mg kg^{-1}	18.0 (DL method)
Trial plots [18]	m^2	100
Replication	Number	3
Hybrids	Variety	Odeskii 385 (Одесский 385 МВ) (FAO 380) Gran 6 (Гран 6) (FAO 260)
Hydro-thermal coefficient	HTC	0.7-0.8
Agro-chemicals	Herbicide	Maister Pover ® OD, dispersion in oil Laudis ® 30 WG, a water dispersible granule

The agrochemicals were given to the maize in the five leaf phase (GS 15) [19]. In the study, herbicides were used according to the manufacturer's instructions. Herbicide active substances [20, 21]:

- *Maister Pover* ® OD (foramsulfuron – 31.5 g L^{-1}, iodosulfuron-methyl-sodium – 1.0 g L^{-1}, metil-tienkarbazon – 10.0 g L^{-1}, cyprosulfamide (phytoprotecteur) - 15.0 g L^{-1}).
- *Laudis* ® 30 (tembotrione 200.0 g kg^{-1}, isoxadifen 100.0 g kg^{-1}).

Maize grains were harvested at the maturity stage (GS 89), when the kernels are hard and shiny. The yield is determined at a standard humidity of 14%.

The weeds were determined according to the method of the Institute of Grain Farming of the Ukrainian Academy of Sciences by superimposing 0.25 square meters of accounting frames along the largest diagonal, (0.5 m x 0.5 m) at 4 points of each of the two incompatible repetitions.

The weeds' dry matter determination method - quantitative - by weight, which determines the number of weeds (pieces m^{-2}), their dry and wet weight per unit area (g m-2). Weed plants are cut and weigh. Dry weeds indoors or outdoors until the humidity naturally decreases (when plants are bent, they break). Dry until mass doesn't change (air-dry state). Quantitative method (30 days after maize sowing) - determination of the quantitative composition and quantitative-weight method, taking into account the above-ground biomass of weeds in the air-dry state before harvesting (i.e., based on 1 m^2 of field).

The obtained research results were processed using the software and information complex PIK "Agrostat" [22].

III. RESULTS AND DISCUSSION

In the southern steppes of Ukraine, an important factor shaping plant productivity is the provision of moisture. Accumulation of soil moisture in the 0.00-0.05 m soil layer increases plant productivity [23]. The accumulation of moisture reserve in the 0.00-1.00 m soil layer during the germination of corn hybrids was not the same in the research years:

- In 2019 - 127 mm,
- In 2020 - slightly smaller (120 mm),
- In 2021 - 130 mm (optimal).

Precipitation in the form of rain during the growing season of corn hybrids provided plants and soil with 174.6 mm, 266.2 mm and 180.7 mm (2019-2021) (Table 2). From the soil 2019-2021 116.0, 111.0 and 105.0 mm of moisture were used in the years. In general, the total water consumption in 2019 was 290.6 mm or 2906 m^3 ha^{-1}, but in 2021 it reached 3772 m^3 ha^{-1}.

TABLE 2 TOTAL WATER CONSUPTION OF PLANTS IN A MAIZE TRIALS

Year	Moisture spent, m^3 ha^{-1}		
	Precipitation	***Soil***	***In total***
2019	1746	1160	2906
2020	1807	1050	2857
2021	2662	1110	3772
Year	**The humidity used, %**		
	Precipitations	***Soil***	***In total***
2019	60.1	39.9	100
2020	63.2	36.8	100
2021	70.6	29.4	100

Precipitation consumption differed in vegetation years (2019-2021), the highest was in 2021 (71%) (Table 2, Table 3), when a higher corn grain yield was also established (Table 4). In order to obtain an adequate yield, it is important to ensure an adequate amount of moisture during the maize vegetation period, especially during the critical periods of crop growth and development [4], [8], [24]. Water deficit can also cause decreased grain number in ears [12].

TABLE 3 WATER CONSUMPTION COEFFICIENT FOR MAIZE HYBRIDS, M^3 HA^{-1}

Hybrid (Factor A)	Year	Herbicide (Factor B)		
		None (control)	*Maister Pover*	*Laudis*
Odesskii 385 MB (A1)	2019	1446	751	852
	2020	2164	1171	1293
	2021	1182	598	615
	average	1598	840	920
	± compared to controls' average	0	-758	-678
Gran 6 (A2)	2019	1105	563	612
	2020	1721	879	940
	2021	922	479	522
	average	1249	641	691
	± compared to controls' average	0	-608	-558
P_{05}	**Year**	**F_A**	**F_B**	**F_{AxB}**
	2019	0.15	0.20	0.32
	2020	0.01	0.04	0.04
	2021	0.05	0.07	0.11

The indicator of the efficiency of the selected agrotechnical techniques is the yield of the crop. One of the reasons for yield reduction is weed contamination [25]. The results of the study show that weeds significantly ($P<0.05$) reduced the corn grain yield (Table 4). Analyzing (Table 4) the grain yield of maize hybrids, it can be seen that the productivity was affected by the contrasting weather conditions, the degree of weed pollution, the biological characteristics of the hybrids and the characteristics of herbicides.

For the maize hybrid *Odesskii 385 MB*, the grain yield in 2021 was 2.4 times higher than in 2020 (Table 4), and for the corn hybrid *Gran 6* – 2.5 times (control field where no herbicides were used). For the hybrid *Odeskii 385 MB* trials, where the herbicide *Maister Pover* was used, the yield increase in 2021 compared to 2020 was 2.6 times, and where the herbicide *Laudis* was used, the increase was 2.8 times. For hybrid *Gran 6* trials where the herbicide *Maister Pover* was used, the yield increase in 2021 compared to 2020 was 2.4 times, the same increase was observed where the herbicide *Laudis* was used.

TABLE 4 GRAIN YIELD OF HYBRID CORN, T HA^{-1}

Hybrid (Factor A)	Year	Herbicide (Factor B)		
		None (control)	*Maister Pover*	*Laudis*
Odeskii 385 MB	2019	2.01	3.87	3.41
	2020	1.32	2.44	2.21
	2021	3.19	6.31	6.13
	average	2.17	4.21	3.92
	± compared to controls' average	0.00	+2.04	+1.75
Gran 6	2019	2.63	5.16	4.75
	2020	1.66	3.25	3.04
	2021	4.09	7.87	7.22
	average	2.79	5.43	5.00
	± compared to controls' average	0.00	+2.64	+2.21
P_{05}	**Year**	**F_A**	**F_B**	**F_{AxB}**
	2019	0.13	0.16	0.23
	2020	0.02	0.03	0.04
	2021	0.06	0.07	0.10

Maize hybrid *Gran 6* is 1.3 times more productive than maize hybrid *Odeskii 385 MB* (Table 4) in all test variants. This could be explained by the biological differences of the hybrids, since the maize hybrid *Gran 6* has a shorter vegetation period (Table 1) and is taller (on average 209.1 cm) than the corn hybrid *Odeskii 385 MB*, which is on average 198.0 cm tall. Maize yield and height are influenced by factors such as hybrid and year, as well as the interaction of these two mentioned factors [12]. However, the hybrid effect cannot be attributed only to the genetic differences between the hybrids, as each hybrid had different growth conditions (moisture, temperature, etc.) during the defined development phases, which also affected productivity.

In the experiment (Table 5), the predominance of early summer weeds (more than 66%) over late summer weeds (about 49%) was found. In the corn trials carried out in 2019-2021, weeds characteristic of the south of Ukraine were found:

- Annual weeds - *Chenopodium album* L., *Amaranthus retroflexus* L., *Sinapis arvensis* L., *Setaria glauca* L., *Echinochloa crus-galli* L.
- The most common was *Ambrosia artemisiifolia* L., which is classified as a quarantine weed (or invasive) in Ukraine.
- Perennial weeds – *Convolvulus arvensis* L., *Cirsium arvensis* L., *Sonchus arvensis* L., *Elytrigia repens* L.

In the research conducted in Latvia that *Cirsium arvense* L., *Vicia* spp. and perennial *Sonchus arvensis* L. are common (>40% of fields) in corn crops [26]. In the maize hybrid trials (Table 5), the level of weed invasion depended on the agro-meteorological conditions of the vegetation year, plant development phases and the use of herbicides.

TABLE 5 WEEDNESS OF MAIZE HYBRIDS AR DIFFERENT PHASES OF DEVELOPMENT

Hybrid	Maize development phase	Herbicide, number m^{-2}		
		None (control)	***Maister Pover***	***Laudis***
Odeskii 385 MB	GS 15	154	17	19
	GS 89	137	19	20
	± compared to controls' GS 89	0	-118	-117
Weed air - dry matter, g m^{-2}	GS 89	436	50	54
Gran 6	GS 15	142	15	16
	GS 89	121	16	18
	± compared to controls' GS 89	0	-105	-103
Weed air - dry matter, g m^{-2}	GS 89	418	47	50

During the maize development phase, 154 and 142 weeds m^{-2} were found in GS 15 control plots (without herbicides), but during the grain harvesting period, the number of weeds in GS 89 decreased to 137 and 121 weeds m^{-2} (Table 5), i.e. by 11% and 15%. The use of herbicides also reduced the number of weeds per m^{-2}: *Maister Pover* - by 87%, *Laudis* - by 85%.

It is important to improve corn cultivation technologies on farms [12]. In the future, the response of the hybrid genotype to different agrotechnical methods and agro-climatic conditions should be studied more.

IV. CONCLUSIONS

The trial years (2019-2021) differed in moisture availability, which affected the productivity of corn hybrids. The best provision of soil moisture and rainfall was in 2021, which also contributed to the increase in maize grain yield compared to 2019 and especially 2020.

Maize hybrid *Gran 6* is 1.3 times more productive than maize hybrid *Odesskii 385 MB* in all test variants, which was also influenced by the hybrids' biological differences: maize hybrid *Gran 6* has a shorter vegetation period and is taller (on average 209.1 cm) than maize hybrid *Odesskii 385 MB*.

Perennial weeds characteristic of the south of Ukraine were found in the corn trials conducted 2019-2021 annual. The level of their invasion depended on the agro-meteorological conditions of the vegetation year, the phases of plant development and the use of herbicides.

The number of weeds in maize fields depends on the phase of development of maize. On control plots (without herbicides), this indicator decreased from the development phase of GS 15 to GS 89 in maize hybrids Odessa 385 MV and Gran 6 by 11 and 15%, respectively. The use of herbicides also reduced the number of weeds per m^{-2}: *Maister Pover* - by 87%, *Laudis* - by 85%.

To increase the productivity of corn crops in the south of Ukraine, the technology model, where is used the *Gran 6* hybrid and sprayed the agrophytocenosis with herbicide *Meister Power*, to reduce the weeds in of the maize fields is more effective.

Effective weed reduction requires the use of several agrotechnical elements.

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A Variant for Using Regression Analysis to Assess the Electromagnetic Environment in an Urban Area

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Abstract. **The current study was conducted by making a series of experimental measurements of the electric field strength *E*. The obtained results have been interpreted using the method of mathematical modelling because the object of study – electromagnetic environment (EME) is a multifactorial system. With the accepted limitation of considering the influence of only two factors (frequency and time intervals) a two-factor regression analysis was used. The processing of the obtained data was performed by two-dimensional quadratic objective function.**

Keywords: electromagnetic environment, electric field strength, regression analysis, two-dimensional quadratic objective function.

INTRODUCTION

The dramatic increase in the level of electromagnetic emissions in highly urbanized areas is due to the rapid development of radio communication technologies, which has resulted in an increase in the number of radio-electronic and communication equipment. These processes have a strong impact on various aspects of our daily lives, and have become one of the essential factors characterizing the environment. On the one hand, the electromagnetic radiation of anthropogenic origin above certain intensity levels is biologically active and can cause a number of harmful effects on human health. These issues are most clearly characterized by the concept of radio-wave ecology (environmental impact of television and radio broadcast) [1] - [5]. On the other hand an uncontrolled increase in electromagnetic emissions results in an increase in background noise, which above a certain level can deteriorate the quality of connections and even make parts of the frequency spectrum unusable. This is the problem of electromagnetic compatibility [6] - [8]. These two problems have been the subject of numerous scientific studies. The reason for this is the fact that the electromagnetic environment (EME) is always specific. It is necessary to carry out systematic investigations of the intensity and distribution of electromagnetic radiations under various environmental factors. This implies the study of EME created by various telecommunications equipment, vehicles, power grids, medical equipment, household appliances, etc. in a specific location, frequency range and time-interval.

Object of the current study is the electromagnetic environment (EME) in the area of the city of Veliko Tarnovo, Bulgaria. As we know, the electromagnetic field is characterized by three mutually perpendicular vectors – electric field strength *E*, magnetic field strength *H*, and power flow density of an electromagnetic field (Poynting vector) *S*. The energy of the electromagnetic field can be characterized by using one of the vectors. In real conditions, the conditions of electromagnetic field propagation can be influenced. Then, the energies of *E* and *H* are not equal. Therefore, the component that would characterize the field most completely is measured.

EXPOSITION

A. Measurement requirements in urban areas

The measurements in this study were carried out in the frequency range (1÷100) *MHz*. International Special Committeee on Radio Interference (CISPR) has developed recommendations and standards for measurement of

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parameters of electromagnetic fields in this frequency range, as follows:

– for frequencies $(30\ kHz \div 30\ MHz)$ H and E can be measured. When measuring H, a circular or square antenna up to *0,6 m* is used. A vertical rod antenna of length *1 m* is used when measuring E.

–for frequencies $(30 \div 300)\ MHz$ E is measured using $\lambda/_2$ horizontal vibrator.

A selective voltmeter SMV-11 (FMA-11 antenna system) and a selective micro voltmeter SMV- 8, 5 (DP-1 antenna system) were used as meters. They are graduated in decibels relative to$1\ \mu V$.

The measurements are compliant with CISPR recommendations regarding the influence of the environment, such as trees, buildings, the soil with its parameters (absolute permittivity ε and relative permittivity ε_r), the height of the antenna system, presence of objects commensurate in size with the wavelength λ of the measured signals. The measurements were made at randomly selected sites, therefore a schedule of distribution of levels and averaging of the results was drawn up. For frequencies up to $100\ MHz$ there is a linear variation of the electric field strength with height variation. For this reason, the measurements were performed with the antenna raised to a height of $(4 \div 10)\ m$, which corresponds to the CISPR recommendation for measurements in urban areas.

In urban areas EME is complex and is a combination of external and internal EME. In this particular case the study focuses on obtaining and processing large arrays of measured values of electric field strength E [5], [7], [8]. They determine the external electromagnetic environment with respect to the radio-electronic devices located near the point of measurement. Obviously, the analysis of the electromagnetic environment is complicated by multiple factors.

The internal EME is determined by the electromagnetic radiation (background) of industrial equipment, radio-electronic devices, high current devices, motors, fluorescent lamps, high voltage transmission lines, as well as by the mutual interference caused by operating radio-electronic devices located nearby each other. The internal electromagnetic environment is related to the nearby zone (induction zone) and has a very complex character, manifested as interfering radio emissions or interfering voltages on power lines and objects. The internal EME which results from mutual interference is of special scientific interest related to the operation of complex radio-electronic systems (ships, aircraft, radio-electronic equipment with defence and security applications) and requires research in each specific case.

B. Experimental arrangement

The experimental arrangement is shown in fig. 1. The input of the meter receives a set of "*n*" radiation sources which are randomly located in time, space and frequency with different energy and spatial characteristics and parameters of the antenna—feeder devices.

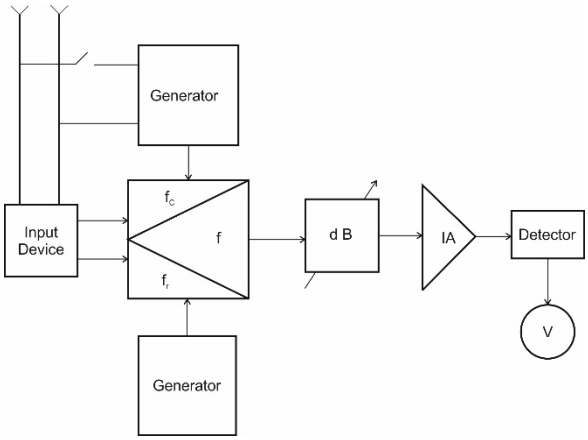

Fig. 1. Experimental system.

The meter converts the space of received signals into a space of measurement results. Fig. 2 shows the functional block diagram of the measurement system. It consists of an input device (antenna system), a receiving amplifier and a recording device. It can be assumed that all interferences (internal and external) are at the input of the meter [9], [10].

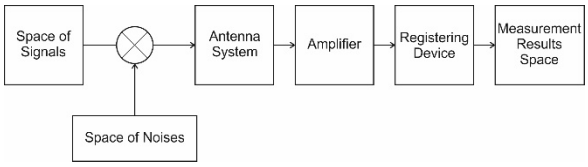

Fig. 2. Functional block diagram of the measurement system.

C. Methodology of the study

There are 4 sub-ranges in the frequency range $(1 \div 100)\ MHz$:

- $f^I = (1{,}5 \div 5)\ MHz$,
- $f^{II} = (5 \div 10)\ MHz$,
- $f^{III} = (10 \div 20)\ MHz$,
- $f^{IV} = (30 \div 100)\ MHz$.

Measurements of the sites at selected points were performed for these sub-ranges and other measurements were made in an anechoic chamber.

One 24 hour cycle is divided into 10 time-intervals $(t_1, t_2, \ldots t_{10})$ according to table 1. For each interval measurements were made sequentially for all frequencies $(1 \div 100)\ MHz$ at three selected points and five points in the vicinity, meeting the requirement for relative accuracy of the measurement.

The multi-factor conditioned electric field strength can be generally represented by the function

$$E = \varphi(P, G, D, f, A) \quad dB\left[\mu V/_m\right] \qquad (1)$$

where: P – power of the far emitter; G – coefficient of directional action of the antenna-feeder device; D – gain

factor of the antenna feeder device; f – frequency of the far emitter; A – a parameter defining the conditions for electromagnetic field propagation.

TABLE 1 TIME-INTERVALS FOR MEASURING THE ELECTRIC FIELD STRENGTH

Time-intervals		Time-intervals	
t_1	$(00^{00} \div 02^{24})\ h$	t_6	$(12^{00} \div 14^{24})\ h$
t_2	$(02^{24} \div 04^{48})\ h$	t_7	$(14^{24} \div 16^{48})\ h$
t_3	$(04^{48} \div 07^{12})\ h$	t_8	$(16^{48} \div 19^{12})\ h$
t_4	$(07^{12} \div 09^{36})\ h$	t_9	$(19^{12} \div 21^{36})\ h$
t_5	$(09^{36} \div 12^{00})\ h$	t_{10}	$(21^{36} \div 00^{00})\ h$

Dependence of E on the frequency f and the time-intervals $(t_1, t_2, \dots t_{10})$ is assumed because a significant part of the arguments in 1 are with unknown distribution laws. Therefore, E can be represented as a sum of random vectors in the vector space.

$$\left\|\vec{E}\right\| = \left\| \begin{matrix} \overrightarrow{E_{11}} & \overrightarrow{E_{12}} \dots & \overrightarrow{E_{110}} \\ \overrightarrow{E_{21}} & \overrightarrow{E_{22}} \dots & \overrightarrow{E_{210}} \\ \dots \dots & \dots \dots \dots & \dots \dots \\ \overrightarrow{E_{91}} & \overrightarrow{E_{91}} \dots & \overrightarrow{E_{910}} \end{matrix} \right\| \quad (2)$$

In (2) the columns correspond to the time-intervals and the rows correspond to the seasonal measurements, as follows: $\overrightarrow{E_{81}}\ \overrightarrow{E_{82}} \dots \overrightarrow{E_{810}}$ – for the winter $\overrightarrow{E_{91}}\ \overrightarrow{E_{92}} \dots \overrightarrow{E_{910}}$, $\overrightarrow{E_{11}}\ \overrightarrow{E_{12}} \dots \overrightarrow{E_{110}}$ and $\overrightarrow{E_{21}}\ \overrightarrow{E_{22}} \dots \overrightarrow{E_{210}}$ – for the spring; the other rows are for the summer. The vector space in expression (2) can be considered uniform and the environment in which it exists – linear [8], [11].

D. Mathematical model

[12] - [15] shows that it is possible to use various approximation functions to model the dependence of the electromagnetic field on various factors. In the current study only the influence of the frequency f and the time-intervals $(t_1, t_2, \dots t_{10})$were taken into account. A model of polynomial type has been adopted as an appropriate model to study the electromagnetic environment. We switched to a two-factor regression analysis where the processing of the experimental data was performed using a two-dimensional quadratic function of the form

$$y = b_0 + b_1 x_1 + b_2 x_2 + b_{11} x_1^2 + \\ + b_{22} x_2^2 + b_{12} x_1 x_2 \quad (3)$$

where: y – output value (electric field strength E in dB); x_1 - frequency f; x_2 – time-interval; x_1 and x_2 – values of the factors influencing the process; $b_0, b_1 \dots b_{12}$ – regression coefficients.

The vector of regression coefficients is determined by the matrix equation

$$[b] = \|[X]^T[X]\|^{-1} \cdot \|[X]^T[Y]\|$$

where: $[X]$ – input matrix corresponding to the regression form of the model; $[X]^T$ – transposed matrix.

The statistical study presented the primary model of the generalized electromagnetic environment. The generalized model of the electromagnetic environment defines the external EME for radio-electronic devices operating at the point of measurement and is the electromagnetic background interference for them [2], [12], [16]. The goal is to minimize the influence of this electromagnetic background interference and to find for which frequencies and time-intervals the minimum of the function y (electric field strength E) can be obtained.

A computer program was developed to calculate the regression coefficients (table 2).

Then, the model from expression (3) is transformed into the form

$$y = 14{,}2 + 1{,}25x_1 + 1{,}13x_2 + 6{,}19x_1^2 + \\ + 0{,}59x_2^2 + 1{,}55x_1x_2 \quad (4)$$

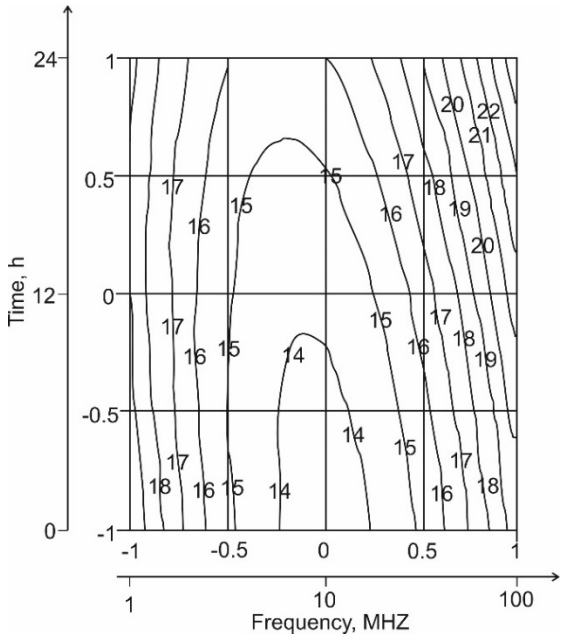

Fig. 3. Graphical results.

TABLE 2 REGRESSION COEFFICIENTS

Regression coefficients	
b_0	14,20057578
b_1	1,250516653
b_2	1,138633251
b_{11}	6,190785408
b_{22}	0,597690761
b_{12}	1,557432413

Expression (4) represents the mathematical model of the electromagnetic environment of the herein studied urban area in Veliko Tarnovo city, Bulgaria. The graphical interpretation of (4) is shown in fig. 3.

III. CONCLUSION

The conducted study of the electromagnetic environment in the city of Veliko Tarnovo, Bulgaria allows us to draw the following conclusions:

- Examination of model (4) shows that the function y (the electric field strength E) is influenced by x_1 (frequency f) and x_2 (time − interval), the fifth element being very small and the sixth element giving the correlation between x_1 and x_2. All regression coefficients are significant. The verification of the solution was limited to the numerical algorithm.

- Significant values of E at the points of measurement have been recorded in the time-intervals $t_1, t_2, t_5, t_6, t_9, t_{10}$.

- Levels of E in different frequency ranges have been registered as follows:

f^I – до 35 dB; f^{II} – $(35 \div 40)\ dB$;

f^{III} – $(35 \div 45) dB$; f^{IV} – $(18 \div 54)\ dB$.

The industrial interference levels are significant in value and it is therefore imperative to make engineering calculations on a case-by-case basis regarding shielding, grounding, filtration and appropriate placement of radio-electronic equipment. As the distance from the emitting object increases $(10 \div 20)\ m$ the field intensity decreases.

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Polyelectrolyte Complex Nanoparticles of Soluble Lignin and Chitosan as Interfacial Modifier

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Abstract. **A water-soluble non-stoichiometric polyelectrolyte complex (LCP) was obtained as a result of the interaction of oppositely charged kraft lignin and high molecular chitosan by mixing their dilute water solutions. The sizes of the LCP nanoparticles were characterized by a bimodal distribution at pH 6, and their values were essentially smaller than the sizes of the chitosan particles. It was found that the LCP nanoparticles were characterized by remarkably lower values of surface tension at the air-water and the water-organic liquid interface in comparison with the initial biopolymers. With decreasing pH and increasing concentration of the LCP nanoparticles in the water solution, their adsorption ability at the interfaces was enhanced. The interface tension at the water-heptane interface changed non-linearly with increasing the polyelectrolyte complex concentration that was associated with the "saturation" effect. The dependence of the ability of the LPC nanoparticles to stabilize oil-in-water emulsion on pH values of the water phase was found.**

Keywords: kraft lignin, chitosan, polyelectrolyte complex, interfacial modifier, oil-in-water emulsion.

I. INTRODUCTION

The strategy of the EU based on the Bioeconomy and the Circular economy principles focuses on the rational and effective utilization of polymeric by-products and wastes. Lignin could play more than a catalytic role in the deployment of bioeconomy in the EU, due to its huge multiple and flexible utilization opportunities and vital links to a great spectrum of biobased industries.

Technical lignins, by-products of the industrial pulping process, have found widespread application as a renewable resource at a competing price level for obtaining surface active agents that are used both as an emulsifier, an emulsion stabilizer and a dispersant, used in asphalt, bitumen, latex and soaps, herbicides, insecticides, clay suspensions, etc. Lignin-based surface-active agents can stabilize emulsions and suspensions due to various mechanisms such as an electrostatic repulsion, a formation of condensed interfacial films and space interactions at the interface. This application is conditioned by an amphiphilic nature of water-soluble lignin macromolecules [1] – [3] due to the presence of hydrophobic aromatic rings and ionogenic functional groups in phenyl-propane chains that give them the properties of weak polyelectrolyte. To increase surface activity, technical lignins must be modified chemically to obtain favourable surface-active properties. The known methods for modification have several drawbacks, such as high energy demand, complexity, and the necessity of a step-by-step modification by utilization of organic solvents, etc. The polyanionic nature of soluble lignins due to the presence of ionogenic functional groups allows to interact them with opposite-charged polyelectrolytes in aqueous solutions with the formation of polyelectrolyte complexes [4] – [7].

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Chitosan (Ch) is a co-polyaminosaccahride containing amine and amide groups in its glucose units. Over 100 billion tons of chitosan have been obtained annually via the deacetylation process of chitin, a by-product of a marine industry including shellfish and fish processing. The structural and composition features of chitosan make it an attractive material for chemical modification with the aim to improve its properties (ionogenic, amphiphilic, hydrophobic). The presence of amino groups is conditioned by its property as a weak polycationic electrolyte with pK_b of 6.2-7.0 [8].

Polyelectrolyte complexes are self-assemblies that are formed as a result of the electrostatic interaction of oppositely charged polyelectrolytes [9], [10]. Much attention is paid to the study of reactions between oppositely charged polyelectrolytes since their study is of interest both from the fundamental and practical point of view. The polyelectrolyte complexes can be regarded as advanced products due to the simplicity of their preparation technology and a wide range of possible applications, for example, in papermaking [11], production of binders [12], improvement of soil structure [13], medicine [10], etc. The driving force of the formation of polyelectrolyte complexes is the gain in entropy caused by the release of low-molecular ions due to the interpolyelectrolyte reaction. The formed polyelectrolyte complexes can be fully soluble in water, and form stable colloidal systems or precipitates that depend on many factors such as the chemical structure of polyelectrolytes, the ratio of interacted charged groups, their molecular mass, concentration, medium pH, etc.

Although there are many works on the preparation and study of lignin/chitosan products [14] – [16], there is limited literature devoted to the research of the behaviour of water-soluble lignin-chitosan polyelectrolyte complexes at different interfaces.

The aim of the work was to study the behaviour of a non-stoichiometric polyelectrolyte complex (LPC) formed between kraft lignin and chitosan in a water medium as an interface modifier.

II. Materials and Methods

A. Materials

Commercial softwood kraft lignin (KL) was used for obtaining a water soluble, non-stoichiometric polyelectrolyte complex. The content of Klason lignin in the sample was 92,5%. The chemical composition of the lignin was studied by elements (Elementar Analysensysteme GmbH, Germany) and functional groups (methoxyl, aliphatic hydroxyl, carbonyl, phenolic hydroxyl and carboxyl groups) analysis using the Fibok-Shvappakh method, acetylation, interaction with hydroxylamine hydrochloride, and potentiometric and conductometric titration, according to [17]. The purified lignin had the following chemical composition: 63.9 % C, 5.5 % H, 2.7 % S, 27.9 % O; OCH_3 – 12.2 %, total OH – 9.7 %, phenolic OH – 5.1 %, aliphatic OH – 4.6 %, COOH – 5.4 %, CO – 3.5 %. The average molecular weights of the lignin (Mw, Mn), determined with SEC-MALS20 (Malvern, United Kingdom) in DMSO with lithium bromide as an eluent at 60ºC, were close to 15.7 kDa and 5.7 kDa, respectively. KL was dissolved in 0.01 M NaOH for obtaining 0.1 g dl^{-1} water solution. Viscometric and surface-active properties of water solutions of the biopolymers and LPC were measured after 24 h of their obtaining. Bi-distilled water was used as a solvent.

Chitosan (Ch) with a deacetylation degree of 85 % was purchased from Sigma-Aldrich. Its average molecular mass (Mw) was 400 kDa calculated from the viscometry results. It was dissolved in 0.1 M HCl for obtaining a 0.1 g dl^{-1} water solution.

Lignin-chitosan polyelectrolyte complex (LCP) with a composition (n-/n+) = 3/1 (KL /Ch charge ratio) was obtained by mixing equal volumes of the prepared water solutions of the biopolymers for obtaining LPC with a concentration of 0.01-0.1 g dl^{-1} in the reaction mixture at room temperature. A charge density of KL and Ch macromolecules was determined from the conductometric curves of their water solutions in the presence of $1 \cdot 10^{-3}$ M NaCl. The solution pH values were changed by using concentrated NaOH and HCl solutions.

B. Methods

The size and zeta-potential (Z) of the LCP particles were determined in the reaction mixtures, using a ZS Zetasizer Nano ZS (Malvern Instruments, United Kingdom). The surface tension (σ) at the air-water and the n-heptane-water interface was measured by the Wilhelmy and Du Nouy methods, respectively, using a tensiometer K 100M (KRUSS, Germany), at 25ºC. Reduced viscosity for LPC, KL and Ch solutions was determined with a capillary Ubbelohde viscometer at 25°C with a flow time of the bi-distilled water close to 170 sec. The stabilizing effect of LPC in terms of the volume and time of water separation was studied in heptane oil-in-water emulsions (O/W) at a volume ratio of 40/60, obtained with a rotor homogenizer Ultra-Turrax T10 basic (IKA Labortechnik, Germany) for 1 min at 9500 rpm. Surface pressure-area isotherms for water solutions were obtained at 25°C using a KSV NIMA Langmuir through the double-barrier device (KSV Chemicals, Finland) with a barrier speed of 10 mm/min. Three replicates were done for each test.

III. Results and Discussion

The interpolyelectrolyte reaction between KL and Ch macromolecules has electrostatic nature and in the acidic medium can be represented by the following scheme:

$$KL\text{-}COO^{-}Na^{+} + Ch\text{-}NH^{+}_{3}\,Cl^{-} \longrightarrow$$

$$KL\text{-}COO^{-+}\,NH_3\text{-}Ch + nNa^{+} + nCl^{-}$$

where: $KL\text{-}COO^{-+}\,NH_3$-Ch is a stoichiometric LPC.

As rule, stoichiometric polyelectrolyte complexes are fully hydrophobic products and precipitate from reaction mixtures [9], [10]. Water-soluble complexes are prepared at a non-stoichiometric mixing ratio of oppositely charged polyelectrolytes, as in our case. It is known [18] that the formed products may be regarded as specific block-copolymers consisting of hydrophilic and hydrophobic blocks. In our case, the chains of lignin and chitosan, forming ionic bonds, may be considered as hydrophobic blocks, while the disconnected fragments of the polymer chains with free phenolic hydroxyl and carboxyl groups of KL and amino groups of Ch as

hydrophilic blocks. The amphiphilic structure of soluble technical lignins determines their surface-active properties [1], [2], [19].

Fig. 1 shows a dependence of surface tension at the air-water interface for the LCP reaction mixture and the biopolymers water solutions depending on pH values. The values of the surface tension of the studied solutions at the air-water interface are aligned as follows: σCh > σKL > σLCP. The LPC is characterized by lower values of the surface tension in comparison with the case of KL and Ch solutions with the same concentration. This indicates a synergetic effect governed by the peculiarities of the polymer structure of the formed complex particles; more precisely: hydrophilic-hydrophobic balance within the particles is decisive.

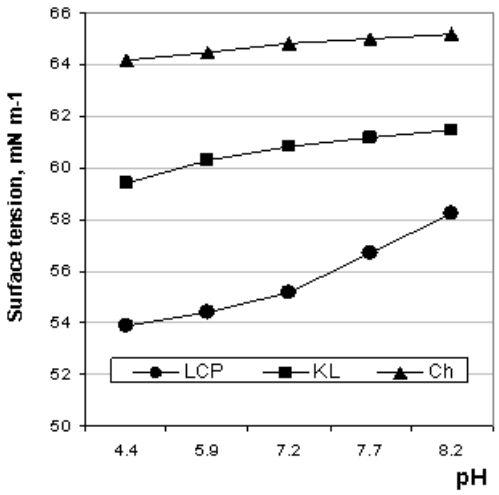

Fig. 1. Surface tension of KL, Ch and LPC water solutions at the air-water interface vs pH.

With increasing the LCP concentration in water solution from 0.01 g dl^{-1} to 0.1 g dl^{-1} and decreasing pH values from 8.2 to 4.4 (Fig. 2), the surface tension at the air-water interface remarkably drops from 59.6 mN m^{-1} to 50.4 mN m^{-1}, reflecting the enhancement of hydrophobicity of the formed LCP structure with increasing the concentration of the biopolymers and the grow of the conversion degree in the polylectrolyte complex [7]. The essential decrease in the surface tension occurs in a pH range of 4.4 – 5.9, in which the soluble LCP particles are characterized by the maximal content of the hydrophobic structural fragments, due to the high degree of dissociation of both Ch amino groups (pKb 6.5) and KL carboxyl groups (pKa 5.1).

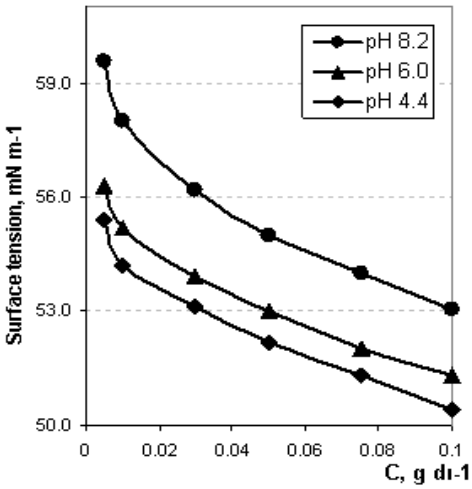

Fig. 2. Surface tension vs LCP concentration at various pH values.

It is found that water-soluble LCP is nanoparticles that are correlated with the findings in other work [20]. The sizes of the LCP particles are characterized by a bimodal distribution at pH 6 with an average hydrodynamic radius of 61 nm, corresponding to the formed LCP nanoparticles, and 12 nm, being caused by the presence of low molecular lignin molecules (Fig. 3). The Ch particles in water solution at the same pH were characterized by a monomodal size distribution with an average particle size more than 100 nm. The average size of the Ch particles was higher than those of KL and LCP nanoparticles.

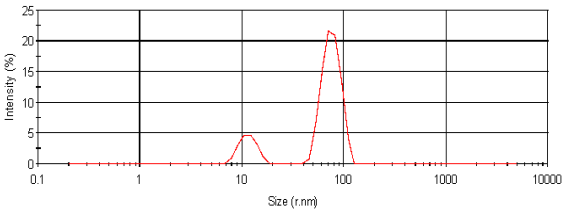

Fig. 3. Particle-size distribution pattern of the LCP particles at pH 6.0.

This finding is in accordance with the results of the viscometric study of the LCP and the biopolymers (Fig. 4). It can be seen that, in the pH range of 4.4 – 8.2, the values of reduced viscosity of the LCP reaction mixture change from 0.69 g dl^{-1} to 0.85 g dl^{-1}, which are significantly lower than those of the Ch water solution, whose values are close to 0.76 – 1.04 g dl^{-1}. These results testify to the formation of compact polymeric structures in the water-soluble LCP nanoparticles.

Due to the partial compensation of the KL negative charge with the positively charged chitosan macromolecules at pH 6.0, the obtained LCP nanoparticles had a smaller value (in an absolute sense) of average negative zeta potential (- 17 mv) in comparison with the zeta potential value for the KL particles (- 31 mv).

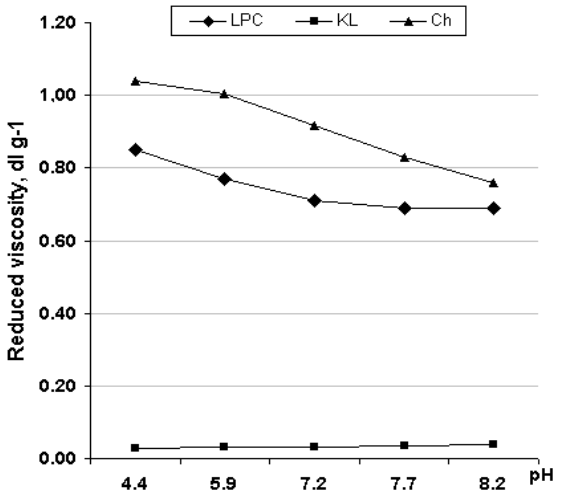

Fig. 4. Reduced viscosity of water solutions of 0.01 g dl^{-1} KL, 0.001 g dl^{-1} Ch and LCP with the same concentration of KL and Ch.

Surface pressure–area (π-A) isotherms of the biopolymers and the LCP at the air-water interface were studied with a KSV NIMA Langmuir through the double-barrier device (Fig. 5). The presence of the hydrophobic structures in the LCP nanoparticles and their more compact form in comparison with Ch nanoparticles, as evidenced by the obtained viscometric results (Fig. 4), favour the LCP nanoparticles orientation and packaging at the interface via interparticle interaction due to hydrogen and hydrophobic bonding that leads to the formation of a surface mono- and then, multilayers with increasing of the compression values. As a result, the initial and final pressure of the surface film, formed by the LCP nanoparticles, have higher values in comparison with those for the films formed by the individual biopolymers (Fig. 5). The high start surface pressure for the LCP nanoparticles testifies that the interaction between the LCP nanoparticles at the interface exists yet at the initial stage, and the formed LCP film is stronger than the films formed by KL and Ch.

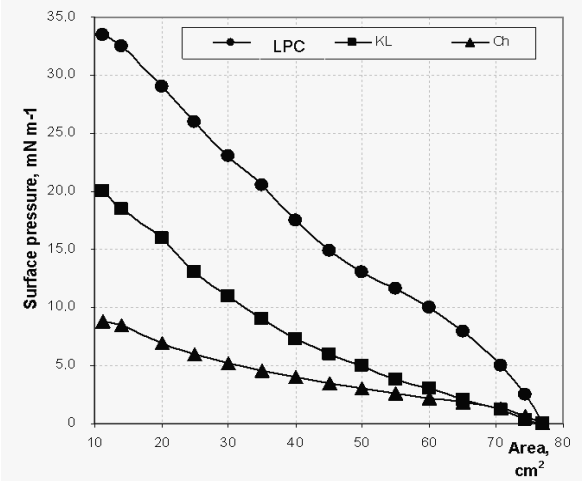

Fig. 5. Surface pressure–area isotherms of films formed with KL, Ch and LCP water solutions.

The concentration dependences of surface tension curves at the heptane-water interface for water solutions containing KL, Ch and LCP, as well as for water without any additive are given in Fig. 6. It can be seen that, at all the used concentrations, the LPC nanoparticles are able to more extent adsorb at the heptane-water interface than the biopolymers. This can reflect a synergetic effect, governed by the peculiarities of the "core-shell" structure of the formed complex nanoparticles, promoting their adsorption at the interface. At the same time, the surface tension values at the heptane-water interface change non-linearly with increasing the concentration of the LPC nanoparticles in the water solution and achieve the minimal value of 36.9 mN m^{-1} at the LPC concentration of 0.05 g dl^{-1}. It can be supposed that the character of the found correlation σ-C is associated with the "saturation" effect of the LCP nanoparticles at the interface.

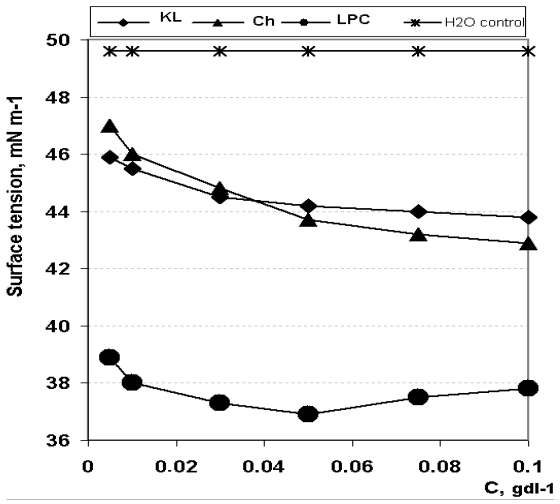

Fig. 6. Surface tension of KL, Ch and LCP water solutions at the heptane-water interface.

The study of the LCP nanoparticles as a stabiliser of O/W emulsion was carried out using the rapeseed oil-water emulsion. The ability of the LCP nanoparticles to stabilize the rapeseed oil-water emulsion was examined depending on the pH value at the defined concentration of the applied polyelectrolyte solutions. The separation process of the emulsion over time resulted in the appearance of a distinct interface between the water and oil phase volumes. Fig. 7 shows the values of the separation volume of the rapeseed oil-water emulsion containing the LCP nanoparticles with a concentration of 0.1 g dl^{-1}, depending on the pH water solution. It can be seen that the emulsion prepared with the water solution of the LCP nanoparticles in an acidic medium at pH 4.4 is characterized by lower separation water volumes, consequently, by higher stability compared with the emulsion stabilized with the alkali LPC solution at pH 8.2.

The different behaviour of the nanoparticles at the interface can be conditioned by a higher degree of conversion in the LCP polyelectrolyte complex in the acidic medium due to the maximal protonation of chitosan macromolecules, enhancing the LCP hydrophobicity. The growth of the hydrophobicity of the LPC nanoparticles gains the formation of more organized structured

interfacial layers and more effective spatial stabilization of the emulsion droplets.

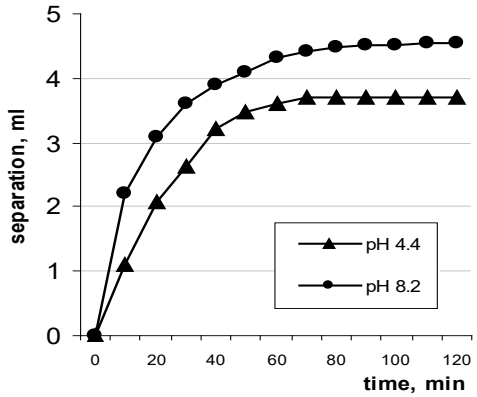

Fig. 7. Water phase separation in the rapeseed oil-water emulsion vs time, depending on pH value of 0.1 g dl^{-1} LCP water solution.

IV. Conclusions

A water-soluble non-stoichiometric polyelectrolyte complex consisting of kraft lignin and high molecular chitosan macromolecules was obtained. The formed particles of the polyelectrolyte complex were nanosized and characterized by remarkably lower values of surface tension at the air-water and the heptane-water interface in comparison with the initial biopolymers. With decreasing pH and increasing concentration of the nanoparticles, their adsorption ability at the interfaces was grown. The ability of the formed nanoparticles to stabilize the O/W emulsion increased in the acidic medium as a result of the enhancement of the conversion degree in the polyelectrolyte complex due to the maximal protonation of chitosan macromolecules.

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Wetland Change Detection Using Sentinel-2 in the Part of Latvia

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Abstract. **In the article, the possible impact of changes on wetland were analysed by the semi-supervised classification method of statistical analysis. The Sentinel-2 raw data between two different seasons are combined together. The data preparation is shortly described in the article. Data is clustered with unsupervised method. The article describes a supervised method – how data credibility and classification can be estimated if its reference is poor quality.**

Keywords: Wetlands, raised bogs, Sentinel-2, Semi-supervised classification, K-means, credibility.

I. INTRODUCTION

During the last fifteen years, interest in peatlands has significantly increased. Peatlands – a type of wetland – are among the most valuable ecosystems on Earth, providing a wide range of important ecosystem services including global biodiversity preservation [1, 2], mitigating water supply [3], [4], recreation [5], flood risk minimization [3], and climate change mitigation [6], [7], [8].

In Latvia, the most important wetland areas comprise more than 12400 rivers and 2256 lakes larger than one hectare with artificial water reservoirs occupying around 3.7% of the territory of Latvia [8]. A natural peatland is a wetland ecosystem in which organic matter production exceeds its decomposition. Under conditions of almost permanent water saturation and a lack of oxygen, dead plants and mosses accumulate as peat [9, 10]. Relatively intact swamps occupy 4.9%, while peat deposits (these consist of swamps and some types of wet forests on peat soils) occupy 10.4% of Latvia's territory [11]. Latvia is rich in peat resources, reaching 1.5 billion tonnes in the peatlands, and there are significant mineral deposits in the country [12].

As peat mines are abandoned, the areas, that were previously used for peat extraction, can start to regenerate naturally over time [13]. This regeneration can result in changes to the land cover, such as the growth of new vegetation, the development of wetlands and the expansion of peat bogs. These changes can have important ecological benefits, such as the restoration of important habitats for plants and animals, as well as providing important ecosystem services, such as carbon storage and water filtration.

However, it is also important to identify potential land cover changes that may occur during the regeneration process. For example, the expansion of new vegetation may lead to changes in the hydrology of the area, which may affect the local water balance and the availability of water resources for other uses. Additionally, changes in land cover can also impact the surrounding landscape, potentially leading to changes in the amount of sunlight that reaches the ground, changes in soil moisture, and changes in nutrient cycling [14].

Therefore, identifying areas of potential land cover change is important for understanding the potential impacts of bog habitat regeneration on the surrounding landscape, as well as for informing land management and restoration practices to ensure that ecological and social objectives are met.

In this paper, semi-supervised classification method – a technique used in remote sensing to classify land cover based on satellite imagery – is used. This approach involves combining both labelled and unlabelled data to train a classification model.

Semi-supervised classification is a technique used in remote sensing to classify land cover based on satellite imagery. Sentinel 2 is an Earth observation satellite

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developed and operated by the European Space Agency (ESA). Its imagery has 13 bands in the visible, near infrared and shortwave infrared part of the spectrum. It has a spatial resolution of 10 m, 20 m, and 60 m depending on the spectral band [16]. This paper presents a methodology for part of Sentinel-2 tile 34VEJ, which is part of the Latvia (Fig. 1).

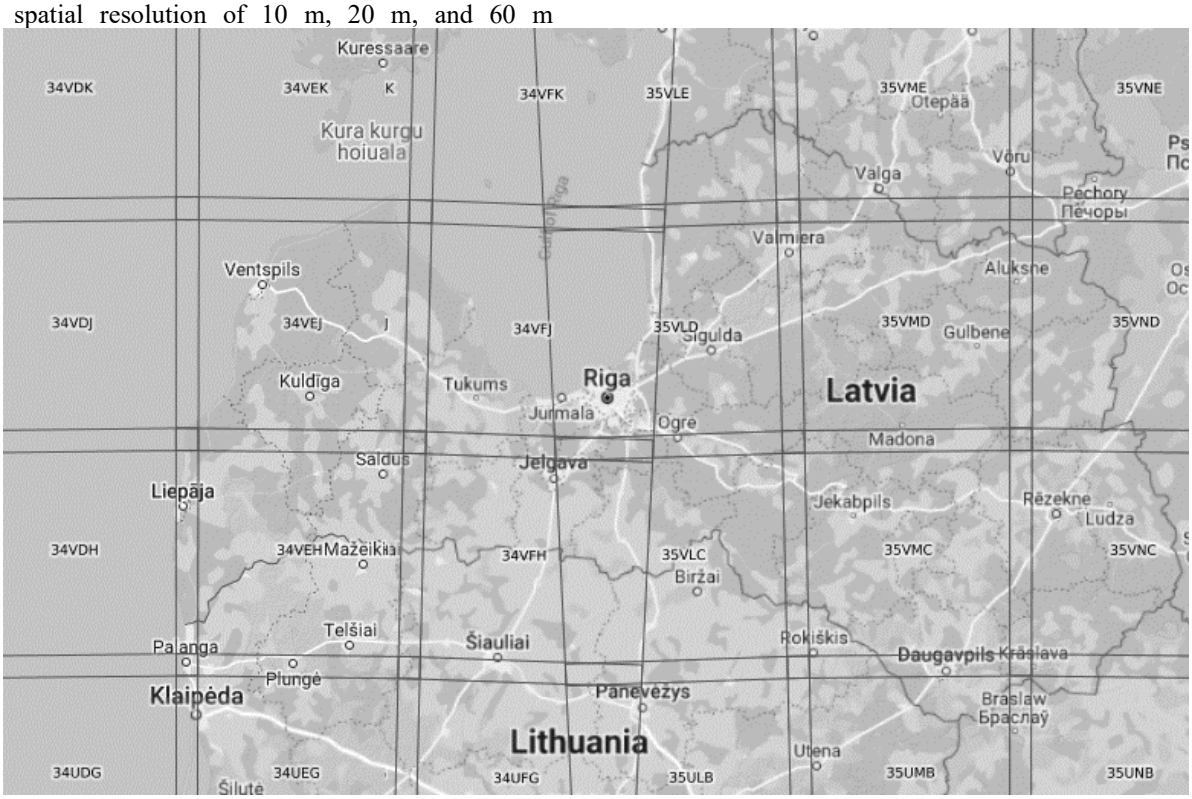

Fig. 1. Sentinel -2 UTM Tiling Grid for Latvia. [17]

II. Materials and Methods

A. Semi – supervised classification

Semi-supervised learning is a technique of machine learning that utilizes both labelled and unlabelled data to train a model.

In our case it combines the benefits of both unsupervised and supervised learning by using the unlabelled data to guide the clustering process and the labelled data to improve the generalization of the clusters. Semi-supervised learning has been shown to be effective in many real-world scenarios where labelled data are scarce, expensive, or difficult to obtain. It is a powerful tool that has been applied to various domains such as computer vision, natural language processing., etc.

Learning problems of this type are challenging as neither supervised nor unsupervised learning algorithms are able to make effective use of the mixtures of labelled and unlabelled data. Various approaches for data classification with partial labelling has been explored in [18], [19], [20], [21], [22], [23], [24], [25]. Our classification is based on semi-supervised algorithm, basis of which is described in [18], [25].

B. Algorithm

Our objective was to classify Sentinel-2 tile 34VEJ into 12 categories (Artificial objects, Agriculture, Forest, Bog habitats, Swamp forests (91D0*), Intact raised bogs (7110*) and Degraded raised bogs with potential or natural regeneration (7120), Transitional bogs and raised bogs (7140), Peat extraction sites, Licensed peat sites, Abandoned peat sites, Water, Other (unclassified)). To achieve the objective, tile 34VEJ of Sentinel-2 level 1C images were used. For this tile, the boundary mask of Latvia was used.

Tile was split in 16 overlapping fragments. We have also outdated information consisting of 2018 Copernicus Land Cover (CLC) data on man-made features, forests, as well as information from the Peat Association on developed bogs (abandoned peatlands) and licensed peatlands, as well as the Nature Conservation Management System “Ozols” data on bog habitats in 2021. Our algorithm is robust and even imprecise reference is still effective.

Initial classification of overlapping fragments can produce conflicting labelling for some areas. This was solved by providing a measure of confidence for classification - how certain we are that the category we have assigned is the correct one. We have named this measure credibility, each pixel in an image has a credibility value ranging from (theoretically) 0 (no confidence) to 1 (perfect confidence). In case of labelling conflict, classification with highest confidence was assigned.

First step is to divide image into clusters (unsupervised) based on spectral similarity. Any clustering algorithm could have been used. For this publication, K-means was picked due to its speed.

Let n be the number of categories, R_i,i ∈ [1,n] reference of the category i within the image, m - number of clusters and C_j,j∈[1,m] set of pixels in cluster j. We will use notation ‖ S ‖ for number of pixels in set S. If a cluster overlaps with reference set of exactly one category, it is obvious choice to assign that category to all pixels in such cluster. Equally obvious is credibility value of 1 for all pixels in cluster.

If a cluster overlaps more than one set of reference, the category it overlaps the most should be assigned. However, such approach had issues with smaller reference sets: if ‖ R_k ‖ ≪ ‖ R_j ‖ ∀j≠k , then category k will be ill-represented in final classification. Therefore, adding weights was required. On the other hand, too large weights caused over-representation of small categories, so we introduced max weight limit w_M. Final weight for category i is

$$w_i = min\left(\frac{\|R\|}{\|R_i\|}, w_M\right). \quad (1)$$

Cluster i is assigned to category

$$arg\ max_j \left(w_i \frac{\|C_i \cap R_j\|}{\|C_i\|}\right). \quad (2)$$

Credibility is assigned ignoring weights

$$C_{ik} = \frac{\|C_i \cap R_k\|}{\sum_j \|C_i \cap R_j\|}\ . \quad (3)$$

Finally, we are left with clusters, that do not overlap any reference at all. We use pixels from already assigned clusters to assign temporary category labels to all unassigned pixels based on spectral similarity. Any supervised algorithm can be used for this step, we used KNN [26]. Afterwards, we treat those temporary labels as reference set for clusters that did not overlap actual reference:

$$arg\ max_j \left(\frac{\|C_i \cap L_j\|}{\|C_i\|}\right), \quad (4)$$

where L_j is temporary labels of category j. Credibility is assigned analogically:

$$C_{ik} = \frac{\|C_i \cap L_k\|}{\sum_j \|C_i \cap L_j\|}\ . \quad (5)$$

III. Results and Discussion

The images of tile 34VEJ with the least cloud cover are selected (to avoid any effect on ground cover). Then images of two different seasons are selected. For the combination of the part of tile 34VEJ images is selected image for the June 14, 2021 and image for the May 12, 2021.

The tiles are separated in 16 overlapping fragments, divided into the following parts along each axis: [0, 1/3], [2/9, 5/9], [4/9, 7/9], [2/3, 1].

Prepare a mask with populated areas from the available data of the dataset. Score the number of points in each pellet fragment after applying the mask. The reference of this pellet is made from 2018 Copernicus Land Cover (CLC) data on Artificial objects, forests, as well as peat association information on developed bogs (Abandoned peat sites) and licensed peat sites, as well as Nature Conservation Management System "Ozols" for habitats: Active raised bogs (7110) and degraded raised bogs in which natural regeneration is possible or in progress (7120), Transitional bogs and bogs (7140), and the water layer created after clustering.

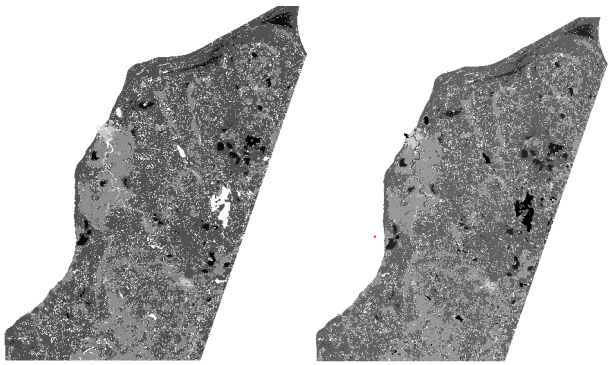

Fig. 2. Prepared reference before clustering and prepared reference after clustering.

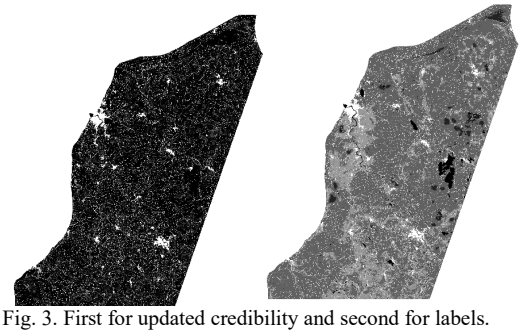

Fig. 3. First for updated credibility and second for labels.

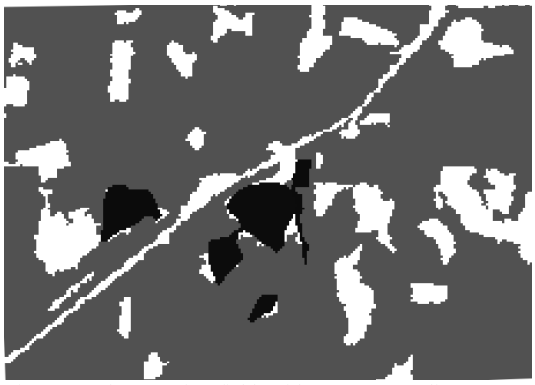

Fig. 4. Reference for field with center coordinates 57,46215° 21,93763° (EPSG:4326).

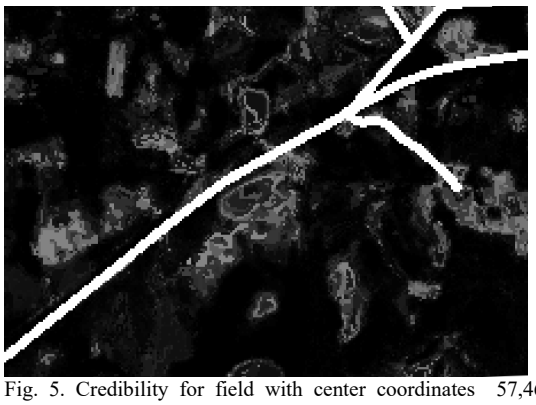

Fig. 5. Credibility for field with center coordinates 57,46215° 21,93763° (EPSG:4326).

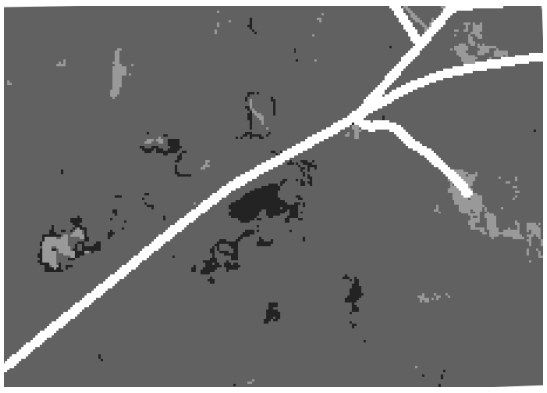

Fig. 6. Final labels for field with center coordinates 57,46215° 21,93763° (EPSG:4326).

IV. Conclusions

Analysing the data of the obtained results, it has been found that spectrally similar layers can be determined with the help of this algorithm. If Credibility is darker, then it is better. The obtained results provide important information about changes in the bog biotope.The obtained results provide important information about changes in the bog biotope.

Since the granule is divided into several overlapping fragments, a situation may arise that reference data for a class is missing in some fragments, thus it is necessary to improve the algorithm that takes into account clustering information from neighbouring areas.

Using this approach to satellite data, spectrally similar land cover as wetlands can be determined, but it is important that the reference data contains enough information about this class so that this method can be applied.

If, when preparing reference data, information about forests and meadows is used, then with the help of this method it is possible to restore information for these classes.

Further studies are related to the changes of the reference groups during the time when the previous classification result is the reference of the classifier of the next time period.

One potential conclusion from comparing semi-supervised learning with supervised and unsupervised learning algorithms is that semi-supervised learning can provide benefits over the other two approaches in scenarios where labelled data are limited or expensive to obtain. By leveraging the unlabelled data, semi-supervised learning can improve the accuracy of the model while reducing the need for a large amount of labelled data. This can be particularly useful in real-world applications where labelled data are scarce or difficult to obtain. However, the specific benefits of semi-supervised learning may vary depending on the specific problem domain and dataset, and it is important to evaluate the performance of different learning approaches on a case-by-case basis.

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Industrial Hemp Varieties Productivity Potential in the Latvian Climatic Conditions

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***Abstract*. Varieties grown for fibre-only will be established, managed and harvested differently than varieties grown for seeds or dual-purpose. The aim was analysed yield productivity and length of vegetation period dependency of the two types of hemp variety and identified perspective hemp variety for highest yield under different meteorological conditions in Latvia. Varieties/line from diverse European and Latvian origin (seed hemp varieties/ line 'Adzelvieši', 'Pūriņi', KA-2-2011, 'Finola', 'Henola' and fibre hemp varieties 'USO 31', 'Futura 75', 'Austa') were sown in randomized field experiments in Latvia. Biomass, stem, seed yield, fibre contents and vegetation period length were assessed across tree growing seasons from 2020 to 2022. Results show that hemp, seeds and fibre varieties/line, performed well giving high yield productivity between variety. Agrometeorological conditions for hemp growth and yield were favourable in 2022. In Latvian local climatic conditions, the seed hemp line KA-2-2011 and fibre hemp variety 'Futura 75' identified significant higher of biomass and stem yield as well as the seed hemp variety 'Henola' and fibre hemp variety 'Austa' significant higher of seed yield and fibre contents. The yield potential dependent from length of vegetation period length. The trial analyses identified positive and significant correlations between length of vegetation period and biomass (r = 0.97), stem yield (r = 0.98), and negative between length of vegetation period and seed yield (r = -0.89).**

Keywords: hemp, variety, fibre, vegetation period, yield.

I. INTRODUCTION

Industrial hemp (*Cannabis sativa*) well adapted for growing in different European climates [1], [2]. In Europe the France is the largest agricultural area (with almost 18,000 ha), followed by the Lithuania (over 9,000 ha), Estonia (4555 ha) and 10th place the Latvia (875 ha) in 2019 [3]. According in Latvia date in 2022 of hemp area (1263 ha) already higher [4]. In Latvia is expected that in future its production will increase, because EU policy focuses more on the 'European Green Deal' goals.

Hemp is an eco-friendly and multipurpose crop that provides raw material to a large number of traditional and innovative industrial applications [5], [6]. Moreover, tasks set maximizing the use of Latvia's renewable natural raw materials in the production of various industrial, food and feed products in the Latvian Bioeconomy Strategy for 2030 require [7]. Depending on markets and infrastructure the most valuable parts of the plant may vary, but the majority of its potential products are produced from the

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fibre, seeds and flowers. Therefore, a host of agronomic characteristics are important for successful crop production, including seeds, stem yield and crop phenology.

Currently, according to the EU Plant variety database, there are 96 registered hemp varieties (cultivars), for fibre, seeds, and dual-purpose. Most of these cultivars have been originally developed in Hungary, Italy, France, Latvia, Lithuania, Romania, Holland, Poland, Spain, Russia, Slovenia, Czech Republic, and Serbia [8]. In this research includes Latvian origin varieties of populations 'Adzelvieši', 'Purini' and new perspective line KA-2-2011 that more typical for seeds purpose but cannot be excluded for dual-purpose.

The timing of the harvest of hemp plants grown for fibre has a major effect on fibre quality. Hemp grown for fibre is harvested when male plants are at 100% bloom [9], as that is when the primary bast fibre output peaks [10]. Hemp seed matures about three to four months after planting, depending on many factors including sowing time, latitude, ambient temperature, amount of rain or irrigation during the growth period, genetics of the hemp variety, and availability of soil nutrients. When stressed by environmental or edaphic factors, hemp plants may bloom earlier. Harvesting should begin when most of the seeds (90%) have matured [11].

The selection of hemp varieties is one of the keys to a sustainable yield in a growing system and depending on end-use, varieties is defined used differently. The previous study [12], [13] already analysed hemp varieties productivity different aspects under variable climatic conditions in Latvia. However not included important genetic characteristics of the variety the days to maturity (regional adaptation). The aim was analysed yield productivity and length of vegetation period dependency of the two types of hemp variety and identified perspective hemp variety for highest yield under different meteorological conditions in Latvia.

II. Material and Methods

Experimental place. The field trial was carried out in Institute of Agricultural Resources and Economics, Department of Plant Breeding and Agroecology at Vilani in the middle of Latgale (56˚34‘10"N, 26˚58'01"E) Latvia from 2020 to 2022. Experimental material for the study consisted of 8 hemp genotypes: seed hemp varieties/ line 'Adzelvieši', 'Pūriņi', 'KA-2-2011', 'Finola', 'Henola' and fibre hemp varieties 'USO 31', 'Futura 75', 'Austa'. Hemp was grown in a Humic Gleyic Podzol.

TABLE 1. THE MAIN AGROCHEMICAL PARAMETERS OF THE ARABLE SOIL LAYER

Year	Organic matter contents, %	Soil acidity (pH_{KCl})	Available P_2O_5, mg kg^{-1}	Availa-ble K_2O, mg kg^{-1}
2020	7.41	6.61	151	112
2021	6.60	7.30	199	183
2022	7.0	6.85	169.5	143.5

The field trials were laid out in a randomized block design of four replicates, the one plot size was 25m^2. Seeds were sown during the first and second decade of May using an experimental sowing machine (SN-16) with an inter-row distance of 12.5 cm and seeding rate – 60 kg ha^{-1}. Complex fertilizer Yara Mila NPK(S) 18-11-13(7) 300 kg ha^{-1} was applied after the first cultivation of soil, 35 days after sowing, were fertilized with 60 kg ha^{-1} of nitrogen, as recommended in a previous study [14].

Four sub-plot of 1 m^2 from one plot were selected, for each variety/line, weighted green biomass yield and then dry straws (humidity average10%) was weighted and plant sample breaked by laboratory tool LM-3; obtained fibre was weighted and fibre contents in the straw was calculated by the formula (1):

$$Fc = Wf \times 100 / Wstr \quad (1)$$

where: Fc – fibre content in the straw, %,
Wf – weight of obtained fibre, g,
Wstr – weight of straw before scutching, g.

The hemp stems are obtained and weighted after drying the green stalks from one sub-plot. Harvesting was carried out using a grain harvester Sampo SR 2035 and reaper KD-210 (duplex type). Seeds were cleaned with "MLN" sample cleaner. The yield of seeds was weighed and then re-calculated to weight by 100% purity and 12% humidity.

Meteorological conditions. Agro-meteorological conditions characteristics were used by Rezekne hydrometeorological station.

TABLE 2. METEOROLOGICAL CONDITIONS

Month	Long-term average	2020	2021	2022
Temperature, ºC				
April	4.3	5.02	5.4	5.0
May	11.1	9.07	10.7	10.0
June	14.8	18.07	19.2	17.3
July	16.9	16.03	21.5	17.3
August	15.5	16.07	15.7	19.5
September	10.7	13.06	9.8	9.0
Precipitation, mm				
April	32	27.01	22.4	40.9
May	52	84.7	95.5	70.2
June	75	73.1	51.0	108.5
July	81	66.3	8.2	44.7
August	71	60.0	116.8	87.6
September	62	43.3	35.9	17.3

Statistical analysis. Software Excel (Microsoft, USA) was used for data statistical analysis. The difference between the yields properties were determined using analysis of variance (ANOVA). Significant differences among the measured characteristics of hemp were compared by Fisher's protected least significant difference (LSD) tests ($p \leq 0.05$). The correlation coefficient used to understand relationships the days to flowering and vegetation period length dependency among agronomic important yield traits.

III. RESULTS AND DISCUSION

Hemp genotypes of the biomass yield showed higher biomass yield in 2022. In 2021 (Table 1.), less precipitation and higher average daily temperature were observed in June and July, which is affects shorter of plant height, early flower blooming and as result lower biomass yield.

In research included the seed hemp genotypes have dioecious and fibre hemp varieties monoecious plants. In research proved that significant highest of yield performed and depended from hemp variety (Table 3.). Biomass yield of seed varieties ranged from 13.50 to 20.27 t ha^{-1} and fibre varieties from 25.47 to 37.33 t ha^{-1}. The genotypes were harvested with significant ($p \leq 0.05$) higher biomass and stem yield of the seed line KA-2-2011 and fibre variety of the 'Futura 75'. Compared results were observed that for seed hemp varieties of the biomass yield and stem yield significant lower like for fibre hemp varieties. The fibre content was influenced by variety heritability and a significant ($p \leq 0.05$) highest were recorded of 'Henola' at 36.3% and 'Austa' at 42.32%. Similar results to [1], [12] – [16] that biomass and fibre yield are known to vary widely between hemp varieties, agronomic practices and environmental conditions. According to [1], [16], hemp is a high-yielding crop that was reported to produce up to 20 t ha^{-1} of dry biomass per cropping season in diverse environments (Italy, Latvia, Poland), under favourable conditions. If compared with Sweden, [17] reported that the total biomass yield of the three monecious hemp varieties ('Felina', 'Fedora', and 'Futura') varied between 7.8 and 14.5 t d.m. ha^{-1}. In the study by [18] in Switzerland with 29 varieties, stem dry matter yield range from 5 to 13 t ha^{-1} and seed yield from 250 to 1200 kg ha^{-1}.

The highest seed yield was observed of the variety 'Henola' (Table 3.). In study seeds yield of seed hemp varieties/line ranged from 2.02 to 3.25 t ha^{-1} and fibre varieties from 0.50 to 0.94 t ha^{-1}. The hemp fibre varieties have a significant lower seed yield in Latvian climatic conditions. In addition, were observed that hemp seeds are sensitive to seed loss by the winds and birds. The seeds dehisce easily during maturity stage. According to [19] the morphology of certain closely grouped fertile heads of certain varieties (e.g., 'Finola', 'USO') can limit this phenomenon. Thus, in practice, harvesting start before at the seeds attain maturity. This minimizes the wind risk of seed loss.

An alternative to single-use fiber production is the dual-purpose production of seeds and stems, which is currently the main production strategy in Europe and more suitable variety have 'Futura 75' [20] from varies what included in study. But from these results were identified genotype more suitable for dual purposes of the new line KA-2-2011 with and more highest stem yield and seed yield.

TABLE 3. HEMP OF THE AGRONOMIC IMPORTANT TRAITS

Varieties/lines	Biomass yield, t ha^{-1}				Stem yield, t ha^{-1}	Fiber content, %	Seed yield, t ha^{-1}
	2020	2021	2022	Average			
Seed varety/line							
Adzelvieši	14.9	11.9	13.7	13.50c	7.53c	23.99b	2.02b
Pūriņi	21.0	17.8	19.4	19.40a	10.80ab	23.13b	2.27b
KA-2-2011	21.6	17.4	21.8	20.27a	13.17a	23.76b	2.19b
Finola	13.7	10.8	19.0	14.50bc	7.80c	25.80b	2.41b
Henola	19.5	16.4	21.2	19.03ab	9.07bc	33.76a	3.25a
LSD0.05				*4.76*	*2.95*	*6.79*	*0.61*
p-value				*0.03*	*0.01*	*0.03*	*0.01*
Fibre variety							
USO-31	21.6	17.1	19.5	25.47b	19.40b	32.28	0.94
Futura 75	32.9	23.1	36.5	37.33a	30.83a	33.44	0.50
Austa	21.90	15.6	22.9	27.30a	20.13b	42.32	0.86
LSD0.05				*11.09*	*9.57*	*11.09*	*0.94*
p-value				*0.08*	*0.05*	*0.09*	*0.52*

The hemp vegetation period length is indirect factor for yield potential. According to correlation coefficient the days to flowering (r_f) and vegetation period length (r_v) relationships with agronomic important yield traits are similar and after results significant influence of the hemp yield.

The positive significant ($p \leq 0.01$) relationship showed between the vegetation period length with biomass yield (r_v=0.96) (Fig. 1.) and stem yield (r_v=0.98) (Fig. 2.). In research all included varieties have highest biomass and stem yield with later vegetation period.

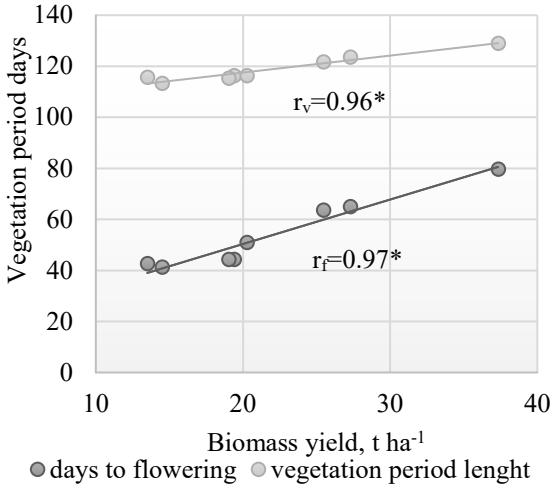

Fig. 1. Hemp varieties/line of the biomass yield relationships between vegetation periods days.

* − correlation significant at $p \leq 0.01$

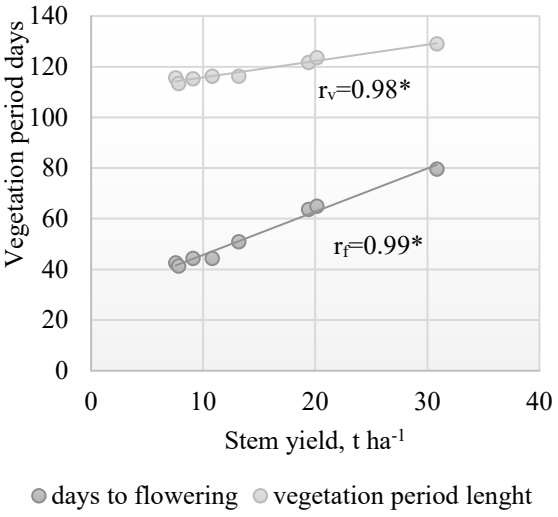

Fig. 2. Hemp varieties/line of the stem yield relationships between vegetation periods days.

* − correlation significant at $p \leq 0.01$

The negative significant ($p \leq 0.05$) relationship showed between the vegetation period length and seed yield (r_v= -0.89) (Fig. 3.). Dates proved that early hemp varieties have highest seed yield potential compared with fibre variety.

The positive relationship showed between the vegetation period length and fibre contents (r_v=0.64) (Fig. 4.). The fibre content more dependent from variety genetic characteristics but not from vegetation period length or days to flowering. Furthermore, a study by [21], [22] reveals that hemp varieties genetic development remains limited to a few main traits, examples, fibre content and flowering time. According to [23], fibre content and flowering time traits showed large heritable variation, controlled by robust genetic mechanisms that can be used in breeding programs.

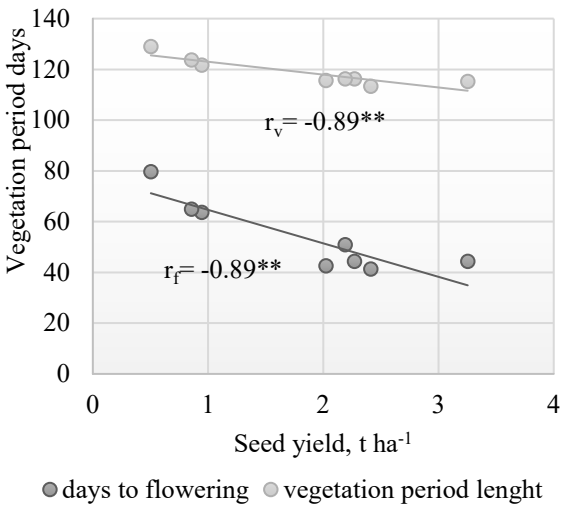

Fig. 3. Hemp varieties/line of the seed yield relationships between vegetation periods days.

** − correlation significant at $p \leq 0.01$

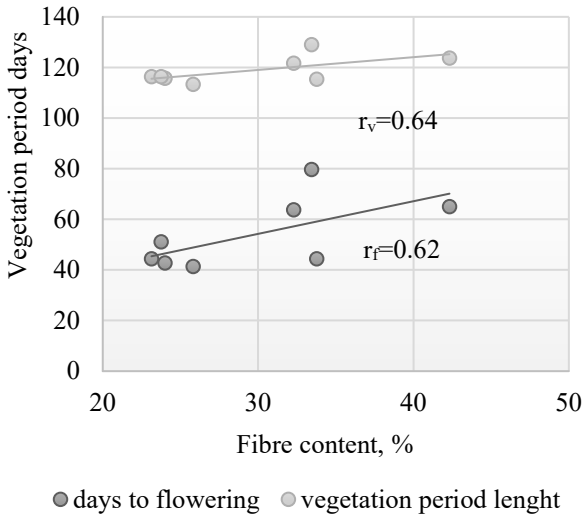

Fig. 4. Hemp varieties/line of the fibre content relationships between vegetation periods days.

In this study vegetation period of seed hemp varieties is between 113 and 116 days and fibre hemp varieties between 121 and 129 days. The seeds hemp varieties flowering start more early comparing to fibre hemp varieties (Table 4.). The fibre variety later days to flowering that also affect seed yield potential in Latvian conditions. The development of industrial hemp [24] largely depends on the amount of sunlight, particularly on the length of the day (long-day conditions increase the vegetative growth phase). According to [7], [8], hemp is a short-day plant, strongly photosensitive (flowers according to day length; not physiological maturity), and the day length influences the quantity of light received by the hemp plant, impacting the production of distinct hemp types.

Hemp classification [24] includes northern hemp – a dwarf variety with a short vegetation period of 60– 75 days, and southern hemp – tall-growing with a vegetation period of 140–160 days. However, at our latitudes in Latvia, the intermediate type is the most common similar like Polish hemp varieties [25] represent the intermediate type: they have a vegetation period of 120–140 days. However, were observed in Latvia vegetation period length is shorter of range of 110–130 days (Table 4.).

In the study the hemp variety / line was observed complete resistance to lodge in strong winds and rain during 2020 to 2022 vegetation period (Table 4.).

TABLE 4. HEMP VARIETIES/LINE OF THE VEGETATION PERIODS LENGHT AND LODGING

Varieties/lines	Days to flowering				Vegetation periode lenght, days				Lodging
	2020	2021	2022	Average	2020	2021	2022	Average	
Seed hemp varieties/line									
Adzelvieši	42	45	41	42.7	118	113	116	115.7	9
Pūriņi	46	43	44	44.3	118	112	119	116.3	9
KA-2-2011	58	49	46	51.0	117	111	121	116.3	9
Finola	42	43	39	41.3	113	114	113	113.3	9
Henola	47	45	41	44.3	118	112	116	115.3	9
Fibre hemp varieties									
USO-31	56	61	74	63.7	120	121	124	121.7	9
Futura 75	72	77	90	79.7	126	130	131	129.0	9
Austa	56	61	78	65.0	126	119	126	123.7	9

IV. CONCLUSIONS

In Latvian local climatic conditions, the potential seed hemp line KA-2-2011 and fibre hemp variety 'Futura 75' for significant higher of biomass and stem yield as well as the seed hemp variety 'Henola' and fibre hemp variety 'Austa' for significant higher of seed yield and fibre contents were identified.

The hemp yield dependent from length of vegetation period and days to flowering. The analyses identified positive and significant ($p \leq 0.01$) correlations between length of vegetation period and biomass ($r = 0.97$), stem yield ($r = 0.98$), and negative significant ($p \leq 0.05$) between length of vegetation period and seed yield ($r = -0.89$).

In Latvia results showed that suitable the intermediate type of hemp with optimal 110–130 days length vegetation period. However fibre hemp varieties with later vegetation period have lower seeds yield due to their late maturity.

The hemp varieties/ line were observed complete resistance to lodging in Latvian climatic conditions.

V. ACKNOWLEDGEMENTS

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Characterization of the Zooplankton Community of a Shallow Lake with Organic-Rich Sediment

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Abstract. **In this research, the ecological quality of the lake Vēveru (Latvia, Rēzekne district) according to zooplankton was investigated. Lake Vēveru has a large sapropel deposit with rich reserves of sapropel. Removal of sapropel requires organization of spatio-temporal monitoring to control the state or disturbance of the existing ecosystems in the long term. Zooplankton samples were collected and analyzed using standard methods in the open pelagic and littoral zones of the lake in different seasons. Quantitative samples of zooplankton in each sampling site were collected from the surface water layer at the depth of 0.5 m by filtering 100 l of water through an Apstein-type plankton net (64 µ). Biodiversity of zooplankton taxa in Lake Vēveru shows that the food base of juvenile and planktophagous fish is sufficient. The Shannon index according to the diversity of zooplankton taxa ranges from 0.84 to 1.52 by abundance, from 1.52 to 2.21 by biomass.**

Keywords: Lake Vēveru, sapropel, zooplankton, Rotifera, Cladocera, Copepoda.

I. INTRODUCTION

Lakes are a great national treasure (fresh water source can be used for hydroenergy production, recreation, fishery etc.). They are important from the natural and economic point of view. Yet lakes tend to age, bog up and disappear [1].

Latvia has 2256 lakes with the water surface area over 1 ha and the total area about 1001 km^2, which is 1.5 % of the territory of Latvia. A significant part of lakes contains sapropel deposits. Sapropels are dark and exceptionally organic-rich sediments typically deposited under highly anoxic conditions where deep water ventilation is absent [2]. Sapropel continues to accumulate, reducing the average depth of the lake by 3-5 millimeters every year. In such lakes fish feeding and spawning conditions deteriorate rapidly. Fish feeding objects – zooplankton and zoobenthos – decrease in diversity and biomass resulting in suboptimal feeding and growth conditions. The decrease in macrophyte diversity and total hard/sandy bottom area lead to a loss of spawning substrate for the majority of fish species. In addition, fish and wind induced organic sediment resuspenison leads to higher oxygen consumption and increase in internal phosphorus loading [3]-[4].

Sapropel extraction is mentioned as one of the lake recovery measures. Restoration of Lakes through Sediment Removal has been conducted e.g. in Sweden, Czech Republic [1], [5]-[6]. During the period of sapropel removal, increase in the water turbidity is noted due to the nutrient flow into the water mass, pH increases, the habitat of planktonic and benthic organisms is disturbed [7]. Turbidity correlated negatively with abundance of Cladocera and biomass of Copepoda [8]. Unfortunately, very few studies assessing the effectiveness of this approach are available, hence there is no comprehensive confidence [6]. There are no scientifically based, long term studies on the impact of sapropel removal on Latvian lake ecosystems.

Zooplankton is one of the important components of the ecosystem. Zooplankton is an important food base for juvenile and planktophagous fish [9]-[12], and also serves as an ecological monitoring object for water bodies, determining the trophic state of the lake. Zooplankton is a dynamic system in which species composition can change significantly during the season. In the temperate climate zone, changes in the zooplankton species composition of lakes are influenced by many factors, including temperature, food, competition, predation and exposure to

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anthropogenic factors [9]-[20]. Zooplankton, especially Cladocera and Copepoda and macroinvertebrates are the organisms with the greatest filter-feeding capacities. Filter-feeding organisms feed on algae, suspended detritus, and other particles in the water column and through this activity may substantially affect water clarity, nutrient concentrations and sedimentation rates [21]-[22].

Aim of research – to evaluate the composition of zooplankton community of a shallow lake Vēveru with organic-rich sediment as a potential food base for fish.

II. MATERIALS AND METHODS

Compared to other regions of Latvia, the largest total area of lakes is in Latgale – 331.5 km^2, and the total amount of sapropel identified in Latgale is 404 822.1 thousand m^3 [23].

Lake Vēveru (Vieveru) is located in the Feimaņi hills of the Latgale highlands. The lake belongs to the Daugava catchment region, its catchment area is 80 ha. No ditch or river flows into Vēveru Lake, but on the East side a ditch flows into the neighboring Kovališku Lake. According to the typology of Latvian lakes, Vēveru lake corresponds to very shallow (average depth less than 2 m) clear water (water color less than 80 Pt-Co) lakes with high water hardness (water electrical conductivity greater than 165). According to the 2018 data of The Latvian Geospatial Information Agency, the area of water surface of Lake Vēveru is 7.82 ha. The largest length of the lake is 460 m, the largest width is 226 m and the length of the coastline is 1366 m. The greatest depth of the lake is 3.1 m, the average depth is 1.9 m. The water volume of Lake Vēveru is approximately 0.15 millions m^3 [24]. After Lake Vēveru Mineral Passport (2020) a sapropel deposit of 5.994 ha in Lake Vēveru with total sapropel reserves of 30300 tons (sapropel layer thickness 1.00-8.57 m, average 5.04 m).

The hydroecological studies of Lake Vēveru were carried out in July and September 2021 and in February and May 2022. The sampling of zooplankton were performed in July, September (2021) and May (2022).

The sampling of zooplankton were performed in the littoral/ inshore (at four to five sites) and the open water (at two sites) parts of the lake (see Fig.1-2). Sampling sites were characterised by abundant stands of charophyta *Nitellopsis obtusa* in the deepest parts and mostly by *Nuphar lutea*, *Potamogeton* sp., *Phragmites australis*, *Typha* sp., by slough habitats in the shallow or inshore parts and by soft substrate (mud, detritus).

Quantitative samples of zooplankton in each sampling site were collected from the surface water layer at the depth of 0.5 m by filtering 100 l of water through an Apstein-type plankton net (64 μ). The samples were preserved in ethanol (at least 70% solution) APHA Plankton 10200, 2005 [25]). The analysis of zooplankton samples was conducted using *ZEISS Axiovert 40C* microscope (100-400 x magnification). The zooplankton 1 ml subsamples were analysed 6x repeatedly using gridded Sedgewick Rafter counting chambers, in total 6 ml sample's subvolume was examined APHA Plankton 10200 (2005) [25]. Specimens of zooplankton were determined by species, genus or family applying relevant identification guides - [27], [29]-[43]. The individual biomass of zooplankton taxa was obtained from information available in literature sources [38], [44].

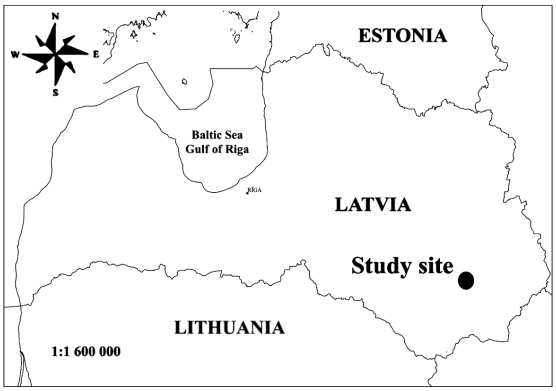


Fig. 1. Location of the study site.

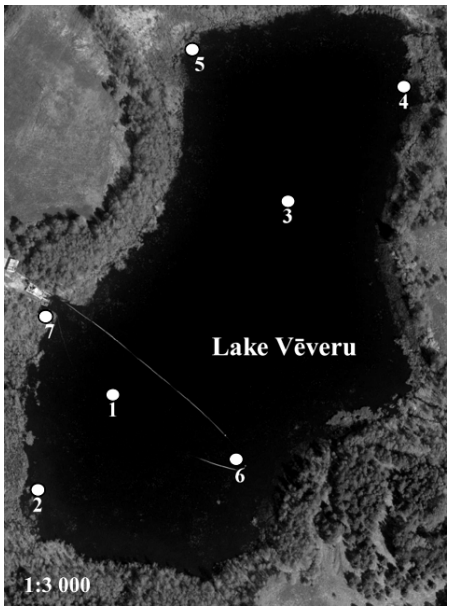


Fig. 2. Sampling sites in the Lake Veveru.

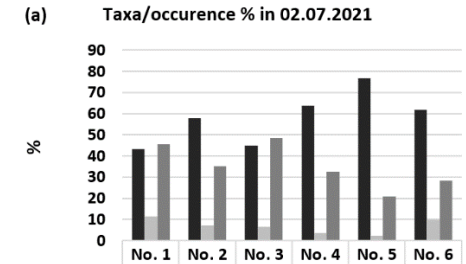
III. RESULTS AND DISCUSSION

The biological diversity of zooplankton taxa in Lake Vēveru, according to the obtained data, shows that the food base of juvenile and planktophagous fish is sufficient, as zooplankton taxa were found in the lake, which feed on both juvenile and planktophagous fish. For example, taxa of the Rotifera group, such as *Brachionus angularis*, *Polyarthra vulgaris*, *Keratella cochlearis*, *Rotifera* sp., are more important in the growth process for juvenile fish. For example, having analysed results in more details of experimental data with juvenile fish (carps) feeding, which taxons have been eaten up, it can be seen that after the experiment, the number of Rotifera group taxons *Brachionus angularis*, *Polyarthra vulgaris*, *Rotifera* sp has decreased. The number of Cladocera group taxa, as well as the number of adult Copepodita and Nauplii, is also slightly reduced. In the control samples, the most common taxa have been *Keratella cochlearis*, *Polyarthra vulgaris*,

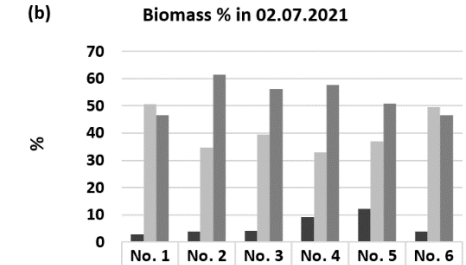
Synchaeta sp., *Pompholux sulcata*, *Bosmina longirostris*, *Bosmina longispina*, Copepodits and Nauplii. In this case, the results of the experiment also confirm that juvenile fish mainly use smaller zooplankton organisms as feed [45]-[46]. While for adult fishes food base are more important taxa of the Cladocera such as *Daphnia cucullata*, *Bosmina longirostris*, *Diaphanosoma brachyurum* etc. taxa and Copepoda such as *Cyclops*, *Eudiaptomus graciloides* etc. group taxa [45], [47]-[51].

According to the obtained data of Lake Vēveru in percentage terms of the summer, autumn and spring in 2022, by the number of taxa/occurrence between the sampling sites, the Rotifera group was the most widely represented, followed by the Copepoda and Copepoda groups (Fig. 3-5). In the summer samples of 2021, the Rotifera group was from 76.8% (place No. 5) to 43.2% (place No. 1), followed by the Copepoda group from 48.6% (place No. 3) to 20.8% (place No. 5) and Cladocera group from 2.3 % (place No. 5) to 11.3 % (place No. 1). On the other hand, the Rotifera group was from 85.2% (place No. 6) to 81.7% (place No. 4) in the autumn samples of 2021, followed by the Copepoda group from 14.6% (place No. 3) to 11.3% (place No. 1) and Cladocera group from 6% (place No. 1) to 1.8% (place No. 6). It should be noted that the Copepoda group had a large number of immature specimens - Nauplii and Copepodita, in terms of the number of taxa/occurrence, which was also the basis for the higher obtained percentage result. In the spring samples of 2022 in Lake Vēveru, the percentage distribution of the number of taxa/occurrence between the sampling sites was similar to the distribution of the summer and autumn of 2021, i.e. the Rotifera group was the most widely represented from 94.3% (place No. 5) to 81.6% (place No. 4), followed by the Copepoda group from 18.2% (place No. 4) to 5.7% (place No. 5) and the Cladocera group from 0.2 % (places No. 3 and No. 4) to 0.1 % (places No. 1 and No. 5). The Copepoda group had a large number of immature specimens - Nauplii and Copepodita, in terms of the number of taxa/occurrence also in spring, which was also the basis for the higher obtained percentage result.

According to the obtained taxon biomass data in the summer of 2021, autumn and spring of 2022 (Fig. 3-5), it can be seen that the percentage of biomass is made up by the taxa of the Copepoda and Cladocera groups, as they are significantly larger and heavier compared to the taxa of the Rotifera group. In the summer of 2021, the percentage distribution of Copepoda by biomass was from 61.4 % (place No. 2) to 46.5 % (place No. 1; No. 6), followed by the Cladocera group from 50.6 % (place No. 1) to 33 % (place No. 4) and Rotifera group from 12.1 % (place No. 5) to 2.8 % (place No. 1). In the autumn of 2021, the percentage distribution of Copepoda by biomass was from 67.2 % (place No. 6) to 38.5 % (place No. 5), followed by the Cladocera group from 45.3 % (place No. 5) to 18 % (place No. 6) and Rotifera group from 16.2% (place No. 5) to 9.9% (place No. 4). But in the spring of 2022 the percentage distribution of Copepoda by biomass was from 16% (place No. 1) to 5.9% (place No. 5), followed by the Cladocera group from 0.5% (places No. 1 and No. 4) to 0.1% (place No 5) and the Rotifera group from 94% (place No. 5) to 83.6% (place No. 1).

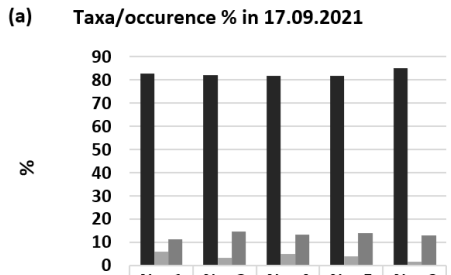


	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
ROTIFERA	43.2	57.8	45	63.7	76.8	62
CLADOCERA	11.3	7.1	6.5	3.6	2.3	9.7
COPEPODA	45.5	35.1	48.6	32.6	20.8	28.4

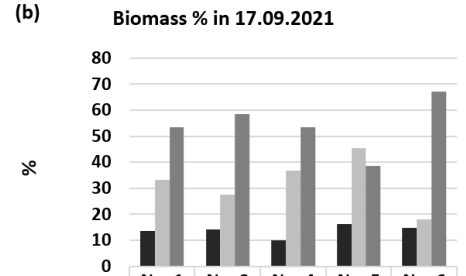


	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
ROTIFERA	2.8	3.8	4.1	9.2	12.1	4
CLADOCERA	50.6	34.8	39.6	33	36.9	49.5
COPEPODA	46.6	61.4	56.2	57.8	50.9	46.5

Fig. 3. The percentage of taxa (a) and biomass (b) of the Rotifera, Cladocera & Copepoda groups in summer 2021 (sampling sites No. 1-6).



	No. 1	No. 3	No. 4	No. 5	No. 6
ROTIFERA	82.7	82	81.7	81.9	85.2
CLADOCERA	6	3.4	5	4	1.8
COPEPODA	11.3	14.6	13.3	14.1	13



	No. 1	No. 3	No. 4	No. 5	No. 6
ROTIFERA	13.5	14.1	9.9	16.2	14.8
CLADOCERA	33.2	27.4	36.7	45.3	18
COPEPODA	53.4	58.5	53.4	38.5	67.2

Fig. 4. The percentage of taxa (a) and biomass (b) of Rotifera, Cladocera & Copepoda groups in autumn 2021 (sampling sites No. 1, 3, 4-6).

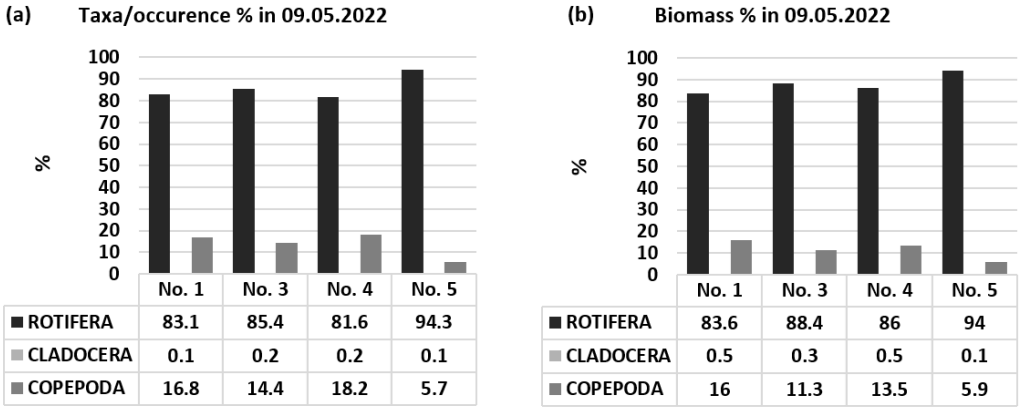


Fig. 5. The percentage of taxa (a) and biomass (b) of Rotifera, Cladocera & Copepoda groups in spring 2022 (sampling sites No. 1, 3-5).

Shannon's biodiversity index [52]-[54] according to the diversity of zooplankton taxa ranged from 0.84 to 1.52 in summer, from 1.07 to 1.52 in autumn, and from 1.55 to 1.96 in spring. Accordingly, the Shannon Biodiversity Index, according to biomass, ranged from 1.52 to 1.88 in summer, from 1.46 to 2.21 in autumn, and from 0.56 to 1.23 in spring.

Analyzed the diversity of zooplankton taxa from the obtained data in summer, autumn and spring by sampling sites covering the entire lake (Table 1), can be concluded that the Rotifera group was the most numerically represented, i.e. from 10 to 14 taxa in summer, where at all sampling sites have 6 in common, from 12 to 20 taxa in autumn and from 10 to 12 taxa in spring. All sampling sites have 8 taxa in autumn, and 10 in spring. The second largest group in terms of taxon diversity in summer and autumn was Cladocera, i.e. 5 to 8 taxa in summer, with only one taxon in common, and 3 to 9 taxa in autumn, with 2 taxa in common. In spring, the second largest group in terms of taxon diversity is Copepoda, i.e. from 1 to 4 taxa, where 1 taxon is common. On the other hand, in both summer and autumn, Copepoda was third with 3 taxa, while in spring Cladocera was third with 2 to 3 taxa, with 1 taxon in common. It should be added here that a large number of juveniles (Nauplii and Copepodites) were found in all samples, which are also used as food by both planktophagous fish and juvenile fish. In general, a similar percentage distribution of zooplankton groups in terms of number and biomass can also be observed in other lakes of Eastern Latvia [55]-[61]. Accordingly, the obtained data confirm that, at the given moment, the fish food base in Vēveru lake is favorable for the development of both juvenile fish and planktophagous fish.

CONCLUSIONS

According to the data obtained from our research, the quantitative and qualitative composition of zooplankton in the Lake Vēveru is not homogeneous. The distinguishing feature of the zooplankton species is seasonality, for example, some species are found only during a particular season or, in turn, occur throughout the season, but reach their peak in a given season. The obtained data confirm that, at the given moment, the fish food base in Vēveru lake is favorable for the development of both juvenile fish and planktophagous fish, because zooplankton taxa were found in the lake, which feed on both juvenile and planktophagous fish.

TABLE 1 COMPOSITION OF ZOOPLANKTON TAXA IN LAKE VĒVERU

Species (taxon)	***Site***						
ROTIFERA	***Date***	***No. 1***	***No. 2***	***No. 3***	***No. 4***	***No. 5***	***No. 6***
Dicranophorus sp. Nitzsch, 1827	02.07.21.						
	17.09.21.					+	+
	09.05.22.						
Cephalodella gibba (Ehrenberg, 1832)	02.07.21.						
	17.09.21.						+
	09.05.22.						
Cephalodella sp. Bory de St.Vincent, 1826	02.07.21.						
	17.09.21.					+	
	09.05.22.						
Trichocerca capucina (Wierzejski & Zacharias, 1893)	02.07.21.				+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+					
Trichocerca cylindrica (Imhof, 1891)	02.07.21.	+	+	+		+	
	17.09.21.			+	+	+	+
	09.05.22.						
Trichocerca longiseta (Schrank, 1802)	02.07.21.						
	17.09.21.						
	09.05.22.						
Trichocerca similis (Wierzejski, 1893)	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+

Species (taxon)	***Site***						
	09.05.22.						
Trichocerca sp. Lamarck, 1801	02.07.21.						
	17.09.21.						+
	09.05.22.						
Gastropus stylifer (Imhof, 1891)	02.07.21.	+		+	+	+	+
	17.09.21.			+	+	+	+
	09.05.22.						
Ascomorpha ecaudis Perty, 1850	02.07.21.						
	17.09.21.						
	09.05.22.	+		+	+	+	
Polyarthra sp. Ehrenberg, 1834	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
Ploesoma hudsoni (Imhof, 1891)	02.07.21.						
	17.09.21.	+		+	+		
	09.05.22.						
Synchaeta sp. Ehrenberg, 1832	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
Asplanchna priodonta Gosse, 1850	02.07.21.	+		+	+		+
	17.09.21.	+		+	+		
	09.05.22.	+		+	+	+	
Lecane luna (Müller, 1776)	02.07.21.						
	17.09.21.					+	+
	09.05.22.						
Lecane lunaris (Ehrenberg, 1832)	02.07.21.						
	17.09.21.			+		+	+
	09.05.22.						
Lecane flexilis (Gosse, 1886)	02.07.21.						
	17.09.21.			+			
	09.05.22.						
Lecane sp. Nitzsch, 1827	02.07.21.						
	17.09.21.					+	
	09.05.22.						
Lepadella ovalis (O.F. Müller, 1786)	02.07.21.		+			+	
	17.09.21.	+				+	+
	09.05.22.	+				+	
Lepadella patella (Müller, 1773)	02.07.21.	+					
	17.09.21.						
	09.05.22.						
Squatinella sp. Bory de St. Vincent, 1826	02.07.21.						
	17.09.21.				+	+	
	09.05.22.						
Euchlanis dilatata Ehrenberg, 1832	02.07.21.						
	17.09.21.					+	+
	09.05.22.						
Brachionus angularis Gosse, 1851	02.07.21.					+	
	17.09.21.						
	09.05.22.	+		+	+	+	
Brachionus calyciflorus Pallas, 1766	02.07.21.						
	17.09.21.						
	09.05.22.	+		+	+	+	
Keratella cochlearis Gosse, 1851	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
Keratella quadrata Müller, 1786	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
Kellicottia longispina Kellicott, 1879	02.07.21.	+		+	+		+
	17.09.21.						
	09.05.22.	+		+	+	+	
Notholca acuminata (Ehrenberg, 1832)	02.07.21.						
	17.09.21.						
	09.05.22.					+	
Conochilus sp. Ehrenberg, 1834	02.07.21.	+	+	+	+	+	+
	17.09.21.					+	+
	09.05.22.						
Collotheca sp. Harring, 1913	02.07.21.		+		+		
	17.09.21.						
	09.05.22.						

Species (taxon)	***Site***						
Pompholyx sulcata Hudson, 1885	02.07.21.	+					
	17.09.21.						
	09.05.22.					+	
Filinia longiseta (Ehrenberg, 1834)	02.07.21.						
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
Testudinella patina (Hermann, 1783)	02.07.21.	+				+	
	17.09.21.					+	+
	09.05.22.						
Bdelloid sp. Hudson, 1884	02.07.21.	+	+				
	17.09.21.	+					
	09.05.22.						
Rotifera sp. Scopoli, 1777	02.07.21.				+		
	17.09.21.				+		+
	09.05.22.						
CLADOCERA	***Date***	***Site No. 1***	***Site No. 2***	***Site No. 3***	***Site No. 4***	***Site No. 5***	***Site No. 6***
Diaphanosoma brachyurum (Liévin, 1848)	02.07.21.	+	+		+	+	+
	17.09.21.	+		+	+	+	
	09.05.22.						
Sida crystallina (O. F. Müller, 1776)	02.07.21.						
	17.09.21.					+	
	09.05.22.						
Daphnia (Daphnia) cucullata Sars, 1862	02.07.21.			+	+		
	17.09.21.				+		
	09.05.22.						
Ceriodaphnia sp. Dana, 1853	02.07.21.		+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+		
Scapholeberis mucronata (O. F. Müller, 1776)	02.07.21.		+	+		+	
	17.09.21.						
	09.05.22.						
Graptoleberis testudinaria (Fischer, 1851)	02.07.21.			+	+		+
	17.09.21.						
	09.05.22.						
Acroperus harpae (Baird, 1835)	02.07.21.	+	+			+	
	17.09.21.			+		+	+
	09.05.22.						
Alonella nana (Baird, 1843)	02.07.21.		+				
	17.09.21.			+	+		+
	09.05.22.						
Alona sp. Baird, 1843	02.07.21.						
	17.09.21.			+		+	
	09.05.22.						
Chydorus ovalis (Kurz, 1875)	02.07.21.	+	+	+			+
	17.09.21.					+	
	09.05.22.			+		+	
Bosmina (Bosmina) longirostris (O. F. Müller, 1776)	02.07.21.	+	+	+	+		+
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
Eurycercus (Eurycercus) lamellatus (O. F. Müller, 1776)	02.07.21.						
	17.09.21.			+			+
	09.05.22.						
Pleuroxus (Peracantha) truncatus (O. F. Müller, 1785)	02.07.21.						
	17.09.21.					+	+
	09.05.22.						
Polyphemus pediculus (Linnaeus, 1758)	02.07.21.		+		+	+	
	17.09.21.					+	
	09.05.22.						
COPEPODA	***Date***	***Site No. 1***	***Site No. 2***	***Site No. 3***	***Site No. 4***	***Site No. 5***	***Site No. 6***
Acanthocyclops sp. Kiefer, 1927	02.07.21.	+	+	+	+		+
	17.09.21.	+					+
	09.05.22.	+		+	+	+	
Cyclops sp. Müller, 1785	02.07.21.						
	17.09.21.						
	09.05.22.						
Mesocyclops sp. Kiefer, 1927	02.07.21.						
	17.09.21.						
	09.05.22.	+		+	+		
Thermocyclops oithonoides (G.O.Sars, 1863)	02.07.21.		+	+	+		+
	17.09.21.						

Species (taxon)	Site						
	09.05.22.						
Eudiaptomus graciloides (G.O. Sars, 1863)	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+		+
	09.05.22.			+	+		
Copepodite	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+		+	+	+	
Nauplii	02.07.21.	+	+	+	+	+	+
	17.09.21.	+		+	+	+	+
	09.05.22.	+					

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Assessment by Macroinvertebrates of the Ecological Quality of Shallow Lake with Rich Sapropel Sediments

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Abstract. **In this research, the ecological quality of the Lake Vēveru (Latvia, Rēzekne district) according to macroinvertebrates was investigated. The Lake Vēveru has a large sapropel deposit. The Lake Vēveru is relatively little affected by human economic activity, the only moderate impact is sapropel mining in the lake in 2009-2012, it is planned to resume industrial sapropel mining in the lake. During the period of sapropel removal, a decrease in the transparency of water is noted due to the nutrient flow into the water mass, pH increases, the habitat of planktonic and benthic organisms is disturbed. Macroinvertebrates samples were collected and analyzed using standard methods in the open pelagic and littoral zones of the lake in different seasons. The ecological quality of the lake was assessed in accordance with the requirements of the European Water Framework Directive in Latvia. To characterize the ecological status of the lake the Latvian Lake Macroinvertebrate Multimetric Index was used. According to the Ecological Quality Ratio (EQR) the lake indicates a good ecological status of the water. However, a moderately low species diversity index indicates the dominance of certain taxa. In general, macroinvertebrates species that are often and widely found in Latvia and are environmentally tolerant have been found in the lake. Water temperature, pH, conductivity, dissolved oxygen, oxidation reduction potential, chlorophyll-α were measured with a *HACH OTT DS5* Probe. Water transparency was measured using a Secchi disc.**

Keywords*: *macroinvertebrates, sapropel, physical, chemical parameters of water.

I. INTRODUCTION

The EU's biodiversity strategy for 2030 is a comprehensive, ambitious and long-term plan to protect nature and reverse the degradation of ecosystems. In 4 June 2021, Nairobi/Rome – leaders in global politics, science, communities, religion and culture united to officially introduce the UN Decade on Ecosystem Restoration - a rallying call for the protection and revival of millions of hectares of ecosystems all around the world for the benefit of people and nature. There has never been a more urgent need to revive damaged ecosystems than now. The ongoing accumulation of sediment in freshwater ecosystems is a problem that is continuing to develop at a worldwide scale [1]. Degraded lakes represent the loss of substantial economic benefits [2]. Water protection is one of the priorities in Latvian environmental protection policy.

Latvia has 2256 lakes with the water surface area over 1 ha [3]. 1126 lakes have been surveyed in Latvia, 655 of which have been recognized as sapropel deposits of industrial significance. The Latvian State Bureau of Geology indicates that the lake sapropel resources are more than 930 million m^3. Compared to other regions of Latvia, the largest total area of lakes is in Latgale - 331.5 km^2, and the total amount of sapropel identified in Latgale is 404822.1 thousand m^3 [4]. The large amount of sapropel in Latvia's lakes makes it a strategic natural resource of national level. Sapropel is a valuable product with a wide range of uses [5-9], however, its accumulation poses a threat to the lake ecosystem functioning - the area and depth of the lake decrease, the physico-chemical parameters of the water change, oxygen deficiency occurs

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in winter [10], biodiversity, including ichthyofauna decreases, lake succession takes place [11]. Finally a lot of oxygen is consumed for the oxidation of organic matter in silts in winter; as a result, its content at the bottom drops, which causes a sharp decrease in the biomass of benthos [12].

Lakes can be renovated (remediated) by extraction of organic sediment (sapropel) [13-14]. There is a double advantage of ecological recovery: a renovated lake and a valuable product sapropel which can be used for different purposes [15]. Deepening of the lake bed to deplete the sediments is an effective but aggressive method, because in its implementation there is a significant interference in the processes taking place in the lake ecosystem [13], [16]. Nevertheless, studies focused on the effects of sapropel removal on lake ecosystems are very limited and fragmentary. Removal of sapropel requires organization of spatio-temporal monitoring to control the state or disturbance of the existing ecosystems in the long term.

This research aims to determine the ecological quality of the sapropel-rich Lake Vēveru according to macroinvertebrates. The sapropel has been mined from 2009 to 2012 and it is planned to resume industrial sapropel mining. Thereby, this data could be the basis for further research on the impact of disturbance on the lake ecological quality.

The macroinvertebrates of lakes are among the commonest, a very diverse and most widespread of freshwater fauna organisms and detritus decomposers. Macroinvertebrates have a broad taxonomic spectrum, different strategies of life histories, different habitat preferences and varied roles in the feeding web, also species composition changes with changing lake trophic status. Formation of the composition of macroinvertebrates, abundance and biomass also depend on macrophyte stands (species, density) and sediments [17], [18]. For example, in eutrophic lakes the composition of the macroinvertebrate fauna is characterized by the dominance of Gastropoda and Chironomidae. Therefore, they are very good indicators and highly useful in indicating the changes of aquatic ecosystems [19], [20].

II. Materials and Methods

Lake Vēveru (Vieveru) is located in the Feimaņi hills of the Latgale highlands. The lake belongs to the Daugava catchment region, its catchment area is 80 ha. No ditch or river flows into Vēveru Lake, but on the A side a ditch flows into the neighbouring Kovališku Lake. According to the typology of Latvian lakes, the Lake Vēveru corresponds to type 1 very shallow (average depth less than 2 m) clear water (water colour less than 80 Pt-Co) lakes with high water hardness (water electrical conductivity greater than 165 µS cm^{-1}).

According to the 2018 data of The Latvian Geospatial Information Agency, the area of water surface of the Lake Vēveru is 7.82 ha. The largest length of the lake is 460 m, the largest width is 226 m and the length of the coastline is 1366 m. The greatest depth of the lake is 3.5 m, the average depth is 1.9 m. The water volume of the Lake Vēveru is approximately 0.15 million. m^3 [21].

After Lake Vēveru Mineral Passport (2020) a sapropel deposit consists of 5.99 ha with a sapropel layer thickness of 1.00-8.57 m, an average of 5.04 m.

The hydroecological studies of the Lake Vēveru were carried out in July and September 2021 and in February and May 2022 (Fig.1-2). The sampling of macroinvertebrates were performed in July, September (2021) and May (2022). Simultaneously measurements of the physicochemical parameters of water and water transparency (by a Secchi disk) were done. In February 2022, only the physicochemical parameters of water were measured when the lake was covered by ice.

Physico-chemical water parameters – water temperature °C, conductivity µS cm^{-1}, dissolved oxygen mg l^{-1}, chlorophyll α µg l^{-1} and oxidation-reduction potential mV – were measured in situ using a *HACH Hydrolab DS5* multiprobe. The measurements of physico-chemical water parameters at the deeper parts of the lake were performed starting from the lake surface to the bottom (up to limits of ± 1 m) with a measurement range of one meter and at the very shallow parts in a surface water layer (in ± 1.0 - 0.5 m limits). Surface water sampling (in ± 0.5 m limits) for detection of biological oxygen demand and their laboratory analysis was performed according to standard methods [22].

The sampling of macroinvertebrates was performed in the littoral/ inshore (at four to five sites) and the open water (at two sites) parts of the lake (Fig.1-2). Sampling sites were characterised by abundant stands of charophyta *Nitellopsis obtusa* in the deepest parts and mostly by *Nuphar lutea*, *Potamogeton* sp., *Phragmites australis*, *Typha* sp., by slough habitats in the shallow or inshore parts and by soft substrate (mud, detritus). Macrophytes were identified by Plants of Lake Shores [Ezeru krastmalu augi] (2016), online https://www.latvijasdaba.lv, and by Charophytes of Great Britain and Ireland. Botanical Society of the British Isles, London (1986).

Semi-quantitative (2021) and quantitative (2022) samples of macroinvertebrates were collected using a Hydrobios hand net with a mouth opening of 25x25 cm (500 µm mesh) in the wadeable (up to 0.5 m) depths by the sweeping technique [23]. Quantitative samples of zoobenthos on soft bottom were collected using Ekman grab sampler (225 cm^2) (2-3 replicate samples at each site), obtained samples were sieved through a 0.5 mm screen. The samples were preserved in ethanol (at least 70% solution) for latter identification and counting. Specimen identification was done with a *ZEISS Stemi 508doc* stereomicroscope using the literature: Timm 2015 [24], Kriska 2013 [25]. Animals were identified to the lowest taxonomic level where possible.

The ecological status according to European Water Framework Directive was measured using Latvian Lake Macroinvertebrate Multimetric Index [26], [27].

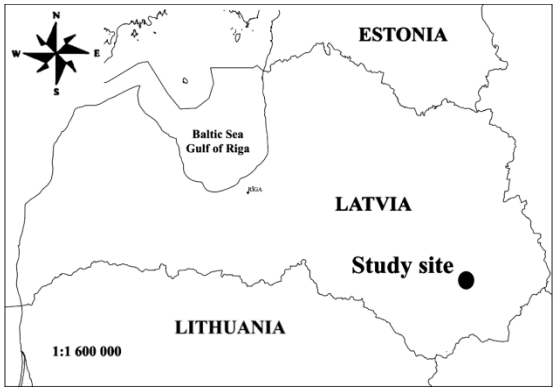

Fig. 1. Location of the study site.

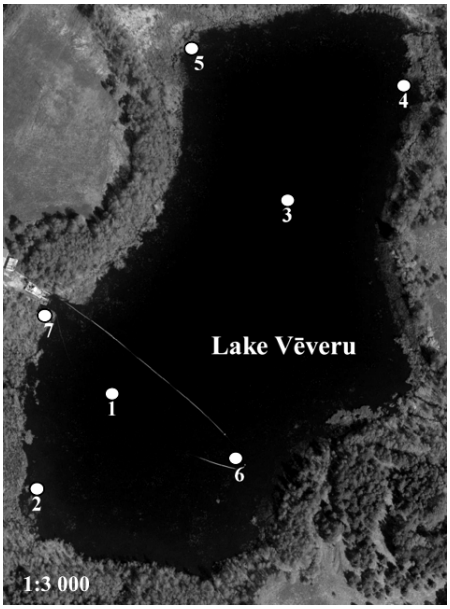

Fig. 2. Sampling sites in the Lake Vēveru.

III. RESULTS AND DISCUSSION

A. Physico-chemical parameters

Average water temperature in the deepest part (2.7 m) of the lake seasonally ranged between 25.00°C in 2021 summer (July) and 2.78°C in 2022 winter (February). Average dissolved oxygen concentrations were lowest in winter 1.16 mg l^{-1} (lowest 0.35 mg l^{-1} near sediments) and the higher in 2022 spring (May) and summer 9.66 and 9.42 mg l^{-1} respectively. In winter, low dissolved oxygen is a common phenomenon in ice-covered lakes, and anoxic conditions of winter are characteristic of shallow eutrophic lakes with high oxygen depletion [28]. Also, biochemical oxygen demand was higher in winter 7.25 mg l^{-1}, in spring was 4.95 mg l^{-1} and in autumn (2021 September) 2.18 mg l^{-1} due to phytoplankton, bacterioplankton, and decomposition of organic matter. Secchi depth ranged between 1.90 m in summer and 2.20 m in autumn to 1.10 in spring which mainly depend on phytoplankton. Accordingly, the highest concentrations of chlorophyll-a were observed in spring (average 3.94 µg l^{-1}). High concentrations also were in winter under ice cover (maximum 11.00 µg l^{-1}) because there is an internal nutrient supply, especially phosphorus which may increase under anoxic conditions in winter [29]. Value of pH was typical for Latvian lakes (average pH 7.45), only in winter under ice cover average pH was 6.75, and similarly also oxidation reduction potential decreased (average 218 mV), and indicated low oxygen conditions in winter [30]. In common, the hard (average electro conductivity 418 µS cm^{-1}) clear-water lakes with such chlorophyll-a concentrations correspond to good - moderate ecological status [26].

B. Macroinvertebrates

Thirty-seven taxa of macroinvertebrates, belonging to Annelida, Mollusca, Insects and Crustacea were recorded from four sites during the sampling period (Tab. 1) in the lake. The macroinvertebrate community was found to be influenced by the type of substrate. The most considerable species diversity was obtained using the sweeping technique between macrophytes. Ekman grab sampling at sites 2 and 3 was impacted by rich detritus layer and abundant stands of charophyta *Nitellopsis obtusa* respectively and macroinvertebrates was not obtained. Only from the soft substrate at site 1 (the depth 2.2 m) four taxa were recorded (Tab. 1). It is noted that macroinvertebrate species composition and richness were mainly affected by habitat conditions [31], [32], [18]. For example, in similar research of shallow charohyta lakes dominant species in Chara stands were the gastropods *Valvata piscinalis* and *Bithynia tenticulata* [17]. Also, the abundance of individuals was low. In 2021 summer and autumn, it was 180 specimens m^{-2} and 40 specimens m^{-2} respectively. In 2022 spring, it was 40 specimens m^{-2} at site 1 and in the littoral part at site 5 and 7 it was from 42 to 157 specimens m^{-2} respectively. In 2022 spring the Crustacea, Coleoptera and Trichoptera were the most abundant across the sites (39%, 24% and 10%, respectively) and more diverse were Coleoptera (Dysticidae, Hydrophilidae) and Trichoptera (Limnephilidae), dominant was crustacean *Asellus aquaticus*. In general, in the Lake Vēveru has been found macroinvertebrate taxa that are often and widely distributed in Latvian freshwaters and are more or less environmentally tolerant [20], [24], [32], [33]. The macroinvertebrate composition of the Lake Vēveru corresponds from high to moderate ecological status (Chironomidae (Diptera), Ephemeroptera – *Cloeon dipterum*; Trichoptera - Limnephilidae, *Limnephilus* spp.; Gastropoda – *Bithynia* sp., Planorbidae; Crustacea – *Asellus aquaticus*; Odonata – Libellulidae, Aeshnidae, *Erythromma najas*, Coenagrionidae; Hydracarina) [34], [35]. One of Dytiscidae, *Cybister (Scaphinectes) lateralimarginalis* which is the only species of the Cybisterini tribe in Latvia and mainly occurred in the Eastern Latvian freshwaters, also was obtained in the Lake Vēveru. This lake is suitable habitat for the species because it prefers habitats with a high percentage of plant cover, with mud and medium coarse detritus. In small and shallow lakes surrounded by forests and swamps, the species tends to be found throughout the lake area [36], [37].

TABLE 1 MACROINVERTEBRATES COMPOSITION AND OCCURRENCE OF THE LAKE VĒVERU

Taxa	A score of Biological Monitoring Working Party (BMWP), taxa composition and occurrence among sampling dates and sites						
	BMWP	***Date***	***No. 1***	***No. 4***	***No. 5***	***No. 7***	***Total taxon***
Annelida							
Haemopis sanguisuga (Linnaeus, 1758)	3	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Bivalvia							
Sphaerium corneum (Linnæus, 1758)	3	02.07.21.			+		+
		17.09.21.					
		09.05.22.					
Gastropoda							
Planorbis carinatus O.F.Mueller	3	02.07.21.					+
		17.09.21.		+	+		
		09.05.22.					
Planorbarius corneus (Linnaeus, 1758)	3	02.07.21.					+
		17.09.21.				+	
		09.05.22.					
Bithynia sp. Leach, 1818	3	02.07.21.			+		+
		17.09.21.					
		09.05.22.			+	+	
Viviparus contectus (Millet, 1813)	6	02.07.21.			+		+
		17.09.21.					
		09.05.22.					
Valvata (Cincinna) piscinalis (O.F. Muller, 1774)	3	02.07.21.	+				+
		17.09.21.					
		09.05.22.					
Arachnida							
Hydrachnidia Gen. sp.	1	02.07.21.		+	+		+
		17.09.21.					
		09.05.22.			+	+	
Ephemeroptera							
Baetidae*, Cloeon dipterum* (Linnaeus, 1761)	4	02.07.21.			+		+
		17.09.21.			+		
		09.05.22.				+	
Odonata							
Anisoptera*, Libellula quadrimaculata* Linnaeus, 1758	8	02.07.21.					+
		17.09.21.					
		09.05.22.			+		
Anisoptera*, Brachytron pratense* (Muller, 1764)	8	02.07.21.					+
		17.09.21.				+	
		09.05.22.					
Anisoptera*, Brachytron pratense* (Muller, 1764)	8	02.07.21.					+
		17.09.21.				+	
		09.05.22.					
Zygoptera, Coenagrionidae, *Enallagma* sp. Charpentier, 1840	6	02.07.21.					+
		17.09.21.				+	
		09.05.22.					
Zygoptera, Coenagrionidae, *Erythromma najas* (Hansemann, 1823)	6	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Zygoptera, Coenagrionidae, *Ischnura* sp. Vander Linden, 1820	6	02.07.21.	+				+
		17.09.21.					
		09.05.22.					
Odonata *Gen*. sp	6	02.07.21.			+		+
		17.09.21.					
		09.05.22.					
Hemiptera							
Cymatia coleoptrata (Fabricius, 1777)	5	02.07.21.					+
		17.09.21.			+		
		09.05.22.					
Ilyocoris cimicoides (Linnaeus, 1758)	5	02.07.21.			+	+	+
		17.09.21.			+	+	
		09.05.22.				+	
Notonecta (Notonecta) glauca Linnaeus, 1758	5	02.07.21.				+	+
		17.09.21.					
		09.05.22.					
Nepa cinerea Linnaeus, 1758	5	02.07.21.			+		+
		17.09.21.					

Taxa	A score of Biological Monitoring Working Party (BMWP), taxa composition and occurrence among sampling dates and sites						
	BMWP	***Date***	***No. 1***	***No. 4***	***No. 5***	***No. 7***	***Total taxon***
		09.05.22.					
Coleoptera							
Dytiscidae, *Hyphydrus ovatus* (Linnaeus, 1761)	5	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Dytiscidae, *Hygrotus* sp. Stephens, 1828	5	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Dytiscidae, sp.	5	02.07.21.					+
		17.09.21.				+	
		09.05.22.				+	
Dytiscidae, *Cybister (Scaphinectes) lateralimarginalis* (De Geer, 1774)	5	02.07.21.			+		+
		17.09.21.					
		09.05.22.					
Hydrophilidae, *Hydrochara caraboides* (Linnaeus, 1758)	5	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Hydrophilidae, *Enochrus* sp. Thomson, 1859	5	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Noteridae, *Noterus* sp. Clairville, 1806	5	02.07.21.					+
		17.09.21.				+	
		09.05.22.				+	
Hydrophilidae, *Coelostoma (Coelostoma) orbiculare* (Fabricius, 1775)	5	02.07.21.			+		+
		17.09.21.					
		09.05.22.					
Haliplidae, *Haliplus* sp. Latreille, 1802	5	02.07.21.		+	+		+
		17.09.21.					
		09.05.22.					
Trichoptera							
Polycentropodidae, *Cyrnus flavidus* McLachlan, 1864	7	02.07.21.		+			+
		17.09.21.	+				
		09.05.22.					
Limnephilidae, *Limnephilus flavicornis* (Fabricius, 1787)	7	02.07.21.					+
		17.09.21.					
		09.05.22.			+	+	
Limnephilidae, *Limnephilus* sp. Leach, 1815 (*L. stigma*)	7	02.07.21.			+		+
		17.09.21.					
		09.05.22.			+		
Diptera							
Chironomus sp. Meigen, 1803	2	02.07.21.	+		+		+
		17.09.21.					
		09.05.22.	+				
Brachycera, Stratiomyidae, *Stratiomys* sp. Geoffroy, 1762	3	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Lepidoptera							
Larvae		09.05.22.			+		+
Crustacea							
Gammaridae, *Synurella ambulans* (Muller, 1846)	6	02.07.21.					+
		17.09.21.					
		09.05.22.				+	
Isopoda, *Asellus aquaticus* (Linnaeus, 1758)	3	02.07.21.					+
		17.09.21.			+	+	
		09.05.22.			+	+	

No. 1 (by Ekman grab), No. 4 (by hand net), No. 5 (by hand net), No. 7 (by hand net), + (occurrence)

The assessment of the ecological status of the Lake Vēveru was based on the littoral samples of macroinvertebrates in 2022 spring. The littoral zone of lakes plays a crucial and dynamic role in regulating the flows of nutrients and materials from the watershed [32], [20]. The ecological status of the Lake Vēveru by the Latvian Lake Macroinvertebrate Multimetric Index was estimated as good (Tab. 2). Only the Shannon-Wiener species diversity index characterises the lake as a bad ecological status lake because the dominant taxa in spring was *Asellus aquaticus*. It is noted that the isopod *Asellus aquaticus* shows the strongest association with high total phosphorus concentrations in lakes [32].

TABLE 2 INDICATORS OF ECOLOGICAL QUALITY ASSESSMENT OF THE LAKE VĒVERU

Indicators	**Parameters of assessment of ecological quality**		
	Value of index	***Ecological quality ratio (EQR)***	***Assessment of ecological quality***
BMWP[1] index Haemopidae (count 1) score 3 Bithyniidae (1) 3 Hydrachnidia (1) 1 Baetidae (1) 4 Libellulidae (1) 8 Coenagrionidae (1) 6 Naucoridae (1) 5 Dytiscidae (3) 5 Hydrophilidae (2) 5 Noteridae (1) 5 Limnephilidae (2) 7 Chironomidae (1) 2 Stratiomyidae (1) 3 Gammaridae (1) 6 Isopoda (1) 3	82	-	good (light organic pollution)
Total number of taxa	20	0.57	good
EPTBO[2] taxa	12	0.59	good
ASPT[3] index	5.40	0.68	good
Shannon-Wiener species diversity index H’	2.00 (1.70-2.30)	0.38	bad
Average EQR		0.55	good

[1] BMWP - Biological Monitoring Working Party
[2] EPTBO - Ephemeroptera, Plecoptera, Trichoptera, Bivalvia, and Odonata taxa
[3] ASPT - Average Score Per Taxon index

CONCLUSIONS

Overall, the ecological status of the Lake Vēveru by the Latvian Lake Macroinvertebrate Multimetric Index and by the macroinvertebrate composition of Lake Vēveru was estimated as good. The obtained data can be the basis for further research on disturbance impact on the lake ecological quality if the Lake Vēveru will be used for the industrial sapropel mining.

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Estimation of Salmonella spp. Prevalence and Diversity among Free-Living Turtles and a Zoo Collection

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Abstract. **Salmonellosis infection is caused by bacteria of the genus *Salmonella*. There are many pathways for the pathogenic bacteria to spread which is through contaminated food, water, and contact with animals. The research was conducted to detect *Salmonella* spp. carriage in free-living aquatic turtles and zoo turtles. Turtles are frequent inhabitants of zoos and the owners of a large number of bacteria in their outer skin and shell surfaces that under adverse conditions can multiply and lead to the development of infection. However, they are known to be a frequent source of *Salmonella* infection without showing signs of disease. The risk of human infection exists if personal hygiene is not followed after contact with a turtle. Identification of bacteria of the genus *Salmonella*, the main causative agent of the disease was determined by the standard method on chromogenic *Salmonella* LAB-Agar™ (BIOMAXIMA, Poland) agar. The inoculation was incubated under aerobic conditions at 37 ± 1°C for 72 h. Serotype (D serotype) was determined by serotyping in 11 from 16 (68.75%) Zoo inhabitants but not found in 25 free-living turtles. Our present research is of theoretical and practical value for the study of free-living turtles as well as from the collections of zoos under protection in Latvia and Europe. It is necessary to remember the possibility of infection with pathogenic bacteria.**

Keywords: bacteria, Chromogenic Agar, infection, salmonellosis, turtle.

I. INTRODUCTION

Salmonella spp. species are motile Gram-negative facultative anaerobes of the *Enterobacteriaceae* family that can survive for several weeks in a dry climate and several months in water [1]. Most of the described species are pathogenic. More than 90% of reptiles carry *Salmonella*, sometimes strains that are highly invasive and virulent to humans [2]. *Salmonella* spp. is divided into 60 serogroups and over 2400 serotypes [3-4].

Salmonellosis, one of the most common infectious diseases affecting humans and animals, is widespread worldwide. Non-typhoidal *Salmonella* spp causes 93.8 million cases of gastroenteritis and 155 000 deaths in humans every year [5]. Subspecies cause more than 99% of human *Salmonella* spp. cases I serotypes and about half by *Typhimurium* and *Enteritidis* serotypes [6]. Humans often become infected with salmonellosis through contaminated animal faeces or contaminated soil. Infectious disease can also be spread indirectly through human clothing that has been in contact with reptiles or through animal bites and scratches [7-9]. Most *Salmonella* spp. pathogenic infections in humans result in a mild, self-limiting illness characterized by diarrhoea, fever, nausea, and abdominal cramps [1,10]. However, the infection can circulate in the bloodstream, bone

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marrow, or nervous system, leading to sepsis and even death. These serious complications can be hazardous for infants, children, pregnant women, and older adults with weakened immune systems [11]. Recently, reports of salmonellosis in free-living reptiles have attracted increasing attention. Wild and captive reptiles, particularly lizards, snakes, and turtles, are considered natural reservoirs for a wide variety of *Salmonella* subspecies and serovars readily colonized by vertical and horizontal transport [12-13]. *Salmonella* spp. in reptiles is generally limited to the intestinal tract without invasion of extraintestinal tissues. Only under stress conditions, such as parasitism and trauma, can cause infectious pathological processes [14]. Most *Salmonella* spp. isolates that cause disease in mammals are *Salmonella enterica* subsp. *enterica*, which shed these bacteria in the faeces [15-16]. Reptiles are responsible for somewhere about 6% of sporadic cases of human salmonellosis [17]. Despite the presence of *Salmonella* spp. as a reptile pathogen and its significant zoonotic potential, there is a lack of information on the colonization of *Salmonella* spp. in free-living turtles and zoological collections. Therefore, the purpose of the present study was to reveal *Salmonella* spp. from the intestines of different turtle species in the group of the local Latgale Zoo and the territory of the Silene Nature Park NATURA2000 (Latvia) (N 55.690835°; E 26.788760°) (Fig. 1).

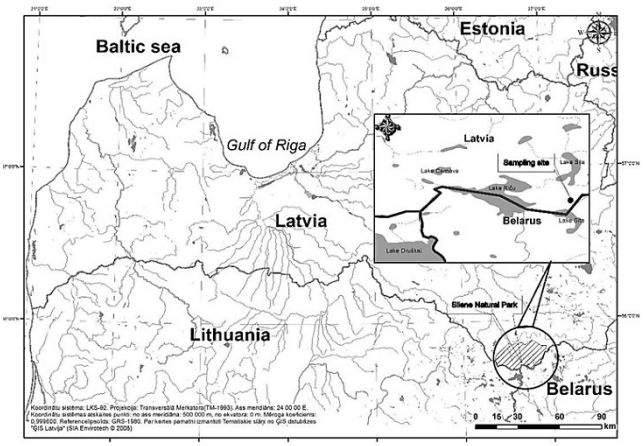

Fig. 1. Sampling site. Silene Nature Park NATURA2000 (Latvia) (N 55.690835°; E 26.788760°).

II. MATERIALS AND METHODS

Sample Collection

During the study period, 41 samples of cloacal swabs were taken from different species of turtles, namely 16 reptiles that were in zoological exposition - *Testudo* (*Agrionemys*) *horsfieldii*, *T. graeca*, and quarantined turtles *T.* (*Agrionemys*) *horsfieldii*, *Trachemys scripta*, *Emys orbicularis* (L.), living in the Latgale Zoo, as well as 25 samples of free-living tortoises – *Emys orbicularis*, *Trachemys scripta* from Silene Nature Park were tested for the presence of *Salmonella* spp. (Fig.1). Before sampling, the reptiles were examined and weighed by a veterinarian. Wild free-living animals, as well as from the zoo's collections, were subjected to physical immobilization. To collect material, the tips of sterile bacteriological swabs (CliniswabTS transport swabs) made of soft viscose fiber were carefully inserted into the cloaca to a depth of 2.5 cm and rotated for 10 s to obtain material from the cloaca. Next, the tubes were transferred to a preservative medium. Before taking a smear, the area around the cloaca was treated with sterile distilled water to prevent sample contamination. All tested reptiles showed no symptoms associated with the presence of *Salmonella*. Cloacal swab samples (CliniswabTS sterile transport swabs) from reptiles were collected immediately to avoid contamination with environmental materials and processed within 24 hours. All turtles were considered healthy at the time of sampling based on daily observations by zookeepers.

Cultivation conditions and identification of *Salmonella* spp. isolates

The collected material was delivered to the laboratory within 2 hours and inoculated on a differential medium: Chromogenic *Salmonella* LAB-Agar™ (BIOMAXIMA, Poland). All cultures were incubated for 72h at 37 ± 1°C under aerobic conditions. Based on studies carried out by the classical method of cultivating microorganisms [18-19], it was noticed that after incubation of the inoculations on the differentiated Chromogenic *Salmonella* Lab-AgarTM medium, the growth of bacterial colonies was visible after three days, which were a red colour, medium size, and round with smooth edges [20,30]. The *Salmonella* spp. isolates were stored at -20°C for further serotyping analysis. Individual colonies were selected, and Gram microscopy was performed. Gram-negative bacteria were isolated.

Serotyping of *Salmonella* spp. isolates

Serotyping is a subtyping procedure that separates strains of different microorganisms into various groups based on their antigenic composition [21]. *Salmonella* spp. serotyping methods are based on the determination of the phenotypic characteristics of microorganisms that are simple, fast, economical, and informative. For research, a pure *Salmonella* spp. culture was used, and incubation occurred for 18-24 hours on nutrient slant agar at a temperature of 37±1ºC. A drop of dissolved serum was applied to the glass with a pipette, and an entire loop of the studied culture was taken from the nutrient agar and placed at a distance of 2-3 mm from the drop. To determine the O-antigen, a culture should be taken from the upper part of the slant agar, and to determine the H-antigen, condensate from the lower growth area (the most mobile individuals). The culture was emulsified in serum for 1 min. The agglutination reactions were interpreted in accordance with the Kauffmann-White protocol [22]. The Kauffman-White scheme is a serological classification of *Salmonella* spp. according to antigenic formulas of *Salmonella* spp. serotypes is formed based on the immunoreactivity of two surface structures of *Salmonella*: the O-antigen and the H-antigen. The reptile

was marked *Salmonella* positive if collected samples were tested positive.

III. RESULTS AND DISCUSSION

Prevalence of *Salmonella* from cloacal samples of turtles

Salmonella species are widely distributed in domestic and wild animals and those living in captivity and most infections in humans are acquired from eating contaminated foodstuffs [16]. According to the Quality Control certificate, it was noticed that after incubation of the inoculations on the differentiated Chromogenic *Salmonella* Lab-AgarTM medium, the growth of bacterial colonies was visible after 72h, which were red in color, medium size, and round with smooth edges. Based on the culture medium Chromogenic *Salmonella* Lab-AgarTM certificate, it was noted that *Salmonella* was identified in samples (Table 1). The isolated cultures of *Salmonella* were identified with sera corresponding to serotypes: serotype B and serotype D. The results were summarized by O- serotyping, the serovar was determined according to the Kauffmann-White scheme. The isolated cultures have given a positive agglutination reaction with serum O:9. It has been receiving antigenic formula O:9, which denoted *Salmonella enterica* subsp. serotype (D serotype). Results revealed that *Salmonella* spp. was isolated from 11 turtles (68.75%) from Zoo turtle species but was not found in free-living specimens (Fig. 2).

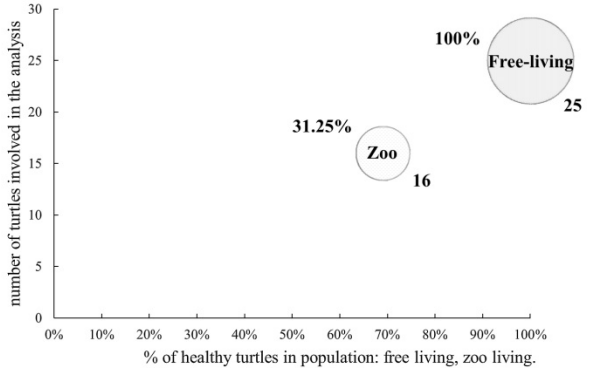

Fig. 2. % of healthy turtles in population: free-living, Zoo-living.

Potentially, there is a risk of *Salmonella* spp. infection from reptiles, so conducting a study on their carriage made sense. Overall, there are more than 2300 *Salmonella* spp. serotypes, and virtually all of them are considered pathogenic [23].In the present study, an isolate from turtles, *Salmonella* species *enterica* (serotype D), was presented using bacteriological and serological analyses. Serotypes differ from each other in the presence of particular antigens: O (thermostable somatic), Vi (thermolabile capsular), and H (flagellar) antigens [24].

The relatively high prevalence of *Salmonella* spp. in the zoological collection can be explained by the high population density in the exposure, minimal exposure to unsanitary conditions, and, possibly, contact with contaminated food. Fresh foods can also become a source of infection. Researchers [25] demonstrated a low prevalence of *Salmonella* spp. in captive turtles, with only one asymptomatic carrier out of 14 studied.

Infected animals often show no signs of illness. It is estimated that 90% of all reptiles carry and excrete *Salmonella* spp. in their feces [26]. The findings highlight the possible potential zoonotic risk when handling reptiles in a Zoo.

The distribution of *Salmonella* spp. in reptiles can reflect their environment [27]. Species of *Salmonella* are ubiquitous and persistent bacteria that can survive for several weeks in a dry climate and several months in water. *Salmonella* species survive well in environmental conditions and persist for up to 10 months. This persistence allows *Salmonella* spp. to be transmitted through environmental surfaces long after the reptile has been returned to its cage [4]. Thus, turtles are kept in aquariums with water that can be contaminated with *Salmonella*, which poses increased risks for infection transmission. Moreover, recent reports indicate that lizards and snakes, compared with turtles, maybe the most common source of reptile-associated salmonellosis in humans [26]. Based on a large number of literary sources and scientific studies, the following assumptions can be made: any clinically healthy animal (reptile) should be considered a potential source of salmonellosis. This highlights the importance of maintaining the strictest hygiene measures in zoological gardens and personal hygiene when in contact with the animal and its microenvironment. Transmission of *Salmonella* spp. from reptiles can occur through environmental pollution. The high temperature and humidity of the reptile house are likely to contribute to the growth and survival of *Salmonella* spp. in the environment [28]. Reptiles can also become infected by ingesting arthropod prey [29].

Particular attention should be paid to reptile salmonellosis in zoological gardens where people, especially young children, come into direct contact with reptiles. Thus, systematic monitoring of the prevalence of salmonellosis in reptiles in the zoological garden appears be necessary to reduce the risk of transmission of salmonellosis from reptiles to humans.

If *Salmonella* spp. is found in the culture, objectively evaluating the results is also necessary. Thus, healthy reptiles can be carriers of *Salmonella* spp., so if the animal does not have clinical signs of salmonellosis, it does not need to be treated. The use of antimicrobials in specific regimens can stop the shedding of *Salmonella* spp., but there is no evidence yet of how long the treatment effect will last. The choice of antibiotic is based on bacteriological culture data. The use of antibiotics can cause the development of microbial resistance. Also, re-infection is possible with insufficient sanitation of the environment (terrarium) of the reptile.

TABLE 1. DATA ABOUT INFECTION PREVALENCE, DETENTION CONDITIONS, WEIGHT, AND THE REASON FOR QUARANTINE OF *SALMONELLA* IN TURTLES FROM THE ZOOLOGICAL COLLECTION

Conditions of Detention	Tortoise Species	Weight (kg)	Average Weight (kg)	Reason for Quarantine	*Salmonella spp.*
1. Quarantine	Central Asian tortoise (*Testudo (Agrionemys) holsfieldii)*	1.601	1.011±0.42	coccidiosis, kidney failure	not detected
2. Quarantine	Central Asian tortoise (*Testudo (Agrionemys) holsfieldii*))	0.411		kidney failure	not detected
3. Exposition	Central Asian tortoise (*Testudo (Agrionemys) holsfieldii*)	0.705	0.615±0.06	–	not detected
4. Exposition	Central Asian tortoise (*Testudo (Agrionemys) holsfieldii*))	0.515		–	not detected
5. Exposition	Central Asian tortoise (*Testudo (Agrionemys) holsfieldii*))	0.625		–	detected
6. Quarantine	Long-necked tortoise (*Deirochelys reticularia*)	0.335	0.441±0.08	Avitaminosis A	detected
7. Quarantine	Long-necked tortoise (*Deirochelys reticularia)*	0.574		Avitaminosis A	detected
8. Quarantine	European pond turtle (*Emys orbicularis*)	0.339	0.379±0.03	Avitaminosis A	detected
9. Quarantine	European pond turtle s) *Emys orbicularis*)	0.419		Avitaminosis A	detected
10. Exposition	Greek tortoise (*Testudo graeca*)	0.663	0.684±0.06	–	detected
11. Exposition	Greek tortoise (*Testudo graeca*)	0.935		–	detected
12. Exposition	Greek tortoise (*Testudo graeca*)	0.741		–	detected
13. Exposition	Greek tortoise (*Testudo graeca*)	0.542		–	detected
14. Exposition	Greek tortoise (*Testudo graeca*)	0.605		–	detected
15. Exposition	Greek tortoise (*Testudo graeca*)	0.620		–	detected
16. Quarantine	Pond slider (*Trachemys scripta*)	0.621	0.621	rachitis, avitaminosis D	detected

Salmonella spp. has a high serological diversity and a high zoonotic potential, which may pose a risk to other animals and humans [30].

IV. CONCLUSIONS

This study provides the first set of scientific data on estimating *Salmonella* spp. prevalence and diversity among reptiles in a local Latgale Zoo and the territory of Silene Nature Park NATURA 2000 (Latvia) (N 55.690835°; E 26.788760°). In this study, only the *Salmonella enterica* subsp. (D serotype) was represented and obtained from turtles in Latgale Zoo (Latvia). Hygiene practices would also be recommended to personnel employed in the zoological gardens in order to minimize the risk of infection from turtles to humans. Visitors to the zoological parks should be informed about the potential risks of maintaining these animals. Immunocompromised individuals, pregnant women, and young children should avoid direct and indirect contact with reptiles.

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The Factors of Green Marketing Affecting Consumer Purchase Intention in Latvia

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Abstract. **Remarkably, the percentage of environmentally friendly practices used in marketing is growing. The understanding of how to use environmentally friendly practices is the primary cause for this high grade. The vast majority of customers have a good understanding of green technology and the beneficial influence that they have on the environment. According to the findings of a recent research, customers' awareness of environmental concerns may be increased via eco-friendly marketing strategies. Consumers in Latvia have placed a considerably greater emphasis on environmentally responsible practices as a means of marketing. Research goal: to identify the factors of green marketing affecting consumer purchase intention in Riga, Latvia. Research method: a survey. For the purpose of processing the data in the SPSS environment, the following methods were utilized: descriptive statistical analysis, analysis of reliability, analysis of factors, analysis of regression. Main findings: due to the very fluid and complicated nature of the current business climate, this study investigates the facts and realities surrounding green customers.**

Keywords: Green marketing, green purchase, consumer purchase intention, consumer attitude.

I. INTRODUCTION

Things need to be consumed, destroyed, replaced, and rendered obsolete at various phases where the link between man and nature has unleashed a paradox of the depletion of the ozone layer and the cause of degeneration. Since the beginning of the 21st century, environmental challenges such as global warming, the depletion of natural resources, pollution, and shifting climate patterns have emerged as critical problems that threaten the continued existence of society. The government and environmentalists have raised a significant problem that, as a responsible member of society, you are obligated to work toward resolving. Every individual society is responsible for making it their primary mission to bring about significant social change. There will be no progress made in greening the economy unless or until there is a shift in the attitude that people have about the environment. It is no longer possible to tackle the world's environmental problems just via technological advancement; rather, this challenge calls for a sea change in attitudes, business patterns, consumption patterns, perceptions and behaviors, marketing specialists, and business strategies.

The process of designing goods and services and advertising them in order to fulfill the requirements and wishes of customers at a reasonable price and with a low effect on the environment is referred to as "green marketing." Given that there are only so many resources available and an infinite number of things that people desire, it is essential for the marketing department to make effective use of those resources while minimizing waste and working toward the overall goal of the firm. Therefore, one should predict the rise of green marketing. In the end, green marketing examines how marketing operations make use of these constrained resources, all while meeting customer demands, both on an individual and industry level, and working toward the achievement of the organization's primary goal. As a result of the current state of the market, a greater number of businesses than ever before are making an effort to launch their strategic activities in a socially responsible way, putting a focus on environmentally friendly items to make green consumption easier. To be more specific, the need for this study is to identify and explore the factors influencing green marketing in Latvia and its impact on green purchase intentions, with the end goal of estimating the structural relationship between green marketing strategies, consumer attitudes, and purchase intentions of customers. The goal of the current research is to identify the factors of green marketing affecting consumer purchase intention in Riga, Latvia. To attain this goal the following research

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tasks were set: (1) to analyze theoretical background of green marketing and customer purchase patterns; (2) to create an empirical research instrument (questionnaire); (3) to perform a survey and interpret results.

II. MATERIALS AND METHODS

Business organizations have changed their practices toward the creation and use of environmentally friendly goods, along with consumer behavior globally. Academics have also shown a great deal of interest in environmental concerns. Numerous researchers have discovered that customers have changed their patterns of purchase and now prefer environmentally friendly items over conventional ones [1]. In order to properly create and deploy market solutions to meet those objectives, marketing professionals and academics are now working to identify and understand green customers and their wants. Green goods, which are thought to have a minimally negative influence on the environment, are now required of businesses. In order to safeguard the environment by minimizing the negative effects of product usage on the environment, marketers are marketing these green goods and pushing people to buy them instead of traditional items. In addition to using more stringent emission controls and obtaining raw materials in an environmentally responsible manner, these techniques entail the manufacture of goods using organic ingredient [2].

John Grant, in his well-known work "The Green Marketing Manifesto", built a model for the transition to a "true" green business [3]. The author identifies the following levels of eco-logicalization:

- Eco-friendly (first level): a set of new standards. This level is implemented through communication.

- Greener (second level): sharing responsibility. Implemented through collaboration.

- The most eco-friendly (third, highest level): support for innovation.

Thus, Green Market includes a wide range of activities, including product modification processes, changes in production, packaging, and advertising [4].

Green marketing" is a method for promoting a product by highlighting the environmentally friendly nature of the business that makes or sells the product. Ecological advertising should be at the core of each business's strategy. It not only manages the four Ps of marketing (product, place, price, and promotion), but also applies public policy procedures without limits. Ecological marketing is inextricably intertwined with the study of material and energy flows in industrial systems, as well as other aspects of ecological sustainability such full producer accountability, life-cycle analysis, resource and material fluxes, and eco-efficiency. As a result, "green marketing" is a vast field that provides invaluable insights into business tactics and regulatory mandates. From a managerial or organizational standpoint, environmental considerations must be baked into every stage of the marketing process, from product development to consumer usage through final disposal. Green marketing postulates that customers will shift their purchasing habits toward companies that demonstrate a commitment to social and environmental responsibility. Green marketing, which has traditionally focused on environmental concerns, has lately prompted businesses to expand their marketing efforts to include a sustainability component. The predominant focus is now on the societal, economic, and environmental factors. Despite the fact that the "green market" is just a subset of the overall market [3]. Because of this, Green Marketing is presently operating in the Green industry, where it has helped to create a fair number of jobs and contribute significantly to the economy. In the business sector, products that save energy and resources while reducing or eliminating the usage of hazardous agents and waste are often referred to as "green" or "eco-friendly," despite the fact that no one customer can be said to have zero influence on the environment.

As per green, sustainability is a growing management principle that prioritizes strategies that both protect the planet and boost bottom line results for businesses. It's a lofty but difficult social goal, and many businesses are responding by taking steps to better secure and protect the environment. green marketing's strategic potential is expanded. "a complete and responsible strategic management strategy that identifies, forecasts, fulfills, and meets stakeholder requests for an appropriate reward that does not adversely influence human or natural environmental well-being." This rationale emphasizes the value of a long view and the significance of non-customer stakeholders in the success of ecological marketing [5]. There has to be more thought put into environmental marketing than just using an ecological marketing plan or selling "green" products. The term "ecological" should be used to describe both the finished product and the manufacturing process. Research and development needs need a close inspection of the ecological marketing idea. Taking first place in the Green Marketing competition is a chance for consumers to have a positive impact on the world and give their businesses a leg up in the face of intense competition.

P. Baldwin also found that, in response to growing global concern about the environment, many companies are promoting their products using eco-friendly advertisements. By emphasizing the benefits of ecologically preferable products, green advertising hopes to convince customers to buy them. It has been shown that advertising that emphasizes environmental concerns may change consumers' attitudes and encourage them to buy greener products [6].

According to F. Rubik and others [7], the international efforts to implement environmental labels are only getting started. There is debate about whether or not ecolabels really help businesses. Eco-labels may benefit shoppers, but they may also lead to a market for products with more damage than is socially optimal. make the switch. Eco-labels can help consumers to make an educated choice and find all necessary information faster. are an informative decision support tool for consumers

Numerous studies have revealed no association between customers' attitudes and their environmental

behavior and have concluded that consumers' attitudes are influenced by their knowledge and personal experiences. However, there are discrepancies in the mentality of consumers and their conduct when it comes to green consumerism. Consumers' knowledge of the environment and environmental consciousness are key components of their green purchasing behavior. They suggested a model in which personality characteristics, cognitive factors, and situational factors were connected with environmentally responsible behavior and further revealed that motivation to act toward the preservation of the environment is directly linked with consumer personality components. They suggested the following factors as being correlated with environmentally conscious behavior: personality traits like perception, environmental attitude, environmental responsibility, values, and commitment; cognitive traits like knowledge and awareness; demographic traits like age, gender, income, and educational attainment; and external traits like influence from outside or situational factors, group dynamics [8] – [9] – [10] – [11].

It has been discovered that customer demand and perception for green goods are unequal. The buying habits of customers may be influenced by a number of variables. These factors include consumer values, attitudes toward the environment, knowledge of environmental issues, willingness of consumers to take action to protect the environment, availability of green products, prices of green products [12], perceptions of the efficacy of green products, perceptions of environmental performance, and firm commitment, among others. The motivations behind customer purchases and outside influences have a role as well.

It is discovered that there are still significant obstacles in the way of more environmentally friendly purchasing patterns spreading. According to D`Souza and others, Alwitt & Pitts, Syal and others, consumers' concern for the environment has an indirect impact on their purchasing decisions regarding green products. This effect is mediated by consumers' attitudes toward the green features of the individual products and their perceptions of the effects using those products will have on the environment. Low association between consumer attitudes and environmentally friendly behavior was reported by Alwitt. Consumers are always found to place the most value on a product's or service's price, which is one of the most important factors in determining whether or not to make a purchase [13]-[14]-[15].

As a quantitative approach to determining the interrelations and dependencies between green marketing and consumer purchase intentions in Latvia, this portion of the research will use a survey technique with a standard questionnaire preparation to ensure reliability and validity.

Survey research has been the most accepted due to numerous restrictions including time constraints and convenience involved in the technique, particularly in the domain of psychological research. The researcher also has the advantage of learning about the respondent's cognitive process, which is not feasible with the observation approach. In addition to the study, the researcher has thought about manufacturing sectors and their environmentally friendly goods.

Through the use of green marketing variables, the questionnaire aims to identify the most significant consumer group's attitudes and green purchasing intentions toward green goods (Green Innovation, Green Promotion, Green Packaging, Green Pricing and Eco Labeling).

Scale validation- Likert scaling of the summarized rating was used for the questionnaire's scale validation. The Likert scale, which ranges from Strongly Agree to Strongly Disagree, is used. Customers must choose one of five replies that best describes their position on each item. For positive things, the response options are 1 = Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, and 5 = strongly Disagree; for negative items, the response options are inverted.

Study population- Riga, which has a notable attitude toward green goods, is included in the study's population. Urban communities and those that prioritize environmental concerns and eco-friendly goods are both included in these states. This study's emphasis on Riga has proved useful in evaluating consumers' purchasing intentions and attitudes toward environmentally friendly items.

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Selection of the sample- A sample is taken from a sampling frame. A sampling frame is the predetermined population that has been identified in the research from which a sample must be drawn, and sampling units are the components taken into account or chosen from a population sample. It was observed that the sample matched the population parameter of the research variable's population variance and expected degree of error. The sample size was determined based on each answer, assuming an expected level of 5% error in the

estimates of the means using the variance information from the pilot research. The sample size is thus set at 113, while the number of sample consumers was 152.

TABLE 1 STRUCTURE OF THE QUESTIONNAIRE

I section: Respondent Demographic question		
Q1	Gender of respondents	Closed: 2 alternatives
Q2	Age of respondents	Closed: 4 alternatives
Q3	Education qualification	Closed: 3 alternatives
Q4	Preference in terms of support green method	Closed: 2 alternatives
II section: General questions		
Block 1	Green motivation	3 statements 5-7
Block 2	Green promotion	3 statements 8-11
Block 3	Green packaging	3 statements 12-14
Block 4	Green pricing	3 statements 15-17
Block 5	Eco labels	4 statements 18-21
Block 6	Consumer attitude	4 statements 22-25
Block 7	Purchase intentions	3 statements 26-28

Table 2 represents the construction of survey variables.

TABLE 2 STRUCTURE OF THE QUESTIONNAIRE

Block number	**Block theme**	**Survey variables**
1	Green motivation	3
2	Green promotion	3
3	Green packaging	3
4	Green pricing	3
5	Eco labels	4
6	Consumer attitude	4
7	Purchase intentions	3
Total		27

The method used for data processing was factor analysis.

This survey comprised 152 respondents in total, and a sample of 152 was selected to ensure that the study was completed as planned, implying 152 respondents from the city of Riga. The population of the research includes Riga, which has a significant attitude toward green products. These states include both urban populations and those that stress environmental issues and eco-friendly items. The focus of this research on Riga has been beneficial in assessing customers' purchase intentions and attitudes toward ecologically friendly goods. These include both normal IT employees and employers. Entrepreneurs were chosen because they are acquainted with the organization's objective, vision, and neutrality of green marketing, as well as their ability to forecast the organization's future. The author sent a link to a Google form to responses through LinkedIn.

Socio-demographic characteristic of the research sample: gender, age, and education were used to examine survey participants' demographics. The survey participants' demographics were assessed based on their gender, age, education and work position. Out of 152 responders, 56.58% were male and 43.42% were female. It is apparent that male workers outnumber female employees in Riga's information technology industry. The most number of respondents fall in age group of 26-35 and which is 52.63%. Further, followed by age group 19-25 and which is 30.26% and further it is followed by age group 36-49 and above 50. 38.16% of respondents were IT specialists, with the remaining 30.92% being data managers. Following that were 17.31% of technicians and 13.82% of IT personnel. 57.89% of participants have undergraduate degree, 32.89% of participants have postgraduate degree and 9.21% of participants have diploma.

III. RESULTS AND DISCUSSION

The authors analyzed descriptive statistics according to the sections in survey questions; those are green motivation, green promotion, green packaging, green pricing, eco labels, and consumer attitude and purchase intentions (see Table 3).

TABLE 3 KMO BARTLETT'S TEST

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.949
Bartlett's Test of Sphericity	Approx. Chi-Square	2668.293
	df	210
	Sig.	.000

The approved value of KMO is 0.500, and here it is 0.949, indicating that the goods were adequate. The next step is to undertake factor analysis since it fulfills more than the necessary adequacy. Factor analysis entails multiple techniques and sophisticated tabular representations, which are all described here (see Table 4).

TABLE 4 TOTAL VARIANCE EXPLAINED

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.505	59.549	59.549	12.505	59.549	59.549
2	1.418	6.751	66.300	1.418	6.751	66.300
3	.875	4.167	70.468			
4	.666	3.170	73.638			

5	.639	3.041	76.679			
6	.577	2.746	79.425			
7	.535	2.546	81.971			
8	.485	2.309	84.280			
9	.385	1.832	86.112			
10	.366	1.742	87.854			
11	.337	1.607	89.460			
12	.325	1.549	91.009			
13	.312	1.485	92.494			
14	.288	1.370	93.864			
15	.265	1.260	95.124			
16	.227	1.080	96.204			
17	.190	.907	97.111			
18	.176	.837	97.948			
19	.158	.753	98.701			
20	.144	.686	99.387			
21	.129	.613	100.000			
Extraction Method: Principal Component Analysis.						

Table 4 shows the total variance that was accounted for via examination of the essential components. The eigenvalue, which is the amount of change in the starting variables accounted for by each individual element, may be found in the Total column. This number is included in the table. The column labeled "percent of Variance" represents the amount of variation that can be ascribed to each component as a percentage of the overall variance across all variables. The beginning starting point for the number of factors in a factor analysis is the same as the first starting point for the number of variables. We will not, however, make the assumption that all 21 variables are always the same. Only the first two variables will be maintained in this situation. Consider the Eigenvalues, which may be seen as the initial variances of the variables. The variables are standardized since the author performed the component analysis using a correlation matrix. This means that each variable has a variation of one, and the total variance equals the number of variables used in the research, which in this case is 29. The study's author used a correlation matrix. The key pieces that comprise this column may be identified. Following the first component, this explains as much of the remaining variation as possible, follows the second component, which also explains as much of the remaining variation as possible, and so on. The first element always explains the greatest amount of variation (and hence has the highest eigenvalue). As a result, each consecutive component will be responsible for a gradually less share of the overall variation. This column shows the contribution of each component to the overall variance as a percentage of the total variation. The next column shows the total percentage of difference that can be accounted for by the current variable as well as all variables that came before it. The eigenvalues are shown in the next column, Extraction Sums of Squared Loadings. The first component, which always explains the most variation (and hence has the highest eigenvalue), is followed by the second component, which explains as much of the remaining variance as is realistically feasible, and so on. As a result, each subsequent component will account for a decreasing proportion of the variance. This column displays the variation that may be assigned to each individual component of the whole as a percentage of the overall variance. This column displays the total percentage of difference that may be ascribed to the current variable as well as any previous variables. Because the major purpose of component analysis is to explain the inter-correlation that occurs between the variables rather than to discover the factors, assessing variance and covariance is significantly more important than comparing the mean. To do a factor analysis, the software program SPSS was utilized; as a result, all twenty-one questions have a common variance estimated by SPSS software; nevertheless, each question has its own variance as well as its own error variance. From total of 21 variables two factors have been classified: factor 1 - green motivation, green promotion, green pricing; factor 2 – green packaging, eco labels.

Figure 1 depicts a scree plot graph that exhibits the eigenvalues versus the factor number. The scree plot examines the overall value of the first eigenvalues as well as the percentage of variation. The scree plot shows that the line from the second component is flat, indicating that each consecutive factor accounts for less and less of the total variation.

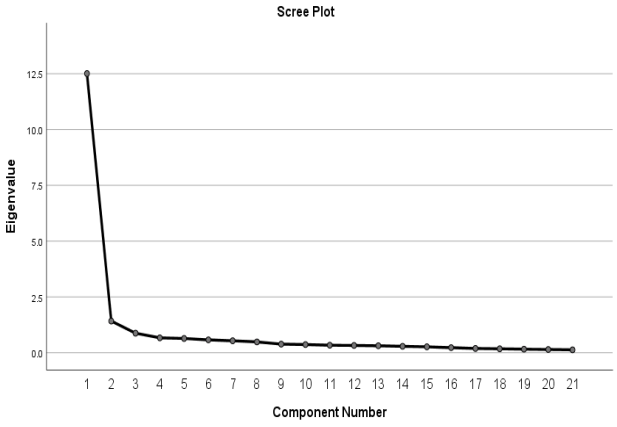

Fig. 1. Scree plot.

Table 5 presents the rotated component matrix.

TABLE 5 ROTATED COMPONENT MATRIX

	Component	
	1	2
eco-labels provide sufficient information regarding products.	.783	
green labels can change my attitude towards green purchase intentions.	.773	
It is good to buy products with recycled and usable packaging on the product.	.768	
ecological products build by positive attitude towards product.	.754	
Eco-labels are eye catching on green products.	.744	
higher price if the eco-friendly gives more health benefits when compared to normal products.	.738	
organic labels on products	.725	
the information on packaging is an important measure.	.702	
to purchase this product because of its environmental concern.	.687	
paying a higher price if the eco-friendly variant performs better than a normal brand.	.685	
eco-labels are easy to read and influence my purchase decision.	.666	
Attractive Ecological Packaging influences my purchase decision	.664	
paying a higher price as buying an ecofriendly brand is better than buying an inexpensive product that harms the environment.	.657	
Biodegradable packaging is an important consideration for me.	.644	.
taking chances in buying new, different and ecological products.		.824
I see an innovative or modified product		.815
designed with the environmental concern.		.753
Green Products is using eco friendly technology.		.746
Green Products is low fuel-using.		.689
Green Products are creative and attractive.		.682
Green Products are healthier & safer.		.662
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.		
a. Rotation converged in 3 iterations.		

According to the nature of the survey questions, the above table is indicated without the section name. This procedure really aids in comprehending factor reduction. Table 17 illustrates the factor loadings and how all the variables are weighted for each factor, as well as the correlation between the variables and the factor. The author utilized the option to eliminate correlations less than 0.50. This step clarifies the result, and the author assumes that the low correlation value is of no utility. The columns beneath the component option are the extracted rotated factors. According to the SPSS footnote beneath the table, two components were retrieved after three rounds of the varimax rotation algorithm. These are the considerations that researchers are most concerned about. The first point is that eco-labels give enough information about items; green labels may improve my attitude toward green purchasing intentions. It is preferable to purchase items with recyclable and reusable packaging; ecological products are built on a favorable attitude toward the product. Green items with eco-labels stand out. increased cost If the eco-friendly variant performs better than a standard brand, eco-labels are easy to read and influence my purchase decision, Attractive Ecological Packaging influences my purchase decision, paying a higher price as buying organic. We observe a novel or modified product, developed with the environment in mind, Green Products are employing environmentally friendly technologies. Green Products use less fuel and are more inventive and appealing. Green products are healthier and safer to use. It displays the reduced factors of 21 variables. The decreased factor includes the relevance of green marketing as well as the variables that support it. The identified factors are green packaging and green promotion.

IV. CONCLUSIONS

This research has identified different factors of green marketing that affects consumer purchase intention and those are classified in to most value factors and least value factors and most value factors are green packaging and green promotion and whereas the least value factors are green motivation, green pricing and eco labels. Because of the enormous influence that green motivation, green advertising, green packaging, green pricing, and eco labeling have on the customer attitude towards purchasing.

The results prove the idea that green marketing qualities (such as green innovation, green packaging, green pricing, eco labeling, and green promotion) tend to influence consumer preference toward environmentally friendly items.

According to the research the most value load factors are the following : eco-labelling (giving sufficient information); recycled packaging; higher pricing.

Even if environmentally friendly commerce is in its infancy in Latvia, it is possible for a green marketing campaign to be effective in positively influencing consumer attitudes and intentions to make purchases.

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Digital Twin: Orchard Management using UAV

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Abstract. **Orchard management can benefit greatly from the use of modern technology to reach higher yields, decrease costs and achieve more sustainable farming. Implementation or such a smart farming approach into orchard management can be realised via application of unmanned aerial vehicles (UAV) for data collection and artificial intelligence (AI) for yield estimation and forecasting. On top of that, a digital twin of the orchard can be implemented to represent the physical system of the orchard in the digital format allowing implement modern data-driven decision-making based on fruit-growing automation.**

The aim of this study is to present a digital twin based on application of UAV and AI for orchard management that is being developed as part of a research project lzp-2021/1-0134. At this moment, we are developing a user-centred design which is oriented to satisfy horticulture specialists' needs for an autonomous monitoring system and to help them in decision-making. Within the framework of this study an enterprise model of orchard management is designed, which supports the digital twin concept and provides autonomous orchard monitoring. The study is scoped with subjects: apples, pears and cherries, and yield management based on orchard monitoring using UAV.

Keywords: cyber-physical system, digital twin, data-based decision-making, smart horticulture.

I. Introduction

Due to the impact of artificial intelligence and robotization development, the modern fruit-growing industry overcomes business process transformations to continue with the new technologies and improve production workflows. Therefore, it is a problem to model new agribusiness processes, which new technologies like digital twins and artificial intelligence will support. The artificial intelligence is already well known, but the digital twin concept requires some introduction. The digital twin is a virtual representation of a physical object or process capable of collecting information from the real environment to represent, validate and simulate the physical twin's present and future behaviour [1]. The digital twin is a modern approach to design management systems based on cyber-physical system application. Cyber-physical systems integrate sensing, computation, control and networking into one infrastructure, which must be human- and business-centred. As a result, new approaches to analyse and design modern management systems must be developed to overcome their complexity and multidisciplinary nature. It is a key technology of modern data-driven decision-making for complex system management based on industry robotization. It can be considered a type of gamification paradigm evolution resulting from boundary blur between real and virtual worlds due to the development of IoT and BigData technologies, which digitise our world. Digital twin based recommendation system triggers activities, which must be accomplished to achieve a set of business goals.

Pylianidis et al. (2021) identified 28 use cases of the digital twin application in agriculture developing their comprehensive literature review [2]. From the similar projects, the "Digital-Twin Orchard" can be mentioned [3]. Its authors created a system that can create a digital twin for every tree in an orchard by using spinning 3D cameras. This digital-twin enables the improvement of production and dynamic prediction of disease, stress and yield gaps using an end-to-end AI platform. Another related project is OliFLY application, by using it,

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accompanied by real-time imaging of pest traps in the orchard, olive growers are able to monitor olive fly occurrence in the orchards from their homes or offices [4].

Smart horticulture leverages modern information and communication technology to advance high yield, cost-effective and sustainable agriculture through collection of data on environmental parameters, smart processing of the data and other activities that support data-driven decision making. Such smart horticulture services can be achieved via application of UAV for data collection activities and AI for data processing. However, the new technologies change the agribusiness processes and request overthink the old-school of fruit-growing processes, asking for new competence and decision-making workflows. The previous models of commercial orchards must be upgraded and new enterprise models must be developed.

Nowadays, we look at entrepreneurship from an engineering point of view proposing the enterprise engineering discipline (Fig.1) - the triangle, which joins three cornerstones: enterprise modelling, business modelling and cyber-physical system modelling. Enterprise modelling is a discipline, which designs the structure of enterprise to provide service for a specific domain, segment or niche. Business modelling describes processes and logistics which support the designed structure of the enterprise. Meanwhile, cyber-physical system modelling is infrastructure which supports developed business models. At the same time, the spiral model (Fig.1) shows validation and improvement of each discipline's milestones to harmonise them and to obtain stronger synergy for enterprise goal achievement.

Fig. 1. Enterprise engineering (EE) triangle: EM - enterprise modelling, BM - business modelling, CPSM - cyber-physical system modelling.

Capability Driven-Development (CDD) is one of the enterprise modelling methodologies, which proposes effective business process organisation through enterprise capabilities [5]. ARTSS methodology is developed as an extension of the CDD considering the digital twin paradigm [6]. ARTSS is more compatible with eco-cyber-physical system development, because ARTSS provides a meta-class "Service", which is more suitable for the description of digital tools like image classification or autonomous systems like data collection using UAV.

The management of business goals can be achieved through the application of key performance indicators (KPIs) and measurement properties. KPIs motivate workers to achieve better results while displaying enterprise scores of success. Meanwhile, the measurement properties describe the current environment, - they must help to make correct decisions to achieve better results considering KPIs. If KPIs and measurable properties can be measured and expressed in the quantified form, then it is possible to provide a decision-making solution, which is based on the artificial intelligence application. These relations can be defined using some modelling methodologies and provided to users through a management program based on the digital twin paradigm.

Our project lzp-2021/1-0134 is directed to develop a digital twin for orchard management, which is based on application of UAV and AI. At the end of the project, we plan to achieve a technology readiness level "TRL7", which considers a prototype validated using the LivingLab approach. At this moment, we are developing a user-centred design which is oriented to satisfy horticulture specialists' need for an autonomous monitoring system for orchard management, which can support their decision-making.

The aim of the study is to present a digital twin based on application of UAV and AI for orchard management that is being developed as part of a research project lzp-2021/1-0134.

We applied an enterprise modelling methodology called ARTSS to model a smart orchard management system and structured expert knowledge to measure the environment using artificial intelligence and UAV with the objective to providing advantageous adjustments for fruit-growers.

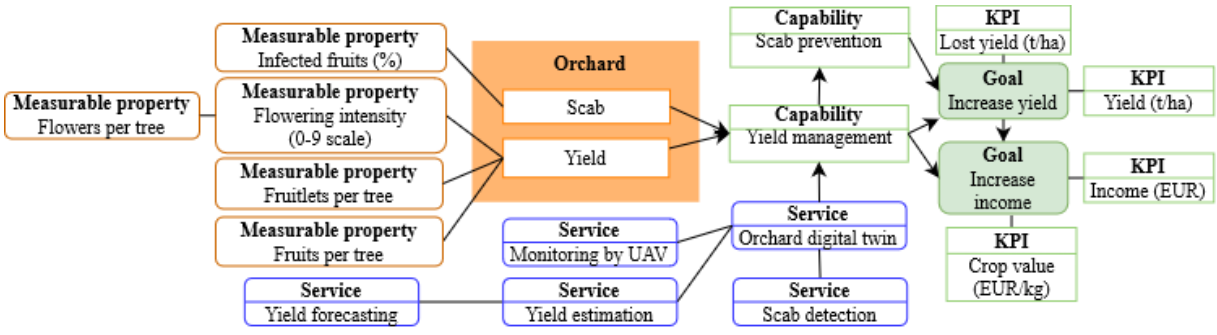

Fig. 2. Capability model of digital shadow for orchard management.

II. Materials and Methods

The scope of project lzp-2021/1-0134 was developed using a brainstorming approach based on the review of modern studies. We selected two use cases for the orchard digital twin: 1) scab detection; 2) yield estimation and forecasting. The scab detection was selected, because we had AI technology for scab detection developed in project lzp2019/1-0094 [7]. Meanwhile, the decision to include yield estimation was mainly impacted by the comprehensive analysis made by the Chinese Academy of Agriculture Science [8].

Capability Driven Development is an enterprise modelling methodology which represents enterprise capabilities, where a capability is an ability and capacity that enable an enterprise to achieve a business goal in a certain context. A focus area of the methodology is making the designs of management systems more accessible to business stakeholders to articulate their business needs more efficiently [9]. To achieve the aim of the study, we applied ARTSS notation to design a capability model of the orchard digital twin. ARTSS is a branch of CDD [6]. ARTSS provides a meta-class "Service", which is more suitable for the description of digital tools like image classification or autonomous systems like data collection using UAV.

The stages of plant phenology used in the model development were described according to BBCH scale [10][11]. The flowering intensity was estimated on a scale from 0 (no flowers) to 9 (all fruiting branches are abundantly flowering).

III. Results and Discussion

The digital twin created recommendation could be used as a decision support system tool. It could be useful in several directions: yield amount predictions, harvest time estimation, production management according forecast, modelled amount of fruits influencing fruit quality, growth and yielding regularity, as well as pest influence on the outcome of sales possibilities (dessert, processing etc.).

The developed capability model presents the orchard digital shadow, which provides a functionality to monitor orchard remotely using UAV, where yield estimation and scab detection is achieved using AI. Speaking about modern solutions of AI, measurable properties like flowers, fruitlets, fruits, leaves and scab caused damages on leaves and fruits can be detected using convolution neural networks with architecture like YoLoV5 or YoLoX. The application of convolution neural networks (CNNs) is a data-hungry approach, which requires a large collection of labelled data, images or video records, which are applied for their training.

However, the industrial progress has introduced plenty of tools like LabelStudio, Roboflow or MakeSense, which simplify image annotation process providing a user-friendly environment including automatic classification by using pre-trained CNN models. In addition, AI experts and data scientists are working on methodologies, which are intended to overcome data collection expenses.

Table 1. Examples of adjustment to environment changes for apples and pear

Measurable properties	Capability	Adjustment (recommendation)	Impact on KPI
Apples & flowering intensity > 5	Yield management	Thinning of flowers and protecting flowers from spring frosts by active protection measures.	Provides stable yields year by year & adequate fruit quality. Increases crop value.
Apples, Pears & flowering intensity < 5	Yield management	Reduce nutrient supply, reduce moisture level and irrigation rates down to 70% of optimal moisture level, introduce growth regulation media and technologies.	Reduce growth and promote induction of the flower buds, their development for the next cycle at the low yield condition.
Apple, Pears & fruitlets of off year	Yield management	Reduce nutrient supply, reduce moisture level and irrigation rates down to 70% of optimal moisture level, introduce growth regulation media and technologies.	Reduce growth and promote induction of the flower buds, their development for the next cycle at the low yield condition.
Apples & infected fruits > 0%	Yield management	Plan harvest strategy: for storage (sorting after storage, partly for storage sorting during harvest, only for juice) and sales.	Decrease of lost yield during storage & increase of income.
Apples & infected fruits > 0%	Scab prevention	Decide and perform plant protection measures against scab.	Decreases lost yield & increases productivity in next year.
Apples & fruits per tree	Yield management	Timing of harvest including planning of workers.	Decreases lost yield during harvest and storage.

Flowers/ fruitlets/ fruits per tree	Yield management	Prognosing harvest organisation, fruit sale and orchard management for next season.	More stable and predictable productivity, increased crop value and income.

TABLE 2. EXAMPLES OF ADJUSTMENT TO ENVIRONMENT CHANGES FOR CHERRIES

Measurable properties	Capability	Adjustment (recommendation)	Impact on KPI
Cherries & flowering intensity > 5	Yield management	Protect flowers from spring frosts (when forecasted) by active protection measures (heating, watering, spraying, covering etc.).	Decreases lost yield & increases yield.
Cherries & fruitlet density ≥ 6 fruitlets per 10 cm of branch & BBCH = 72 (sepals beginning to fall)	Yield management	Provide the nutrients and water for the trees near the optimum level by additional irrigation and leaf fertilising until the harvest.	Decrease of lost yield (dropped fruits) & increase of high-quality yield. Increases crop value.
Cherries & BBCH = 75 (fruit about half of final size)	Yield management	Assess the expected yield, plan harvest organisation and fruit sale.	Decreases lost yield (over ripened, rotted fruit) & increases income.
Cherries & BBCH = 81 (beginning of fruit colouring)	Yield management	Protect yield from bird (covers, bird repellent devices)	Decreases lost yield (bird damaged fruit) & increases income.
Cherries & BBCH = 87 (fruit fully coloured)	Yield management	Test the fruit taste and firmness, and start to harvest.	Decreases lost yield (over ripened, rotted fruit) & increases income.
Flowers/ fruitlets/ fruits per tree	Yield management	Prognosing harvest organisation, fruit sale and orchard management for next season.	More stable and predictable productivity, increased crop value and income.

Some examples of such methodologies include:

- augmentation algorithms, which automatically generate modified images and search for the best;
- policy for image transformation like AutoAugment;
- transfer-learning algorithms, which improve recognition quality retraining pattern-CNNs trained on adjacent domain datasets or extra huge datasets like ImageNet and COCO;
- Table 1. Examples of adjustment to environment changes for apples and pear, Table 2. – adjustments for cherries;
- active training, which focuses on optimization of human resources using spiral model for image annotation, requesting supervision only when it is required;
- weak supervision, which overviews methods related to the application of low-quality labelled data obtained using unsupervised methods or through crowdsourcing, or joining datasets with different classification hierarchy or annotation formats.

As the vertical development of the modelled system (see Fig. 2), the concept of trustworthy AI is the future challenge considering industrial evolution from Industry 4.0 to 5.0, which proposes cobots and social safety in cyber-physical space. This direction mainly depends on the scientific revolutions in the field of AI.

The horizontal development is more perspective speaking about the model development, if it is viewed from a trade-off point of view between awaiting research and existing solutions. The described digital shadow can be transformed to digital twin, that is really transition from precision agriculture to smart farming. Autonomous harvesting and spraying by using UAV can be mentioned as trending development vectors. However, cross-domain studies as human detection are interesting, because it is not only a use-case for orchard security, but it can be applied as a trustworthy AI element to fly around a human.

Regarding applicability in fruit production, the model has been developed for decision support in the adaptation of growing technology elements to the yield quantity and quality in the current year. So, the decisions for fruit thinning or supplementary fertilisation and irrigation could be supported by the assessment of fruitlet amount in the trees. Similarly, yield protection, harvest organisation and production sale could be supported by the detection of fruit ripeness stage and scab infection level.

The development of the capability model should continue in the further improvement of model accuracy and applicability for current fruit crops as well as in the adaptation for other ones. This can be achieved by expanding the range of indicators to be assessed – fruit rot infection level, incidents of insect damage, fruit size, level

of chlorophyll degradation of fruits etc. and by keeping the involvement of cultivar-specific numeric values.

IV. Conclusions

Orchards are a complex system comprising a series of interdependent components: abiotic environment, biotic factors and crop management techniques. The only component that can be purposefully managed is the cultivation techniques and the selection of its parameters, which is not so simple due to the longevity of the orchards. The result of the decisions can be evaluated only with a deviation of several years. This problem can be solved by applying the digital twin concept. This study identified the main principles of creating a digital twin of apple, pear and cherry orchards, the application of inclusive assessments and their potential impact on orchard management decision-making.

The identified principles have been formally specified in form of orchard digital shadow capability model using ARTSS notation. The capability model lays groundwork for the development of digital shadow-based orchard management systems. The model can be expanded to develop digital twin-based orchard management systems. It can also be used as an example to expand upon or adapt to different subfields of horticulture.

The goal of the project lzp-2021/1-0134 is to develop and implement the autonomous apple, pear and sweet cherry orchard management system. Application of capability model to specify domain knowledge for the further development of digital twin orchard management system enabled straightforward collaboration between system developers and experts of the horticulture domain by providing an accessible notation and tools.

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Product Market Expansion Strategy for Business Development of the Companies Operating in the Field of Premises Cleaning

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Abstract. **The long-term strategic development of cleaning companies cannot be implemented by providing only one type of service - cleaning of premises.**
Within this research the author studied the theoretical aspects of corporate strategies, product market expansion strategy for business development of the cleaning companies, to understand the industry of cleaning of premises and challenges of that industry.
A monographic and descriptive method was used to analyze the theoretical aspects of company strategies, secondary data analysis and expert interview were used to describe the situation of premises cleaning industry, but quantitative research method such as analyzing of statistical data of the cleaning of premises companies, in connection with the comparative, analytical, deductive, logical approach method was used in this research.
The research identifies factors that the expansion of the range of services is relevant in every business and every industry, because every industry develops over time, new regulations are adopted that can affect the respective industry, which means that companies are constantly forced to adapt to changing business, economic and political conditions.
The research finds that if the company has successfully developed, has found its market share, and is working with good results, this does not mean that the company can relax and not think about its development.

Keywords: strategy, development, expansion of services.

I. INTRODUCTION

The expansion of the range of services is relevant in every business and every industry, because every industry develops over time, new regulations are adopted that can affect the respective industry, which means that companies are constantly forced to adapt to changing business, economic and political conditions. Competition does not take place only in the way that competitors offer something new, unique on the market or want to surprise customers with new options.

The rapid digital development, technologies, transition to the use of environmentally friendly materials, raw materials and tools force every company to constantly think about its development, because the company that will be the first to introduce a new digital solution will be more competitive and more in demand from customers. Digitalization requires companies to invest a lot of money in development, so companies cannot continue to operate in the same way as it was implemented times ago.

Even if the company is a leader in its industry, further development is not possible, i.e. increasing turnover and profit if the company continues to provide only one type of service, because companies that additionally provide related, other services are able to achieve better turnover indicators, which shows that the topic is relevant precisely from the aspect that one type of service provider it is important for the company to expand its range of services.

The purpose of the research is to investigate whether companies in the cleaning of premises industry of the Republic of Latvia can increase their turnover if they provide only one kind of services, for instance - the cleaning services.

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II. Characteristics of the Product Market Expansion Strategy

Several strategy and business consultants, theorists and scientists [1] – [3] have recognized that no core business is eternal, or that every product has its own life cycle. In business, various matrices or tools are used to measure the company's strategy, based on the assessment of the company's product (service) life cycle or market expansion opportunities, for example SWOT or PEST matrix, Boston matrix, McKinsey matrix, Ansoff "product-market" matrix.

The companies must understand how their entire industry is changing otherwise the company cannot invest wisely in the organization. As well it is important to understand where the industry is going, to understand the activities of the closest competitors to get understanding of the full context for a longer period [4].

How to know when the core business needs to change, and Zuk refers that safest way is not to take risks and look somewhere far away, but to acquire new values within the company. The company must use those assets and opportunities, which the company already has and then the company may offer richer new types of core business.

Corporate-level strategic decisions are based on industry-specific aspects. Each company is individual, considering the specifics of its operation, development opportunities, product, and service sphere. Stahl and Grigsby describe corporate level strategies, which is visible in Table 1 below [5].

Table 1 Corporate level strategies (adapted from Stahl & Grigsby)

General description	***Specification***
Concentration	One product or one market
Horizontal diversification	Related/concentric or unrelated/concern group company
Vertical integration	Forward-oriented integration ("forward") or forward integration ("backward")
Merger and Acquisition	Voluntarily or by force
Joint Ventura	Local or international
Restructuring	Downsizing, Disposal, Bankruptcy, Liquidation

As visible in Table 1 above, there are several ways of reorganization and how the companies may expand their businesses – by concentration, or by horizontal or vertical diversification, to carry out merger and acquisition, to agree on Joint Ventura agreements or make internal restructuring.

A lot of depends on the market and industry of the product. For example, in the cleaning of premises industry, a company that provides only cleaning services and has its own customer base can expand its market share in a limited way, for example, by participating in newly announced public procurement tenders or when a new customer enters the market, but of course the company may use active sales method and try to find new clients independently.

As another option to expand the market share at the cleaning of premises industry, is to "squeeze" some other competitor out of the market, which is not easy and companies do not always want to act with such methods, or there is a fourth option - to try to win public procurement tenders with dumped prices.

It can be challenging for companies to make the right strategic decision: whether the company should stay in its core business, where it has accumulated extensive experience, knowledge, customer base, familiar business conditions, or diversify the business into new products and markets related to the existing product or service? [5]

Kim and Maborn describe six differences between fierce competition and blue ocean strategies, which can be seen in Table 2 [1].

Table 2 From fierce competition to creating blue oceans (adapted from Kim & Maborn)

	Fierce competition	***Creating of Blue Ocean***
Industry	Focuses on competitors within the industry	Looking at alternative industries
Strategical group	Focuses on the competitive position within the strategic group	Look at strategic groups within the industry
Group of customers	Focuses on serving a group of buyers better	Changes the definition of an industry buyer group
Range of service or product offering	Focuses on maximizing the value of products and services within the industry	View the offer of additional products and services
Functionally – emotional orientation	Focuses on price improvement within the functional-emotional orientation of the industry	Reflect on the emotional functional orientation of the industry
Time	Focuses on adapting to external trends as they occur	Changes external trends

As visible in Table 2, operating in Blue Ocean means to carry out activities with less stress and less competition and to expand existing business widely and more focusing on existing products and services, by adding extra services or products.

The basis of the "blue ocean strategy" is to direct the company's efforts to acquire new customers, new services, and new markets, and not to spend energy in the fiercely competitive business areas of the company, fiercely competing with competitors.

Regarding service synergies in relation to related services Kaplan and Norton state that the goal of related services are generating economic savings [6].

Fallon indicates that the signs when the company need to think about the growth, are:

1) the growth of the best product has decreased.

2) customers start demanding something completely different (different) [7].

Pētersons points that if a business unit produces only one product, then the life cycles of the business unit and the product coincide, but when several products appear, the turnover of the business unit consists of the sum of the turnover of all manufactured products, and its life cycle does not end with the exit of a product from the market [8].

The main thing in the theoretical aspects of company strategy will always be to maintain the existing business, to direct its development, because every company experience growth, but when it reaches a certain state of development, the company must think about what strategy to apply in order not to fall under the Boston matrix at the stage of development cows', which may be followed by the stage 'Howling Dogs' [4].

In 1950, Igor Ansoff came up with the idea that different companies should apply the most suitable product markets strategies.

Several authors like Forand, Hanlon refers to Igor Ansof's product market expansion model, which is shown in Table 4 below [9] – [10].

TABLE 3 IGOR ANSOF'S PRODUCT MARKET EXPANSION MODEL (ADAPTED FROM FORAND & HANLON)

Markets	**Products**	
	Existing	***New***
Existing	Market Penetration Strategy	Product Development Strategy
New	Market Development Strategy	Diversification Strategy

As visible in Table 3 from Igor Ansof product market expansion model there is following classification depending on the market and product, considering the following criteria – existing or new. Both – the market and the product may be existing or new.

According to Igor Ansoff, companies can follow one of four strategies, see in Table 4.

TABLE 4 PRODUCT MARKET MATRIX [11]

TYPES OF STRATEGIES	**CHARACTERISTICS OF STRATEGIES**
MARKET ENTRY	• Low risk strategy • Selling existing products to existing customers using known products and existing learned markets • The aim: - maintain or increase the market share of existing products; - increase the use of the product among existing users.
MARKET DEVELOPMENT	• Medium risk strategy • Selling existing products to new customers • The aim: - development of new geographical markets; - introduction of additional distribution channels; - adaptation of different price policies to attract different customers; - creation of new market segments.
PRODUCT DEVELOPMENT	• Medium risk strategy • Selling new products to existing customers • The aim: - Develop modified products that are suitable for existing customers; - develop new company competencies; - Offer innovative products instead of uncompetitive or immature products.
DIVERSIFICATION	• High risk strategy • Offer new products in new markets • Types of diversifications: - horizontal diversification – new product, related market; - vertical diversification – the company enters the business of existing suppliers or customers; - concentric diversification – a new product that is closely related to the existing product in a new market; - diversification of the conglomerate – a completely new product in a completely new market. • The aim: - Learn new markets, learn new products, enter new markets with new products.

As visible in Table 4, each of four strategies are with certain level of risk and provides criteria for new products and new markets.

The companies` strategy would be the most suitable product development strategy, offering new products and services to existing customers, which is less risky, and which also corresponds to the needs of customers, because the customers to whom cleaning companies already provides cleaning services for premises, all have different types of facilities, all of which require engineering communications management services.

III. RESEARCH METHODOLOGY

The purpose of this research is to investigate whether companies in the cleaning of premises industry of the Republic of Latvia can increase their turnover if they provide only one kind of services, for instance - the cleaning services.

To achieve the goal of the research, three tasks were set: 1) to analyze the theoretical basis of corporate strategies and product market expansion strategy for business development of the companies; 2) to describe the companies operating in the industry of cleaning of premises; 3) to compare the companies operating in the industry of cleaning of premises from that point - which companies achieve better results considering number of services.

The research question: is the long-term strategic development of the company in cleaning industry of the

Republic of Latvia possible if the company offers only one kind of services - the cleaning services?

The results of the application the monographic and descriptive method was used to analyze the theoretical aspects of company strategies, secondary data analysis and expert interviews were used to describe the situation of premises cleaning industry, but quantitative research method such as analyzing of statistical data of the cleaning of premises companies, in connection with the comparative, analytical, deductive, logical approach method, provided an answer to the question raised by the author. Direct data collection method such as expert interview was used in research. Quantitative data analysis methods such as statistical data analysis - descriptive statistics was used to analyzing cleaning of premises companies and their financial results. Qualitative data analysis method such as drawing conclusions was used at the conclusion part of the research.

An expert interview is a type of survey that provides for obtaining information while the respondent and the researcher are in a socio-psychological interaction. The purpose of the interview is to gather information. For reason to research cleaning of premises industry and to understand the possibilities to expand the cleaning of premises companies business and turnover, the research employed a qualitative approach - an expert interview [12].

An expert interview was created as a semi-structured interview which is a data collection method that relies on asking questions within a predetermined thematic framework, where the questions are not set in order or in phrasing. Semi-structured interviews are qualitative in nature [13].

In expert interview author used following questions and themes for discussion like: How you evaluate the cleaning of premises industry companies comparing 2 indicators: 1) number of services they provide and 2) amount of turnover; Do you see long term expansion for cleaning companies which provides only 1 or few kind of services, like cleaning of premises and territories; What are main opportunities and challenges for cleaning of premises industry companies to expand their business? It must be noted that all the papers will be printed using grayscale printing technology.

IV. Results and Discussion

After analysis of industry of the cleaning of premises of the Republic of Latvia, there are basically three type of companies offering premises cleaning services:

• House management service companies, which main business is the house management service for multi-apartment buildings, and some of those companies besides provides also premises cleaning service;

• Premises and territory cleaning service companies, which have expanded their range of services with house management services and lot of other services. From these companies, there are 2 sub-types:

- Companies, which provides only premises cleaning services;
- Companies, which provides both premises and territory cleaning services.

• Real estate brokerage service companies which have expanded their range of services including house management services and premises territory cleaning services.

All types of companies use to provide several additional services, which are similar and related with housekeeping generally, such as: engineering communication service, plumber, electrician, repairman services, janitor services, cleaning the roof from snow, repair works, electrician, plumber services, general cleaning works, territory management, grass mowing, permanent waste collection and removal, road surface, stairs, driveway surfaces, footwear and indoor non-destructive non-slip materials, snow and ice cleaning, building management, water release from building utilities (water supply and heating, continuous (24/7) technical security, fire detection and alarm notification signalling systems for the infrastructure; maintenance and repairs of security equipment and wireless security systems, ventilation and conditioning system, low current system, maintenance of engineering communications, technological equipment, as well as other services.

After studying several public procurements announced by state and local government institutions of the Republic of Latvia, the author concludes that there are procurements in which the customer wants to purchase only a narrow service - cleaning of premises and territories, but there are procurements where the customer wants a wide range of services - both cleaning of premises and territories and additional services, like, engineering or water communication services and several kind of repairman services.

Based on the above, the author concludes that those companies, which can offer several types, or a full spectrum of services (as “one-shop agency”) are in much better position.

The study of the companies established in the Republic of Latvia, that provide cleaning services of premises and territories, management of commercial objects and management services of houses was done according to the information published on their websites, what services each of these companies offers. The summary of the provided services can be seen below in Table 6.

Cleaning of premises market is divided and concentrated, therefore the market participants of the premises cleaning industry of the Republic of Latvia should develop their strategy as a product market development strategy expanding their range of services with related services, such as the management of commercial objects and the house management services, which is a medium-risk strategy.

TABLE 5 SERVICES PROVIDED BY PREMISES CLEANING, COMMERCIAL PROPERTY MANAGEMENT AND BUILDING MANAGEMENT COMPANIES [14]

Company	Cleaning of premises and territories			Housekeeping for private and commercial sector		Services for mainatning and repair of engeneer communications	Other related services							Number of services
	Cleaning of premises	Cleaning of territories	General cleaning works	House keeping for private sector	House ceeping for commercial sector		Building	Repair works	Moving services	Catering	Trainings and seminars	Supply	Chemical cleaning for furniture	
SIA Hagberg	X	X	X	X	X	X	X	X			X			9
SIA Concord Service group	X	X	X	X	X	X	X	X		X				9
Civinity group	X	X	X	X	X	X	X	X						8
SIA Marivo	X	X	X	X	X	X	X	X						8
SIA Impel Serviks	X	X	X			X	X	X				X		7
SIA Cleanhouse	X	X	X	X	X								X	6
SIA BCS	X	X	X						X				X	5
SIA Vizii	X	X	X											3
SIA LiiR Latvija	X	X	X											3
SIA MRS Secure plus	X	X	X											3

As visible in Table 5, if we compare the biggest company in industry of premises cleaning, Civinity group of companies (SIA Civinity Solutions, SIA Civinity Mājas, SIA Civinity Mājas Jūrmala, SIA Civinity are the leader in the industry, with turnover EUR 21 543 421 (in year 2021) and second biggest company is SIA Hagberg with turnover EUR 12 361 898 (in year 2021), because they provide wild range of services - not only cleaning of premises and territories, but also housekeeping of private and commercial buildings, management services of engineer communications, repairs and other services. It means that other companies with lower turnover provides less services.

As visible in Figure 1, the existing service providers in the cleaning of premises industry do not have much opportunity for growth or increasing profits, so it remains either to redistribute the market or to force the existing service providers out of the market and aggressively conquer the marketplaces of other competitors.

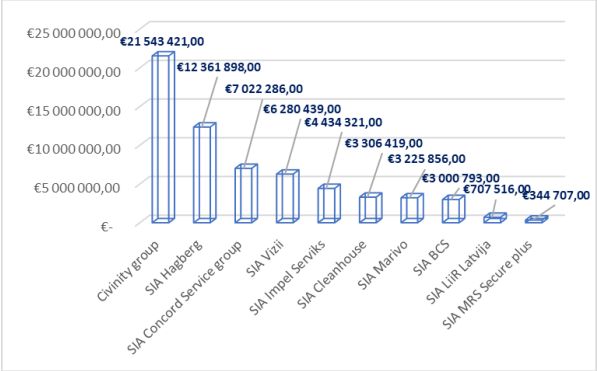

Fig. 1. Turnover data of premises cleaning companies (EUR) [14].

The long-term strategic development of cleaning companies cannot be implemented only by offering cleaning services for premises, therefore the strategy of cleaning companies must be based on a new offering product to customers, thus increasing their turnover and profit, as well as expanding the range of services will ensure business diversification.

As cleaning of premises market is quite divided and concentrated, it means that the market participants of the premises and territory cleaning industry of the Republic of Latvia should develop their strategy as a product market development strategy, which is a medium-risk strategy, expanding their range of services with related services, such as the management of commercial objects and the house management services.

The author chose the expert interview as a method for the research to evaluate the cleaning of premises industry, to find out industry essential main problems and to understand cleaning of premises companies' possibilities to expand their business and necessity to expand their services. Expert was a business consultant from Latvia, with wide professional management work experience in various cleaning companies of the Republic of Latvia, as well with international experience in crisis, change management, restructuring management and M&A transactions, with international Business and Finance education, in middle age (around 35-45 year).

The results of the expert interview allowed author to conclude that the cleaning of premises company, providing only one or few kinds of services, like cleaning of premises and territories, even if the company is a leader of the cleaning industry, cannot achieve high growth and to expand business by achieving much higher turnover and profit as in previous years. The interviewee admitted that the market of cleaning of premises industry is divided and occupied by several strong competitors, therefore only fierce competition or expansion of the services can help cleaning of premises companies to expand their business. The interviewee expressed the opinion that fierce competition or market division is activity in high risk, but less risky for the company is to think about expression of kind of services or to consider carrying out a merger and acquisitions transactions. The expert indicated that turnover results in cleaning of premises industry shows that leader in cleaning of premises industry – Civinity group,

SIA Hagberg, SIA Concord Service group provides approximately 8-9 kind of services and achieve higher turnover results comparing with other market participants, and this is one of the reasons why companies can achieve higher turnover results, due they provide not only premises and territories cleaning, but also engineering services, housekeeping management services, repairs and several other services. By providing more services, the company can be more competitive and gain more market share, because for instance, premises cleaning service is in sector B2B – Business to Business, but housekeeping management services are in sector B2C – Business to Customer, which proves that by expanding kind of services, the company may expand the market share and as a result – to improve turnover results.

As a result of the entire research, applying the research, gave an answer and allowed to draw conclusions that the long-term strategic development of companies cannot be implemented only by offering cleaning services of premises, as the range of services provided by companies must be expanded.

V. Conclusions

1. The companies, which operates in the areas of premises and territory cleaning, commercial property management and building management, provides up to 9 services and achieve higher turnover comparing with companies, which provides less of services.

2. After studying several announcements for public procurements announced by state and local government institutions, there are procurements in which the customer wants to purchase a wide range of services - both premises and territory cleaning, engineering communications service, services of plumbers, electricians, repairmen, as well as other services, therefore if the premises cleaning companies want to improve their competition and to win in such tenders, they needs to think about a service expansion strategy.

3. The market of the premises and territory cleaning industry is strictly divided and the market is fragmented, as result there is not much opportunity to expand only in the premises and territory cleaning industry.

4. The market participants of the premises and territory cleaning industry of the Republic of Latvia should develop their strategy as a product market development strategy, which is a medium-risk strategy, expanding their range of services with related services, such as the management of commercial objects and the house management services.

VI. Limitations of the Research

The research period is limited in time - from January 1, 2020, to December 31, 2022. The study found that were tools that companies can use to ensure consumer satisfaction and, as a result, increase the competitiveness of the companies.

The research is limited in the territory of the Republic of Latvia. The companies which are analyzed in this research, are limited narrowing down these companies which are: 1) members of the industry associations, it is, Members of the Latvian Professional Cleaning and House Management Association, reg. No. 40008142427, which is an association of employers, manufacturers, suppliers, research institutions and professionals operating in the field of professional cleaning and management which provide premises and territory management services.

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