Task 2.3 Regional Biomass and Nutrient Availabilities, Strumica, North Macedonia

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SDEWES-Skopje

Table of contents

1 Regional biomass and nutrient availabilities in Strumica region

1.1 Introduction

1.1.1 Background

The Strumica region is in the south-eastern part of North Macedonia. The region is represented by municipality of Strumica, which is the largest producer and exporter of agricultural products in the country. Strumica extends to an area of 321.9 km² and is located near the crossroads of the borders with Bulgaria and Greece, both EU members countries (Figure 1). A vast part, i.e., 46% of the arable land belongs to the plains relief part that are located at an altitude of 250-300m and are of primary importance for agriculture in the region. The total agricultural area in the region is 24,000 ha, and 87% belongs to the farmers dominated by arable land and gardens. Both grain and vegetable crops are equally represented on such lands, whereas on the hilly areas where varieties of high-quality tobacco are represented. The specific geographical and topographic position of the Strumica is characterized by two zonal climates, Sub-Mediterranean, with greater or lesser crossing with eastern-continental climate.[1]

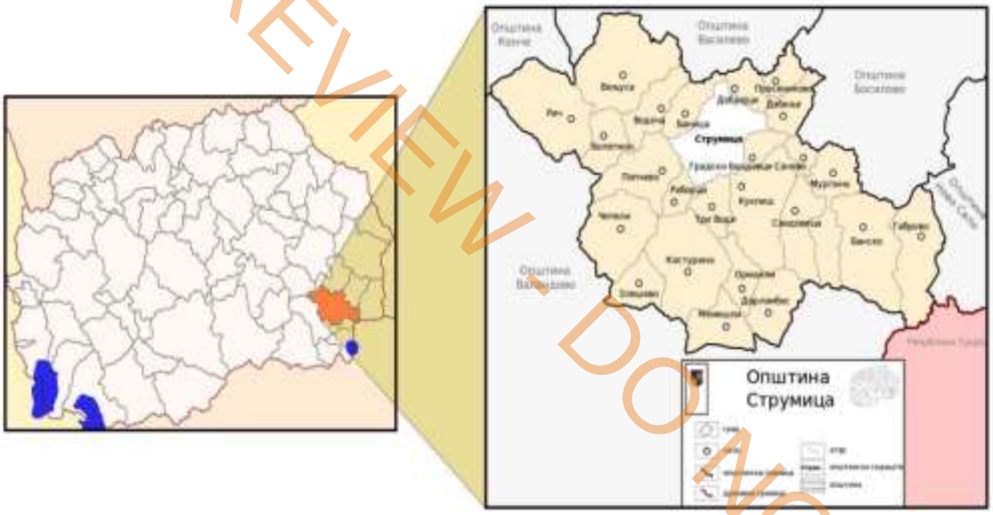

Figure 1: Geographical position of the municipality of Strumica

Source: https://strumica.gov.mk/wp-content/uploads/2020/07/Општински-план-за-отпад-2017-2022.pdf

On a national scale, the share of the total active population employed in agriculture in 2019 is 13.9%. Out of a total of 111,033 people engaged in agriculture, 35% are unpaid family workers, 49% are self-employed, 15% are full-time employees. Crop production is leading branch, where more than 50% of the employees are focused, and the remaining are occupied with mixed production and livestock breeding. However, one of the key hurdles in the agricultural sector is the aging workforce. According to 2016 survey by the State Statistical Office, only 4% of agricultural holders are under the age of 35, 34% are between 35 and 54 and 62% are older than 55 years.

Based on the same study, the education level of the people engaged in the agricultural sector was assessed. The highest percentage (42.7%) have completed other secondary school, followed by primary school with 34.6% and non-completed primary school with 8.1%. Additionally, 5.4% have

[1] https://strumica.gov.mk/wp-content/uploads/2020/07/Општински-план-за-отпад-2017-2022.pdf

completed bachelor in a different background and 4% of the people have completed a secondary school in agriculture. The share for master's and PhD is negligible.[2]

According to the latest Census, conducted in 2021, Strumica has 49,555 inhabitants with 49% male and 51% females of out which 60%, and 58% respectively are considered as working population (between 20 - 65)[3]. The favourable climatic conditions, richness of natural resources, proximity and connection to European borders and markets, makes this region a solid base for the sustainable economic, rural, and bio-based development.

The main economic branches in the municipality are agriculture and animal husbandry (40%), textile industry (25%), wood industry (13%), food industry (10%), as well as mining and metal processing. Moreover, for processing and higher finalization of the primary agricultural production, the facilities are separated into a few categories, such as production of canned vegetables, milk and meat processing, facilities for processing and fermentation of tobacco, mill-bakery industry, mini production sweets manufacturing plants etc. [4]

In-depth information on the agricultural holdings, number, and area of cadastral plots, as well as farms sizes in municipality of Strumica are depicted on the **Figure 2**.

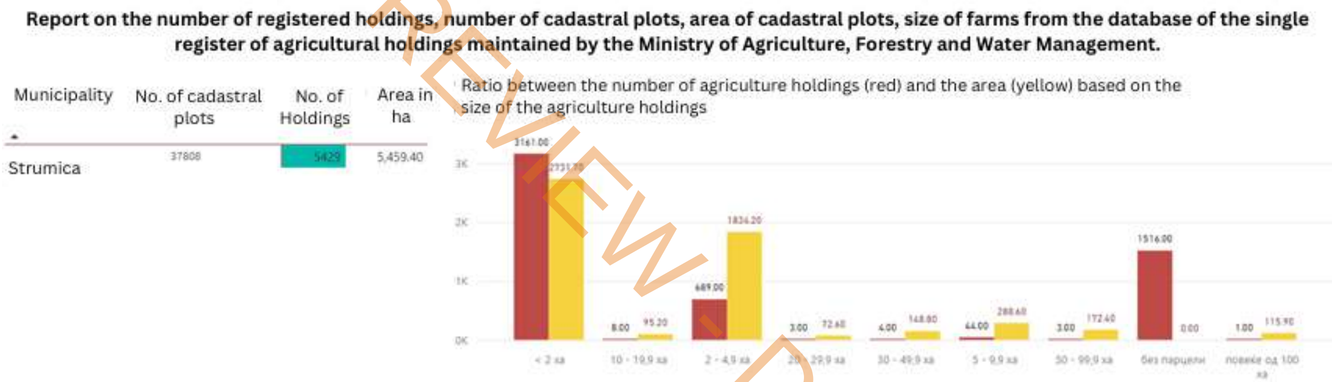

Figure 2: Number of registered agricultural holdings, number and area of cadastral plots, size of farms in municipality of Strumica

Source: Database of the unified register of agricultural holdings at the Ministry of Agriculture, Forestry and Water Management

On a positive note, Strumica is one of the best ranged municipalities in the context of Livelihood Vulnerably Index (LVI) as shown on Figure 3. It is a composite index that considers the interaction of three components exposure, sensitivity, and adaptive capacities to address associated effects or risks[5] using IPCC methodology. LVI aims to estimate vulnerability across different territorial and community levels using 96 datasets (variables), considering evident disparities in overall development, resource use, allocation, demographic, and socio-economic aspects among the country's eight statistical and planning regions. For example, the adaptive capacity component includes socio-demographic features and social networks; the sensitivity component includes food, health and water aspects; exposure refers to soil, precipitation and temperature.

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2 https://api.klimatskipromeni.mk/data/rest/file/download/7e77d1acb9ea1677e56fb75cfbefd79b7d97f2b26ed0177fc4e02aebcfc011a1.pdf

3 https://makstat.stat.gov.mk/PXWeb/pxweb/mk/MakStat/MakStat__Popisi__Popis2021__NaselenieSet/T1003P21.px/

4 https://strumica.gov.mk/wp-content/uploads/2020/07/LEAP1.pdf

5 https://api.klimatskipromeni.mk/data/rest/file/download/f897ed8237922eb53195d9068a14d8cb66624114934f17c22d4c259e1c45292a.pdf

Municipality	LVIm	AVI	LVI IPCC	Average	Rank
Rankovtse	0.769	0.736	0.318	0.608	1
Kratovo	0.757	0.730	0.291	0.593	2
Staro Nagorichane	0.722	0.703	0.230	0.552	3
Zelenikovo	0.679	0.679	0.252	0.537	4
Kriva Palanka	0.713	0.670	0.195	0.526	5
Studenichani	0.674	0.670	0.230	0.525	6
Probishtip	0.701	0.672	0.194	0.522	7
Kumanovo	0.705	0.677	0.184	0.522	8
Makedonska Kamenitsa	0.685	0.661	0.201	0.516	9
Karbintsi	0.711	0.657	0.176	0.515	10
Chucher-Sandevo	0.680	0.660	0.200	0.513	11
Veles	0.685	0.668	0.183	0.512	12
Lozovo	0.704	0.659	0.170	0.511	13
Arachinovo	0.675	0.656	0.201	0.511	14
Plasnitsa	0.703	0.657	0.163	0.508	15
Demir Kapija	0.668	0.643	0.195	0.502	16
Petrovets	0.677	0.649	0.178	0.501	17
Gradsko	0.661	0.645	0.194	0.500	18
Shtip	0.682	0.659	0.156	0.499	19
Sopishte	0.664	0.646	0.183	0.498	20
Bosilovo	0.648	0.638	0.198	0.495	21
Novatsi	0.681	0.643	0.153	0.492	22
Debar	0.669	0.645	0.149	0.488	23
Delchevo	0.706	0.649	0.100	0.485	24
Chashka	0.674	0.630	0.149	0.484	25
Konche	0.663	0.635	0.151	0.483	26
Negotino	0.633	0.631	0.181	0.482	27
Lipkovo	0.664	0.627	0.145	0.479	28
Radovish	0.652	0.621	0.151	0.475	29
Rosoman	0.632	0.619	0.167	0.473	30
Vevchani	0.680	0.631	0.106	0.472	31
Makedonski Brod	0.691	0.623	0.101	0.472	32
Sveti Nikole	0.660	0.633	0.121	0.471	33
Vinitsa	0.643	0.619	0.148	0.470	34
Ilinden	0.643	0.625	0.139	0.469	35
Kavadartsi	0.610	0.619	0.161	0.463	36
Bogovinje	0.644	0.607	0.137	0.463	37
Centar Zhupa	0.659	0.622	0.106	0.462	38
Dolneni	0.685	0.615	0.085	0.462	39
Demir Hisar	0.666	0.620	0.098	0.461	40
Dojran	0.619	0.608	0.155	0.461	41
Valandovo	0.612	0.606	0.160	0.459	42
Ohrid	0.665	0.622	0.091	0.459	42
Teartse	0.633	0.604	0.139	0.459	44
Zhelino	0.640	0.607	0.128	0.458	45
Vasilevo	0.608	0.600	0.158	0.455	46
Gostivar	0.631	0.604	0.126	0.454	47
Vrapchishte	0.635	0.598	0.126	0.453	48
Jegunovtse	0.636	0.602	0.119	0.452	49
Tetovo	0.638	0.605	0.111	0.451	50
Zrnovtsi	0.630	0.604	0.118	0.451	51
Krushevo	0.656	0.601	0.089	0.449	52
Brvenitsa	0.635	0.596	0.113	0.448	53
Mogila	0.652	0.597	0.081	0.443	54
Cheshinovo-Obleshevo	0.618	0.587	0.118	0.441	55
Debartsa	0.668	0.605	0.046	0.440	56
Struga	0.653	0.602	0.059	0.438	57
Bogdantsi	0.582	0.580	0.130	0.431	58
Gevgelija	0.585	0.578	0.125	0.429	59
Kochani	0.609	0.584	0.094	0.429	60
Prilep	0.634	0.588	0.040	0.421	61
Krivogashtani	0.636	0.568	0.049	0.418	62
Novo Selo	0.580	0.562	0.111	0.418	62
Strumitsa	0.542	0.561	0.115	0.406	64
Resen	0.631	0.567	0.009	0.402	65
Bitola	0.598	0.567	0.040	0.402	66
Mavrovo and Rostusha	0.590	0.548	0.052	0.397	67
Pehchevo	0.660	0.568	-0.042	0.395	68
Berovo	0.654	0.571	-0.040	0.395	69
Kichevo	0.624	0.544	-0.042	0.375	70
Skopje	0.490	0.544	0.007	0.347	71

Figure 3: Major components values, livelihood vulnerability indices and ranking, per municipality

Source: Sectoral report in agriculture and forestry prepared for the development of the 4NC on climate change

Despite multiple advantages of the region, there are still many challenges that need to be overcome to accelerate its modernization in this sector. Some of these are:

- small scale farms;
- small economic size of the agricultural holdings.
- population ageing;
- depopulation of the rural areas.
- lack of proper education;
- deficit of operators in agriculture.
- insufficient level of know-how.
- low level of competitiveness of the farms and the sector.
- decreased productivity caused by climate change.

By addressing these challenges, a significant improvement will be achieved in the agricultural sector in Strumica, which is a vital step towards alignment with the EU requirements.

1.1.2 Scope

The Strumica region will primarily be focusing on composting. Several biomass streams for composting will be further explored to assess their availability, quality and spatial distribution. The second value chain that could be of interest is packaging and insulation materials from agricultural residues and mycelium.

The agricultural residues and biodegradable waste from processing industries can be repurposed and used elsehow. Production of compost is one of the bio-based value chain streams that the region will be focusing on. Around 22.000 t/y of such waste ends up in the landfills[6], instead of utilizing residues from primary producers, industries and communal level levels in a more circular and economically viable way. Despite reducing the waste generated and cutting the CH_4 emissions from the landfills, compost improves soil health and lessens erosion, conserves water, and reduces household food waste. At the beginning, the regional focus will be on the agricultural residues from the primary producers and biodegradable waste from the food, vegetable processing and production industries. Those streams will be assessed as part of the first phase, and if there is sufficient data and knowledge additional expanding will be conducted with the communal waste from residential and commercial sectors, although gathering such information might be a great challenge as no bio-waste separation system is placed on a regional level. On the output side this value chain can evolve and progress in many pathways, for instance, joint collection of agriculture residues from local farmers and their distribution to the recently opened biogas plant up to 2MW located around 90km from Strumica. As a by-product from the heating process, the plant will produce organic fertilizers available to other farmers.

A second bio-based value chain that possibly could be investigated further in the region is the mycelium-based packaging and insulation materials, an innovative model that utilizes regional agricultural residues and mycelium as a bonding substance. These bio-based products could be useful for many different purposes in various sectors, such as the food and drink industry, hospitality, forestry and building sector, etc. In addition to being innovative for the region, these bio-based products are biodegradable, sustainable, flame resistant, lightweight and shock absorbent, durable and flexible, while the production process generates no wastewater and uses significantly less energy than traditional solutions. However, this value chain will be taken into consideration only if the market is assessed to be mature enough for advanced bio-based products.[7]

Since the Strumica region will be elaborating the possibilities of composting, the nutrient availability is significantly important as the compost improves the soil's ability to hold and deliver specific nutrients. This process is vital for the nutrient retention as it increases the soil exchange capacity, thus supplies the plants with needed food in the form of NPK (Nitrogen, Phosphorus and Potassium). Stabilization of organic residues improves the nutrient content and availability to be used as compost in agriculture. The adequacy of a composting is subordinate upon the groups of organisms that occupy and stabilize the natural squanders. Any handle disappointment may be due to a few uneven chemical and physical conditions within the compost heaps which are unfavourable for microbial development. One of the major natural parameters required to be appropriately controlled within the operation of composting processes is nutrient balance. The foremost vital supplement parameter is the carbon/ nitrogen or C/N proportion. Phosphorus (P) is following in significance, and sulphur (S), calcium (Ca) and follow amounts of a few other components, all play a portion in cell metabolism.

Nonetheless, the benefits of biodegradable residues recycling are numerous, one of them being the reduction of accumulation of waste products in nature. Additional added value is that it aligns with sustainable and circular concepts such as cleaner production, zero-waste, and bio-based economy.

[6] According to the Civil Engineering Institute Macedonia during the development of the Regional Plan for integrated waste management. In North Macedonia, there is no standardized landfill, therefore in this context, landfill only refers to a place where the waste is disposed.

[7] https://www.scaleup-bioeconomy.eu/en/news/news-scale-up-cross-regional-assessment-workshop-presentations-and-report-available/Presentation_Strumica_SDEWES-Skopje.pdf

1.2 Biomass Availability

1.2.1 Biomass availability of primary agricultural residues

To assess the biomass availability, data on local, regional and national level were reviewed. The first step was an analysis of the agricultural land use. Figure 4 depicts the situation in Strumica. Almost 25.000 hectares are used for agriculture, the largest part for pastures and meadows, followed by garden crops, such as tomatoes and peppers.

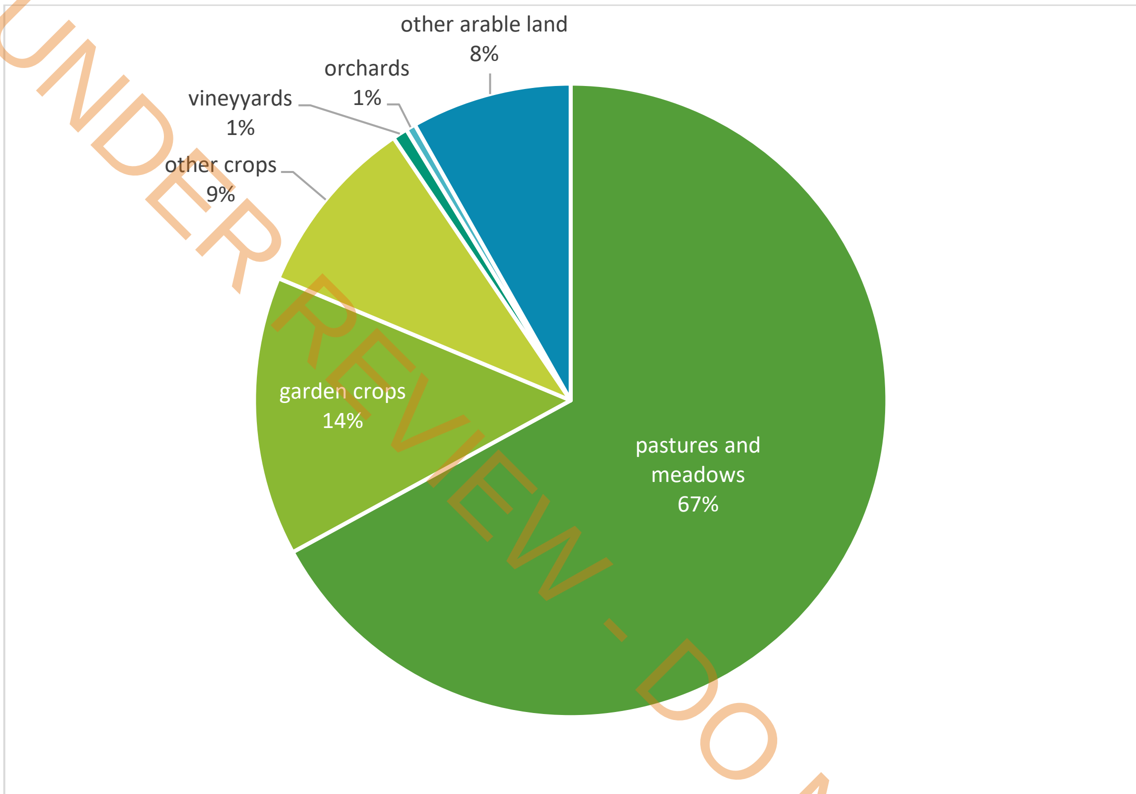

Figure 4: Agricultural area by category of use in hectares according to the NUTS 2013, for Strumica, 2022

Source: MAKStat database

The principal agricultural crops are shown on the Figure 5. The graph shows the production of grain, forage and vegetable crops in Strumica. The garden crops, such as tomatoes, peppers, cucumbers, cabbage and melons are good for more than 140.000 tons per year in Strumica.

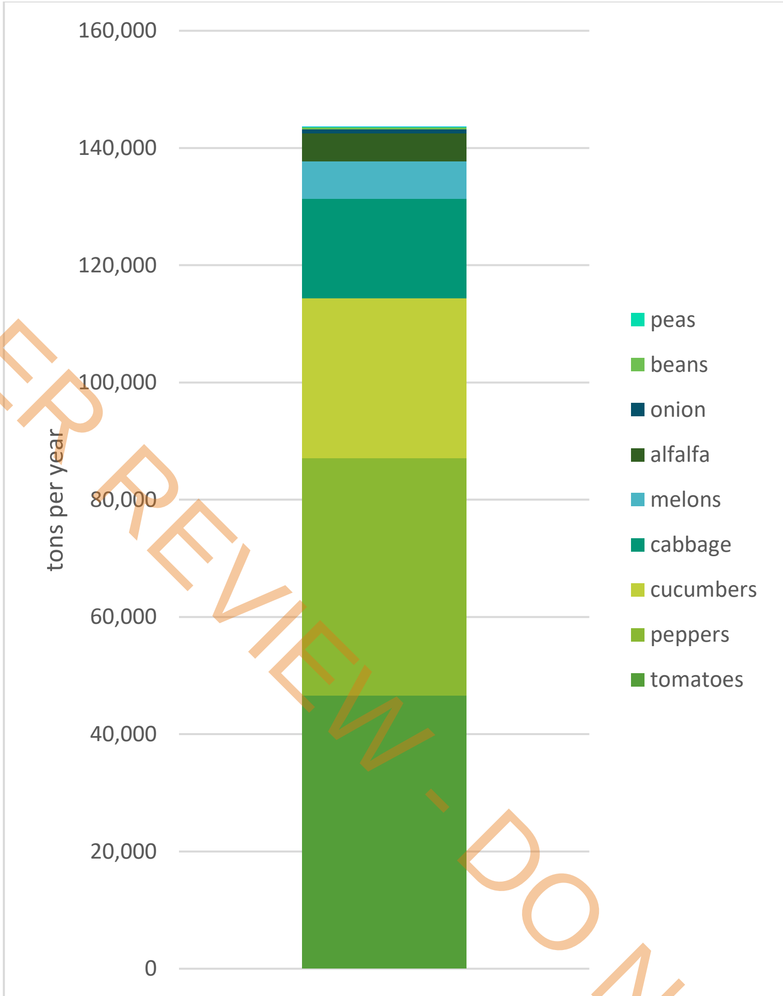

Figure 5: Production of most important garden crops, for Strumica, 2022

Beside vegetable production, the region is known for its fruit production. The apples are front-runners in the total number of fruit trees, as well the number of fruit-bearing trees and total production, as shown below (Figure 6, Figure 7).

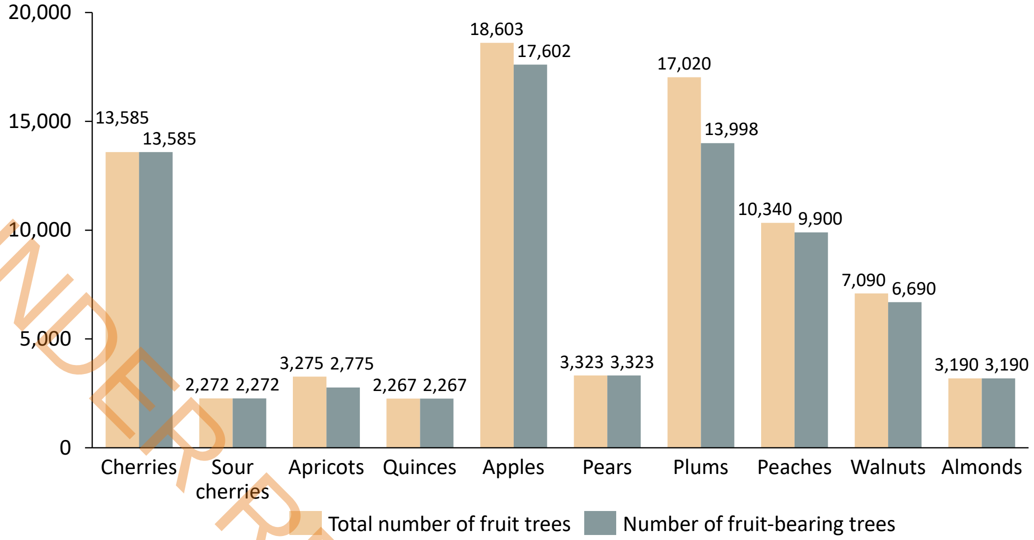

Figure 6: Number of fruit trees and fruit-bearing trees, according to the NUTS 2013, for Strumica, 2022

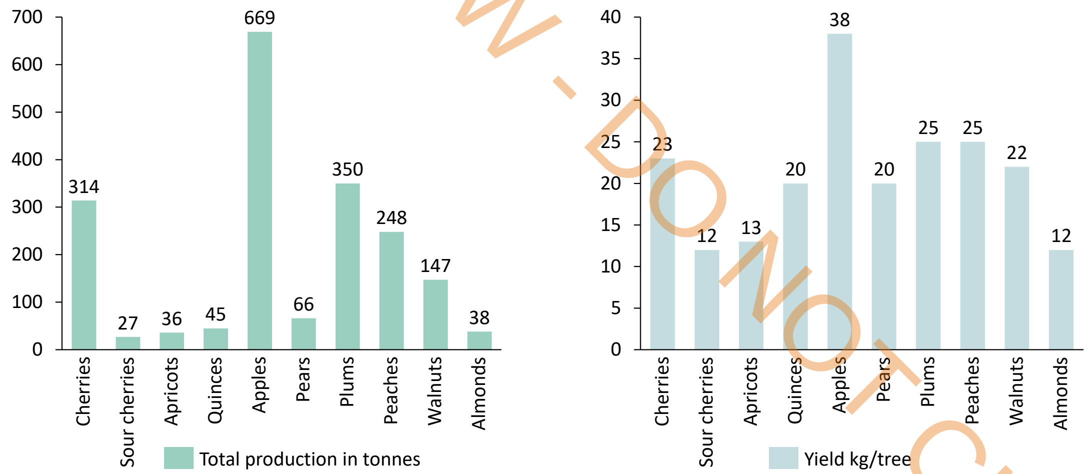

Figure 7: Production of fruit, according to the NUTS 2013, for Strumica, 2022

Source: MAKStat database

Although wine production is not the primary stream for Strumica, the region has a decent amount of production. This category is worth mentoring due to the pruning residues that might contribute to the compost processes. Some of the key information are area and production of vineyards available in Strumica. In 2022, the total harvested area is 170 hectares. Moreover, the total number of vines is accounting for 946 000 and the number of bearing vines is 914 000. To give a better overview of the potential, the total production in tons is 5 780 or 34 001 kg/hectare.[8]

In addition to the agricultural residues, it is important to consider the forest residues as well. In Figure 8, an overview of the forest area by tree types in South-East region is shown, totalling at 142 739 hectares for 2022. Such information is important to assess the forest residues potential of the region. Furthermore, the afforestation in the same year is set at 14 hectares of coniferous trees and the afforestation in and outside the forest is calculated at 71 hectares. The gross felled timber, specifically residues are accounted with 4 978 m^3 on annual level.

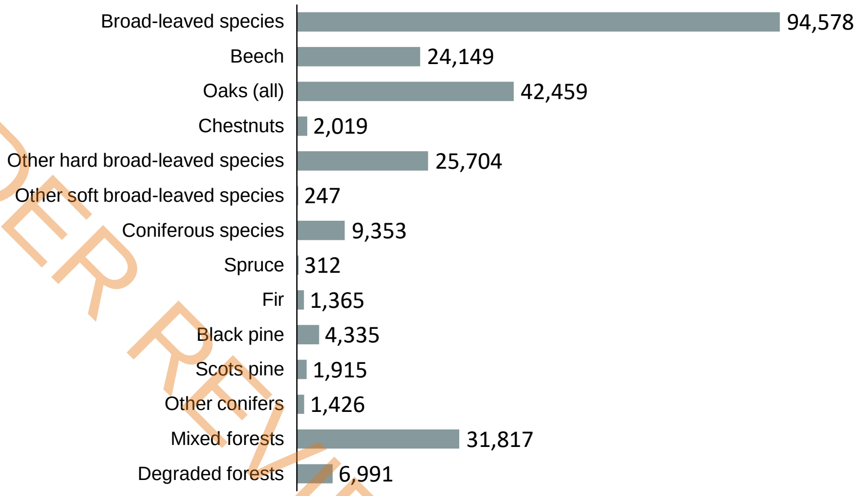

Figure 8: Forest area by type in South-east region, 2022 (in hectares)

Source: MAKStat database

Another waste stream that could be of potential use is the municipal biowaste from the households and commercial sector. Figure 9 represents the amount of waste by categories on national level, where is evitable that the households are producing most of the waste.

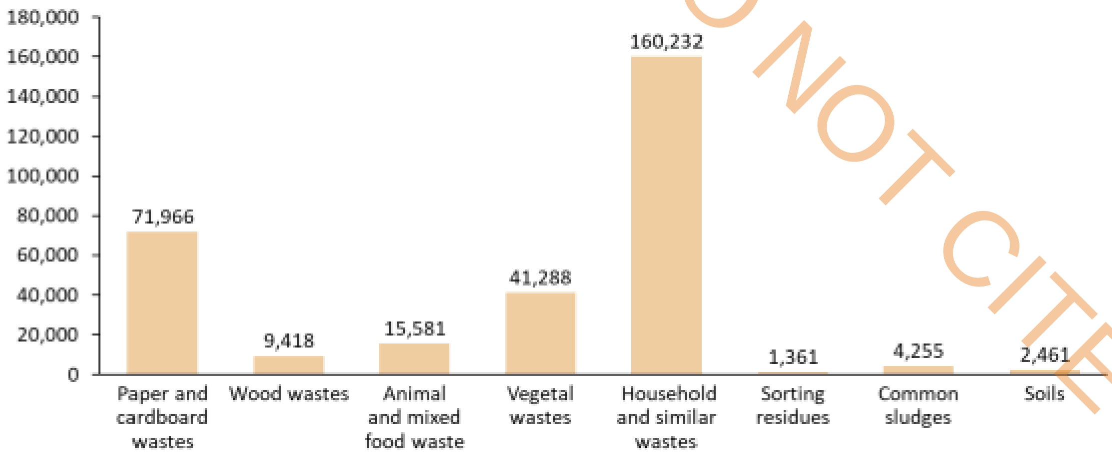

Figure 9: Amount of waste-by-waste categories, North Macedonia, 2020, in tonnes

Source: MAKStat database

8 https://makstat.stat.gov.mk/PXWeb/pxweb/en/MakStat/MakStat__Zemjodelstvo__RastitelnoProizvodstvo/625_RastPro_Op_14_Lozja_ml.px/table/tableViewLayout2/

Focusing on the municipal waste only, the generation of waste on regional level for the South-East region accounts for 71,724 tonnes, whereas the collected municipal waste is 57,717 tonnes in 2022. [9] The SSO is not providing waste data on municipal level, so according to the Plan for waste management in the municipality of Strumica 2017-2022, an average of 60% of the total communal waste is organic (food waste) per annum. More detailed information on the waste fractions in Strumica is available under Table 1.

Table 1: Quantities of municipal waste divided by fractions in Strumica (in tonnes / year)

Total	Biodegradable	Paper and cardboard	Plastic	Glass	Textile	Metals	Nonmetals	Hygienic	Inert	Hazardous waste	Other
23744	10096	2410	2478	2555	168	100	544	2885	993	341	1174

Source: Study for analysis of composting potentials in domestic conditions in the south-east planning region

Table 2 provides an overview of the biodegradable residues from agricultural crops as presented in the local environmental action plan of the municipality of Strumica.

Table 2: Sown area of agricultural crops and potential organic residues quantities in Strumica

Agricultural crops	Sown area (ha)	Organic residues (t)
Cereals	2383	4766
Garden crops	1640	3280
Fodder crops	480	960
Industrial crops	580	1160
Oil crops	38	76
Fruit crops	120	240
Vine crops	137	274

Source: Local environmental action plan of municipality of Strumica- 2024-2029

In the study the areas for agricultural crops are considerably lower than the MAK Stat database figures. In the MAK database the area for garden crops is more than twice as large (3.300 ha vs. 1.640 ha). The organic residues produced for garden crops (3.280 ton per year) are much lower than expected when looking at the agricultural production (more than 140.000 ton per year). Assuming a waste percentage in the sector of typically 20% of waste in the production stage and 5% in the handling and storage stage (FAO-figures), one would expect something in the order of 35.000 ton per year. A closer look at the figures in the environment action plan, will therefore be necessary.

9 https://makstat.stat.gov.mk/PXWeb/pxweb/en/MakStat/MakStat__ZivotnaSredina/325_ZivSr_reg_08_11_KomOtp_ml.px/

1.2.2 Biomass availability of secondary residues from processing industries

To closely depict the situation regarding the generated biowaste from the main industries, a questionnaire was prepared and shared with the business sector in Strumica. The survey consisted of 10 questions related to the company environment itself, produced waste and further waste management. A total of 15 industries and companies submitted their response, as listed below:

- Production of canned vegetables and fruits
- Wood processing industry and manufacture of other furniture
- Production of plants for horticultural arrangement
- Production of beverages (alcoholic and non-alcoholic)
- Meat processing
- Milk processing.
- Oil processing.
- Production of cleaning chemicals
- Production of plastic packaging
- Trade

Additionally, the vocational high school for agriculture provided their responses as well, as they have organic waste and are composting as part of the school practices. According to the type of the enterprises, they are predominantly small or medium-sized, and only one micro and one large-sized provided their feedback.

One of the main questions in the questionnaire is whether an industry has biowaste after the processing activities and to what extent. However, 26% of the answers were that they are producing almost no waste or have leftovers and an additional 13% have only small amounts of nylon and plastic packaging as waste. Furthermore 20% of waste generated is classified as cardboard, stretch film, chipboard, and plywood. In addition, 20% responded that within their processes they have bio-waste, such as vegetables and fruit residues or gardening and plant residues. Some of the industries have mixed waste, such as waste from cardboard packaging, plastic packaging, organic waste from non-compliant milk inconvenient to process, waste from plastic packaging. Residues of this kind can be used for eco-tiles, as is the case in the two municipalities Gevgelija and Kochani, part of South-East planning region. The project that started in 2022 has gained great success and plans on expending in other municipalities in the South-East region. Moreover, Strumica as the leading processing industry municipality could have a major part in reducing the plastic packaging and transforming it into durable and eco-friendly products.[10]

The largest vegetable and fruit processing industry in Strumica provided a detailed overview of their waste, which includes glass, cardboard and foil. Organic waste was said to be returned to the farmland. Details about these residues and their current use, however, were not given. This needs to be investigated further. This stream is considered an important potential source for biomass.

The quality and quantity of waste generation depends on the raw material processed. Hence, omitting those industries that are with very limited waste generation, 26% stated that the residues quality can be classified as good, whereas 20% consider their waste with low quality as raw materials temper during processing. Some waste types, such as cardboard and foil, are in good condition and can be reused,

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[10] https://inovativnost.mk/2022/06/11/ова-се-првите-еко-плочки-направени-од-от/

the glass is broken and needs further processing and there are also non-disposable animal products, but the biodegradable waste is suitable as poultry feed.

Furthermore, regarding the current use of the waste, most of the responses were negative, i.e **73% are not benefiting from their residues**. Some industries are using their own waste for heating purposes, others to produce secondary products or are selling it to the authorized companies specialized for certain types of waste. Few of the industries are emphasizing the environmental impact, thus contributing to the regional bioeconomy development as they are providing the biowaste to the local farmers or are repurposing it for composting.

Another important issue is to assess the waste management status quo in Strumica. Although on the national and regional level, there is a regulatory framework and plans that regulate to a certain extent the waste disposal, yet their full onsite compliance is lacking. There is no unified waste management approach for various types of industries, however some of them are supplying the nearby farms as poultry feed or are being composted. In general, as stated in the survey, the industries with larger amounts of bio-waste are collecting it in separate containers after the production process and then it is removed by the public company for waste management. Additionally, the paper and cardboard waste is sorted out as well in separate containers and collected by authorized company for such waste type.

In general, the industries are not being financially compensated for properly selecting waste and are charged for the service depending on the waste type. For instance, for the meat industry the service is around 700 MKD (11.5 EUR) per container, the wine industry is charged 1 MKD (0.02 EUR) per kilogram for paper and cardboard, and the wood debris disposal by authorized company costs around 3000 MKD (50 EUR) per container. However, the largest production facility for non-alcoholic beverages is being reimbursed for biowaste selection.

Regarding the current level of waste management control, around 60% of the stakeholders engaged in the survey consider that there is not enough control and further enhancement in that field is swiftly needed. The rest are either partially satisfied or believe that the control level is sufficient for the time being.

At last, having in mind the opportunities that SCALE-UP project provides and possible identification of synergies with the bio-waste management of the industries in Strumica, a closing question about their interest in applying and benefiting from the support program innovation business model was also included in the survey. Delightfully, almost 80% are willing to join an activity that would deal with bio-waste, e.g. organized collection and further treatment of this such waste to produce compost or other bio-based products, processes and services.

1.3 Nutrient Availability

1.3.1 Nutrients in fertilizers and compost

For suitable development and advancement, the plants ought to have compelling access to nutrients at reasonable concentrations. The basic components are partitioned in different categories: primary macronutrients (nitrogen, phosphorus, and potassium), secondary macronutrients (calcium, magnesium, and sulphur), and micronutrients (chlorine, press, boron, manganese, zinc, copper, nickel, and molybdenum). The main benefit of compost is not to make the soil immediately richer in important elements like nitrogen, phosphorus, and potassium for plant growth. Instead, it helps improve the structure of the soil and allows the plants to absorb nutrients more easily. This leads to a better balance in the soil.

The most important influencing factors on the composting process of different organic waste are:

- The size of the particles of the compostable material.
- Microorganisms (from the classes of bacteria, fungi, yeasts, actinomycetes, algae and protozoa).
- Aeration;
- Porosity;
- Moisture content (40 – 60%);
- Temperature (30 – 60°C);
- pH value of the material from the compost pile (6.5 - 7.5);
- Nutrients and C/N ratio (Appropriate levels of phosphorus and potassium; C:N ratio = 25:1; brown mass: green mass = 1.5 part : 1 part);
- Absence of toxic substances, waste (metal pieces, plastic, pesticides, wood treated with chemicals, etc.).[11]

However, concentrating on the nutrients, some general nutrient properties of composts should be highlighted. The nutrient content in the crop residues for each of the different components is varying, for instance for N is between 1.5 and 2.5, for P is 0.2 and 0.5 and for K is between 1 and 2. [12] Moreover, C/N ratio is also of the key factors that impact the length of the composting process. Hence, having non-optimal proportions of C/N different from 30 will extend the time of compost making. Phosphorus is the second limiting element for crops after nitrogen, as it responsible for cell growth and development. Last, but not least of the primary nutrient, the potassium is crucial for enzymes, coenzymes, protein synthesis, and photosynthesis in the composting cycle.

In a study within the scope of the Strumica River Watershed Restoration Project, soil properties were comprehensively investigated, including water-physical and chemical aspects and calcium carbonate presence. Fertilizers, both organic (manure, cover cropping, composting, vermiculture) and mineral, were explored. The study highlighted that high-quality soil contains about 50% solid matter (45% mineral, 5% organic), 25% water, and 25% air, influencing its productive value, commonly referred to as soil fertility. Factors determining soil fertility include an active organic layer, organic matter content, soil pH, favorable composition, water-physical properties, ability to retain water and nutrients, and nutrient supply. Organic matter, a crucial chemical property, decomposes in the soil, impacting its structure, water-air regime, and nutrient content. Rich in phosphorus, potassium, and organic nitrogen, it provides accessible nutrients through microbial decomposition. Soil organic content depends on practices, soil type, and climate, with clay soils containing more. Changes in cultivation practices can decrease organic matter, requiring measures like manure application, crop rotation, residue incorporation, cover crops, and green manure. With prolonged cultivation, biogenic elements are exported, leading to soil depletion. A deficit of essential nutrients affects soil fertility. To achieve quality yields, supplementing biogenic elements is necessary. Sources include organic and mineral fertilization, weathering, and atmospheric deposition. Organic fertilizers, derived from various waste sources, include farmyard manure, green manure, and compost. Green manure, from specific crops, benefits soil with increased nitrogen, organic matter, erosion protection, reduced leaching, and enhanced microbiological activity. Properly chosen, green manure can introduce approximately 100 kg N/ha, 30 kg P/ha, and 130 kg K/ha into the soil (

[11] https://eastregion.mk/wp-content/uploads/2022/02/Анализа%20за%20состојба%20со%20пожетвени%20остатоци%20во%20Брегалнички%20регион.pdf

[12] https://www.sciencedirect.com/science/article/abs/pii/S0956053X17305846

Table ***3***).

Table 3. Green manure crops

Crop	Rooting Depth (cm)	Enrichment with N (kg/ha)
Lupine	60-230	160-300
Peas	30-90	80-130
Beans	80-130	75-130
Red Clover	100-200	75-130
Alfalfa	200-300	290-390
Oats	/	35-90
Mustard	/	35-90

Compost, an aerobically decomposed organic matter rich in nutrients, enhances soil structure. To optimize microbial activity and humus formation, a varied mix of waste materials is crucial—green components (fruit/vegetable remnants, tea/coffee leftovers, etc.) and brown components (dry leaves, small branches, sawdust, eggshells, etc.). Soil, especially from gardens and those containing carbonates, is a vital component. It aids in moisture retention, absorbs volatile substances (especially NH4-N), and neutralizes organic acids formed during organic matter fermentation. Under favorable conditions of heat, moisture, and oxygen, decomposition occurs rapidly, sometimes within two weeks. Without optimal conditions, decomposition continues but may extend to several months. Summer requires 10-14 weeks, and winter demands 14-18 weeks for the organic matter to decompose, resulting in mature compost characterized by a homogeneous black texture. Research underscores the benefits of 4 tons of compost per hectare, surpassing the impact of 10 tons of composted manure or 20 tons of fresh manure. Recommended applications are 2-3 kg/hole during planting, mixed with soil for an aerobic layer, and 1-2 kg/stem during vegetation at a depth of 5-15 cm.

On the other hand, mineral fertilizers contain one or more biogenic elements and are categorized as simple and complex, physiologically acidic, neutral, and alkaline (Table 4). They are also classified based on the active material into N, P, K, in various combinations and concentrations, with common examples being NPK triple combinations (e.g., 4:12:9, 11:15:15) and double PK combinations (e.g., 16:20, 20:20, 13.5:46). [13]

Table 4. Commonly used types of mineral fertilizers

Type of mineral fertilizer	Active substance	Content in %
Nitrogen fertilizers	Calcium ammonium nitrate (CAN)	27% nitrogen
	Ammonium sulfate	21% nitrogen
	Ammonium nitrate	34% nitrogen
	Sodium nitrate (Chilean saltpeter)	15-16% nitrogen
	Calcium nitrate (Norwegian saltpeter)	13-16% nitrogen
	Ammonium chloride	24-25% nitrogen
	Urea	46% nitrogen
	Calcium cyanamide (CaCN2)	18-22%
Phosphorus fertilizers:	Superphosphate	16-18% P2O5
	Thomas phosphate flour (Thomas phosphate)	16-18% P2O5

[13] https://southeast.mk/wp-content/uploads/2020/12/Integralna-zastita-brendiran-v2.pdf

	Triple superphosphate	42-48% P2O5
Potassium fertilizers:	Potassium sulfate	48-52% K2O
	Potassium carbonate	60% K2O
	Potassium chloride	40 and 60% K2O
Calcium fertilizers:	Limestone	70-90% CaCO3
	Unquenched lime	90-95% CaO
	Saturational manure	20-25% CaO + 15% organic matter

The latest data for fertilizer use in 2021 in North Macedonia is 50.5 kg per hectare of arable land, significantly lower than the world average of 161.5 kg per hectare based on 184 countries in the same year. [14] The price for imported mineral fertilizer is 20 euros per 25 kg package, while the price for organic fertilizer is 15 euros per 25 kg package or even 10 euros per 30kg package.[15,16,17] (Figure 10) Furthermore, for the production of the organic fertilizers, bio-waste is used, positively influencing climate change and society, thus it provides lower price and better quality. The latter fertilizer is a high-quality organic microbiological fertilizer, bio stimulant, and soil conditioner in solid form, obtained through the processing of barnyard manure by Californian red worms. It's noteworthy to mention that the cost of locally produced organic fertilizer remains lower than that of imported mineral fertilizers.

Figure 10. Different types of organic and mineral fertilizers

14 https://www.theglobaleconomy.com/Macedonia/fertilizer_use/#:~:text=Fertilizer%20use%2C%20kg%20per%20hectare%20of%20arable%20land&text=The%20latest%20value%20from%202021,to%20compare%20trends%20over%20time.

15 https://eco-habitat.mk/product/prirodno-gjubrivo/

16 https://www.sinpeks-shop.mk/index.php?pageid=a23&acckey=20S01000280&ident=004899

17 http://organikanova.com/mk/proizvodi/

A significant portion of agricultural residues from farmers and bio-waste from processing industries is primarily directed towards farmers' fields for soil improvement. However, it's essential to note that a portion of these residues also finds its way to landfills and remains misutilized, instead of contributing to the regional bioeconomy circularity.

In October 2024, as part of the SCALE-UP project, a study visit was organized in Strumica, offering project partners and stakeholders a firsthand look at a successful practice in North Macedonia (Figure 11). The initiative addresses the large amount of biodegradable waste being deposited in landfills in the country. The family-owned business adopted an innovative approach. They decided to collect and transform the waste into compost.

Figure 11. Study visit in Strumica region, composting plant in Novo Selo

The composting plant, in operation for four years, covers a sprawling four hectares. The raw materials used include remnants of herbs, flowers, fruits, as well as reeds sourced from the nearby meadows and swamps. The facility produces an average of 5,000 m^3 of certified organic compost annually. The composting process, with a turnaround time of six months per cycle, involves the dedicated efforts of two agronomists and six skilled machine operators (Figure 12).

Figure 12. Composting processing and machineries

Currently, the compost is distributed solely by tractors. However, the forward-thinking family business is planning to introduce bio-packaging for the compost, aiming to make it more accessible for smaller quantities and various buyers. This step underscores their commitment to sustainability, extending beyond waste reduction to eco-friendly packaging solutions. This success story showcases a comprehensive approach to waste management, turning a significant environmental challenge into an opportunity for positive change and serve as a good example for the interested stakeholders withtin the SCALE-UP project (Figure 13).

Figure 13. SCALE-UP consortium and external stakeholders during the study visit

Although the nutrient availability is getting more attention and there is significant amount of data already available on international scale, Strumica region is lagging behind. It is necessary to carry out comprehensive research aimed at improving the nutritional aspects of the compost on the macronutrient content.

1.4 Discussion of the Results

It is difficult to assess the technical biomass potential from the agricultural sector. Studies show large variations in the quantities, ranging from 10.000 to almost 40.000 tons per year (fresh material). Reasons for the differences are not clear. The variations show the need for a better understanding of the agricultural sector and the way residues are used. The amount in dry material is very roughly estimated at 4.000 to 16.000 ton (dm) per year.

Residues come available in various shapes and sizes. Quality is expected to vary in form, composition, and moisture content. This has an impact on the way the residues can be used. Some could be composted in the open air, other residues better not, as this might cause bad smells or contamination of water and soil. A closed environment would be advisable. Some organic wastes, however, might be better suitable for co-digestion, along with manure, producing biogas and biofertilizers from digestate.

Residues come available at different places: a large part spread over the agricultural land and a considerable part coming available at the food factories. Not all that is produced, can be collected. This is partly due to technical reasons, but there is also a large financial factor. The first limits the technical potential, the second the economic potential. This distinction is important. The technical potential represents the amount that can be collected from the fields and factories within the ecological boundaries. The economic potential also considers factors such as production costs and market demand for the final product. This may limit the actual amount of biowaste that can be effectively collected and utilized.

1.5 Conclusions and Recommendations

1.5.1 Conclusions

Biomass potential in the agricultural sector

In the Strumica agricultural sector the biomass potential is estimated between 10.000 and 40.000 tons per year (fresh material). The lower figure is based on the recent municipal environment study, the higher one on agricultural production figures and typical FAO waste percentages in the sector.

What happens with the biomass is yet not clear. A part is expected to remain at the farms. The part at the food factories is said to be returned to the fields. There are indications that a large part of the agricultural and food-processing waste produced is dumped. A recent study estimates this amount at 22,000 tonnes per year.

The economic biomass potential depends on the collection and processing costs, market value of the compost and competing alternatives. A project's survey indicates that local industries may be interested in improved waste processing. Almost 80% of respondents are willing to engage in bio-waste initiatives, underscoring a proactive stance. While biomass availability poses challenges, it is not a definitive limiting factor; strategic interventions can unlock the region's full bio-based potential.

As regards to nutrient recycling possibilities, Strumica is progressing towards eco-friendly farming. Composting initiatives are welcomed, turning organic waste into a valuable resource and reducing the need for chemical fertilizers. The aim is improving soil quality and providing nutrients for crops: nitrogen, phosphorus and potassium, with phosphorus crucial for crop growth. A project in Novo Selo shows a family-run composting plant converting organic woody waste into organic compost. This could be an example for new initiatives. Strumica still uses much less chemical fertilizers (50.5 kg per hectare) compared to the global average (161.5 kg per hectare).

1.5.2 Recommendations

To enhance biomass availability and nutrient recycling in the Strumica region, several key research and policy initiatives are recommended:

Improved knowledge on biomass resources and utilization	Share local knowledge in the regional platform on the quantity and quality of biomass resources and current utilization in the region. Analyse recent studies and improve estimates on the technical biomass potential and assess the market potential of compost. Analyse the potential for open air composting. Analyse the possibility of joint collection of biowaste for co-digestion in the existing biogas plants.
Policy Support for Modernization	Advocate for and implement policies that support the modernization of agriculture in the region. This could involve financial incentives, training programs, and infrastructure development to address challenges and promote sustainable farming practices.
Promotion of Composting Practices and Demo plants	Develop and implement policies that encourage the adoption of composting practices at both household and industrial levels. This includes establishing a waste separation system for composting household waste, diverting organic waste from landfills, and promoting the use of compost in agriculture. Demo plants will intensify the good examples in Strumica region as many farmers will get a first-hand experience and potentially replicate to improve their agricultural management habits.
Nutrient Recycling Strategies and technical assistance	Invest in research and policies focused on efficient nutrient recycling. This includes identifying ways to optimize the nutrient content of compost, exploring innovative technologies for nutrient extraction from waste, and promoting the use of recycled nutrients in agriculture to reduce reliance on mineral fertilizers. Technical assistance of great importance to highlight the need of identification of nutrients, and their better application in the compost and organic fertilizers.
Collaboration with Regional Platform	Engage with regional platform in Strumica to facilitate knowledge-sharing, and collaborative initiatives. The regional platform can serve as a hub for exchanging best practices, coordinating waste management efforts, and fostering partnerships between local industries and agricultural stakeholders.
SCALE-UP Project Initiatives	SCALE-UP project could assist various stakeholders with the organization of various workshops and training sessions to educate them on sustainable practices, different aspect of the bioeconomy and bio-based value chain. Within the Innovation Program it could help the business idea holders to match with financial support for composting initiatives and facilitating partnerships between industries and local farmers for efficient waste management. Exchanging knowledge and experience with EU countries is one the most important aspects that could serve to upgrade as much as possible and to align with the modern and circular bio-based sector.
Incentivizing Industry Participation	Develop policies that incentivize industries, especially those in wood processing and food processing factories, to actively participate in bio-waste initiatives. This could include tax incentives, recognition programs, and regulatory frameworks that encourage sustainable waste management practices.

By prioritizing these research and policy recommendations, Strumica can foster a more sustainable and resilient bio-based ecosystem, addressing challenges while maximizing the potential for biomass utilization and nutrient recycling.