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Circular Economy and Bioeconomy Interaction Development as Future for Rural Regions. Case Study of Aizkraukle Region in Latvia

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Abstract **– In order to enforce the concepts of bioeconomy and the circular economy, the use of a bottom-up approach at the national level has been proposed: to start at the level of a small region, encourage its development, considering its specific capacities and resources, rather than applying generalized assumptions at a national or international level. Therefore, this study has been carried out with an aim to develop a methodology for the assessment of small rural areas in the context of the circular economy and bioeconomy, in order to advance the development of these regions in an effective way, using the existing bioresources comprehensively. The methodology is based on the identification of existing and potential bioeconomy flows (land and its use, bioresources, human resources, employment and business), the identification of the strengths of their interaction and compare these with the situation at the regional and national levels in order to identify the specific region's current situation in the bioeconomy and identify more forward-looking directions for development. Several methods are integrated and interlinked in the methodology – indicator analysis, correlation and regression analysis, and heat map tables. The methodology is approbated on one case study – Aizkraukle region – a small rural region in Latvia. During the research recommendations for the development of the circular economy and bioeconomy for the case study have been elaborated.**

Keywords **– Bioeconomy indicators; bioresources; economic growth; regional economy**

1. INTRODUCTION

Increasing public awareness of sustainable resource use and economic development has made the issue of the circular economy and bioeconomy increasingly relevant [1]. This is also directly linked to the expected shortage of non-renewable resources [2], [3], population growth [4] and the environmental and climate challenges posed by human activity. The circular economy and the bioeconomy are expected to address these challenges [5], [6].

The use of the bioeconomy term has become particularly common since the adoption of Bioeconomy Strategy (Innovating for Sustainable Growth: A Bioeconomy for Europe) [7] in 2012. However, the scope of the definition is still not strictly defined. There are different interpretations not only in different national strategies but also in scientific literature [8]. Simply put, bioeconomy is a knowledge-based use of bioresources based on innovative biological processes and principles to provide goods and services in a sustainable way across

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all sectors of the economy [9]. As with bioeconomy, the circular economy also has many definitions [10]. Essentially, the concept of a circular economy aims to preserve the value of products, materials and resources as long as possible by returning them to the production cycle at the end of the product life cycle, thereby reducing the amount of waste [10].

Looking directly at the sustainable use of bioresources, the concept of bioeconomy is directly linked and overlaps with the idea of a circular economy, as it involves the use of sustainable, knowledge-based bioresources for the production of products, including through the use of residues and waste from the production and processing of bioresources. In the traditional sense of the circular economy, the reuse and recycling of bio-based products are considered to be mainly related to the biodegradation process. But nowadays, it is becoming more and more popular to know that products made from bioresources at the end of their life, if possible, should be returned in the cycle as raw materials for the production of new products [11]. Therefore, for bioresources, a more accurate term would be the term circular bioeconomy. The most important detail that separates the concepts of bioeconomy and the circular economy is that bioeconomy's focus is on the use of bioresources, while the cycle of circular economy includes the flow of all resources, providing resources for reuse and recycling of resources.

In most cases, these issues are analysed separately, although, in accordance with the concept of sustainability, the bioeconomy should also be circular [12]. Therefore, when considering one or the other of these two issues, bioeconomy should be seen as part of the circular economy and the bioeconomy, not only as a sustainable use of resources for the production of higher added-value products, but also as a concept for ensuring industrial symbiosis and clean, no-waste production and the use of all resource flows, including residues and waste.

In order to enforce the concept of the bioeconomy and the circular economy, the bottom-up approach has been proposed to be applied for the national level: to start with a small region level and to encourage its development, considering the specific capacities and resources of that region, rather than applying generalized assumptions taken from observations at the national or international levels.

Taking into account that the development of the bioeconomy is directly linked to the agricultural, forestry and fishery sectors [13], it is necessary to start directly with an assessment of these sector, of the resources available and of their current use, seen in the context of the level of development of the region, in order to understand whether the current development is sustainable. Consequently, if, at regional level, the aim of developing the circular economy and the bioeconomy would be to promote not only regional and national economic development, but firstly it would have a positive impact on the primary bioeconomy sectors.

This study has been carried out with the aim to develop a methodology for the assessment of small rural areas in the context of the circular economy and the bioeconomy, in order to advance the development of these regions in an effective way, using the existing bioresources comprehensively. The methodology is based on the identification of existing and potential bioeconomy flows (land and its use, bioresources, human resources, employment and business), the identification of the strengths of their interaction and comparison with the situation at regional and national level in order to identify the studied region's current place in the bioeconomy and to also identify the more forward-looking directions for the region's development. Several methods are integrated and interlinked in the methodology – indicator analysis, correlation and regression analysis and heat map table.

The methodology is approbated on one case study – Aizkraukle region – a small rural region in Latvia. During the research, recommendations for the development of the circular economy and bioeconomy for the case study have been elaborated.

2. METHODOLOGY

In order to achieve the goal of the research, three main research topics were identified, which will be addressed with the developed methodology:

- Are the bioresources available in the region and are they fully exploited for economic development?
- Which bioresources available in the region are currently under-exploited?
- How to make more effective use of the bioresources available in the region in the context of the circular economy and bioeconomy to promote economic development?

In order to find answers to these questions and to achieve the objective of the study, a methodology algorithm (Fig. 1), was divided into five main phases:

1. Data collection;
2. Data analysis;
3. Determination of bioresources;
4. Assessment of the sustainable use of bioresources;
5. Development of recommendations.

Essentially, the first half of the algorithm is focused on identifying and analysing the current situation, and the second half on evaluating prospects, looking for opportunities and a practical solution for promoting the sustainable use of bioresources.

The first two phases are the collection and analysis of publicly available data using several data analysis methods. In this case, indicator analysis, correlation and regression analysis and heat map tables are used. For better understanding and analysis of data and results, heat map tables have been used, which, with the help of colour, can show trends in a visually perceptible manner and mutually compare values. Looking at the potential of bioresources in the context of the circular economy and bioeconomy, attention should be paid not only to statistics on the volume of existing bioresources, but also to factors that directly and indirectly affect them (Fig. 2).

The two most important factors are the use of available land (for what purpose existing land resources are used) and the human resources that manage these land resources. The interaction of these two factors most directly affects the volume and types of bioresources produced, employment and business development and trends. While, the volumes and types of bioresources, have a mutual impact on the volume and assortment of produced products. As a result, it has impact also on the amount and type of waste generated. Therefore, in this study, the available bioresources are also considered in relation to entrepreneurship, employment and the level of territorial development. These three factors are also important in assessing the potential for bioeconomy development, which pertains to labour availability, competition and efficiency in the use of resources.

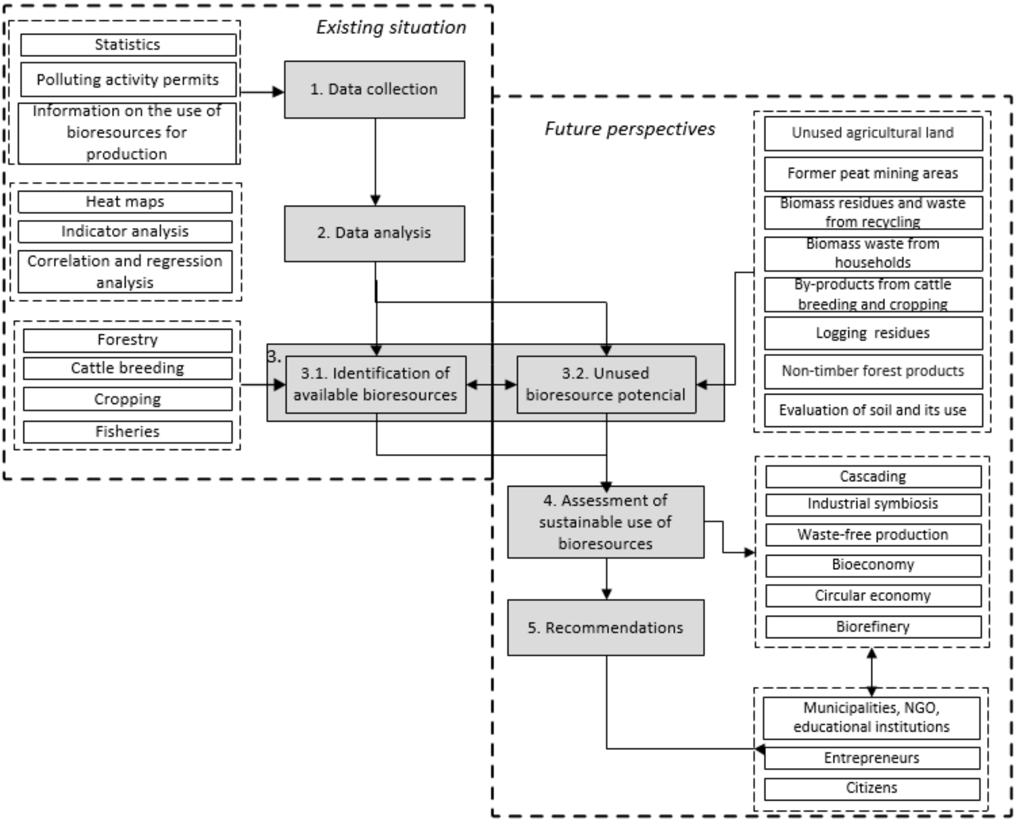

Fig. 1. Methodological algorithm.

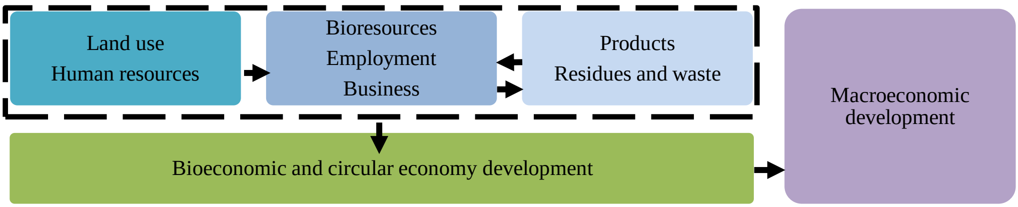

Fig. 2. Use of bioresources in the context of a circular economy and bioeconomy.

At the beginning of the third phase of the algorithm (3.1), the results obtained are used to determine which bioresources are the most accessible, and in the following (3.2), the previous results were used to search for bioresource flows that are not traditionally considered valuable and are currently not being fully utilized, and ways to increase the amount and diversity of bioresources produced. Most bioresources, including those considered to be residues or waste, can become a valuable raw material in the production of new products.

At the fourth stage of the algorithm, an assessment of the sustainable use of bioresources is carried out, taking into account not only the principles of a circular economy and bioeconomy, but also the principles of cascading, industrial symbiosis, zero-waste production and biorefinery, although there are issues that overlap among all these principles. Considering the analysis of the current situation and the unused potential of bioresources, schemes for the use of biological resources in a given area, including both traditional uses and innovative solutions to produce high added-value products are developed in the fourth phase of the algorithm. These schemes allow one to identify the possibilities of industrial symbiosis that are adaptable to different resources. Schemes for the use of bioresources are not based on specific companies and their activities but serve as examples and a source of information on how it would be possible to develop the economy in a given area through the available bioresources and capabilities.

In the final – fifth phase of the methodology, recommendations to strengthen capacity for the successful use and management of bioresources in line with the basic principles of the circular economy for small rural areas are developed.

Indicator analysis was used for the assessment of the current situation, and a graphical representation of the data with heat map tables was used to visualize the results. For the analysis of the current situation, five groups of regional level indicators were used, divided into two parts – direct indicators characterizing the bioeconomy (land use, bioresources) and indirect indicators characterizing the bioeconomy (human resources, employment, entrepreneurship and level of development) (Table 1).

The chosen indicators characterize the current situation of the use of bioresources in the region. They also describe the perspective for bioeconomy development – the available human and labour resources, the current business situation in bioeconomy sectors, which also characterizes competition, and the level of development that shows the efficiency of the existing economy.

A small rural region in Latvia, consisting of a former territory of Aizkraukle district, which consists of 7 municipalities: Aizkraukle, Plavinas, Koknese, Jaunjelgava, Nereta, Vecumnieki and Skriveri (Fig. 3), with a total area of 44 478 ha (4.8 % of territory of Latvia [14]) has been selected for the approbation of the developed methodology.

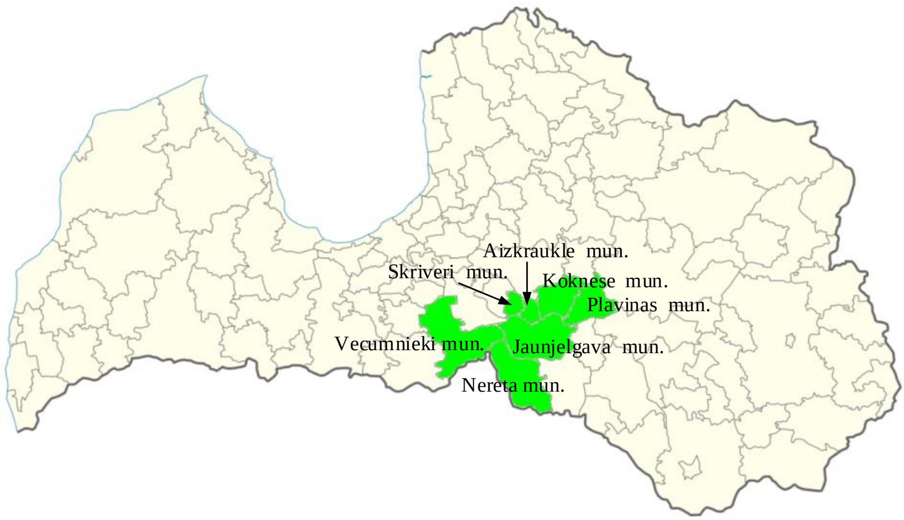

Fig. 3. Territory of the case study in Latvia.

Publicly available and reliable statistics on land use distribution [14], wood resources [15], livestock production [16], crop production [17], declared crop in agriculture, unemployment [18], entrepreneurship [19], human resources [20] and development [21] were used to analyse the current situation. The latest available data (mostly for 2017 and 2018) were used at the time of the study.

TABLE 1. REGIONAL LEVEL INDICATORS INCLUDED IN THE METHODOLOGY

Indicator group	**Indicator**	**Unit**
Direct indicators characterizing the bioeconomy		
Land use	Share of land use in the area	%
	Average size of land unit	ha
	Unused agricultural land	%
Bioresources	Share of crop area at regional level	%
	Share of regional crop areas at national level	%
	Number of animals (by species) at regional level	%
	Number of animals (by species) at national level	%
	Number of animals (by species) per 1 ha of agricultural land	number/ha
	Difference with average number of animals (by species) per 1 ha of farmland*	%
	Average number of animals in the holding	number/holdings
	Difference with average number of animals in the holding*	%
	Share of areas of dominant tree species at regional level	%
	National size of areas of dominant tree species	%
	Regional share of the stock of dominant tree species	%
	National share of the stock of dominant tree species	%
	Wood stocking of ruling tree species per 1 ha	m^3/ha
	Difference with average governing wood stocks of tree species per 1 ha in the country*	%
	Felling age stock of the dominant tree species without felling restrictions on 1 ha	m^3/ha
	Difference with average felling age wood stock of dominant tree species without felling limits of 1 ha in the country*	%
Indirect indicators characterizing the bioeconomy		
Human resources	Share of population at national level*	%
	Land area per capita	ha/population
	Difference with average land area per capita in the country*	%
Employment	Number of unemployed per 1000 inhabitants	unemployed
	Difference with the average number of unemployed per 1000 inhabitants in the country*	%
	Share of unemployed at national level*	%
	Land area per 1 unemployed	ha
Business	Share of primary bioeconomy (agriculture, forestry, fisheries) active enterprises in the region	%
	Number of active agricultural enterprises per 1000 ha of agricultural land	companies
	Number of active forestry enterprises per 1000 ha of forest land	companies
Development level	Development level index	
	Development level index difference with average in country	%

*The index is evaluated only to understand the regional situation in the region.

3. Results and Discussion

Based on the developed methodology for the assessment of small rural regions in the context of the circular economy and bioeconomy, in order to be able to effectively drive the development of these regions through the full use of existing bioresources, the approbation of Aizkraukle region in Latvia was carried out.

3.1. Analysis of Existing Situation

The analysis of the current situation focused on the analysis of primary bioresources and their acquisition opportunities related to the availability of land resources. Since the fisheries sector is not developed in the explored region, only the agricultural and forestry sectors were used in the analysis of the current situation. The results of the indicator analysis on land use in the Aizkraukle region (heat map Table 2) show that most municipalities in the studied region are strongly dominated by the share of forest lands and only then agricultural land.

TABLE 2. BIOECONOMY INDICATOR ANALYSIS FOR AIZKRAUKLE REGION. LAND USE

Indicators	Aizkraukle mun.	Pļavinas mun.	Koknese mun.	Jaunjelgava mun.	Nereta mun.	Skriveri mun.	Vecumnieki mun.	In the region	Regional share at national level, %	In the region, compared to the average in the country, %
Share of land use in the area, %										
Agricultural land	33	31	37	23	27	47	33	33	4.1	–
Forest land	33	54	48	64	63	41	55	51	5.7	–
Bushes	1.1	1.9	1.5	1.6	1.7	1	1.9	1.5	5.0	–
Bog	9.6	1.3	2.8	1.9	1.1	0	1.6	2.6	2.6	–
Water bodies	8.6	4.8	4.3	3.9	2.4	3.4	2.4	4.3	4.4	–
Average size of the unit of land, ha	3.8	7.6	7.9	10.3	14.2	5	10.2	8.4	–	31
Unused agricultural land, %	6.1	20.9	7.6	16.4	16.9	5.8	17.9	13.1	4.1	–

The share of forest land and agricultural land is equally high in Aizkraukle municipality, which, compared to other municipalities, has a high proportion of bogs (9.6 %). This means that the research area has greater perspective for the development of a forest-based bioeconomy and it is worth to pay increased attention to bog resources.

In order to assess the fragmentation of the exploration area, the average size of the unit of land was determined for each municipality of 3.8–14.2 ha, an average of 8.4 ha, which is 31 % higher than the average size of the unit of land on a national scale. Considering that it is technically easier and more economically efficient to manage larger land units; this is a positive indicator for the exploration region. As regards the identification of the potential of unused bioresources, the share of unused agricultural land was identified, which varies greatly between the municipalities, from 6.1 % in the Aizkraukle to 20.9 % in Plavinu municipalities. This shows that there is a marked difference between the effectiveness of the use of bioresources and the development of agriculture between small rural areas.

The share of prevailing crops in each municipality was analysed. Permanent grasslands were found to be the most common (on average 24 % in the region). In general, crop production and vegetable cultivation are not particularly developed in the explored area and do not play an important role. The statistical data show not only that there are enough crops whose cultivation in the area of the Aizkraukle District Partnership is underdeveloped, but also that there is ample scope to diversify the existing assortment.

Three main indicators were used to analyse livestock data – the proportion of animals showing which animals dominate in the areas of the research region, the number of animals per hectare of agricultural land that characterize the density of farm animals, and the average number of animals in a holding that show area-specific large farms or small backyard farms. The research area is characterized by cattle rearing, which is also relatively important at the national level.

Bioresources in forestry in the research area are assessed with four indicators: proportion of areas of dominant tree species, proportion of dominant tree species stock, wood stock and area of dominant tree species. In the Aizkraukle region the most common tree species are birch (31 %) and pine (29 %), but wood is the largest stock pine (36 %) and birch (27 %). At the national level, however, the research area is more relevant to tree species such as black alder and white alder.

However, the availability of wood resources is best characterised by the availability of wood stocks that are available for logging and the harvesting age stock of dominant tree species without felling restrictions. Felling age wood stock with no felling limits of 1 ha is the largest available for aspen (368.62 m^3/ha), spruce (363.62 m^3/ha) and pine (363.62 m^3/ha). Compared to the national average, the survey region is significantly higher (by 11.9 %) in terms of felling age without cutting restrictions on the stocks of black alder. By comparing the municipalities, it can be concluded that the largest wood stocks of felling age per 1 ha are in the Skriveri municipality.

The indirect indicators affecting the bioeconomy were also assessed separately and it was concluded that there were significant differences between the municipalities. Human resources are most available in the municipalities of Aizkraukle and Vecumnieki, while the largest area per capita is available in the municipality of Nereta (18.69 ha), which is 4.6 times more than the average in the country. But the smallest area of land per capita is available in the Aizkraukle municipality. Free labour force or unemployed people who could be employed in the implementation of new bioresource management solutions are most available in the Aizkraukle municipalities, while the largest number of unemployed people per 1000 inhabitants in the municipality is in the Jaunjelgava municipality.

The largest proportion of active enterprises in the primary bioeconomy sectors in the region is in the Nereta municipality, but the smallest in the Aizkraukle municipality, despite the largest number of active agricultural and forestry companies per 1000 ha of agriculture land. This shows that there is a more developed business in the Aizkraukle region compared to other regions of the explored region, but it is not primarily focused on the primary sectors of the bioeconomy. For all regions of the explored region, the development rate index is negative and for only 3 municipalities (Aizkraukle, Vecumnieki and Koknese) it is higher than the average development rate in the country.

TABLE 3. CASE STUDY FOR AIZKRAUKLE REGION. R^2 FOR INDIRECT BIOECONOMY INDICATORS

	Unused agricultural land %	Area of land per capita	Number of unemployed per 1000 inhabitants	Land area per 1 unemployed, ha	Share of primary bioeconomy active enterprises in the region. %	Number of active agricultural enterprises per 1000 ha of agricultural land	Number of active forestry enterprises per 1000 ha of forest land	Development level index	Share of agricultural land, %	Share of forest land, %
Unused agricultural land, %	1									
Land area per capita	0.456	1								
Number of unemployed per 1000 inhabitants	0.001	0.050	1							
Land area per 1 unemployed, ha	0.512	0.770	0.057	1						
Share of primary bioeconomy active enterprises in the region, %	0.288	0.917	0.058	0.718	1					
Number of active agricultural enterprises per 1000 ha of agricultural land	0.624	0.496	0.059	0.562	0.351	1				
Number of active forestry enterprises per 1000 ha of forest land	0.292	0.373	0.064	0.394	0.309	0.869	1			
Development level index	0.406	0.581	0.288	0.197	0.363	0.360	0.239	1		
Share of agricultural land, %	0.450	0.456	0.319	0.247	0.434	0.072	0.001	0.374	1	
Share of forest land, %	0.645	0.855	0.035	0.671	0.772	0.708	0.538	0.570	0.478	1

For a more complete assessment of the indirect bioeconomy indicators and for the search for related factors, a correlation and regression analysis were carried out. A summary of the values of the correlation factor squares for linear regression equations is shown in Table 3.

Some of these results are legislative and logical, such as the number of active forestry companies per 1000 ha of forest land, depending on the number of active agricultural companies per 1000 ha of agricultural land (R^2 = 0.869).

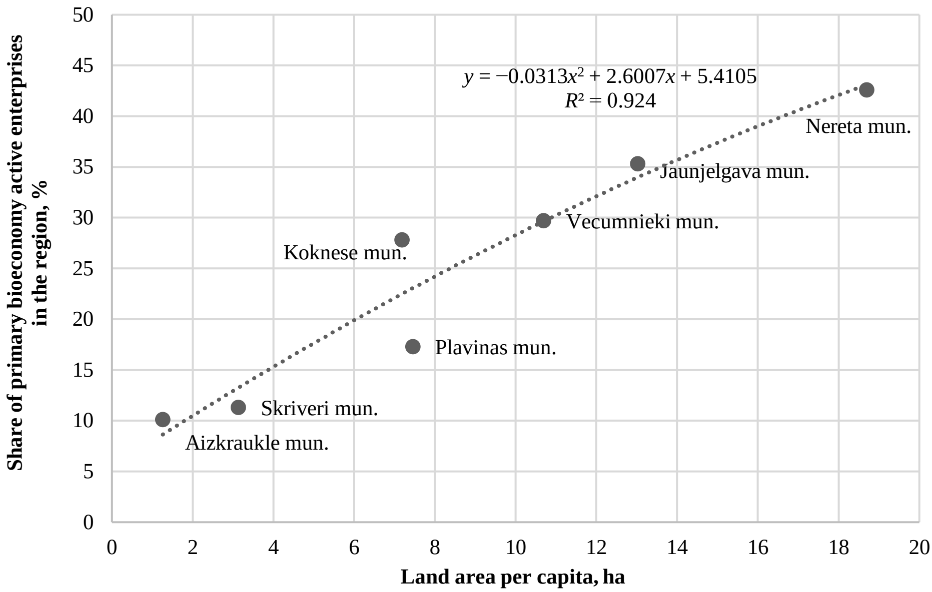

Fig. 4. Share of primary bioeconomy active enterprises in the region (%), depending on land area (ha) per capita.

The strongest correlation ($R^2 = 0.924$) is registered between the proportion of primary bioeconomy active enterprises in the region and the area of land per capita (Fig. 4). From this correlation follows, that if area of land per capita is larger (lower population density), then the number of primary companies in the bioeconomy sectors compared to companies in other sectors is higher.

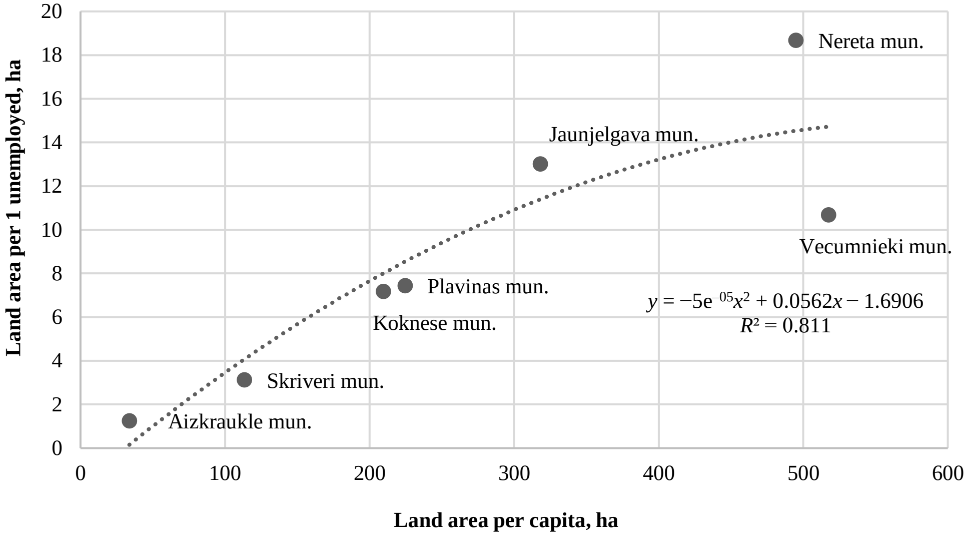

Fig. 5. Land area per 1 unemployed, depending on land area (ha) per capita.

This means that the larger the area available for management, the more likely the primary sectors of the bioeconomy will develop. In the case of the Aizkraukle municipality, it is mainly forestry, since the proportion of primary bioeconomy active enterprises in the region is noticeably correlated with the share of forest land ($R^2 = 0.772$), while the share of agricultural land R^2 is only 0.434.

A close relationship ($R^2 = 0.811$) is observed for land area per 1 unemployed, depending on land area per capita (Fig. 5). There is no link between the indicators for land area per 1 unemployed and unemployed per 1000 inhabitants ($R^2 = 0.057$). This means that employment does not depend on population density (competition for job opportunities).

There is a close relationship between the number of forestry and agricultural enterprises per 1000 ha and the share of forest land in the area, but this is not the case depending on the share of agricultural land. This is logical in terms of the number of farms per 1000 ha agriculture land for the share of forest land (the more forest lands, the fewer agricultural companies managing agricultural land), but it is not logical for the number of forestry companies per 1000 ha of forest land, depending on the share of forest land. In this case, the higher the share of forest land, the smaller the number of forestry companies.

The results of the correlation regression analysis did not demonstrate several assumptions. For example, the results showed that there was no relationship between the number of unemployed people per 1000 inhabitants with other indicators related to business, the level of development and the availability of the environment needed to produce bioresources.

This proves that the level of employment is affected by other factors not described here. It is clear from this phase of the reinforcement of the methodology that the results of the indicator analysis for other regions of research would certainly be different. This approach can therefore also be used for regional comparison.

3.2. Unused Bioresource Potential

Although the Table 4 summary does not cover all unused bioresources and the potential of their harvesting sites, it is nevertheless apparent how much diversity there is and what the estimated volumes are in the area of exploration. These bioresources can be used to produce products at all levels, ranging from lower added-value products for the energy sector to high added-value products for pharmaceuticals, cosmetics and the chemical industry. At the same time, these results demonstrate the effectiveness or ineffectiveness of the use of available resources and confirm the assumption that residues and waste are not primarily perceived and used as resources.

TABLE 4. CASE STUDY FOR AIZKRAUKLE REGION. UNUSED POTENTIAL

Source	Unused potential, estimated volumes in the Aizkraukle region	Remarks
Unused agricultural land	13 810 ha (~13.1 % from total agricultural land in region)	Unused agricultural areas in the region in 2018 [22]
Former peat mining areas	1 216 ha with licensed peat extraction deposits [23]–[25]	Peat is not considered as a bioresource, but the former peat mining areas are treated as an additional place to produce bioresources
Biomass residues and waste from recycling	79 500 t/a digestate 24 800 t/a corn silage 18 800 t/a food waste 1 890 t/a sewage sludge 720 t/a wood ash and sand from cattle houses 80 t/a wastewater waste	The most frequently generated biowaste in major processing companies, wastewater treatment plants and boiler houses in the region
Municipal biomass waste	2 200 t/a	Share of biowaste collected in the region and deposited in landfills [26], [27]
Crop and livestock by-products	226 178 t/a manure 31 791 t/a residues from winter wheat 25 985 t/a residues of summer barley 21 452 t/a residues from summer wheat 14 265 t/a residues from oats 11 791 21 452 t/a residues from winter rapeseed 13 798 21 452 t/a residues from summer rapeseed 6 921 t/a balances from field beans 670 t/a balances of buckwheat	Calculated on the basis of livestock production [6] and crop production [17] statistics in the region for 2018, crop yield indices [28]–[31], average crop yield (2015–2017) [32]
Foresting residues	36 108 m^3/year non-useful part of the trunk 77 576 m^3/year twigs 8 913 m^3/year tops 6 238 m^3/year needle foliage 94 839 m^3/year strains	Calculated on the basis of annual harvesting volumes in major fellings [15]
Forest non-timber resources	11 700 t/a cranberries 5 500 t/a raspberries 24 700 t/a blueberries 17 500 t/a lingonberries 2 000 m^3/year pine needles from logging 2 400 m^3/year tree needles from logging 80 thousand l/a of maple sap 245 000 thousand l/a of birch sap	The theoretical quantities of berries available have been calculated considering the forest types of the region [15] and the biological harvests of theoretical berries, depending on forest types [33]. In addition to the mentioned forest non-timber bioresources, there are others (e.g. forest mushrooms, cones, medical plants, game animals) the amounts of which cannot be determined. The theoretical quantities of tree sap to be obtained have been calculated on the basis of material factors of tree species, age [15], density [34], average quantities of sap [33], [35], nature protected areas [15], etc.

3.3. Sustainable Use of Bioresources

According to the developed methodology, an assessment of the sustainable use of existing bioresources was carried out in the study case. In the case of the Aizkraukle region, the assessment of the possibilities to use 9 bioresource flows: forest residues, wood resources, fruit, berry and vegetable processed products, agricultural residues, corn, forest berries, forest mushrooms, sheep wool, milk, was carried out and schemes were designed to demonstrate the different uses of each bioresource. The cascades proposed are not based on specific companies and their activities but serve as examples and a source of information on how it would be possible to develop the economy in the area of the Aizkraukle region, using available bioresources and capabilities. This also helps to see opportunities for potential plants to produce specific products, using the various resources available in the region, and to exercise the possibilities of symbiosis between the various bioresource processing industries. When designing schemes, the main emphasis was placed on innovative technological solutions.

Considering, that forestry is the main sector in the analysed region, as an example in this publication is represented a scheme for the possibility to use of logging residues accordance with the principles of the circular economy and the bioeconomy (Fig. 6). Demonstrating that the main resource of the forest is not only wood. There are many ways to use logging balances to generate additional income, to reduce the environmental burden and to promote the development of the economy through the sustainable use of these resources.

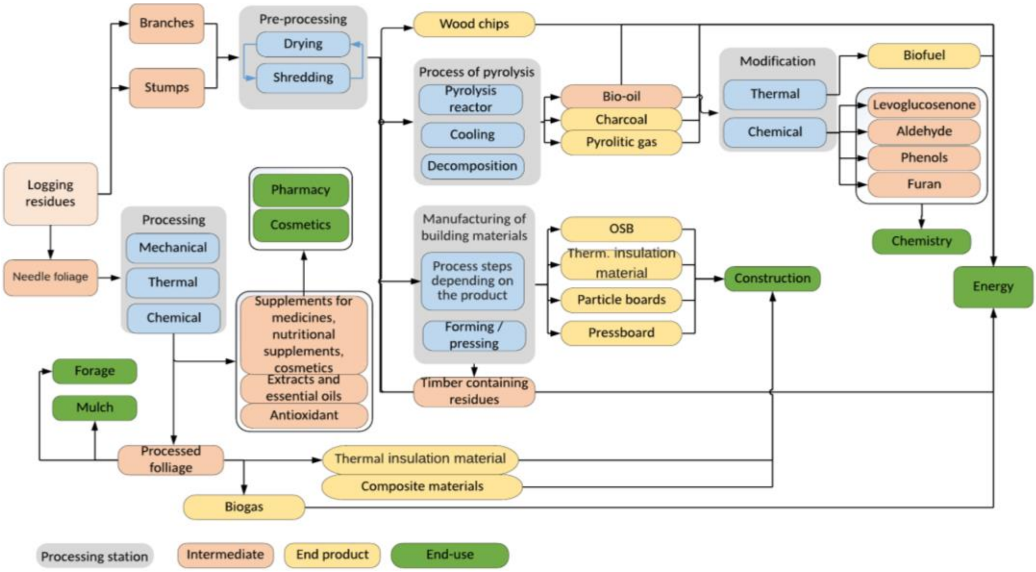

Fig. 6. An example of sustainable use of bioresources. The possibility to use logging residues in accordance with the principles of the circular economy and the bioeconomy.

The most significant harvesting resources are the crown part and strains of wood, which, depending on the species of trees, can represent up to 45 % of the total weight of the tree. In practical terms, there are several restrictions on such a logging waste scheme. For example, it should be noted that not all theoretical quantities of available logging residues can actually and should be taken from the forest. Firstly, this is related to the types of forests in which the crown part of felled trees is needed to ensure the movement of heavy logging techniques and the introduction of assortments from felling areas to the road. As well as the fact that it is not technologically possible to remove all the residues of logging and it is not desirable, as it is necessary to leave the feed base for the development of the next forest.

The implementation of the proposed harvesting residue processing scheme would also result in a number of environmental and climate benefits, such as a reduction in the amount of biomass remaining in clearings and generating CO_2 emissions, and an additional stream of resources that can be used to produce products, including as an alternative to fossil resources.

If unrecycled, the residues of logging, as a resource for export, unlike wood, is not economically justified because in that form there is no demand and transport costs would be disproportionately high. It is therefore necessary to process this part of the resource on the ground and then to assess the possibilities for export of the finished products, which would also be the most economically and socio-economic option for the development of the region's economy and living standards.

In the proposed harvesting residue scenario (Fig. 6), the main flows of resources are branches (without leaves), strains and individual needle foliage of coniferous trees (spruces and pines, delicate branches in diameter up to ~5 mm with needles). Branches and strains can be used to produce harvesting chips that are of lower quality fuels due to impurities (e.g. needles, leaves, soil particles, etc.). The biomass of the purified branches and strains of these impurities can be used as an additive in the manufacture of various construction materials, such as composite materials and particle boards.

Similarly, through the pyrolysis process, both types of logging residues can be used to produce higher added-value products in the energy sector [36]. Using the pyrolysis process, bio-oil, charcoal and pyrolysis gas can be obtained in parallel. Bio-oil or pyrolysis oil is a substance derived from biodegradable material through pyrolysis process by heating biomass in an oxygen-free environment. This results in high bio-oil composition, as well as charcoal and pyrolysis gas. Bio-oil may be used in liquid fuel boilers without prior treatment. After the bio-oil is treated, it may be used as a fuel for internal combustion engines or for the development of valuable chemical compounds (e.g., laevoglucose, phenols, aldehydes, furans, etc.) [37].

Processing needle foliage makes it possible to obtain a wide range of products of high added-value, such as medicines, cosmetics and feeding stuffs. Scientific literature focuses on the use of needles in relation to biological active substances [38]–[41]. Studies have been carried out examining the possibility of using coniferous extracts and essential oils for the manufacture of anticancer medicines [42], [43]. The information about the use of needles in the manufacture of plant protection products, biogas [44], nanofiber pulp [45], nano silicon [46], pulp and paper [47], [48] is available. Intermediate products and final products made from needle foliage are of high export potential, since their future use is mainly attributable to the medical sector. At the same time, the sustainable management of biological residues is also a matter of concern. As regards the use of needle foliage, it is possible to carry out a cleaner production scheme in the manufacture of products in which residues, after extraction using it as mulch in horticulture or fodder, or as a resource for the production of thermal insulation material [49]–[51], thermal packaging or composite material [52], [53]. Thus, it is possible not only to ensure a zero-waste production process but also to increase the return on a single resource stream, to diversify the production range and to become more competitive. For the moment, the main obstacles to the development of needle foliage processing plants is the underdeveloped mechanized collection of raw materials, but this issue can be solved if there were opportunities to realise this resource.

By evaluating all 9 schemes developed within the framework of the study, common uses can be seen for different bioresources. For example, from low value-added products for energy purposes – biogas, to high added value products that can be used in pharmacy – single cell oil. Both products, mentioned as examples, are made from residual streams that remain after the recycling of bioresources. This means that it is possible to find solutions to zero-waste use of bioresources, as well as to industrial symbiosis between different recycling companies.

3.4. Recommendations

In the first European Bioeconomy Strategy (2012), focus was on the science, innovations, education and training, governance and dialogue with society [7]. This principle was used to find a solution for recommendations. Responses to the three key issues for the development of recommendations were structured in line with the European Bioeconomy Strategy, combining three main blocks – "Who?", "How?" and "What?" (Fig. 7). Each of these blocks is divided into three main groups, the interaction of which within the block and between the blocks can have an impact on capacity building. The mutual and cumulative effects of these interactions will not only contribute to the development of the bioeconomy and the circular economy at the regional level, but also to microeconomic development and, as a result, to macroeconomic development at the national level.

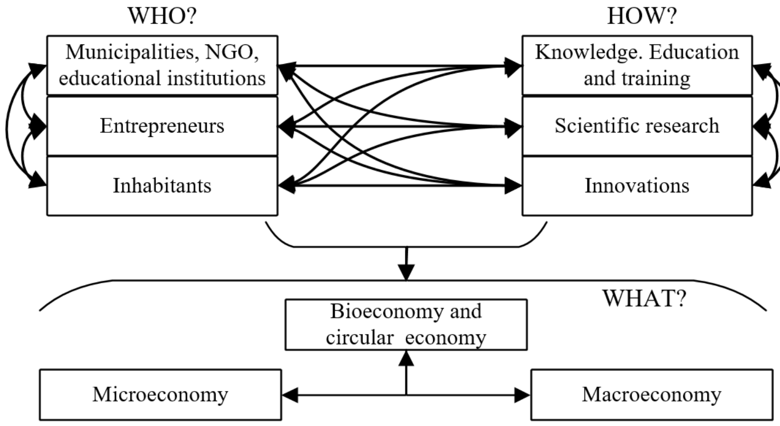

Fig. 7. A recommendation scheme to strengthen the capacity of small rural areas.

The application of the methodology developed for the evaluation of small rural regions in the context of the circular economy and bioeconomy provides opportunities to effectively direct the development of these regions by making full use of existing bioresources. The methodology can be adapted to the assessment and cross-comparison of different regions.

In accordance with the recommendation model based on the bioeconomy strategy developed in the methodology, recommendations focusing on three groups of society involved, both directly and indirectly, in the management of bioresources were developed:

- Municipalities, non-governmental organizations and educational institutions;
- Entrepreneurs;
- Inhabitants.

The economy is a knowledge-based sector. Without it, nothing else will be able to develop. Therefore, the available bioresources are fundamental to the economic development of the Aizkraukle region, but knowledge is a roof that protects and makes the economy home eternal. The issue of the development of the bioeconomy, the circular economy and the economy in the Aizkraukle region will not only be resolved by the creation of one or more large-capacity bioresource refineries. These issues should be viewed as a complex system so that, when developed in one direction, there is no oversight or exploitation of other possibilities than the use of resources available. Building up your knowledge and raising awareness to address what is happening more broadly could lead to sound decisions and take sustainable action.

4. CONCLUSIONS

The study developed a methodology for the assessment of small rural areas in the context of the circular economy and the bioeconomy, in order to make it possible to effectively direct the development of these regions through the full use of existing bioresources, which have been secured for a small rural area in Latvia for the Aizkraukle region. The results of the restructuring demonstrate that such methodology makes it possible to identify the current situation and potential of the availability of bioresources in the research region and to identify underutilized bioresource flows. The methodology developed can be supplemented with other indicators and their analysis tools to allow cross-regional comparisons and assessment of their strengths and weaknesses, and to assess the possibilities for more efficient management of available bioresources.

The case study showed that forestry plays a key role in the region, although sufficient land resources are available for the production of agricultural resources. Bioresource processing is not developed in the area, but is dominated by primary production of bioresources, which means that they do not add value, leading to the development of the economy and the increase in welfare levels. There is a sufficiently large free labour force available for business development, which is not linked to the availability of resources, the current business in primary sectors of the bioeconomy or the level of development in the area. In its recommendations to strengthen regional capacity through sustainable use of local bioresources, the focus is mainly on cooperation between organisations, business and local inhabitants in the fields of knowledge, education and training, research and innovation in the context of the bioeconomy and the circular economy.

The results obtained can be used in the development of planning documents at the level of small rural areas to include achievable and sustainable local resource management targets and other targets, so that entrepreneurs and society as a whole are aware of the available resources, diversity and their exploitation opportunities, and to identify the direction of future research and innovation.

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REFERENCES

[1] Sanz-Hernández A., Esteban E., Garrido P. Transition to a bioeconomy: Perspectives from social sciences. *Journal of Cleaner Production* 2019:224:107–119. doi:10.1016/j.jclepro.2019.03.168
[2] Zhao H. Will Resources Be Exhausted? – “Infinite” Supply of Finite Resources. *The Economics and Politics of China’s Energy Security Transition* 2019:1–27. doi:10.1016/b978-0-12-815152-5.00001-4
[3] Yildiz I. Fossil Fuels. *Comprehensive Energy Systems* 2018:1:521–567. doi:10.1016/B978-0-12-809597-3.00111-5
[4] Mullan B., Haqq-Mirsa J. Population growth, energy use, and the implications for the search for extraterrestrial intelligence. *Futures* 2019:106:4–17. doi:10.1016/j.futures.2018.06.009
[5] Lewandowski I., et al. *Bioeconomy*. Springer, 2018. doi:10.1007/978-3-319-68152-8

[6] Millar N., McLaughlin E., Borger T. The Circular Economy: Swings and Roundabouts? *Ecological Economics* 2019:158:11–19. doi:10.1016/j.ecolecon.2018.12.012
[7] European Commission. The Bioeconomy Strategy, 2012.
[8] Pülzl H., Kleinschmit D., Arts B. Bioeconomy – an emerging meta-discourse affecting forest discourses? *Scandinavian Journal of Forest Research* 2014:29(4):386–393. doi:10.1080/02827581.2014.920044
[9] Global Bioeconomy Summit. Communiqué of the Global Bioeconomy Summit 2015 – Making Bioeconomy Work for Sustainable Development. Berlin, 2015.
[10] Kirchherr J., Reike D., Hekkert M. Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling* 2017:127:221–232. doi:10.1016/j.resconrec.2017.09.005
[11] Carus M., Dammer L. Industry Report. The Circular Bioeconomy — Concepts, Opportunities, and Limitations. *Industrial Biotechnology* 2018:14(2):1–9. doi:10.1089/ind.2018.29121.mca
[12] Lindsey T. C. Sustainable principles: common values for achieving sustainability. *Journal of Cleaner Production* 2011:19(5):561–565. doi:10.1016/j.jclepro.2010.10.014
[13] Spatial Foresight, SWECO, ÖIR, t33, Nordregio, Berman Group, Infyde (2017): Bioeconomy development in EU regions. Mapping of EU Member States'/regions' Research and Innovation plans & Strategies for Smart Specialisation (RIS3) on Bioeconomy for 2014–2020.
[14] Valsts zemes dienests. Zemes sadalījums pa lietošanas veidiem, 2018 [Online]. [Accessed: 09.01.2019.]. Available: http://www.vzd.gov.lv/lv/parskati-un-statistika/statistika/statistika-no-kadastra/ZLV/
[15] Valsts meža dienests. Meža statistika [Online]. [Accessed: 08.01.2019.]. Available: http://www.vmd.gov.lv/valsts-meza-dienests/statiskas-lapas/publikacijas-un-statistika/meza-statistikas-cd?nid=1809#jump
[16] Lauksaimniecības datu centra publiskā datu bāze, 2018. gads [Online]. [Accessed: 08.01.2019.]. Available: http://pub.ldc.gov.lv/pub_stat.php?lang=lv
[17] Deklarēto kultūraugu platību apjoms pa novadiem un pagastiem par 2018.gadu [Online]. [Accessed: 08.01.2019.]. Available: http://lad.gov.lv/lv/statistika/platibu-maksajumi/periods-2004-2016/statistikas-dati-par-2018-gadu/
[18] Nodarbinātības valsts aģentūra. Statistika par bezdarbu [Online]. [Accessed: 08.01.2019.]. Available: http://www.nva.gov.lv/index.php?cid=6#bezdarbs
[19] Lursoft statistika. Aktīvo uzņēmumu skaits pa nozarēm [Online]. [Accessed: 08.01.2019.]. Available: https://www.lursoft.lv/lursoft-statistika/Statistika-Latvijas-novadu-pilsetu-griezuma&id=515
[20] Centrālās statistikas pārvalde. Iedzīvotāju skaits republikas pilsētās, novadu pilsētās un novados [Online]. [Accessed: 08.01.2019.]. Available: https://www.csb.gov.lv/lv/statistika/statistikas-temas/iedzivotaji/iedzivotaju-skaits/galvenie-raditaji/iedzivotaju-skaits-republikas-pilsetas
[21] Teritorijas attīstības indekss, 2018 [Online]. [Accessed: 09.01.2019.]. Available: http://www.vraa.gov.lv/lv/publikacijas/attistibas_indekss/
[22] Lauku atbalsta dienests. Lauksaimniecībā izmantojamās zemes apsekošana [Online]. [Accessed: 08.01.2019.]. Available: http://www.lad.gov.lv/lv/atbalsta-veidi/noderigi/lauksaimnieciba-izmantojamas-zemes-apsekosana-1/
[23] Nature protection plan for nature reserve "Aizkraukles bog and forests". Riga: Latvian Fund for Nature, 2011. (in Latvian)
[24] Jaunjelgava Regional Council. Jaunjelgava region Development Program Database (Analysis of Existing Situation). Jaunjelgava: Jaunjelgava Regional Council, 2013. (in Latvian)
[25] Grupa 93. Description of the current situation of Vecumnieki region. Vecumnieki: Grupa 93, 2013. (in Latvian)
[26] Geo Consultants. Assessment of the composition of municipal, hazardous and industrial waste in waste management areas, management of certain types of waste and possibilities for waste disposal at landfills. Riga: Geo Consultants, 2017. (in Latvian)
[27] Latvijas Vides, Ģeoloģijas un Meteoroloģijas Centrs. Summaries of the Single Environment Information System Database "3-Waste" [Online]. [Accessed: 14.01.2019.]. Available: http://parissrv.lvgmc.lv/#viewType=wasteReports&incrementCounter=1 (in Latvian)
[28] Unkovich M., Baldock J., Forbes M. Variability in harvest index of grain crops and potential significance for carbon accounting: Examples from Australian agriculture. *Advances in Agronomy* 2010:105(1):173–219. doi:10.1016/S0065-2113(10)05005-4
[29] Dai J., et al. Harvest index and straw yield of five classes of wheat. *Biomass and Bioenergy* 2016:85:223–227. doi:10.1016/j.biombioe.2015.12.023
[30] Brunori A., et al. The yield of five buckwheat (*Fagopyrum esculentum* Moench) varieties grown in Central and Southern Italy. *Terra Nova* 2005:102:98–102.
[31] Morgan C., et al. Improving harvest index in oilseed rape (Brassica napus) through modifying canopy architectur. *Agronomy* 2007:3:26–30.
[32] Lauksaimniecības kultūru sējumu platība, kopraža un vidējā ražība. Centrālā statistikas pārvalde, 2018 [Online]. [Accessed: 08.01.2019.]. Available: https://www.csb.gov.lv/lv/statistika/statistikas-temas/lauksaimnieciba/augkopiba/tabulas/lag020/lauksaimniecibas-kulturu-sejumu-platiba-kopraza
[33] Rozentals G., et al. What the forest holder should know. Salaspils: Silava, 2017. (in Latvian)
[34] Cameron A. D. Managing birch woodlands for the production of quality timber. *Forestry: An International Journal of Forest Research* 1996:69(4):357–371. doi:10.1093/forestry/69.4.357

[35] Arlinger J. Program for estimation of sawn timber, pulpwood and energy wood in felling areas. Uppsala: Skogforsk, Salaspils: Silava, 2005. (in Latvian)

[36] Rusanova J., Markova D., Bazbauers G., Valters K. Waste-to-biomethane Concept Application: A Case Study of Valmiera City in Latvia. *Environmental and Climate Technologies* 2014:12:10–14.

[37] Rasrendra C. B., et al. Recovery of acetic acid from an aqueous pyrolysis oil phase by reactive extraction using tri-n-octylamine. *Chemical Engineering Journal* 2011:176–177:244–252. doi:10.1016/j.cej.2011.08.082

[38] Polis O., Korica A., Daugavietis M. Biological active substances retained during the spruce tree foliage storage process. *Mežzinātne* 2009:19:52. (in Latvian)

[39] Daberte I., Barene I., Rubens J., Daugavietis M. Producing and determination of qualitative indices of ordinary pine needles thick extract. *European Journal of Pharmaceutical Sciences* 2007:32(1)sup:32–33. doi:10.1016/j.ejps.2007.05.069

[40] Zeng W.-C., Zhang Z., Jia L.-R. Antioxidant activity and characterization of antioxidant polysaccharides from pine needle (Cedrus deodara). *Carbohydrate Polymers* 2014:108:58–64. doi:10.1016/j.carbpol.2014.03.022

[41] Wu J. P., et al. *Cedrus deodara* pine needle as a potential source of natural antioxidants: Bioactive constituents and antioxidant activities. *Journal of Functional Foods* 2015:14:605–612. doi:10.1016/j.jff.2015.02.023

[42] Hoai N. T., Duc H. V., Thao D. T., Orav A., Raal A. Selectivity of *Pinus sylvestris* extract and essential oil to estrogen-insensitive breast cancer cells Pinus sylvestris against cancer cells. *Pharmacognosy Magazine* 2015:11(44):290–295. doi:10.4103/0973-1296.166052

[43] Kelkar V. M., Geils B. W., Becker D. R., Overby S. T., Neary D. G. How to recover more value from small pine trees: Essential oils and resins. *Biomass and Bioenergy* 2006:30(4):316–320. doi:10.1016/j.biombioe.2005.07.009

[44] Tripathi A. K., Kumari M., Kumar A., Kumar S. Generation of Biogas Using Pine Needles as Substrate in Domestic Biogas Plant. *International Journal of Renewable Energy Research* 2015:5(3):716–721.

[45] Xiao S., Gao R., Lu Y., Li J., Sun Q. Fabrication and characterization of nanofibrillated cellulose and its aerogels from natural pine needles. *Carbohydrate Polymers* 2015:119:202–209. doi:10.1016/j.carbpol.2014.11.041

[46] Assefi M., Davar F., Hadadzadeh H. Green synthesis of nanosilica by thermal decomposition of pine cones. *Advanced Powder Technology* 2015:26(6):1583–1589. doi:10.1016/j.apt.2015.09.004

[47] Sharma N., Mahajan S., Sharma N. Evaluation of different forest wastes of Northern Himalayas. *Journal of Agroalimentary Processes and Technologies* 2012:18(4):324–335.

[48] Lal P. S., Sharma A., Bist V. Pine Needle - An Evaluation of Pulp and Paper Making Potential. *Journal of forest products & industries* 2013:2(3):42–47.

[49] Muizniece I., Vilcane L., Blumberga D. Laboratory research of granular heat insulation material from coniferous forestry residue. *Agronomy Research* 2015:13(2):690–699.

[50] Muizniece I., Blumberga D. Thermal conductivity of heat insulation material made from coniferous needles with potato starch binder. *Energy Procedia* 2016:95:324–329. doi:10.1016/j.egypro.2016.09.014

[51] Muizniece I., Blumberga D., Ansone A. Use greenery from coniferous trees for manufacture of heat insulation material. *Energy Procedia* 2015:72:209–215. doi:10.1016/j.egypro.2015.06.030

[52] Dong C., Parsons D., Davies J. I. Tensile strength of pine needles and their feasibility as reinforcement in composite materials. *Journal of Materials Science* 2014:49(23):8057–8062. doi:10.1007/s10853-014-8513-8

[53] Chauhan M., Gupta M., Sungh B., Singh A. K., Gupta V. K. Pine Needle/Isocyanate Composites: Dimensional Stability, Biological Resistance, Flammability, and Thermoacoustic Characteristics. *Polymer Composites* 2012:33(3):324–335. doi:10.1002/pc.22151