Report on regional biomass availabilities, nutrient balances and ecological boundaries

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EXECUTIVE SUMMARY

This document presents the assessment of the biomass potential and nutrient recycling opportunities within the six SCALE-UP regions: Northern Sweden, Mazovia (Poland), the French Atlantic Arc, Upper Austria, Andalusia (Spain), and Strumica (North Macedonia). It is supplemented by a series of sustainability screening exercises in each region that aim to provide rough indications of where their ecological boundaries might currently lie. The biomass assessment includes an evaluation of agricultural residues and forestry residues. The sustainability screening includes appraisals of the state of water, land and soil, and biodiversity.

Biomass availability and nutrient recycling are essential for a thriving bioeconomy, an economic system that utilizes biological resources to generate products and services. To ensure the sustainability of this adapted economic model, system dynamics must be acknowledged to keep ecological boundaries from being overstepped. Therefore, the state of the environment and potential impacts of bioeconomic activities are considered. Recommendations are given to optimize biomass utilization and nutrient management to enhance bioeconomy growth while keeping environmental impacts in check.

For each region comprehensive reports have been written on biomass availability and nutrient recycling, and on ecological boundaries. To facilitate dissemination within the platforms, on the SCALE-UP webpage and other media, the reports have been summarized into factsheets illustrated by diagrams. The table below shows where the reports can be found. With clickable titles, allowing easy navigation.

Table 1, Overview regions, biomass streams, factsheets and Annexes

Region	Biomass stream	Factsheet	Biomass Potential & Nutrients	Ecological Boundaries
North Sweden	Forestry residues	Biomass & Ecological Boundaries Northern Sweden; Nutrients Northern Sweden	Annex 1: Regional biomass and nutrient availabilities in	Annex 7: Sustainability Screening – Biofuel Region, SE
Mazovia (Poland)	Apple by-products	Biomass & Ecological Boundaries Mazovia (Poland); Nutrients Mazovia (Poland)	Annex 2: Regional biomass and nutrient availabilities in Mazovia region (Poland)	Annex 8: Sustainability Sceening – Mazovia, PL
Strumica (North Macedonia)	Compost from agricultural residues	Biomass & Ecological Boundaries Strumica (North Macedonia); Nutrients Strumica (North Macedonia)	Annex 3: Regional biomass and nutrient availabilities in Strumica region	Annex 9: Sustainability Screening – Strumica, MK
Upper Austria	Beer and bakery by-products	Biomass & Ecological Boundaries Upper Austria; Nutrients Upper Austria	Annex 4: Regional biomass and nutrient availabilities in Upper Austria	Annex 10: Sustainability Screening – Upper Austria, AT
French Atlantic Arc	Building insulation from fibre crops and straw	Biomass & Ecological Boundaries French Atlantic Arc; Nutrients French Atlantic Arc	Annex 5: Regional biomass and nutrient availabilities in the French Atlantic Arc	Annex 11: Sustainability Screening – French Atlantic Arc, FR
Andalusia (Spain)	Olive by-products	Biomass & Ecological Boundaries Andalusia (Spain); Nutrients Andalusia	Annex 6: Regional biomass and nutrient availabilities in Andalusia	Annex 12: Sustainability Screening – Andalusia, ES

There are several observations and conclusions that could be made when reviewing the reports. The most important ones are the large differences in depth and approach between the regions, the effect of production levels and the location where biomass comes available, the effect of feedstock- and product markets, the difficulty to assess the economic potential and ecological boundaries when production chains are not sufficiently known or defined, and the biomass availability compared to the quantities required.

In all regions, special attention has been given to the possibilities of nutrient recycling and to the notion of ecological boundaries. Here, the state of surface water bodies and the multiple pressures they are subject to is of moderate to high concern across all SCALE-UP regions. Soil erosion and other forms of degradation remain a considerable risk in two out of the six regions. And concerns on biodiversity are indicated by the relatively large number of species categorised as endangered and critically endangered in half of the SCALE-UP regions. This need not be seen as an insurmountable challenge to the development of regional bioeconomies, but as a call for a) reflection and serious consideration of the sustainability dimension of the bioeconomy concept, and b) integration of currently disperse initiatives that can drive meaningful innovation and community well-being. As a concrete example, concerns with respect to the impacts of excessive pesticide and fertilizer use on the environment may influence the possibilities for nutrient recycling. In this report, all regions have included recommendations to pay more attention to nutrient recycling and the ecological boundaries.

The information from this report should provide a good base for assessing the economic and environmental potential in the six SCALE-UP regions in the future. Many building blocks have been assembled in the regional reports for future availability and ecological assessments.

A proper mobilization and use of biomass resources require a good understanding of the production chain, conversion processes, a broad knowledge of the sector and its dynamics, and the level of dependence on the environment for production inputs and waste management. Therefore, regional platforms will have to develop their capacities to understand the position of their stakeholders and their needs. The capacity-building activities organized in the SCALE-UP project, including the training program and study tours, are important for the development of the regional platforms. Also, good collaboration with local policymakers is essential. Cross-regional collaboration on horizontal topics can be further pursued to promote and leverage exchange between the six regional platforms.

Table of contents

1 Introduction

Biomass availability and nutrient recycling are essential for a thriving bioeconomy, an economic system that utilizes biological resources to generate products and services. To ensure the sustainability of this adapted economic model, system dynamics must be acknowledged to keep ecological boundaries from being overstepped.

The SCALE-UP project aims at accelerating the bioeconomy in Northern Sweden, Mazovia (Poland), the French Atlantic Arc, Upper Austria, Andalusia (Spain), and Strumica (North Macedonia). It is crucial to understand the regional biomass availabilities and nutrient recycling dynamics in the regions to guarantee a sustainable and circular bioeconomy. In the concept of the bioeconomy, the natural environment continues to serve as the source of productive inputs (e.g. provisioning ecosystem services) and the sink of waste and byproducts that are not valorised (e.g. regulating ecosystem services). For instance, biomass serves as a versatile feedstock for bioenergy, fertilizers, chemicals, and a wide range of other value-added products. Water and soil are essential elements, not just as productive inputs and media underpinning many economic activities, but as sustenance of life. Still, both the resources extracted from nature and its carrying capacity are limited, and so availabilities and qualities along spatial and temporal scales must be carefully kept in check. Nutrient recycling, the process of returning nutrients to the soil, ensures soil health and productivity. Securing the right balance is necessary to prevent the quality of water resources from deteriorating and to protect and restore the biodiversity that depends on them.

This deliverable presents an assessment of the biomass potential and nutrient recycling opportunities within the six SCALE-UP regions. This includes an assessment of available biomass resources, including agricultural residues and forestry residues and how they could be used within the bioeconomy. The report also examines possible opportunities for nutrient recycling within these biomass streams. Additionally, the state of the environment in each of the six regions and the potential (positive and negative) impacts of the bioeconomic activities they pursue are considered using a sustainability screening approach, with a focus on soil, water and biodiversity. Based on this analysis, the deliverable aims to give recommendations on how to optimize biomass utilization and nutrient management in a manner that enhances bioeconomy growth while keeping environmental impacts in check.

Twelve comprehensive reports were written and can be found in the Annex. For each region, a report on the biomass potential and nutrient recycling was written, as well as a sustainability screening, focussing on the ecological boundaries. The reports have been summarized into concise factsheets within the main text of this document. The table below shows where the full reports can be found in the annex, with the titles being clickable, allowing easy navigation within the document; as well as the main topics covered in the reports.

Table 2, Overview Annexes

Region	Biomass stream	Biomass Potential & Nutrients	Ecological Boundaries
		• *Introduction to the region and biomass streams* • *Feedstocks that will be studied* • *Role of nutrients in the value chain* • *Biomass potential* • *Nutrient recycling options*	
North Sweden	Forestry residues	Annex 1: Regional biomass and nutrient availabilities in	Annex 7: Sustainability Screening – Biofuel Region, SE
Mazovia (Poland)	Apple by-products	Annex 2: Regional biomass and nutrient availabilities in Mazovia region (Poland)	Annex 8: Sustainability Screening – Mazovia, PL
Strumica (North Macedonia)	Compost from agricultural residues	Annex 3: Regional biomass and nutrient availabilities in Strumica region	Annex 9: Sustainability Screening – Strumica, MK
Upper Austria	Beer and bakery by-products	Annex 4: Regional biomass and nutrient availabilities in Upper Austria	Annex 10: Sustainability Screening – Upper Austria, AT
French Atlantic Arc	Building insulation from fibre crops and straw	Annex 5: Regional biomass and nutrient availabilities in the French Atlantic Arc	Annex 11: Sustainability Screening – French Atlantic Arc, FR
Andalusia (Spain)	Olive by-products	Annex 6: Regional biomass and nutrient availabilities in Andalusia	Annex 12: Sustainability Screening – Andalusia, ES

2 Methodology

The methodology employed for both parts of the work documented in this report integrates stakeholder engagement, data collection and analysis.

The assessment started with identifying key stakeholders across the six SCALE-UP regions. Then, a cross-regional assessment workshop was organized to gather insights from stakeholders on the needs and priorities in terms of bioeconomy rollout in their respective regions. This two-day online workshop was organized in November 2022, and aimed at mapping the regions' available skills and capabilities, identifying opportunities to link with previous implementations, strategies, and roadmaps, and finally, identifying foreseeable barriers and deployment challenges for the regional bioeconomy.

Following the workshop, BTG developed a template outlining the information needed for the biomass availability and nutrient assessment. BTG then engaged with each region individually to discuss the template and the specific context and requirements of each region. The regional partners then added information from their databases, regional databases, national statistics, as well as other accessible sources of information. The regional partners also conversed with members of the regional platforms and contacted local companies and organisations for additional information and insights. The sources identified during the development of the information packages in Task 2.4 and the training program of WP3 also served as key references for the biomass and nutrient assessment. The work done for the biomass and nutrient assessment also provided content for the training program and helped discover sources for the development of the information packages.

Throughout this process, close communication was maintained between the regional partners and BTG to ensure the accuracy and completeness of the information included in the report. BTG provided guidance and feedback to the regions throughout the process.

After completing the biomass availability and nutrient recycling studies, the key findings were summarized and presented on the SCALE-UP website. On the SCALE-UP website, there is a page dedicated to each of the project regions. This page now includes the highlights of the T2.3 report. This makes the information easily accessible to members of the regional platform, as well as a broader audience.

For the implementation of the sustainability screening, the regional partners of SCALE-UP were introduced by the Ecologic Institute to the approach that was developed and implemented in the BE-Rural project and documented in Anzaldúa et al., 2022[1]. In paragraph 3.3 the step-by-step approach is described.

[1] Anzaldúa, G., Araujo, A., Tarpey, J., Scholl, L., Noebel, R., Tryboi, O., Ma, C. (2022). Note on the development of a sustainability screening for regional bioeconomy strategies. Deliverable of the H2020 BE-Rural project. Available online here: https://www.ecologic.eu/18791

3 Biomass potential and ecological boundaries

3.1 Introduction

The SCALE-UP project aims to accelerate the development of regional bioeconomies in a sustainable way. To achieve this goal, it is important to understand and utilize the available biomass resources within the six SCALE-UP regions: Northern Sweden, Mazovia (Poland), French Atlantic Arc, Upper Austria, Strumica (North Macedonia), and Andalusia.

Biomass serves as a versatile feedstock for various applications within the bioeconomy, including bioenergy production, chemicals, wood products, cosmetics, and various other value-added products.

3.2 Types of biomass potential

For the biomass potential, the following types are distinguished: theoretical, technical and economic (see Figure). The theoretical potential is the maximum amount of biomass that can be considered available, while the technical potential also considers the current technological possibilities, such as harvesting techniques and logistics. In the methodology of Vis and Dees[2], a sub-category of technical potential is included that considers the sustainability criteria. This is referred to as the Base potential.

The economic (base) potential is the part of the technical (base) potential that is economically profitable taking. This potential depends on the price that the biomass application can afford to pay for the feedstock (assumed price level) and the competition with other products. The price that can be paid for the biomass depends on production costs and the market value of the biobased product. The more added value of a product, the more it is generally able to pay for the biomass, so the higher the economic potential. The lower the added value, the less can be paid for the feedstock, and the lower the economic potential of available biomass resources. Collection and transport costs are becoming relatively more important.

[2] Vis, M., & Dees, M. (2011). *Biomass resource assessment handbook*. VDM Verlag.

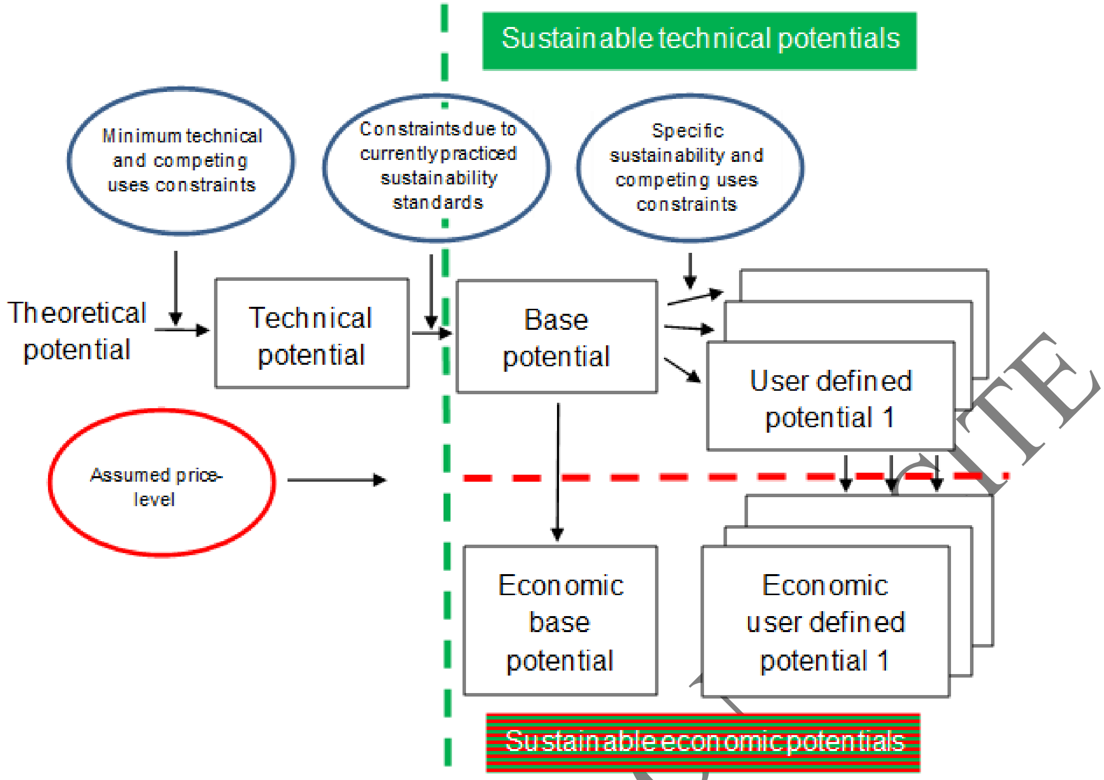

Figure 1, Biomass potential, (Vis & Dees, 2011[3])

3.3 Appraisal of ecological boundaries

Sustainable supply is an important pre-condition for sound biobased production. In the SCALE-UP methodology sustainability criteria are included in the technical (base) potential. In addition, a dedicated ecological boundary check is included.

For the implementation of the sustainability screening, the regional partners of SCALE-UP were introduced by the Ecologic Institute to the approach that was developed and implemented in the BE-Rural project and documented in Anzaldúa et al., 2022[4]. This approach entailed the setup of a screening team to carry out a rough appraisal of the available capacity of regional ecosystems and the expected (positive and negative) impacts of bioeconomic activities relevant to their region (linking to the results of the November 2022 workshop).

The screening teams in SCALE-UP were integrated by each regional partner as the main investigator/author, Ecologic Institute as the supporting partner, and regional stakeholders as reviewers. Their work entailed the development of resource management profiles for the region. These give an introductory overview of water and soil resources, biological diversity, and the governance frameworks in place to manage them. This was followed by the rough appraisal referred to above, which entailed a high-level approximation of the conditions of the regional environment based on available and accessible data at the NUTS3 (or closest) level on the state of water bodies

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[3] Vis, M., & Dees, M. (2011). *Biomass resource assessment handbook*. VDM Verlag.

[4] Anzaldúa, G., Araujo, A., Tarpey, J., Scholl, L., Noebel, R., Tryboi, O., Ma, C. (2022). Note on the development of a sustainability screening for regional bioeconomy strategies. Deliverable of the H2020 BE-Rural project. Available online here: https://www.ecologic.eu/18791

(e.g. reporting data from the Water Framework Directive implementation), soil erosion risk (e.g. modelling data from the RUSLE dataset), and biodiversity (e.g. IUCN red list). The light processing and combination of these data served to establish a baseline from which each team could start to uncover environmental dimensions already at risk from an ecological perspective. In a subsequent step, scientific literature was reviewed to generate short syntheses of the documented effects of specific economic activities (e.g. olive oil production, forestry and use of forestry residues, cultivation of hemp, flax and miscanthus) on the three environmental dimensions explored in the screening. Lastly, these syntheses of associated environmental effects were overlaid against the previously generated baselines and used to generate summary tables and recommendations. The latter is the main result of the screening and aim to engage regional stakeholders and decision-makers in a discussion of the potential positive and negative effects of rolling out the examined bioeconomic activities in their region.

At several points of the screening, regional stakeholders were consulted to collect feedback on the preliminary results generated and to provide access to additional/more suitable data and information for subsequent iterations.

3.4 Types of biomass residues

In the assessment of potentials, the following biomass types have been considered depending on the economic sector and position in the production chain. The biomass types have been selected in consultation with the regions and in line with the proposed biobased production ideas.

1. Forestry (Sweden)
    - 1.1. Primary forestry residues: leftovers from harvesting activities
    - 1.2. Secondary forestry residues: residues from sawmills and pulp and paper industry
2. Crops
    - 2.1. fibre crops, such as miscanthus and hemp (France)
3. Agricultural residues
    - 3.1. Primary agricultural residues, such as straw and prunings (North Macedonia, Spain, Poland, France)
    - 3.2. Secondary processing residues for food production (North Macedonia, Spain, Poland, Austria)
4. Organic waste
    - 4.1. Tertiary residues, released after final use of the product, such as bread (Austria)

An important difference between primary and secondary residues is the location where the residues are available. For secondary residues, this is at a mill or factory, concentrated in one spot. For primary residues, this is spread over the field or forest, making collection and transport necessary for processing.

3.5 Results

In the following pages the results of the assessments are presented in the form of infographics. Each region possesses unique biomass streams with varying qualities, quantities, and potential for different uses. There are big differences. One region has focussed on the forestry sector, others on the agriculture and food production sectors, but not one region on the same. Some have clear bio-based production paths in mind, with well-selected feedstocks, while others are still searching. Some are working in areas that are well documented, others are looking into fields that are hardly studied. Therefore, the results show a wide variety in character and depth.

For each region a short introduction is given to the sector(s) involved and the biomass potential of the streams that have been assessed. The theoretical or technical potential could often be well estimated. This was often not possible for the economic potential as bio-production chains and desired bio-products were often still to be determined. Only in a single case, the economic potential could be assessed. Sometimes, for example for the potential of fibre crops, scenarios were developed to get an educated guess of the economic potential.

3.5.1 Northern Sweden

In Northern Sweden, forestry residues, such as logging residues and sawmill by-products, represent a significant biomass source. These residues can be utilized for bioenergy production, but also for other value-added products such as chemicals.

Biomass Availability & Ecological Boundaries
North Sweden

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Biomass availability

The annual harvest of wood in North Sweden is 31 million m3, mainly used for sawn timber, energy, and increasingly in biorefineries. Half of the roundwood is fed into 28 sawmills and 8 pulp mills of North Sweden, resulting in valuable by-products such as sawdust, bark, chips and shavings.

- By-products from sawmills are currently used for drying sawn goods. Chips are used in the pulp and paper industry, and sawdust and bark for pellets, heat and electricity.
- Logging residues are underutilized due to low commercial value and high extraction costs. The logging residues that are extracted are mainly used for combustion but contain valuable compounds that can be used for diverse products.

Biomass stream	By-products (annual production, dry)	Current application	Possible applications
Sawdust	300 kt	Wood pulp (paper & textiles), wood-based panels, energy production.	High value products, biofuels
Bark	230 kt		
Pulp chips	1 Mt		
Dry wood chips	40 kt		
Shavings	30 kt		
Logging residues	2-4 Mt	Not extracted, combustion	High-value compounds

Ecological boundaries

Resources screened: Category	Resources screened: Sub-Category	Rating	Foresty (and forest biomass extraction) management practices potential impact on environmental dimensions: Potential benefits	Potentially detrimental
Water	Surface water bodies	(red)	Ash recycling; Restoration of surface water bodies; Placing harvest residues away from affected aquatic ecosystems; High water-efficiency processes of production (e.g. for biochemicals)	Combustion of fossil fuels and deposition of acidifying nitrogren and sulfur compounds → soil and surface water acidification; Biomass management/extraction practices → increased runoff, leaching of nutrients, water acidification or eutrophication; Abstraction of large volumes of water for large-scale production processes
	Ground water bodies	(green)		
Land resources		(green)	Retaining forest biomass on vulnerable grounds; Extract logging residues from suitable spruce dominated strands	Overextraction of forest biomass → nutrient- and base cation stock depletion
Biodiversity	Endanger-ed Species	6	Leaving high stumps, snags and coarse woody debris; Continued high environmental consideration in practical forestry; Retaining diverse biomass types and deadwood	Overextraction of deadwood and leaf litte.
	Critically Endanger-ed Species	4		

Recommendations

- Use SCALE-UP platform to **mobilize actors**, to exchange best practices and to address ecological boundaries issues.
- Develop more **efficient forest machinery and logistics**.
- **Identify challenges and solutions** within the logging residue value chain, as well as best practices.
- **Soil**: strategic practices to retain a part of forest biomass on vulnerable grounds, and tailored harvesting methods to prevent soil degradation and nutrient losses.
- **Biodiversity**: management strategies which include the creation of high stumps, retention of diverse biomass types and consideration of harvesting during dense early thinning phases.
- **Water**: Any initiatives that promote the restoration of the affected rivers should be favoured.

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Find the full reports in Annex 1: Regional biomass and nutrient availabilities in
& Annex 7: Sustainability Screening – Biofuel Region, SE

3.5.2 Mazovia (Poland)

Mazovia (Poland) is a major apple producer, generating substantial apple side-streams, including apple pomace, and apple tree prunings. These side-streams can be converted into wood products, fertilizers, functional food ingredients, and other value-added products.

Biomass Potential & Ecological Boundaries
Mazovia, Poland

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Biomass availability

Mazovia is the largest apple production region in Poland. More than 2 million tonnes of apples are produced annually, leaving substantial amounts of residues such as apple prunings and pomace.

- **Apple trees are annually pruned**, leaving a woody biomass which is currently collected and baled and used for heating, but can also be used for wood products or soil improvement.
- More than half of the region's production is processed into products like apple juice. About a quarter of the weight of the apple is skin and flesh and remains after the apple juice obtention process. These solid residues are known as **apple pomace**. This pomace is primarily used as animal feed but can also be used as a functional ingredient in the food industry or for biogas.

Biomass stream (in Mazovia)	Technical potential (dry tonnes/year)	Current application	Possible applications
Apple tree prunings	48 kt/y	Heating	Bioenergy, biofuels, fertilizer
Apple pomace	148 kt/y	Animal feed	Functional food ingredients, biogas

Ecological boundaries

Resources screened: Category	Resources screened: Sub-Category	Rating	Use apple by-products and potential impact on environmental dimensions: Potentially benefits	Use apple by-products and potential impact on environmental dimensions: Potentially detrimental
Water	Surface water bodies	(red)	• Drip irrigation, regulated deficit irrigation • Effective fertilizer management	• Overuse of chemical inputs, particulary nitrogen fertilizers
	Ground water bodies	(green)		
Land resources		(green)	• Consistent use of cover crops • Creating incentives towards planting crops on high slopes and erosion control practices • Conservation tillage or mulching • Responsible use of drip irrigation	• Overuse of fertilizers and chemical inputs, • Diesel use in heavy machinery • Removal of prunings
Biodiversity	Endangered species	5	• Planting a diversity of species • Focusing on connectivity	• Overreliance on harmful pesticides • Hail nets
	Critcally Endangered species	1		

Recommendations

Support collaboration between stakeholders to share experience on residue utilization within ecological boundaries.

Support the **development of storage and production systems** close to agricultural production.

Surface water bodies: Further information should be gathered and verified on the pressures and causes of diffuse pollution.

Soil: Measures should be taken in areas vulnerable to erosion.

Biodiversity: The use of pesticides and hail nets should be kept to a minimum. Cultivation to focus on connectivity with nature.

Share experiences within platform on collection, processing, storage and feedstock quality assurance.

Develop **bioresources regional strategy** with proper support instruments.

Ground water bodies: The expansion of existing, or development of new activities should be planned carefully and located smartly to avoid pressures.

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Find the full reports in Annex 2: Regional biomass and nutrient availabilities in Mazovia region (Poland) **& Annex 8**: Sustainability Screening – Mazovia, PL

3.5.3 Strumica (North Macedonia)

Strumica is the largest agricultural producer in North Macedonia, generating abundant agricultural residues, such as crop residues, manure, and food scraps. These residues can be utilized for composting, producing valuable organic fertilizers that promote soil quality and improve agricultural productivity in a sustainable manner.

Biomass Potential & Ecological Boundaries
Strumica, North Macedonia

SCALE UP community-driven bioeconomy development

Biomass availability

The Strumica region is the country's largest producer and exporter of agricultural products. The region is a major producer of cereals and garden crops, especially in tomatoes and peppers.

In both **agricultural production and the processing industries, significant residues are generated**. As there is no unified waste management approach in the region, the majority ends up in landfills. It is estimated that Strumica's biomass potential is between **10.000 and 40.000 tons per year** (fresh material).

These organic residues from primary producers, industries and communities can be used in a more **circular and economically viable way by composting** or for biogas production and biofertilizer. The use of compost will turn waste into a valuable resource that improves soil quality and provides nutrients for crops.

Sown area of agricultural crops and potential residue 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

Ecological boundaries

Resources screened: Category	Sub-Category	Rating	Agricultural and food production residues for compost production potential impact on environmental dimensions: Potential benefits	Potentially detrimental
Water	Surface water bodies	(red)	Shift to preparation of compost in securely lined spaces and controlled application; Implementing natural water retention measures; Increasing irrigation efficiency	Removal agricultural residues → nutrient runoff & eutrophication; Lack of maintenance & investement on water monitoring infrastructure
	Ground water bodies			
Land resources		(green)	Conservation tillage, maintaining/increasing soil organic carbon and nutrient levels, reducing soil erosion; Incorporating agents in residues for compost, avoiding leachate	Unrestrained removal of agricultural resources → soil erosion; Discharge of processed agri-food residues → soil contamination
Biodiversity	Endangered species	2	Carefully controlling compost quality for desired microorganisms; Applying digestate at appropriate levels → enhance soil microbial biomass	Large-scale removal of residues on which birds may depend; Introduction of new crop varities without consideration on local species, water and nutrients.
	Critically Endangered species	0		

Recommendations

- Promote knowledge exchange on biomass resources and joint collection systems in the **regional platform**.
- Develop proper **regulations** on waste management and compost production.
- **Surface water bodies:** (Ground) water monitoring on potential nutrient leakages and state of surface water in the region
- **Ground water bodies:** Promote reduction of water use in the value chain.
- Promote biomass segregation and collection at the **agro-industry factories** and encourage them to participate in regional composting initiatives
- Develop **pilot plants** and **R&D activities** on integrated composting systems for production of **compost mixes** to meet crop requirements
- **Soil:** Promote leaving part of crop residues in the field to maintain carbon and nutrient soil levels. Promote use of compost or digestate.
- **Biodiversity:** Implement compost quality control regulations.

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Find the full reports in Annex 3: Regional biomass and nutrient availabilities in Strumica region **& Annex 9**: Sustainability Screening - Strumica, MK

3.5.4 Upper Austria

Upper Austria has a diverse food processing industry, generating a wide range of food by-products, such as fruit and vegetable residues, as well as bakery and brewery byproducts. These by-products can be utilized for biogas production, chemicals, functional food ingredients and the development of other innovative bioeconomy applications.

Biomass Potential & Ecological Boundaries
Upper Austria

SCALEUP community-driven bioeconomy development

Biomass availability

Upper Austria has a diverse food processing industry, **generating a wide range of food by-products**, such as fruit and vegetable residues, as well as bakery and brewery by-products. By-products in these sectors are currently used for animal feed, compost and biogas production, and for small other usages in the region, but have the potential for chemicals, food ingredients and other innovative bioeconomy applications.

- There are various by-products generated in the **bakery sector.** On the one hand, biomass is generated during production and, on the other, through unsold surplus.
- During the **beer brewing** process, there are multiple by-products generated, the largest being brewer's spent grains, followed by yeast.

Biomass stream (in Austria)	Technical potential (ktonnes/y)	Main application(s) & price
Spent brewers' grains	150-170 kt	Animal feed (93%), 7.80 - 12 €/t
Spent yeast	12 kt	Animal feed, biogas 7 €/t
Waste dough	21 kt	Internal use, biogas, other industries
Waste bread & baked goods	210 kt	Animal feed (86%), biogas (5%), internal use (3%)

Ecological boundaries

Resources screened: Category	Sub-Category	Rating	Use of bakery by-products and their impact on environmental dimensions: Potential benefits	Potentially detrimental
Water	Surface water bodies	(red)	Use of value chain for wastewater treatment; Adequate fertilizer and chemical management	Improper waste discharge; Excessive fertilizer use
Water	Ground water bodies	(green)		
Land resources		(yellow/orange)	Creating incentives against planting crops on high slopes and for erosion control practices; Conservation tillage or mulching	Poor fertilizer management; Expanded production and intensification
Biodiversity	Endangered species	40	Concrete statements or generalized evidence from literature have not been found.	
Biodiversity	Critically Endangered species	11		

Recommendations

- **Improve logistics** for the waste streams.
- Promote knowledge exchange on biomass resources in the **regional platform**.
- **Surface water bodies:** More care should be given to the proper discharge of waste materials.
- **Ground water bodies:** Care should be taken with regards to water use in the value chain.
- Increase **knowledge exchange** on the use of by-products **between sectors**.
- **Connecting different production processes**, as by-products can be used as a feedstock in other industries.
- **Soil:** Soil resources in the region should be treated cautiously. Measures should be taken in areas with higher rates of soil erosion, such as incentives and the promotion of activities that restore and preserve soils.

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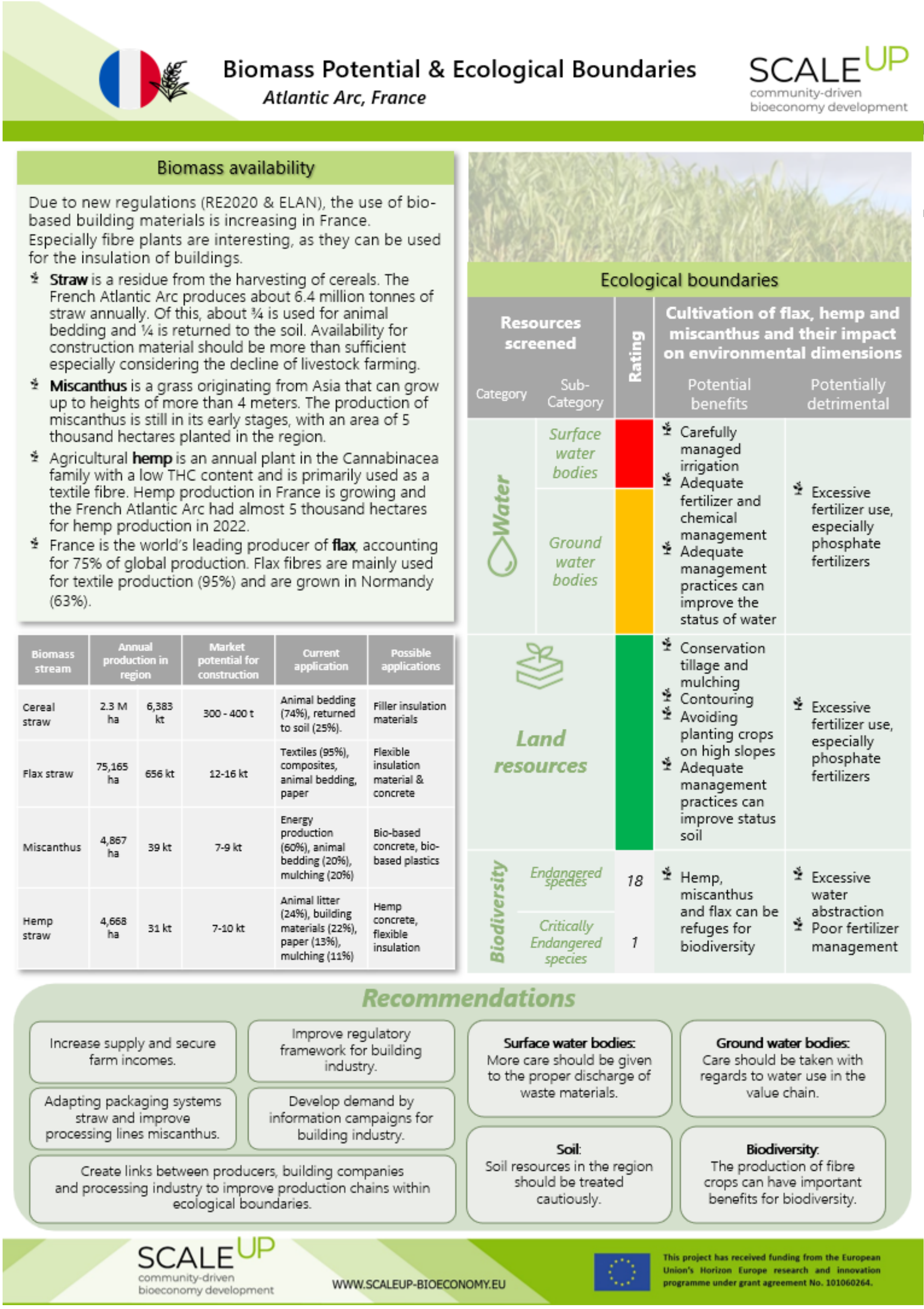
Find the full reports in Annex 4: Regional biomass and nutrient availabilities in Upper Austria
& Annex 10: Sustainability Screening – Upper Austria, AT

3.5.5 French Atlantic Arc

The French Atlantic Arc region is known for its production of straw and fibre crops, such as flax and hemp. These crops can be used to produce paper, textiles and construction products. Due to changes in French building regulations, the market for bio-based insulation products is growing at a fast pace. This provides great opportunity for the use of fibre crops for the insulation of buildings. Different scenarios regarding the growth of the bio-based insulation market have been taken into account.



Biomass Potential & Ecological Boundaries
Atlantic Arc, France

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Biomass availability

Due to new regulations (RE2020 & ELAN), the use of bio-based building materials is increasing in France. Especially fibre plants are interesting, as they can be used for the insulation of buildings.

- **Straw** is a residue from the harvesting of cereals. The French Atlantic Arc produces about 6.4 million tonnes of straw annually. Of this, about ¾ is used for animal bedding and ¼ is returned to the soil. Availability for construction material should be more than sufficient especially considering the decline of livestock farming.
- **Miscanthus** is a grass originating from Asia that can grow up to heights of more than 4 meters. The production of miscanthus is still in its early stages, with an area of 5 thousand hectares planted in the region.
- Agricultural **hemp** is an annual plant in the Cannabinacea family with a low THC content and is primarily used as a textile fibre. Hemp production in France is growing and the French Atlantic Arc had almost 5 thousand hectares for hemp production in 2022.
- France is the world's leading producer of **flax**, accounting for 75% of global production. Flax fibres are mainly used for textile production (95%) and are grown in Normandy (63%).

Biomass stream	Annual production in region		Market potential for construction	Current application	Possible applications
Cereal straw	2.3 M ha	6,383 kt	300 - 400 t	Animal bedding (74%), returned to soil (25%).	Filler insulation materials
Flax straw	75,165 ha	656 kt	12-16 kt	Textiles (95%), composites, animal bedding, paper	Flexible insulation material & concrete
Miscanthus	4,867 ha	39 kt	7-9 kt	Energy production (60%), animal bedding (20%), mulching (20%)	Bio-based concrete, bio-based plastics
Hemp straw	4,668 ha	31 kt	7-10 kt	Animal litter (24%), building materials (22%), paper (13%), mulching (11%)	Hemp concrete, flexible insulation

Ecological boundaries

Resources screened: Category	Sub-Category	Rating	Cultivation of flax, hemp and miscanthus and their impact on environmental dimensions: Potential benefits	Potentially detrimental
Water	Surface water bodies		Carefully managed irrigation; Adequate fertilizer and chemical management; Adequate management practices can improve the status of water	Excessive fertilizer use, especially phosphate fertilizers
	Ground water bodies			
Land resources			Conservation tillage and mulching; Contouring; Avoiding planting crops on high slopes; Adequate management practices can improve status soil	Excessive fertilizer use, especially phosphate fertilizers
Biodiversity	Endangered species	18	Hemp, miscanthus and flax can be refuges for biodiversity	Excessive water abstraction; Poor fertilizer management
	Critically Endangered species	1		

Recommendations

- Increase supply and secure farm incomes.
- Improve regulatory framework for building industry.
- Adapting packaging systems straw and improve processing lines miscanthus.
- Develop demand by information campaigns for building industry.
- Create links between producers, building companies and processing industry to improve production chains within ecological boundaries.
- **Surface water bodies:** More care should be given to the proper discharge of waste materials.
- **Ground water bodies:** Care should be taken with regards to water use in the value chain.
- **Soil:** Soil resources in the region should be treated cautiously.
- **Biodiversity:** The production of fibre crops can have important benefits for biodiversity.

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Find the full reports in Annex 5: Regional biomass and nutrient availabilities in the French Atlantic Arc & **Annex 11**: Sustainability Screening – French Atlantic Arc, FR

3.5.6 Andalusia (Spain)

Andalusia is the world's leading olive-oil producing region and generates substantial residues, including olive pomace and olive tree prunings. These side-streams can be converted into high-value chemicals, fertilizers, and other value-added products.

Biomass Potential & Ecological Boundaries

Andalusia, Spain

SCALE UP community-driven bioeconomy development

Biomass availability

Andalusia, located in the south of Spain, is the world's leading olive oil-producing region, accounting for 80% of Spanish and 37% of global olive oil production. Andalusia has 1.6 million hectares dedicated to olive production. Three main types of olive by-products are generated:

- **Agricultural residues:** residues such as olive tree leaves and prunings. Olive trees are pruned, generating large amounts of prunings which are often burned in the field, causing air pollution and fire risks. The residues are also used for direct combustion, animal feed and pellet manufacturing.
- **Olive mill residues** such as olive pomace and olive stones, depending on the extraction method used. Olive pomace is the main residue after the oil extraction process. About 80% of the olive weight remains as olive pomace, including the olive skin, pulp, stone, seed and fragments of the stones, as well as a small amount of residual oil.
- Also depending on the type of extraction method used, there may be **residues from olive pomace/the oil extraction plant,** such as olive oil mill wastewater and extracted olive pomace, the final solid residue after all oil is extracted from the olive pomace.

These by-products can be used to produce nutraceuticals, bioenergy, biofertilizers, biobased materials, food and feed additives, and other new value-added and commercially viable ingredients and products.

Phase	By-product	Technical potential Andalusia (tonnes/y)
Agricultural (Olive Farmland)	Pruning residues (wood, branches, and leaves)	2.5 Mt
Olive-oil Mill	Olive Pomace	4.2 Mt
	Stone	
	Olive mill leaves	
Olive-pomace or oil extraction plant	Stone	1.6 Mt
	Extracted pomace	

Ecological boundaries

Resources screened: Category	Sub-Category	Rating	Olive production potential impact on environmental dimensions: Potential benefits	Potentially detrimental
Water	Surface water bodies		Extensive olive cultivation; No tillage land management practices with cover crops; Reduced use of water resources and nitrogen in irrigated systems	Water pollution from agrochemicals; Overexploita-tion of water resources; Nitrate pollution
	Ground water bodies			
Land resources			Measures to increase soil water storage capacity; Natural reversion to forests in severely sloping and degraded areas	Continuous tillage and the absence of cover crops; Expansion of olive farms into steep slopes
Biodiversity	Endangered species	45	Traditional, low intensity olive farming practices	Transformation from diverse land-use systems to intensive olive farming and single-crop systems; Habitat enroachment
	Critically Endangered species	17		

Recommendations

- Improve regulatory cohesion, specific training on regulations, improve financial resources and incentives.
- Creation of business plans for bio-based solutions, encouragement of research on innovative bio-based products.
- Increase understanding of regional system dynamics to avoid negative effects associated with olive production.
- Implementation of sustainable agricultural, water, and land management practices.
- Engagement of stakeholders to increase knowledge of the market of the bio-based solutions.
- Improve communication between research and actors in the olive value chain (end users, primary producers...).
- Water demand should be carefully balanced with the requirements of other uses
- An integrated, systematic approach to environmental pressures, with the support of policymakers, experts, and stakeholders.

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Find the full reports in Annex 6: Regional biomass and nutrient availabilities in Andalusia **& Annex 12**: Sustainability Screening - Andalusia, ES

4 Nutrient recycling

4.1 Introduction

Nutrients such as nitrogen, phosphorus, and potassium play an essential role in the bioeconomy. A growing population and agricultural production have led to an increasing use of mineral fertilizers. While these mineral fertilizers have their benefits, such as the ability to be tailored to meet the specific crop needs, and easy transport and use, they are produced from non-renewable resources that can be depleted and require large amounts of energy to produce. The consumption of mineral fertilizers is estimated to be about 2.4 times higher in 2050 compared to the year 2000. This has led to major concerns about the security and sustainability of food production and the bioeconomy[5].

Transitioning from this existing linear nutrient system to a circular system using organic nutrient sources could provide a more sustainable alternative. Nutrient recycling refers to the process of recovering and reusing essential nutrients, such as nitrogen, phosphorus, and potassium, from various organic materials or waste streams, with the aim of returning them to the soil. This practice is crucial for a sustainable bioeconomy, reducing the dependency on synthetic fertilizers, minimizing environmental impacts, and reducing production costs. This is well in line with the Farm to Fork policy. Important aims in this policy are:

1. Reduce nutrient losses by at least 50% without deterioration in soil fertility.
2. Reduction of fertilizer use by at least 20%

In the bioeconomy, nutrient recycling involves collecting organic residues from agriculture, forestry, and other sources. These materials can undergo processes such as composting or anaerobic digestion to produce nutrient-rich products. The residues, compost, or digestate can then be applied directly to fields, completing a closed-loop system. This sustainable approach minimizes waste, enhances resource efficiency, and reduces reliance on mineral fertilizers, contributing to soil health in an environmentally sustainable way[6]. The potential for nutrient recycling depends on the qualities and quantities of biomass streams available in specific regions. As such, understanding and optimizing nutrient recycling strategies is crucial for the deployment of the bioeconomy in the SCALE-UP project regions.

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[5] Brandão, M., Lazarevic, D., & Finnveden, G. (2020, December 15). *Handbook of the Circular Economy*. Edward Elgar Publishing eBooks. https://doi.org/10.4337/9781788972727.

(file:///C:/Users/maris/Downloads/Handbook%20of%20the%20Circular%20Economy%20--%20Miguel%20Brand%C3%A3o%20(editor),%20David%20Lazarevic%20(editor),%20G%C3%B6ran%20--%202020%20--%20Edward%20Elgar%20--%209781788972710%20--%204d79822b63c95a9db4fc3db2f78e882d%20--%20Anna%E2%80%99s%20Archive.pdf)

[6] Hidalgo, M. D., Corona, F., & Martín-Marroquín, J. M. (2020, January 2). *Nutrient recycling: from waste to crop*. Biomass Conversion and Biorefinery. https://doi.org/10.1007/s13399-019-00590-3)

https://link.springer.com/article/10.1007/s13399-019-00590-3

Find the full report in Annex 1: [Regional biomass and nutrient availabilities in North Sweden]

4.2 Results

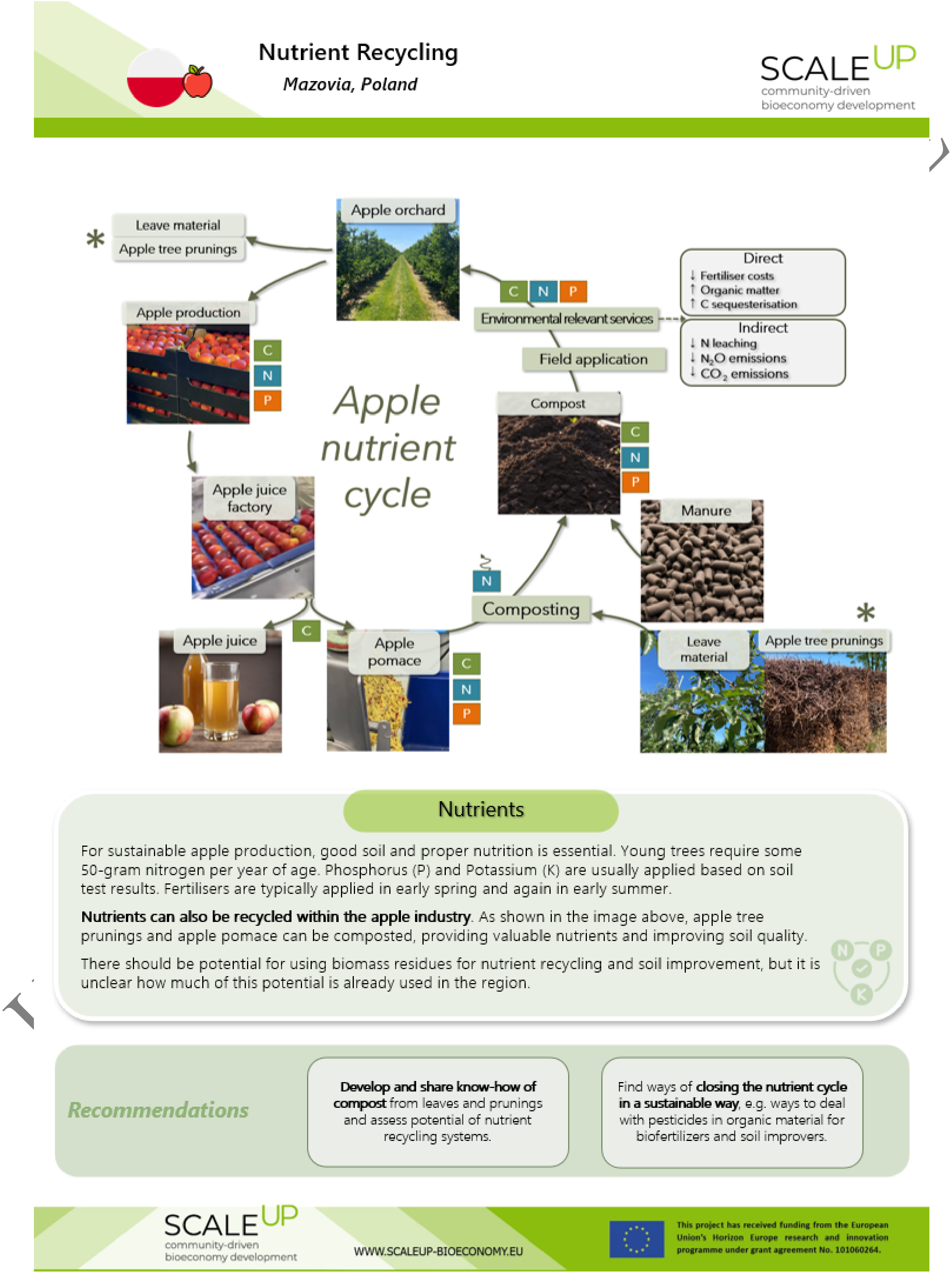
4.2.1 Northern Sweden

In Northern Sweden, forestry residues, such as logging residues and sawmill by-products, represent a significant biomass source.

Find the full report in Annex 2: [Regional biomass and nutrient availabilities in Mazovia region (Poland)]

4.2.2 Mazovia (Poland)

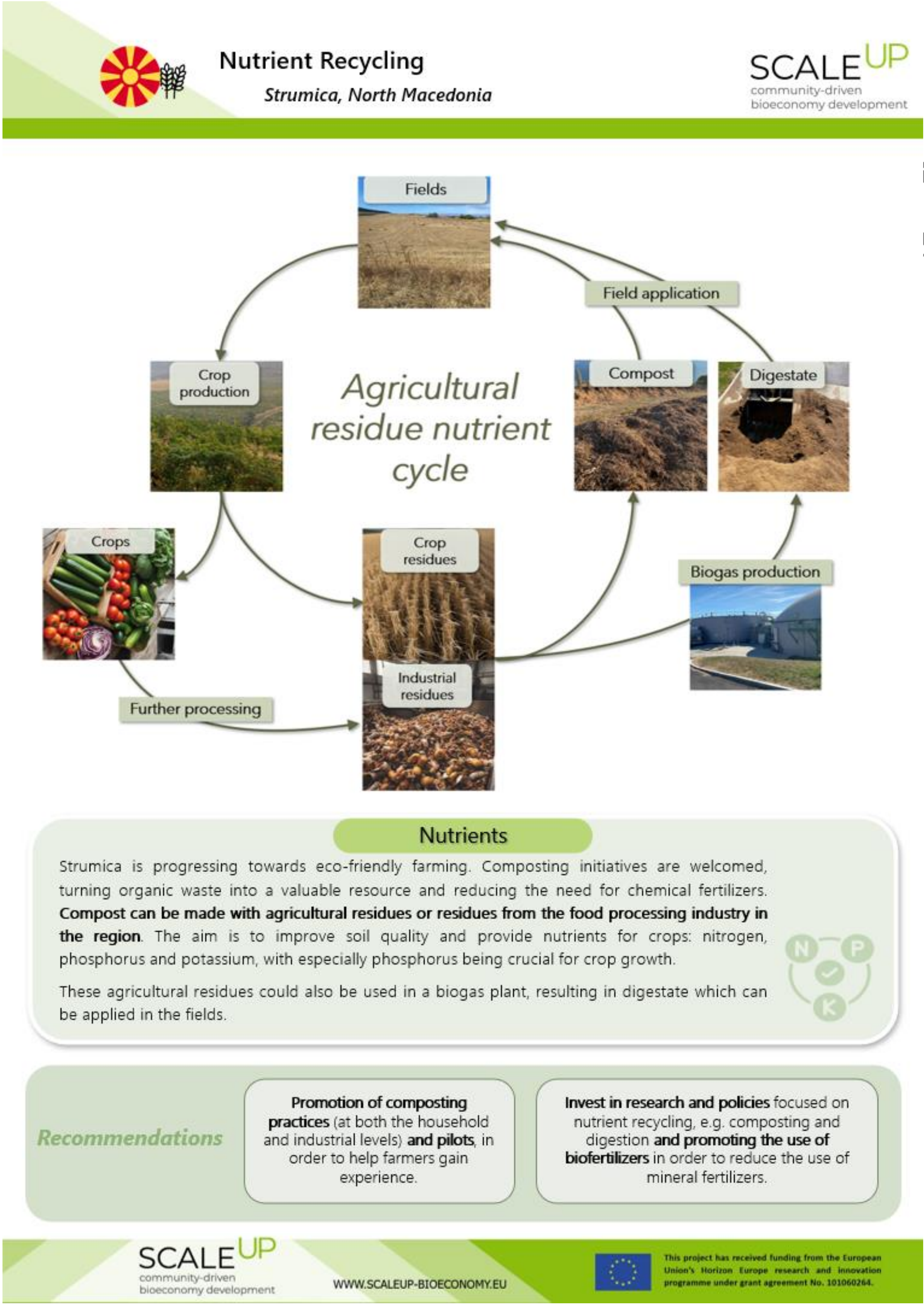
In Mazovia (Poland), organic waste streams, such as apple pomace and prunings, can be utilized for composting, producing valuable organic fertilizers that promote soil health and reduce the reliance on mineral fertilizers.



Find the full report in Annex 3: Regional biomass and nutrient availabilities in Strumica region

4.2.3 Strumica (North Macedonia)

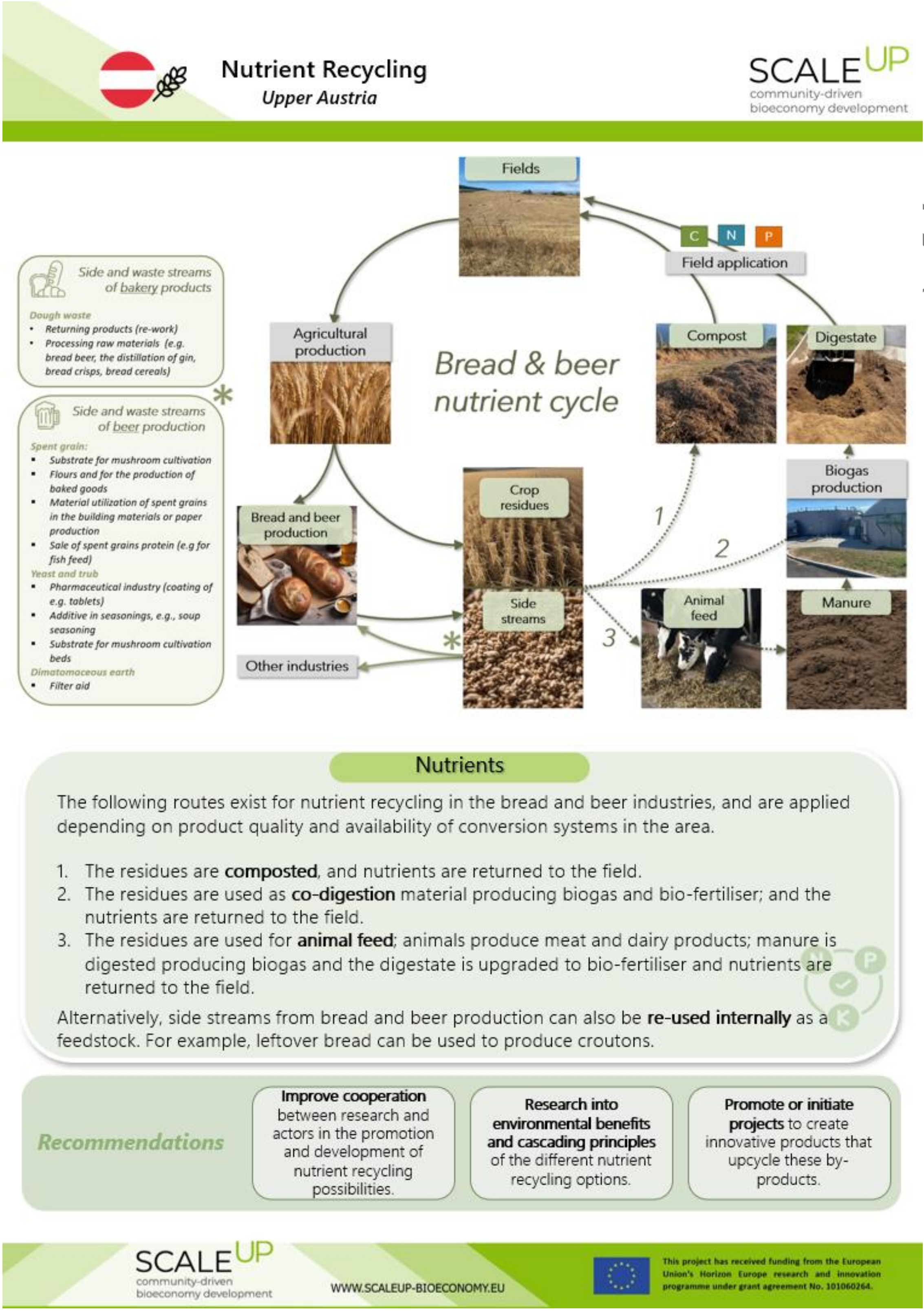
By recycling nutrients from agricultural residues, such as crop residues, into compost, the region can enhance its soil quality. This contributes to improved agricultural productivity and sustainable farming practices.



Find the full report in Annex 4: Regional biomass and nutrient availabilities in Upper Austria

4.2.4 Upper Austria

Food residue streams in Upper Austria can be repurposed for nutrient recycling.



Find the full report in Annex 5: Regional biomass and nutrient availabilities in the French Atlantic Arc

4.2.5 French Atlantic Arc

Nutrient recycling with straw and fibre crops like hemp, flax, and miscanthus in the French Atlantic arc has potential. The production of these crops enhances soil health, retains valuable nutrients, and reduces the dependence on synthetic fertilizers.

Nutrient Recycling
Atlantic Arc, France

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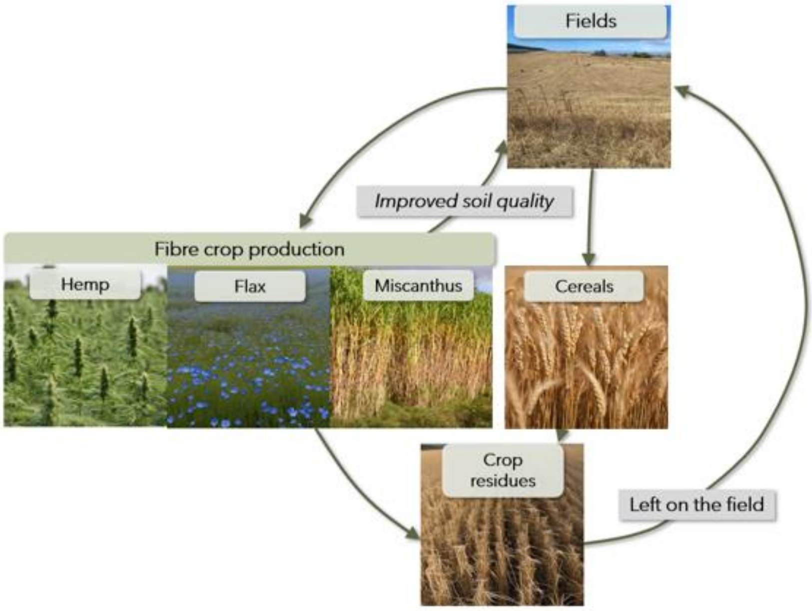

Nutrients

- **Straw** is sometimes used as a soil improver. Straw essentially contains potassium, followed by phosphorus, magnesium and calcium in lesser proportions. Straw is recognized as a "carbon sink" material: when straw is returned to the soil, 85% of the carbon is released into the atmosphere in the form of CO2. When used for construction, the carbon dioxide captured during the farming process is stored in the building for its entire lifespan.
- **Hemp** requires no fertilizers or plant protection products, its deep root system improves soil structure, leading to higher yields for the following crop, and is part of the plot rotation system.
- **Flax** is a fast growing crop that can be grown in poor soils. It requires little fertilizers and can be used as a carbon sink material.
- **Miscanthus** can be used as an ecosystem service. The crop requires no fertilizer and is particularly well-suited to planting in water catchment areas. Secondly, its root system improves soil structure, promotes infiltration and helps prevent run-off.

Recommendation

Study **ecological boundaries and proper nutrient balances** for fibre crop production and soil condition

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Find the full report in Annex 6: [Regional biomass and nutrient availabilities in](#)

4.2.6 Andalusia

Olive mill pomace, prunings and leaves can be recycled through composting, which can then be applied in the olive groves.

Nutrient Recycling
Andalusia, Spain

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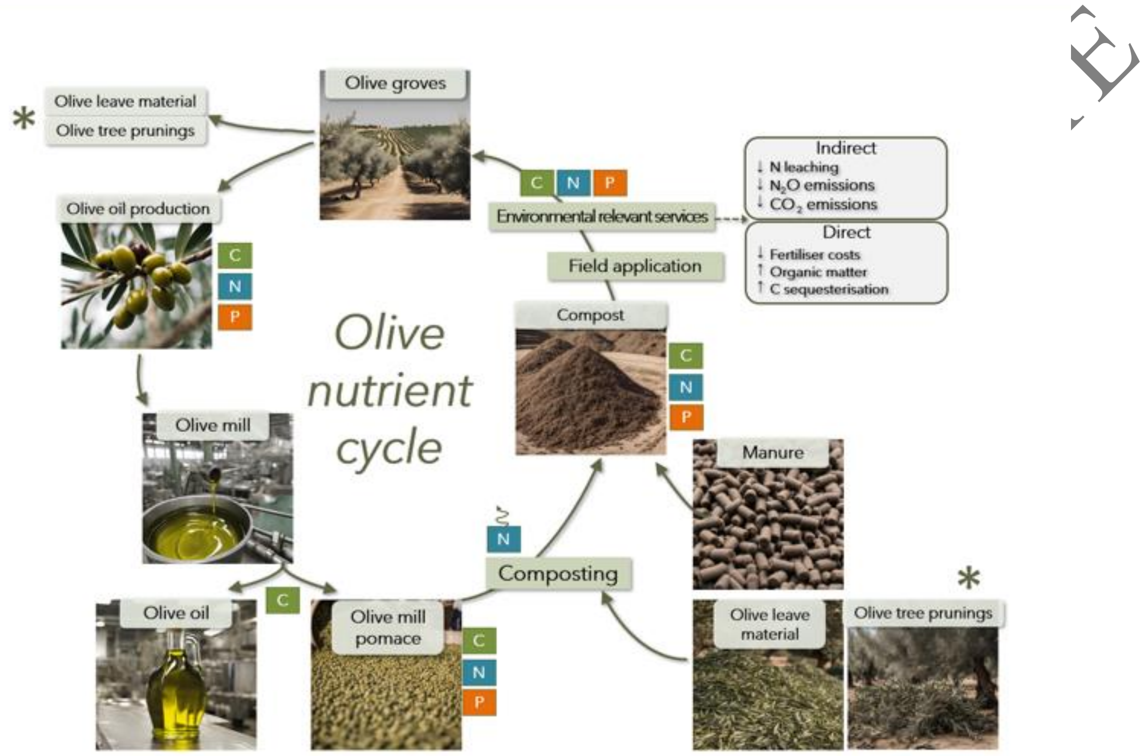

Nutrients

Fertilizer is used in olive groves to supplement essential nutrients such as nitrogen, phosphorus and potassium. The quantities needed differ between olive groves, as it depends on many factors (soil, age, etc.). Various by-products from the olive industry can be used as a bio-based fertilizer. **Olive tree prunings can be shredded and applied directly or used in a compost**. Other by-products, such as **olive pomace, can be composed and applied**. It is estimated that between one and two-thirds of the olive groves can be fertilized with the olive mill pomace produced in Andalusia after composting, leading to a reduction of between 25-60% in chemical fertilizers and to both economic and environmental benefits.

Recommendations

- **Improve cooperation** between research and actors in the promotion and development of nutrient recycling possibilities.
- **Educate stakeholders** on nutrient recycling possibilities. In the SCALE-UP project, a capacity building program is organized, with one of the main topics being nutrient recycling.

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5 Observations

Large quantities of biomass resources are available in the six regions that participate in the EU SCALE-UP project. The large quantities have formed a fertile soil for the development of a range of ideas for using the resources for biobased products. In this document, detailed biomass potential assessments have been made, with an analysis of the ecological boundaries and possibilities for nutrient recycling. In this chapter, we summarise the main observations that we have made when reviewing the situation in the regions:

1. **Large differences in assessments.** The biomass assessments across the six regions revealed large differences in depth and approach. This is due to the nature of the biomass streams selected and the bio-based products proposed. It is also due to the varying levels of available statistics. Some of the regions have large amounts of statistics available and provide detailed potentials, while in other regions only general information and few reports could be found. For the sustainability screening, the built-in flexibility of the approach accounts for these type of differences across regions as regards data availability and accessibility. The approach prioritises having complete “shallow dives” for each region over achieving comparability across them. In the specific context of SCALE-UP, where each region explores a distinct value chain, comparability is in any case limited from the get-go. Yet, working with the available datasets (to set base lines) and scientific literature (to ascertain potential impacts) meant each regional case could arrange these elements differently within the proposed framework to achieve a rough, yet full overview of the three environmental dimensions explored. As an example, this meant that the screening for Andalusia could benefit from more up-to-date and higher resolution data on regional water resources than other cases which employed earlier data from the WFD reporting.

2. **Co-production systems**. Biomass production and processing is often a co-production system: several products are produced simultaneously: main products as well as side products and un-utilized residual streams. Therefore, the potential biomass amounts are not independent. When forestry activities increase, more biomass resources become available. When mills double their production, sawdust quantities double as well. This applies also to agricultural sectors as well, including apple and olive production. While it is not a fully-fledged sustainability assessment and its scope is regional by design, the sustainability screening can give broad indications of the effects that such increased intensity of activities and additional volumes of biomass may have on the known state of water and soil resources and on biodiversity. With these initial in-sights, discussions on how to coordinate across production systems in more sustainable terms can be initiated more efficiently.

3. **Mobilizing biomass resources**. Biomass resources come available at both primary and sec-ondary processes. This has a large impact on its availability. Streams coming available at the food factories or sawmills are relatively easy to collect and store. Biomass coming available in the forest and field require good collection and logistics systems. The availability depends on the way the sector is organised. The scale and design of biomass collection, storage and dis-tribution systems also has implications on environmental aspects.

4. **Dynamics in the feedstock and product market**. Market changes are important. They are dependent on natural resource availability and accessibility and influenced by policy, econom-ic, social, and technical developments, as well as ecological boundaries. Market dynamics can shift due to new data, insights and, later, stricter legislation. It is important to understand these market developments and the projections of resource availability, especially when considering large investments.

5. **Economic potential and burden on ecological systems**. While the theoretical and technical potentials are relatively easy to compute, the determination of the economic potential is more difficult. This is due to a lack of data on market prices and production costs. The economic po-

tential can only be determined after a bio-based solution is chosen and when it is clear what feedstock price the product can afford. In most project regions, the biobased solution was still under consideration. Let alone the biomass price it could afford. Similarly, the potential burden that the value chain of the specific bio-based product chosen could have on the water resources, soil conditions and biodiversity in the region can only be assessed through dedicated, more in-depth studies, like LCAs.

6. **Is there sufficient biomass?** This is difficult to assess. This depends strongly on the biomass situation in the sector, the biomass solution selected and the competition with other uses. Technically there can be more than enough, but economically, potential can be limited. On the other hand, some solutions do not need large quantities, such as cosmetics, as compared to bio-based solutions in the building industry. In the building industries, large quantities are required to keep production costs low. It is important not to overlook the needs of the environment for the same resources, and to do so considering future changes in climatic, economic, and market conditions, to ensure appropriate ecosystem health and functioning.

7. **Building blocks for further development**. The information from this report should provide a good base for assessing the economic and environmental potential in the future. Many building blocks have been assembled in the regional reports. Some are overflooding with data. Proper dedicated assessments can be made when biomass solutions become clear, along with production costs, market potential, the price it can afford for the feedstock and the competition with other products.

8. **Ecological boundaries**. Understanding and then respecting ecological boundaries is essential for securing biomass resources in the long term. The state of water resources, especially surface water bodies, and the integrity of soil resources, remain important concerns, with water pollution, changes in hydromorphology and soil erosion often being recurrent issues in our regions. Concerns have also surfaced with respect to the effect of unsustainable use of water resources and agrochemicals on water and soil quality, and the subsequent impacts of this on biodiversity. This may influence the possibilities for efficient use of production inputs and nutrient recycling, not constraining responses to technical solutions but incorporating governance approaches that are fit-for-purpose and enforceable in each context. All regions have included recommendations to pay more attention to the ecological boundaries.

9. **Nutrient recycling.** Nutrient recycling can be done in many ways in the regions. Parts of the crop are left behind in the field or part of prunings in the orchards. In most regions, agro-industrial residues are reused, composted or used in biogas plants producing biogas and bio-fertilizer. Yet, all acknowledge the potential for improvement and have recommended policy support and promotion of good practices by their platforms.

10. **Platform development.** A proper mobilization and use of biomass resources require a good understanding of the production chain, conversion processes and a broad knowledge of the sector and its dynamics. Therefore, regional platforms will have to develop their capacities and dive into the material to better understand the position of their stakeholders and their needs. The capacity-building activities organized in the SCALE-UP project, including the training program and study tours, are important for the development of the regional platforms. Also, good collaboration with local policymakers is essential. Cross-regional collaboration on horizontal topics like environmental sustainability can be further pursued to promote and leverage exchange between the six regional platforms.

6 Recommendations

The reports contain a wide range of recommendations regarding biomass potentials, ecological boundaries and nutrient recycling options. Upon reviewing the reports, we have compiled the following list of recommendations:

1. **Platform capacity building**: Support the development of the regional platform's capacities, through training programs, study tours, workshops, and focused, meaningful cross-regional exchange. Only with a good understanding of the sector and the environment it is embedded in, proper assessments can be made of the technical, economic, and environmental potentials.

2. **Full chain development.** Biomass resources can be made better available in terms of quantity and quality, when the entire chain from collection, transport, feedstock storage, biomass processing and the application of bio-based products is well developed and gives serious consideration to environmental sustainability. Information exchange between stakeholders with a wide range of interests and specialized knowledge should be promoted. Platforms can play an important role in this respect.

3. **Monitor price and market trends**: Regional platforms should monitor developments in biomass prices and identify price and market data. Stakeholders should be encouraged to exchange information on technical, economic, policy and ecological developments. The implications of increased demand for goods and services on resource availability and environmental sustainability should be seen from a regulatory lens and in a timely manner. Local and regional authorities can and should play an important planning and administration role in this respect.

4. **Economic potential**: Economic biomass assessments can be made when biomass solutions are selected. With the production costs and market potential known, the price can be calculated, in order to understand if the feedstock can be afforded and to understand the competition situation with other products. Economy of scale is important to lower cost prices. For times when economic potential drives substantial price and market developments, economic policy instruments should be at hand and swiftly implemented to avoid disproportionate burden on ecological systems.

5. **Knowledge exchange across regions**. Some EU regions have well-developed bio-based sectors and well-organised platforms. Other regions are still at the beginning of this process. Regions can take up ideas from each other on data collection, biomass assessments and chain developments. Neither mature, nor earlier stage sectors should act in isolation. The shifts in macroenvironmental conditions driven by Climate Change and other societal challenges are posed to put new issues on the regional agenda, some of which will be unfamiliar, thus making concrete examples on how other regions have handled them, valuable. That said, exchange should be well-focused (e.g. along carefully-defined themes) and meaningful to avoid fatigue and inefficiency.

6. **Cross-sectoral use of biomass resources**. Biomass resources that come available in one sector can be used in another sector in the region. Platforms should promote information exchange with other platforms.

7. **Ecological boundaries**. The six regional screening reports produced in SCALE-UP represent a new instance for discussion. They are neither perfect, nor exhaustive. Yet, they reflect the current data capacity for environmental monitoring and assessment in each region to an extent, and give a rough indication of where ecological boundaries could lie. The results of the screenings should be put to discussion within the regional platforms, and preferably in dedicated task forces including environmental experts, with the aim of contributing to ongoing initia-

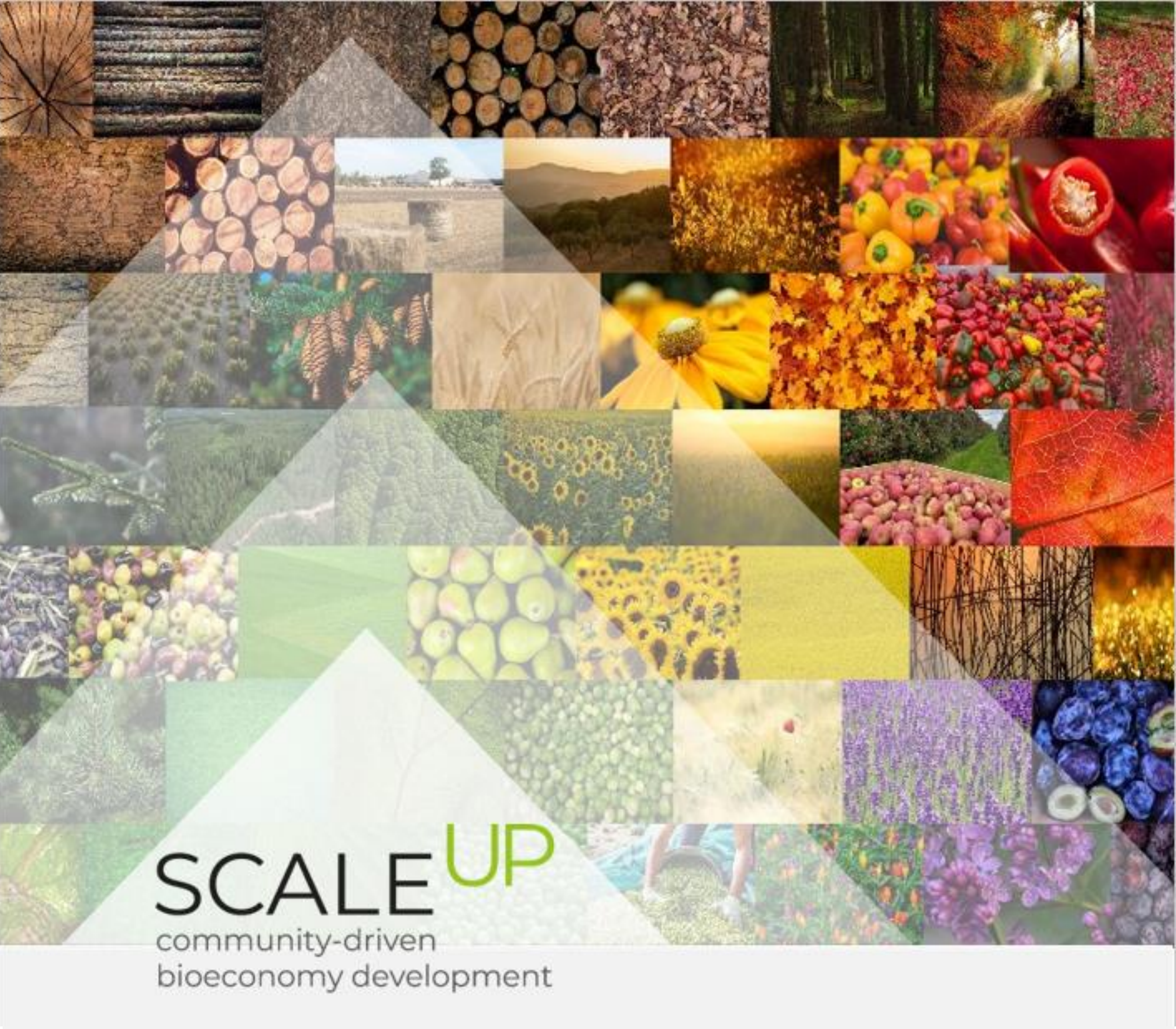
tives on environmental sustainability, revitalising previous initiatives, or kicking off new ones where they did not exist. Where convergence (e.g. as regards challenges, value chains, practices) is identified, knowledge should be exchanged across regions on ecological boundary issues. Ongoing efforts at EU level to support and improve the monitoring of environmental parameters in the context of the bioeconomy nature, soil and water quality is essential and should be encouraged.

8. **Nutrient recycling**. Platforms should stimulate nutrient recycling by organising knowledge transfer activities for stakeholders and the agricultural sector. Nutrient recycling should take place with due consideration to cascading principles: best is to use nutrients for valuable bio-based products. When no longer possible: the nutrients should be used for composting or biogas production and use of digestate for biofertilizer. Platforms could help organise joint collection, processing and quality control. A better understanding and knowledge base on the potential of nutrient recycling as an instrument to avoid the breach of ecological boundaries at regional level is necessary.

9. **Policy development on the use of regional biomass resources**. Regional governments should stimulate the development of the bioeconomy within giving careful consideration to the notion of ecological boundaries. This should be done preferably in cooperation with the regional platforms, and the proposed sustainability task forces. Common and coordinated targets should be formulated and common plans should be developed. Policy measures should be developed within the frame of the EU Bioeconomy Strategy and in line with the EU Farm to Fork Strategy, the EU Biodiversity 2030 Strategy and the Nature Restoration Law, the EU Strategy for Adaptation to Climate Change, the Zero Pollution Action Plan, the EU Circular Economy Strategy, among others. Pilot projects on improving the value chains of bio-based products should be developed, carefully documented and lessons on both good and bad practices should be showcased.

10. **Policy development nutrient recycling.** National and regional governments should stimulate nutrient recycling. Common targets should be formulated, and work plans should be developed. Policy measures should be developed in line with the EU Farm to Fork strategy. Pilot projects on improving nutrient recycling should be developed.

7 Annex



Regional Biomass and Nutrient Availabilities in North Sweden

February 2022

Magnus Matisons and Eva Fridman, BioFuel Region

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101060264.

Table of contents

1 Regional biomass and nutrient availabilities in North Sweden

1.1 Introduction

1.1.1 Background

A short introduction of the region and possible bio-based solutions.

The total land area for BioFuel Region is 221 800 km^2 of which 67 % is forest land (148 920 km^2). The total growing forest stock is 1 314 million m^3 and the annual growth is 45 million m^3. The protected forest area amounts to 42 990 km^2 or 34pprox.. 20 % of the productive forest land. Additional to this there are voluntarily set aside areas made by private forest owners.

The quantity of woody biomass supplied to the market depends on decisions of individual forest owners whether to perform harvesting operations or not. The main market driver for the forest owners when to deliver to market is the timber prices. Price for wood energy has no or little influence. The annual harvest in the region is on average 31 million m^3. In addition to domestic wood, imported round wood can also contribute to the regional market.

Sawn timber products and pulp and paper products have dominated the use over a long time but the use of forest biomass for energy purposes has grown rapidly over the past decades. In the near future, the use of forest biomass in biorefineries is expected to increase rapidly. Forestry is a co-production system, i.e. several products are produced simultaneously, such as saw logs, pulpwood and logging residues (branches and tops left in the forest after harvest operations). Therefore, the potential amounts of the different assortments are not independent. As a result of forest industry activities large amounts of by-products (in this case we focus on sawdust and bark) are available. These by-products are today used mainly for the generation of power and heat in CHPs (Combined Heat and Power plants). As a result of harvesting operations, large volumes of logging residues (LR) are available in the region. Most of this potential is not used today because of the higher costs of harvesting, transport and storing compared to the marked price for sawdust and bark. What is used, is mainly used for combustion. The illustration below shows the present flows of woody biomass from the forest and between different industry segments.

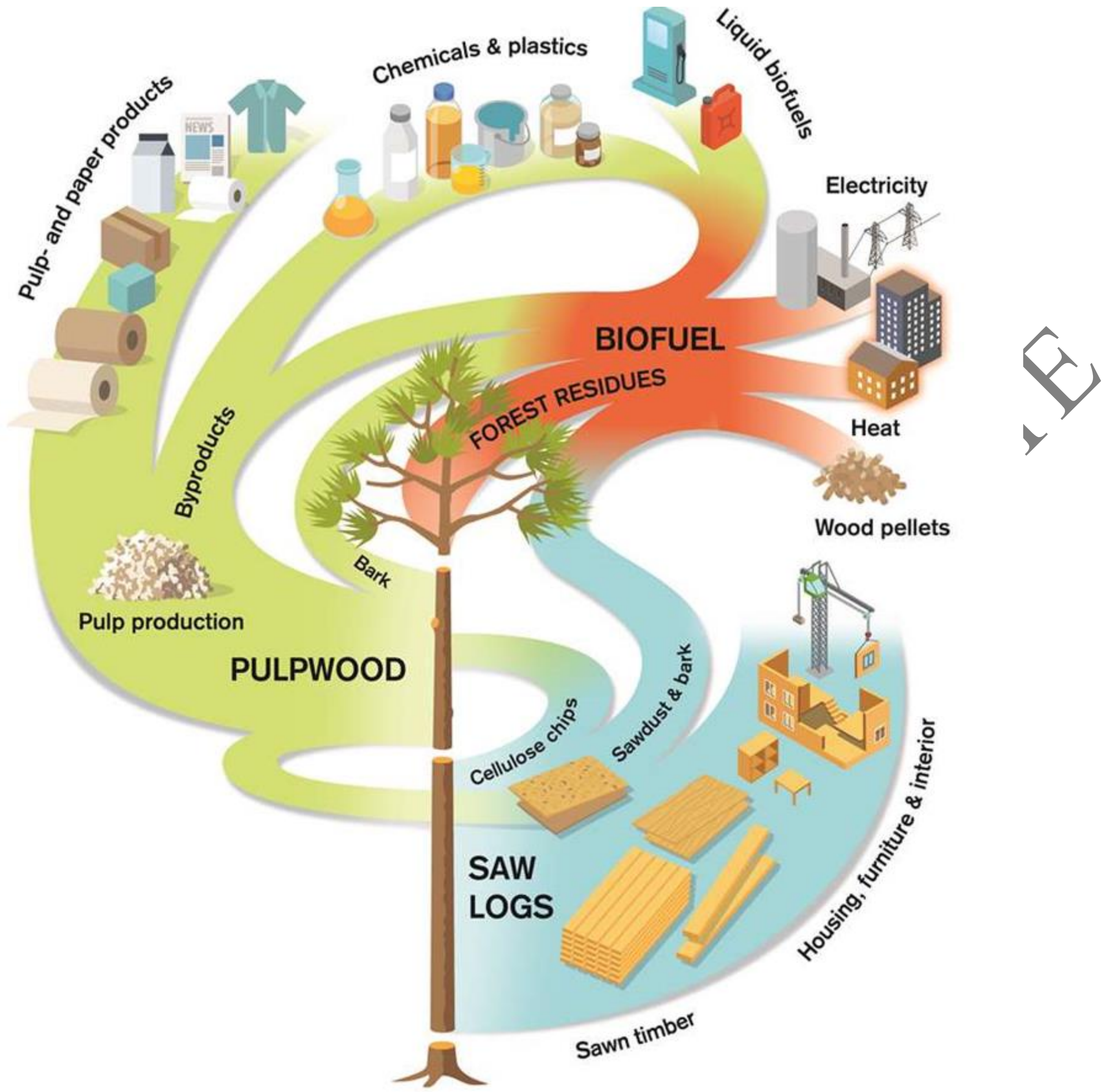


Figure 1. The value chain of the forest biomass showing the flows of woody biomass from the forest and between different industry segments (own image).

1.1.2 Scope

To describe a value chain from forest industry by-products and forestry by-products to a biobased end product is not straight forward. Many biorefining technologies will depend on input of several different woody biomass assortments and have an output of several end products. Assortments or by products not suitable for biorefining, or side streams after a biorefinery process, will be available for the energy market. The quality of biomass assortments can be improved with different methods of pre-treatment e.g., comminution, drying, fractioning, sorting and compaction etc.

<u>Forest industry by products</u>

In this report, five different forest industry by product assortments are included; sawdust, bark, cellulose chips (c-chips), dry chips, and shavings (see Figure 2). Dry chips and shavings represent rather small volumes and c-chips are exclusively used by pulp and paper industries and are not considered as an available biomass assortment. As data has been collected from many different sources presented with different units, it has been important to determine the conversion rates between ton, m3sub, MWh for the different assortments (Table 1).

Figure 2. Picture of assortments, A = Bark, B = C-Chips, C = Sawdust and D = Shavings (Persson, L [7])

Table 1: Conversion rates between ton, m^3sub (solid volume under bark), MWh for the assortments sawdust, bark, c-chips, dry chips, and shavings with the assumed moisture content in precent. Nd stands for no data (Persson, L [7]).

Assortment	Raw ton	m^3sub	MWh	Moisture content (%)
Sawdust	1	1.2	2.3	50%
Bark	1	1.3	2.0	55%
C-Chips	1	1.1	2.2	50%
Dry Chips	1	2.0	4.3	17%
Shavings	1	Nd	4.2	Nd

Compared to many other forest industry by-products, sawdust has unique qualities that makes it desirable for energy production, fibre board production as well as for emerging biorefining technologies. Sawdust has a well-defined and homogeneous quality, low ash content and few elements that can have a negative impact on biorefining process parameters. Particle size distribution is small with many small particles of similar size. Sawdust already exists in large quantities at the sawmills and the infrastructure for procurement is already available.

[7] Persson, L. Mapping the market of unrefined forest industry by-products in northern Sweden. Rapport från Institutionen för skogens biomaterial och teknologi, 2021:10 Umeå, 2021 (https://stud.epsilon.slu.se/17846/3/persson-l-20220623.pdf)

Bark

Before processing of round wood in sawmills and pulp mills, logs are debarked resulting in huge amounts of bark available near the big industries. Of the round wood input approx. 10% will end up as bark. The heterogeneous nature of bark with high ash content and big particle size distribution makes it problematic for many biorefining technologies but pre-treatment and mixing with other assortments can make some barthe k acceptable. Bark is today used together with other wood fuels for generation of heat and green electricity in CHPs near big cities.

Logging residues (LR)

LR have a bulky, heterogenes and troublesome nature with a mix of stem wood, bark and foliage. After crushing/chipping, particle size distribution is normally high with high proportions of fine particles, and not seldom, a varying proportion of non-organic materials originating from collection. Altogether this makes LR the most challenging biomass resource to mobilize, handle and to refine. Pre-treatment and mixing with other assortments can make some LR acceptable.

1.2 Biomass Availability

1.2.1 Biomass availability feedstock 1

As by-products come from a main process such as sawing wood at a sawmills or pulp-and paper mills, the potential volume available of these by-product assortments is connected to the volumes processed. About half of the annual harvested roundwood (37 m^3 sub timber) in Sweden 2017 is fed into 104 bigger sawmills all over Sweden. 28 of those sawmills are together with 8 pulp mills located in Northern Sweden. Pulpwood is debarked before processing. About 10% of the processed logs will result in bark. About half of the timber being fed into a sawmill ends up as sawn goods. From roundwood volume, around 50% becomes sawn wood products, 20% sawdust, 10% bark, 20% chips and shavings. These are average figures and quite a large variation can be observed between individual sawmills. However, these variations are not considered in this report. Some of the by-products can be used internally by the sawmills, mainly for drying of the sawn goods. Woodchips are today used by the pulp and paper industry while sawdust and bark are mainly used by pellet industries or for combustion in CHPs.

Table 2. Amounts of by-products in the sawmills and pulp- and paper industries in the region (Persson, L[8]).

	Production 1000 m3 sawn wood/year	Sawdust (dry ton)	Bark (dry ton)	Pulp chips (dry ton)	Wood chips (dry ton)	Shavings (raw ton)	Total volume by-products (dry ton)
Sawmills (28)	4 792	396 902	175 747	1 031 369	42 348	27 463	1 673 829
Pulp/paper mills (8)		2 551	55 073				57 624
Total	**4 792**	**399 453**	**230 820**	1 031 369	42 348	27 463	**1 731 453**

[8] Persson, L. Mapping the market of unrefined forest industry by-products in northern Sweden. Rapport från Institutionen för skogens biomaterial och teknologi, 2021:10 Umeå, 2021 (https://stud.epsilon.slu.se/17846/3/persson-l-20220623.pdf)

1.2.2 Biomass availability feedstock 2

Logging residues

As a result of harvesting operations, large volumes of logging residues (LR) are available in the region. These LR's are hardly utilized at all since LR have a low commercial value due to their location far away from most existing end consumers and the costs of harvesting, transport and storing is too high compared to the price of forest industry by products. If we don't extract the logging residues from the forest, they will decompose within 5-10 years in the forest releasing CO2 to atmosphere anyway. Environmental impact of LR extraction is small and well-known and regulated by the national forestry act. What is used, is mainly used for combustion.

In previous projects (forest refine), several studies on the procurement of LR have been carried out. In these studies, we have found that LR is a potential feedstock to produce high value compounds. LR and especially needles, contain high amounts of valuable compounds that can be used to produce a range of added value-products, for example, pharmaceuticals or cosmetic ingredients, platform and specialty chemicals, dietary supplements, biopolymers, bioplastics, foams/emulsions, and coatings. These nature-derived ingredients open possibilities for substituting fossil-based products. LR has complex and varied nature and the needles are rich in chemicals that many biorefining processes cannot handle. Needles and bark can be problematic for many biorefining processes and separation of the needles and/or bark for the extraction of high-value chemicals can improve the quality of the remaining fraction that can be used by other biorefining processes (bio coal, biofuels, etc.).

1.3 Nutrient Availability

Nutrient availability

Agricultural land is harvested once or several times annually, continuously removing organic matter and nutrients from the soils. To compensate for these losses and nutrient leakage, mostly fossil-based fertilizers must be used. In tropical forests most of the nutrients are found in the living biomass while in boreal forests most of the nutrients are found in the forest soils. Harvesting of tropical forests and removing the trees makes it almost impossible to re-establish the forest eco system due to nutrient deficiency. This is why further deforestation in the tropics must be halted. Tropical forests have millions of years of continuity and are rich in biodiversity with many endemic species while boreal forests are young (a few thousand years) poor in biodiversity with few endemic spices. Species in boreal forests have adopted to disturbance e.g., forest fires and can adopt to changes and spread into new niches.

Forest soils in the northern Sweden region are mostly till soils, poor in plant available nutrients thus the trees grow very slowly. Nitrogen is the most limiting nutrient for growth of the trees. If we add nitrogen fertilizers, trees will respond with increased growth. Forest management practices are regulated by the Swedish forestry act to prevent long-term impaired growth potentials and nutrient leakage from forest soils to water recipients. During a rotation period, thinning operations are carried out once or twice and final felling is carried out after approximately 100 years, removing most of the valuable stem wood. During these 100 years' time, nutrients are recycled when needles and twigs continuously litter from the trees. Litter is decomposed and nutrient is reused by the trees. After harvest, forest soils are scarified to make more nutrients available for the planted seedlings. For every tree that is removed, at least two new trees are planted. This practice has resulted in that we today have twice as much forest, in cubic meters, as we had 100 years ago. Increased forest growth together with increasing temperatures increases the rate of weathering and makes more nutrients available for the trees.

Removal of stem wood does not pose a threat to long-term productivity of forests but removal of LR can be problematic on poor soil as most of the nitrogen is found in the needles. LR is removed only from relatively fertile spruce-dominated forests and is not recommended in pine-dominated forests on poor forest land. To prevent the negative impact of LR removal, it is recommended to leave LR in the forest for one season to dry and to drop as much as possible of the needles. It is also recommended to return the ashes after combustion, to forest soils where LR has been removed. However, nitrogen will be lost in the flue gases during combustion, so this recommendation seldom affects the growth of the new stand. However, if we add biomass ashes to peat soils, it has been shown to have a positive effect on tree growth as peat soils are poor in potassium that still is available in the ashes. However, due to concerns about the negative impact on peat ecosystems, this is not recommended. Trials have been made in the region to fertilize forest soils with municipal sewage sludge. Neither this is recommended, as sewage sludge can contaminate forest soils with heavy metals.

1.4 Discussion of the Results

The costs of harvesting, transporting, storing, and handling of the biomass are prime determinants of overall biorefining costs. Thus, it is vitally important to develop local forest biomass supply systems that can efficiently supply biorefineries with sufficient raw material that meets their specific quality and seasonal demands. Biomass resources not fulfilling economical or quality requirements from end users cannot be mobilized.

Low hanging fruits are forest industry by products as they are available in large amounts in one place. To maximize possible synergies, refineries can preferably be integrated just next to existing forest industries. However, most of the forest industry by-products are already used, either internally, or by pellet producers or CHP plants. In the near future, new processes are likely to be developed to upgrade by-products, like sawdust, both into high-value products and to different types of biofuels. It is likely that competition for the forest industry by-products, especially those with a well-defined quality, like sawdust will soon increase.

The tree stem, excluding bark, is a relatively homogeneous material and its chemical and physical properties are well known, while bark and crown components have a much more heterogeneous chemical composition. Thus, for many biorefining processes stem wood (e.g. sawdust and shavings) is arguably the most straightforward production material. Specific quality demands of each biorefining process will determine what biomass assortments are possible to use.

CHPs can compensate for the future shortage of sawdust by burning LR (Logging residues) that today are not fully utilized or other more complex fuels not suitable for upgrading. CHP technology is robust and designed to handle more complex fuels.

Wood fuels often have a wet and bulky nature making road transport over long distances not feasible. Wood fuels are typically sourced within a 100 km radius from the end consumer. Another thing to consider is the biomass suppliers' willingness to sell. In northern Sweden, a few big forest companies have a dominating market position. Business relations and trust has developed between sellers and buyers of wood fuels for several decades. Therefore, it is not realistic to assume that a new facility demanding biomass will be able to source all available biomass. To conclude, biomass availability is highly case-specific and should answer the following question: What biomass assortments of a good enough quality can for several decades be sourced at an affordable price within a 100 km radius from the biorefinery? A potential limiting factor for biomass availability can also be EU policies aiming to regulate forest management practices and determining what assortments can be used for different purposes. In previous studies, we have assumed that 50% of forest industry by-products will be available and based on this assumption calculated marginal cost curves for biomass acquisition.

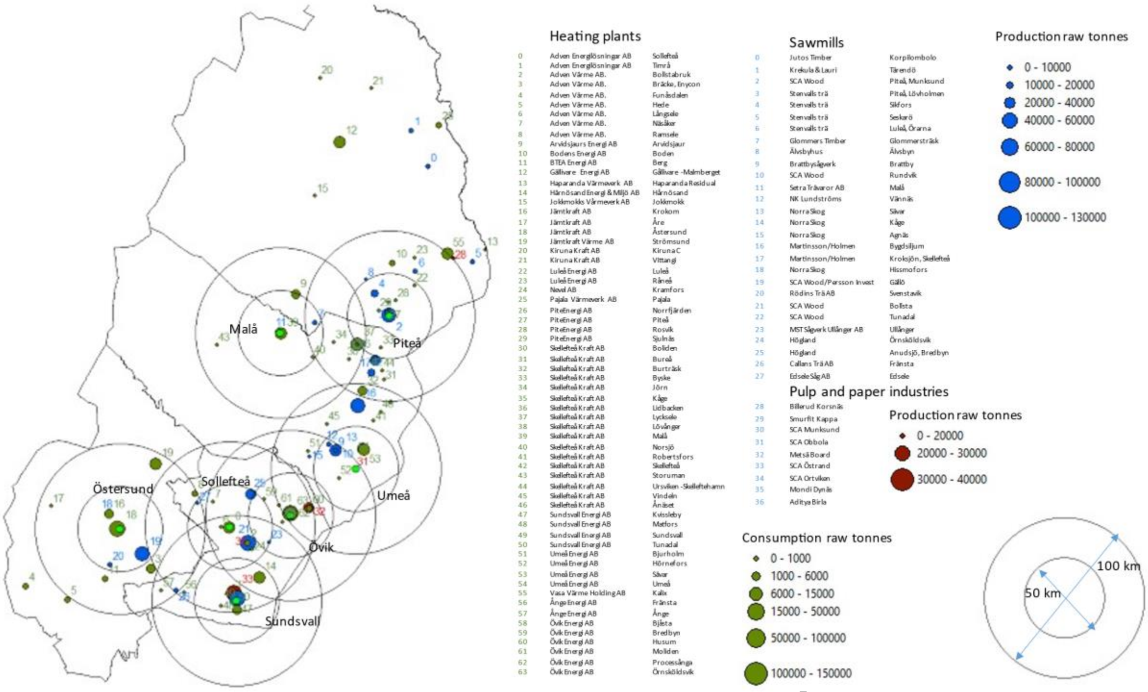


Figure 3. Map of northern Sweden with major industries producing and consuming sawdust and bark. Raw material supply areas for potential biorefineries. (Athanassiadis, D. Analyses from Swedish University of Agricultural Sciences, Forest Biomaterials and Technology)

The use of forestry by-products will lead to the following changes in the market. Heating oil was commonly used for heating in Sweden before the 1980s, but today biomass has a dominant position in the Swedish heat market as a fuel for CHP for district heating. Very little fossil fuels are today used for heating. Biomass is also the main energy source for energy intense forest industries. Today, most of the forest industry by-products are already used, either internally, or by pellet producers or by combined heat and power (CHP) plants. Only outputs with high water content like fibre sludge and green liquor etc. are difficult to use. In northern Sweden, several investments are planned for the production of biocarbon, biofuels and biochemicals based on forest industry by-products (sawdust and bark). These investments are on higher levels in the biomass value pyramid than energy generation. Upgrading is likely to have the following effects.

- Upgrading creates added value to sawdust. This in line with the cascading principle.
- New production creates synergies with the existing forest industries and raises the overall efficiency of both processes. It also reduces energy needed for transports of bulky sawdust as the productions will take place integrated or close to the sawmill. New end users are aiming to find most suitable places that can maximise these synergies.
- When you create added value to a by-product it becomes more economical for forest industries to supply more by products to the market and use less internally. This promotes investments in energy efficient technology. We have seen several examples of this during the past decades.
- Biofuels used for transports today can in the future be upgraded to biobased materials and biochemi-cals can stay and circulate in the society for a longer time and in the end of the life cycle can be used for energy generations.
- CHP plants can compensate for the shortage of sawdust by burning logging residues (branches and tops) that today are not fully utilized or other more complex fuels not suitable for upgrading. CHP technology is robust and designed to handle more complex fuels. If we don't extract the logging resi-dues from the forest they will decompose (5-10 years) in the forest releasing CO2 to atmosphere an-

yway. Environmental impact of LR extraction is small and well known and regulated by the national forestry act.

1.5 Conclusions and Recommendations

1.5.1 Conclusions

Forestry is a co-production system, i.e. several products are produced simultaneously, such as saw logs, pulpwood, sawdust, bark and logging residues. Therefore, the potential amounts of the different assortments are not independent.

The estimation of current residues is given below. The data for sawdust, bark, chips and savings are actual figures. Potential may be higher. The logging residues are a rough estimate of what could be collected on basis of a medium mobilisation scenario within sound ecological boundaries.

Table 3, Estimations on biomass potential and applications (Persson, L[9])

Biomass stream	By-products (annual production, dry)	Current application	Possible application
sawdust	300 kt	wood pulp (paper & textiles), wood panels, energy production	high value products, biofuels
bark	230 kt		
pulp chips	1 Mt		
wood chips	40 kt		
shavings	30 kt		
logging residues	2-4 Mt	largely not extracted, combustion	high value compounds

Logistics: Biorefinery plants need huge amounts of biomass at an affordable price. Efficient biomass logistics is very important for increased availability at an affordable price. The costs of harvesting, transporting, storing and handling of the biomass are prime determinants of overall biorefining costs. Wood fuels often have a wet and bulky nature making road transport over long distances not feasible. Wood fuels are typically sourced within a 100 km radius from the end consumer. Solutions for improved biomass logistics are available here (https://biofuelregion.se/projekt/forest-refine/).

Costs allocation: Calculating production costs for one product in a co-production system is not straightforward. Generally, there is no unambiguous way to allocate costs between the different products in an operation. The forest-based industries and the energy production sector are intricately interlinked, displaying synergies as well as competition. Sawmilling by-products are used for wood pulp (for paper as well as textile fibres) and wood-based panels manufacturing as well as for energy production, while side-streams from chemical pulping are used in the chemical industry as well as for energy production.

[9] Persson, L. Mapping the market of unrefined forest industry by-products in northern Sweden. Rapport från Institutionen för skogens biomaterial och teknologi, 2021:10 Umeå, 2021 (https://stud.epsilon.slu.se/17846/3/persson-l-20220623.pdf)

Dynamics in supply and demand: The demand, and thus price, for sawlogs is one of the most determinant factors for the supply of primary woody biomass, including woody biomass for energy. The supply of primary woody biomass might also be affected by external factors, such as natural disturbances. Energy and material use (mainly wood-based panels but also wood pulp manufacturing) also compete for primary sources of woody biomass. This means that developments in wood-based markets are instrumental to the supply of woody biomass for biorefining purposes, and thus an assessment of sources and uses of woody biomass needs to consider existing forest-based industries. Increased competition for sawdust and bark today used for combustion will make CHP plants look for alternative wood fuels. Logging residues represent a huge, underutilized biomass resource. To mobilize this resource, several actors must make strategic decisions.

Forest resources and climate: Forest resources within the EU are on the increase. Between 1990 and 2020, forest area increased by 9% and the volume of wood in European forests rose by 50%. Over the last 100 years the standing volume in Swedish forests has almost doubled and carbon stocks in forests and forest soil have quadrupled. At the same time, more than 4 billion cubic meters of timber have been felled and delivered to the society. Sustainable forest management has a positive impact on climate change mitigation. If we don't extract biomass from regions with positive forest trends, we face the risk of importing biomass from countries where we can observe a negative trend of deforestation.

1.5.2 Recommendations

For the SCALE-UP regional platform:

- To share information and to promote joint activities to boost the bioeconomy in northern Sweden. One example is the ongoing support to mobilize more logging residues in the region.
- To mobilize actors within the whole value chain and to communicate and exchange best practices for cost-effective deliveries of logging residues with high quality. A wood fuel network including buyers and sellers of wood fuels in northern Sweden should be mobilized in this task.
- To identify challenges and solutions in the logging residue value chain with a web survey. To identify important areas where best practices can be shared and developed. To design workshops and training sessions together with heating plant, entrepreneurs, and suppliers of wood fuels.

For research:

- To make more biomass economically available over vast geographical areas, it is important to develop more efficient forest machinery and transports on road and railway.

Policy:

- All policy measures aiming to hamper active forest management will decrease the availability of all woody biomass assortments.
- An increase in the use of woody biomass to reduce carbon emissions should be promoted through active and sustainable forest management across the EU and should not be hampered by policy constraints.

SCALE UP
community-driven
bioeconomy development

Regional Biomass and Nutrient Availabilities in Mazovia, Poland

February, 2024

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UNIMOS Alliance

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Table of contents

1 Regional biomass and nutrient availabilities in Mazovia region (Poland)

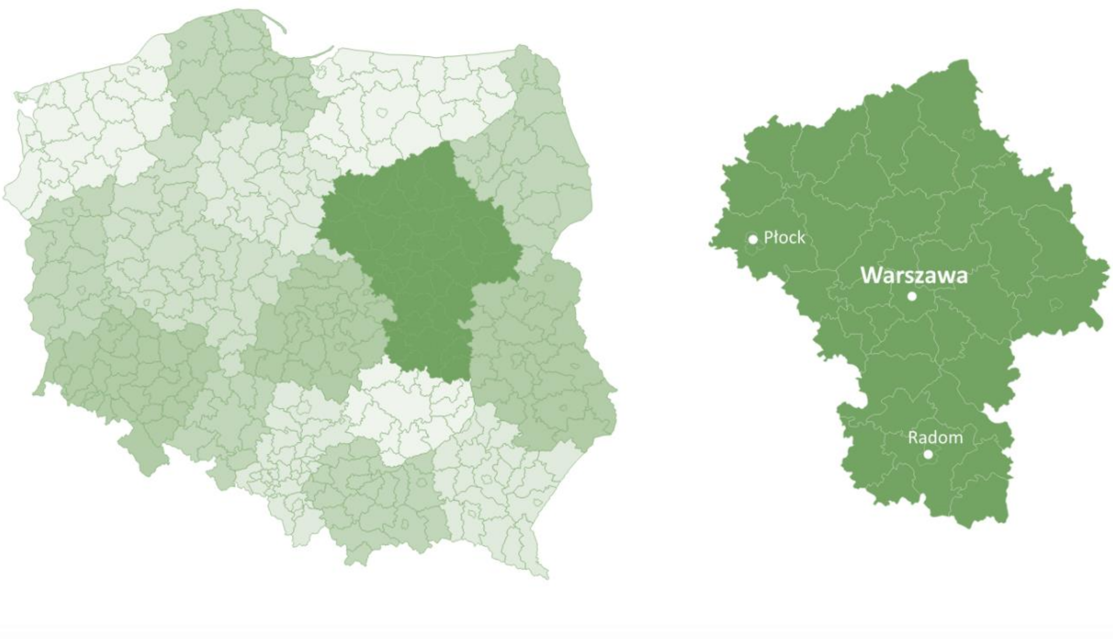
1.1 Introduction

1.1.1 Background

The Mazowieckie voivodeship (Mazovia Region) with Warszawa (Warsaw) - the capital of Poland - is located in the central part of Poland and covers an area of more than 35,500 square kilometers.

According to Statistics Poland, apart from being the largest province in Poland in terms of area and population with 5 425 028 inhabitants, the region is the fastest developing region of Poland. It is characterized by low unemployment, high economic development speed and young and well qualified staff. The development of entrepreneurship in the region is primarily influenced by the existence of business incubators, including academic business incubators, highlighting the transregional role of Warsaw, connected to its role as the capital city of Poland. In terms of technology and innovation ecosystems, there is a high availability of innovative solutions (including Industry 4.0) and there are strong and active clusters operating in traditional and high-tech industries. Research, private and non-governmental organizations can count on tangible support from the regional government for agriculture development, as well as the availability of EU instruments and financing schemes. Mazovia is also one of the most internally diverse areas in Poland showing high internal diversification with a nationwide potential in nearly every field: science, research, education, industry and infrastructure.

Figure 1. Mazovia region map against the map of the country



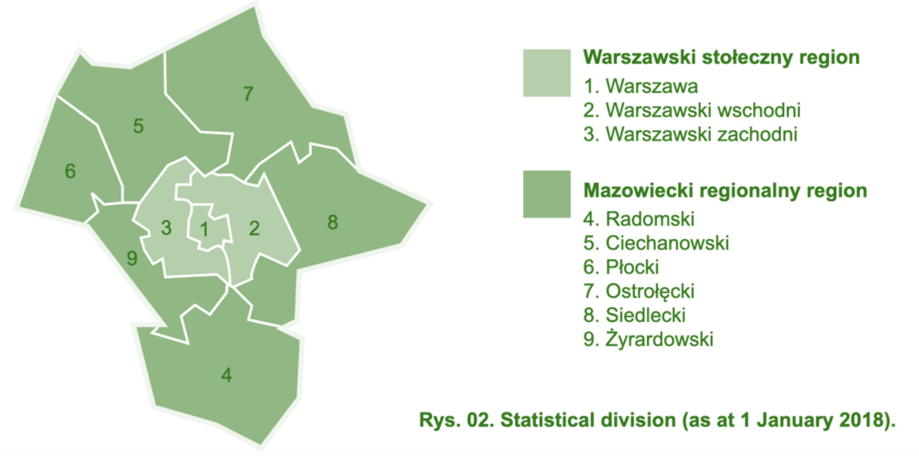
Source: Adapted from https://www.paih.gov.pl/polish_regions/voivodships/mazowieckie#

On 1 January 2018, Mazovia region was divided into 2 statistical units of the NUTS2 level ("regions" according to the systematics used by Eurostat):

- Region warszawski stołeczny (Warsaw Capital), which includes the city of Warsaw together with the following powiats: grodziski, legionowski,miński, nowodworski, otwocki, piaseczyński, pruszkowski, warszawski zachodni and wołomiński,

- Region mazowiecki regionalny (Mazovia region), which covers the rest of the Mazovia region

Figure 2. Mazovia region division according to NUTS2



Source: https://innowacyjni.mazovia.pl

The Mazovian economy is characterized by high industry diversification, being less dependent on cyclical fluctuations than regions uniform in terms of the structure of the economy. There is also a clear regionalization of certain specializations.

Agriculture is one of the most important sectors in the Mazovia and it is characterized by very fertile soils enabling a thriving development of agricultural economy. Usable agricultural land covers about 65% of the area, hence the large role of horticulture, orcharding and related activities (source: Statistics Poland; stat.gov.pl).

Poland is the largest producer of apples in Europe. Apples have been grown in Poland since the 12th century, and today form an integral part of its economy and economic heritage.

Figure 3. Apple harvesting in Poland

Source: own picture.

According to PolishFoodies (polishfoodies.com), in 2021, Poland produced 4,170,000 tons of apples, almost 22% more than in 2020 which put the country on the top of the EU apple-producing charts.

Taking into account the above-mentioned facts and aspects, several possible bio-based solutions have
a chance for the development in the Mazovia region, including:

- production of new functional agri-food products;
- production of new bio-based packaging;
- production of fertilisers based on waste from fruits, grains and vegetables and
- other processing activities.

In order to facilitate the development of new bio-based solutions, it is worth to have in mind financing opportunities available currently in the Mazovia region and related to the EU funds 2021-2027.

The development of possible bio-based solutions should be in line with the RIS 2030 – a strategic framework for the regional innovation ecosystem and smart specialisation of the Mazovia region (Mazowieckie voivodeship). It constitutes a signpost along the paths of regional innovation development and enables better use of the region's resources in the area of research, innovation development or cooperation of entrepreneurs and scientific entities, business support institutions and administration.

In Mazovia region, four main thematic areas are adopted as the basis for the specialisation, on the foundation of which the entrepreneurial discovery process is organised. The four areas are as follows:

1. Safe Food
2. Smart systems in industry and infrastructure
3. Modern business ecosystem
4. High quality of life

For each area of smart specialisation, the assumed economic effects and expected project results were defined, as well as sample technologies supporting the area.

Safe Food is one of RIS2030 specialization areas that focuses on ensuring high quality agri-food products that are safe for consumers and the environment. This can be achieved, by among other ways, through improving products and processes related to their production, processing, storage, distribution and disposal.

The area includes solutions affecting food quality and safety, among others, in the field of:

- farming and breeding techniques (including precision farming),
- fertilisers, plant protection products, feeding stuffs, veterinary medicines,
- machinery, equipment and tools for agriculture and agri-food processing,
- formulation of food products and improvement of technological processes,
- quality testing of agri-food products,
- food storage and distribution (including packaging)

Examples of technologies supporting the area of specialisation:

- Agritech - technologies dedicated to agriculture, both plant and animal production up to the first processing stage.
- Biotech - technologies using biological processes on an industrial scale.
- Foodtech - technologies dedicated to food production from the first processing of agricultural products.
- Qualitytech - technologies and solutions used in quality control.

The smart specialisation of the Mazovia is open, as it assumes the possibility of identifying new development niches at any time of the smart specialisation strategy implementation within so called entrepreneurial discovery process. This approach is crucial to involve stakeholders (including entrepreneurs) as broadly as possible directly in the process of creating, implementing, monitoring, evaluating and updating the strategy for smart specialisation.

Additionally, the Strategic Plan for the Common Agricultural Policy 2023-2027 (CAP SP 2023-2027) prepared by Poland and approved by the European Commission should be taken into account as well. It provides an opportunity to effectively, and sustainably strengthen the competitiveness and development of Polish agriculture and rural development, taking into account aspects of the transition to a green and digital economy.

1.1.2 Scope

According to Agronomist.pl[10], Poland is the largest apple-growing country in the European Union, and the fourth largest producer in the world (after China, USA and Turkey). The two selected value chains are related to apple production – apple pruning (branches) and apple pomace.

The first value chain – apple pruning residues - belongs to the agricultural wastes generated in the agro-food processing sector. Annual pruning is required, and thus generates a substantial number of residues, which must be disposed of. The second one – apple pomace- is left-over solid residue resulting from extraction of juice from apples.

In terms of quality, Polish producers concentrate on high quality of produced apples. They have access to modern cold stores and can offer fresh apples during the whole year. The main investments in apple production are related to the modern storage, sorting and packaging facilities. It's financed mostly by the groups of producers in the regions. Suppliers very often consolidate in associations and are able to plan, sort, pack and supply big, uniform batches of apples. It is noticed that labour resource costs are lowered by hiring workers from East European countries out of the EU.

According to Polish Foodies, there are several types of apples grown in Poland. It is possible to distinguish (polishfoodies.com):

Figure 4. Mutsu apples grown in Poland

[10] Agronomist.pl is online platform with professional knowledge and innovative tools for agricultural producers and food processors.

Source: own picture.

- Popular Polish apple varieties, that include Kostzela (old apple variety with a greenish peel), Antonówka (sour and crumpbly variety coming from Russia that withstands frost), Złota Reneta (perfect for kompot and jam), Kronselska (green, yellow and aromatic), Papierówka or Oliwka Żółta (semi-sweet-semi-sour yellow apples originated in the Baltics perfect for coocking)

- Modern varieties, that include Idared (tart and juicy), Jonagored (slightly sour with a juicy aromatic yellow pulp), Jonaprince (large, crisp, juicy, and sweet), Mutsu (a hybrid of Indo and Golden Delicious, conical in shape and slightly sour, but creamy), Szampion (also called champion, developed in the Czech Republic), Ligol (large and creamy) and Delikates (perfect for desserts).

- International apples, Royal Gala (originally from New Zealand sweet and tender apples started to being cultivated in 90s in Poland), Golden Delicious (aromatic and sweet with a crispy creamy flesh), Pink Lady (Australian cross-breed with sweetness of Golden Delicious and the firmness of Lady Williams apples), Gloster (German apples with tasty flushed red fruit) and Granny Smith (firm juicy Australian apple).

The most popular varieties in Poland are: Idared (21,6%), Jonagold (17,5%), Champion (11,2%), Ligol (7%), Golden Delicious (5,1%), Gala (5%), Gloster (4,8%), Lobo (2,3%). 64% of apples produced in Poland are dedicated to consumption and 36% for industry[11].

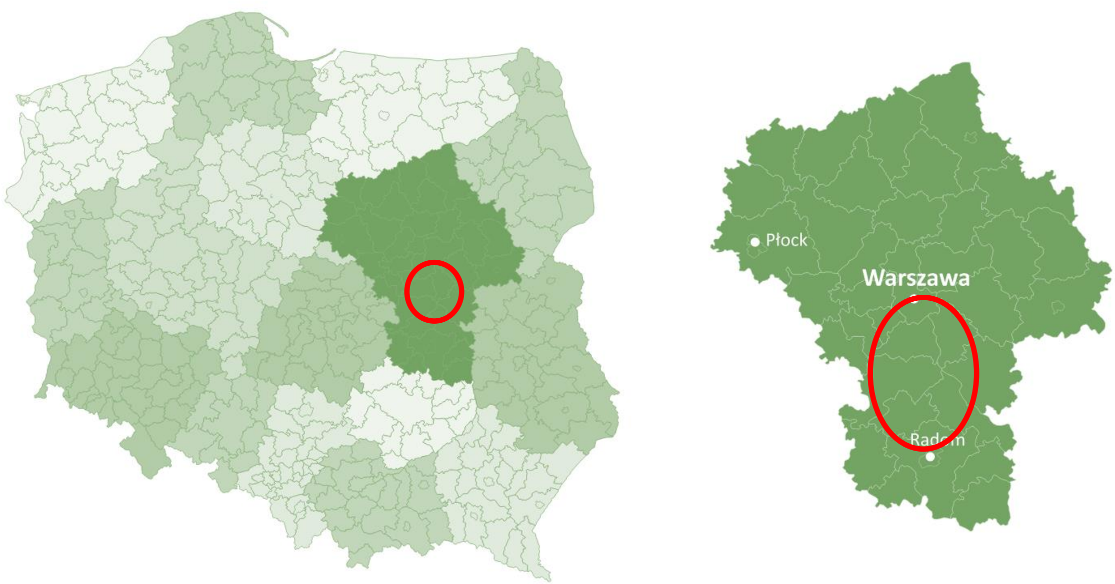
[11] Pietrzak, Michał, Aleksandra Chlebicka, Paweł Kraciński, and Agata Malak-Rawlikowska. 2020. "Information Asymmetry as a Barrier in Upgrading the Position of Local Producers in the Global Value Chain—Evidence from the Apple Sector in Poland" *Sustainability* 12, no. 19: 7857. https://doi.org/10.3390/su12197857

Figure 5. Apple orchard in Poland

Source: own picture.

In relation to the locations, on average, more than 45 percent of the country's apple production comes from the Grojec-Warka region, known as "Europe's largest orchard." Municipalities with the highest concentration of crops are: Błędów, Belsk Duży, Grójec and Warka. Mazovia region has the largest continuous apple orchards area in Poland that covers 68.816 ha.

Figure 6. Main apple production in Mazovia region



Source: own elaboration based www.innowacyjni.mazovia.pl

Polish orchards are set up on the lowland areas, mostly placed on soils made of clays, dust formations and saprophytic sands that gives good oxygenation to significant depths. The level of pH is between 6,1 - 6,7.

The country is situated in moderate climate zone which is very favourable for apple trees. Average temperature from flowering to harvesting time is 16,3 C (with rainfall 615 mm / month) and 2,7 C (with rainfall 320 mm / month) in the vegetation period. In terms of production methods, the central region of Poland has a very good relation of cold and hot days during the year, what makes good balance of sweet and sour taste.

Apple production in Poland in recent years has distinguished itself from other fruit production sectors by gradually increasing production efficiency per unit area, with decreasing production costs. Intensification of orchard production requires the use of an adequate amount of agrotechnical treatments (fertilization, chemical plant protection), which can have a negative impact on the quality of the environment, especially in relation to soil, surface water, groundwater and biological balance.

Polish apple producers are mostly small companies with less than 5 hectares areal (89,3% of all producers). In each region, they set up local trade groups, which associate most of the local suppliers. In terms of commercialization, trade groups are responsible for the sale of the apples but also they store the fruits, sort, pack and organize the transport. They negotiate the prices and the cooperation conditions. The producers with the acreage above 5 hectares (10,7%) mostly work independently and they sell and export the apples directly to the buyers.

Residues of mineral fertilizers and pesticides may cause deterioration of the quality of the environment and produced food. This is why in the interest of producers and consumers of agricultural products, it is necessary to ensure the proper use of the agroecosystem within the framework of integrated fruit production, meaning the appropriate number of agrotechnical treatments, doses and timing of their application, grace and prevention periods), taking into account the balance of economic, social and natural interests.

According to LabManager, Apple trees need access to important nutrients, which come from the soil. However, soil is quite different from orchard to orchard[12].

Apple prunings

In terms of the role of nutrients in the value chain, woody residues are the most promising source of raw materials for the wood industry and could replace traditional wood assortments for bioenergy and industrial use. Additionally, prunings could be used as a lignocellulosic source for particleboard production. According to research studies, apple pruning residues, as a wooden biomass, could partly replace typical wood assortments for small and middle size boilers and commercial power plants, supporting the energy units with renewable fuel. Moreover, they could generate heat, similar to technologies related to waste-to-energy (WtE), zero waste or circular bioeconomy solutions. It is worth noting that pruning-to-energy (PtE) may be especially important in rural areas that are characterized by limited access to forest resources and a large share of apple orchards in the region.

It is possible to use the pruning biomass as a fertilizer. The prunings should be chipped to capture the nutrients from the orchard's 'waste' and return them to the soil. In terms of innovative applications of nutrients, this topic should be explored, preferably in coordination with research and education institutions.

Apple pomace

Apples are a staple fruit grown in temperate climate zones, are among the most widely consumed fruits in the fresh state and are a valued raw material in the processing industry. The fruit is a valuable source of fiber, pectin, vitamins A, B, PP, C, K, which are essential for the human body, as

[12] www.labmanager.com

well as carbohydrates (glucose, fructose), organic acids (malic, citric, tartaric) and minerals. The advantage of apples is that they are low in calories, as a medium-sized apple has about 60 kcal.

Apple pomace is a rich source of nutrients such as phytochemicals, as well as carbohydrates, vitamins and mineral. It consists of a high amount of carbohydrates, of which about 70% are simple sugars, have a high source of arabinose and rhamnose and contain from 10 to 12% glucose (dry weight basis), which is a main fuel source for most tissues throughout human body. Besides carbohydrates, apple pomace is also a source of proteins.

Apple pomace is a rich source of many minerals, which are of interest from the human nutritional point of view. Potassium represents the main portion of the total mineral content of apple pomace and provides 20% of Recommended Dietary Allowances (RDA) after consumption of 100g of apple pomace. Sodium and phosphorus are the next most widespread minerals in apple pomace and provides respectively 13% and 11% of RDA[13].

Apple pomace is also rich source of copper and zinc. Copper is requested in correct superoxide dismutase working, which causes neutralization of free radicals in human body. Zinc is essential trace element for humans, and other organisms, after iron is the second most abundant transition metal in organisms.

1.2 Biomass Availability

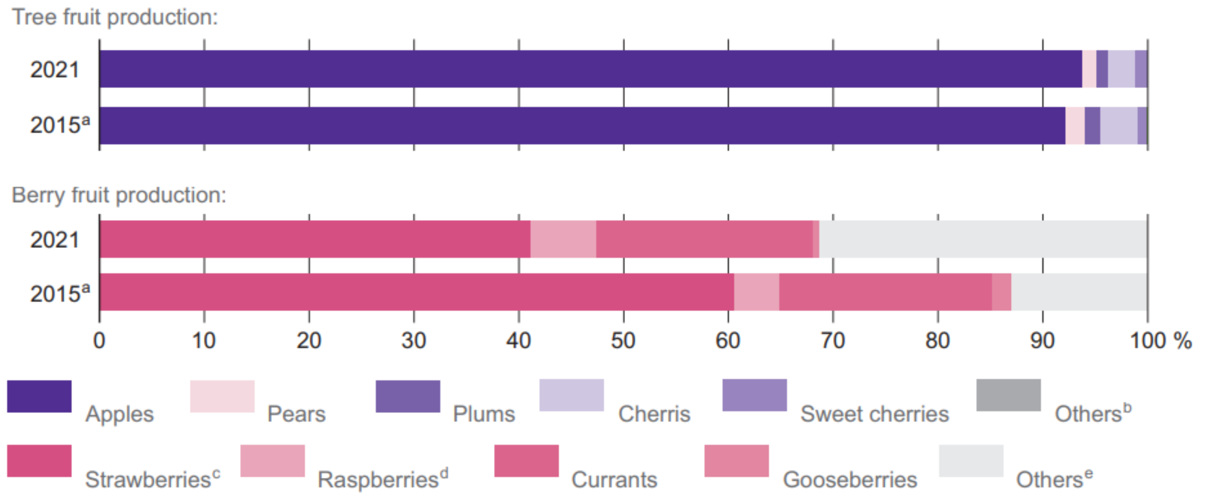
1.2.1 Biomass availability – apple prunings

In Europe, the main permanent crop areas are occupied by olive trees, vineyards, and fruit trees. According to research studies, the assumed theoretical potential of pruned biomass from permanent crops in EU28 is ca. 246 PJ per year and apple orchards represent a share in the permanent crops area of 4.2%, accounting for ca. 450,000 ha. Taking into account that the largest apple producer in the EU is Poland with over 143,000 ha and almost half the country's production of apples is concentrated in the Mazovia region with 68.816 hectares[14].

Figure 7. Fruit Production in Poland

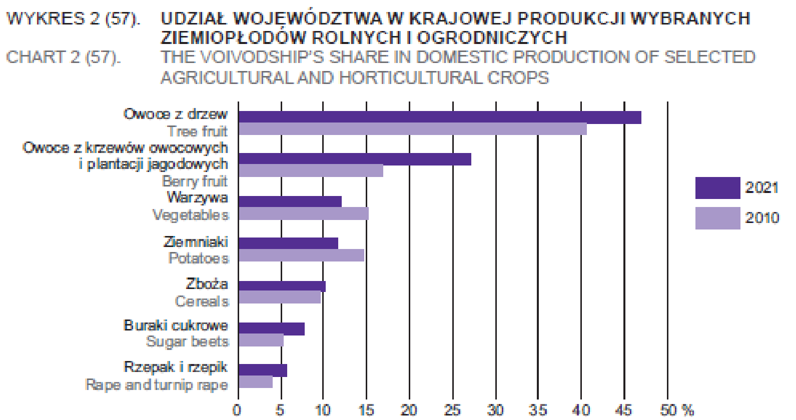
Wyszczególnienie Specification	2020	2021	
	w tys. t in thousand tonnes		2020=100
Ogółem Total	**3948,6**	**4493,5**	**113,8**
Jabłonie Apple trees	3555,2	4067,4	114,4
Grusze Pear trees	61,0	68,6	112,4
Śliwy Plum trees	111,7	117,4	105,1
Wiśnie Sour cherry trees	155,5	166,6	107,1
Czereśnie Sweet cherry trees	51,3	59,1	115,3
Brzoskwinie Peaches	3,8	4,5	120,3
Morele Apricots	3,1	3,1	101,2
Orzechy włoskie Walnut trees	7,0	6,8	96,6

[13] Kruczek, Marek & Gumul, Dorota & Kacaniova, Miroslava & Ivanišhová, Eva & Mareček, Ján & Gambuś, Halina. (2017). Industrial apple pomace by-products as a potential source of pro-health compounds in functional food. Journal of Microbiology, Biotechnology and Food Sciences. 7. 22-26. 10.15414/jmbfs.2017.7.1.22-26.
[14] different-countries-one-environment.pl



a Fruit harvested in orchards and outside. b Peaches, apricots, walnuts. c Including wild strawberries. d Including thornless blackberry. e Chokeberry, highbush blueberry, vine, hazel and others.

Source: Statistics Poland (GUS), 2022



Source: Statistics Poland (GUS), 2022

Figure 8. Fruit Production by voivodship, including Mazowieckie (Mazovia)

TREE FRUIT PRODUCTION IN ORCHARDS BY VOIVODSHIPS

WOJEWÓDZTWA VOIVODSHIPS	2019	2020	2021					
	ogółem total			jabłonie apple trees	grusze pear trees	śliwy plum trees	wiśnie sour cherry trees	czereśnie sweet cherry trees
	w tys. t in thousand tonnes			w % ogółem in % of total				
POLSKA .... POLAND	**3456,4**	**3948,6**	**4493,5**	**90,5**	**1,5**	**2,6**	**3,7**	**1,3**
Dolnośląskie	30,0	21,2	35,9	64,9	3,4	16,3	7,6	5,8
Kujawsko-pomorskie ...	64,1	54,0	60,8	77,4	3,2	6,7	8,6	3,5
Lubelskie	529,0	573,7	611,0	89,6	1,3	3,2	5,1	0,7
Lubuskie	13,0	10,4	75,3	94,0	0,8	1,6	2,0	0,9
Łódzkie	464,9	632,5	575,1	90,3	1,7	2,2	4,8	0,8
Małopolskie	107,7	120,6	132,7	88,4	2,9	5,5	1,8	0,9
Mazowieckie	1522,5	1822,5	2101,8	93,7	1,4	1,1	2,6	1,2
Opolskie	4,8	4,7	11,8	88,4	2,8	1,6	2,0	3,2
Podkarpackie	24,2	37,3	78,0	89,2	2,9	3,7	1,2	0,4
Podlaskie	11,6	9,2	14,3	87,2	5,3	2,1	3,3	1,4
Pomorskie	20,7	11,8	14,5	91,3	2,2	2,0	2,7	1,7
Śląskie	6,1	6,7	12,2	82,3	7,0	5,4	2,2	1,6
Świętokrzyskie	500,7	529,4	593,4	87,7	0,6	4,3	5,0	1,5
Warmińsko-mazurskie	12,0	8,5	9,5	71,2	9,7	10,3	7,2	1,3
Wielkopolskie	104,1	97,0	134,8	75,4	3,2	7,5	7,0	6,2
Zachodniopomorskie ...	40,8	9,2	32,4	87,5	2,6	6,3	1,2	1,2

Source: Statistics Poland (GUS), 2022.

Figure 9 Crop area, yield and harvesting in Poland and Mazovia region

AREA OF CULTIVATION, YIELDS, AND APPLE HARVESTS IN ORCHARDS

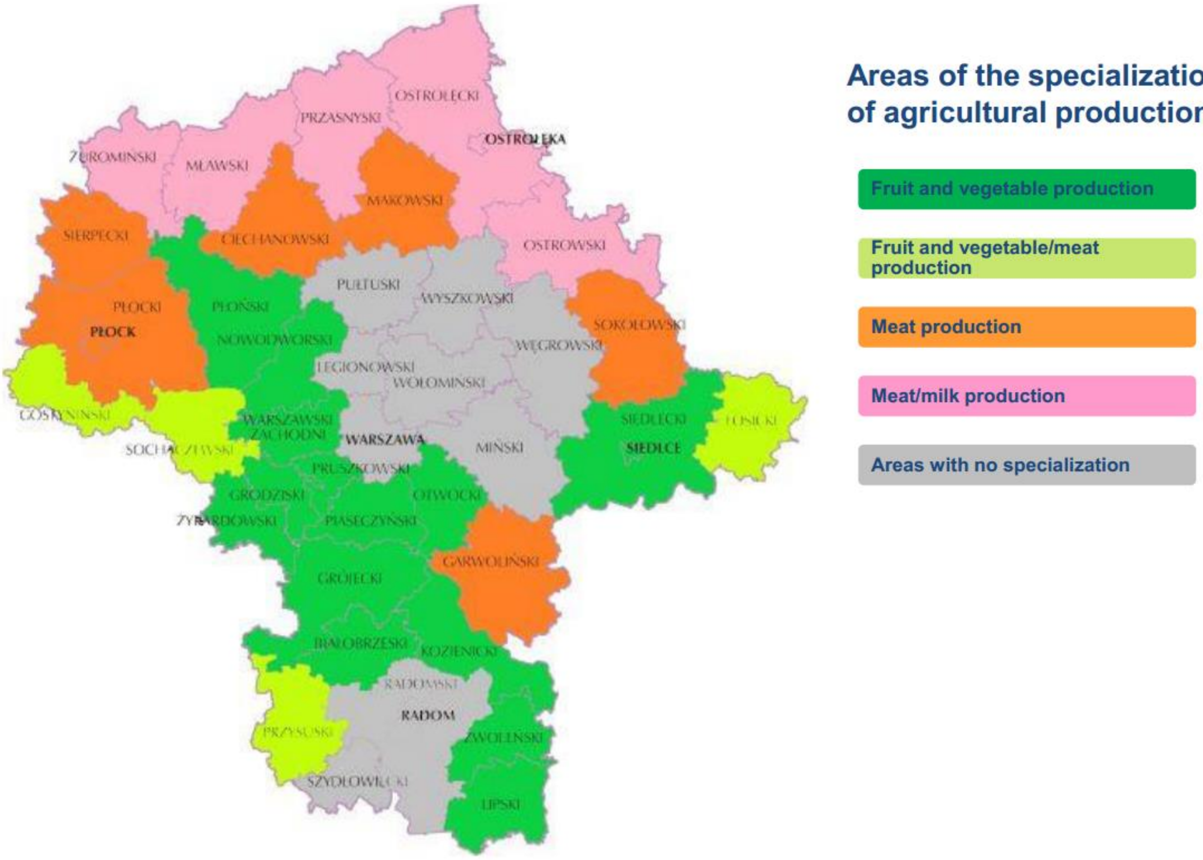
Specification	Area of cultivation (ha)	Yield per 1 ha in decitonnes (dt)	Harvest in decitonnes (dt)	Area	Yields	Harvests
				2020 = 100		
	OGÓŁEM					
Polska	**161 948**	**251,2**	**40 673 766**	**106,1**	**107,8**	**114,4**
Dolnośląskie	1 295	180,0	233 100	126,5	181,5	229,4
Kujawsko-pomorskie	2 590	181,8	470 777	112,9	98,9	111,6
Lubelskie	20 797	263,2	5 473 884	101,3	105,2	106,6
Lubuskie	3 769	187,8	707 911	619,8	182,0	1128,1
Łódzkie	20 572	252,4	5 192 426	99,3	91,5	90,9
Małopolskie	6 110	192,0	1 173 120	104,3	108,5	113,2
Mazowieckie	69 816	282,1	19 695 094	99,9	114,8	114,6
Opolskie	605	172,0	104 057	224,8	144,3	324,3
Podkarpackie	3 852	180,7	695 976	153,3	153,5	235,4
Podlaskie	1 012	123,6	124 995	112,5	153,2	172,3
Pomorskie	1 300	102,0	132 620	122,8	102,5	125,8
Śląskie	813	123,4	100 323	140,8	148,0	208,4
Świętokrzyskie	20 725	251,0	5 201 882	103,9	109,4	113,7
Warmińsko-mazurskie	853	79,5	67 779	100,3	108,9	109,2
Wielkopolskie	4 886	208,0	1 016 334	102,0	150,9	154,0
Zachodniopomorskie	2 954	96,0	283 488	406,5	163,5	665,0

Source: Statistics Poland (GUS), 2020.

Next important regions are Lubelskie District with 22.752 hectares and Świętokrzyskie region with 21.381 hectares and Łódź area 19,512 hectares. In effect, the yearly potential of apple pruning in 28 EU countries is ca. 29 PJ, out of which more than 9 PJ is attributed to Poland[15].

Depending on varieties, the trees are planted in autumn or early spring in rows with 2-4 meters of space in between. The soil must be fertilized in 3-6 months before. Fertilization with nitrogen, magnesium, phosphorus and potassium is necessary during flowering, because they take active part in the process of bud development.

[15] Dyjakon, Arkadiusz & Mudryk, Krzysztof. (2018). Energetic Potential of Apple Orchards in Europe in Terms of Mechanized Harvesting of Pruning Residues. 10.1007/978-3-319-72371-6_58.



Source: Interreg Europe.

According to Kuzin and Solovchenko (2021), potassium (K) is crucial for apple growth, fruit quality, and yield. The apple plant demands it throughout the growing season, peaking during fruit ripening. Currently, themainstream method is through application of the fertilizer to the soils to improve potassium uptake by the rootsand its bioavailability depends on assorted various factors, including pH, interaction with other nutrients in soil solution, temperature, and humidity. Balanced application of potassium is crucial, as its excess leads to competitive inhibition of calcium uptake by plants and the apple fruits affected by the potassium/calciumimbalance frequently develop physiological disorders in storage. New technologies with machine vision might optimize potassium fertilization strategies[16].

The most popular varieties need 140 - 150 days from flowering till harvesting. The potential is growing in accordance with new varieties of low trees and increasing the number of orchards. The intensity of production is picking up above 50 tons/ hectare[17].

[16] Kuzin A, Solovchenko A. Essential Role of Potassium in Apple and Its Implications for Management of Orchard Fertilization. Plants (Basel). 2021 Nov 29;10(12):2624. doi: 10.3390/plants10122624. PMID: 34961094; PMCID: PMC8706047.

[17] Dyjakon A. Harvesting and Baling of Pruned Biomass in Apple Orchards for Energy Production. *Energies*. 2018; 11(7):1680. https://doi.org/10.3390/en11071680

During the growth process, required works include:

- Pruning - aimed at shaping the tree and limiting its growth, which in turn affects the better quality of the fruit that the tree produces;
- Digging - performed in order to cover the trunk of the tree and protect it against negative temperatures;
- Fertilization and watering / determining the uptake by the tree of water and nutrients;
- Spraying - protecting fruit trees against diseases, insects and weeds.

In terms of pesticides, they must be controlled and used only when necessary. The chemical composition is regulated with the appropriate regulations.

According to Dyjakon (2019) there are different management options in apple orchards (Figure 10)[18]. One of the field-based agricultural residues involves cut branches from regular permanent tree crop pruning, such as apples. Amongst permanent fruit crops in Poland, apple orchards cover the largest area, resulting in theoretical energy potential of 9.3 PJ per year. Although these agricultural residues might be used as fuel, large amounts are wasted via open dumping or open burning in the field and, therefore, are referred to as waste agricultural biomass. As such, use of these materials for energy applications would be an effective way of managing the waste, while becoming a useful resource rather than a waste material under conventional management practices (Dyjakon, 2019).

Figure 10. Management options in apple orchard

Source: The Influence of Apple Orchard Management on Energy Performance and Pruned Biomass Harvesting for Energetic Applications, 2019

Pruning is an important cultivation technique that impacts the fruit quality and usefulness of disease control practices. The most popular technique is harvesting and baling of pruned biomass and chipping.

Figure 11. Apple tree pruning baling

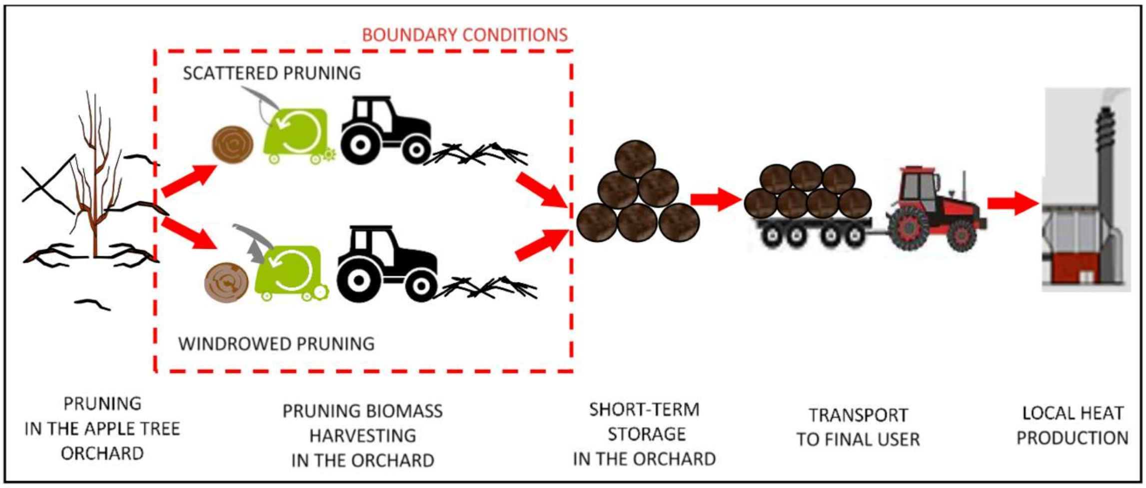
[18] Dyjakon A. The Influence of Apple Orchard Management on Energy Performance and Pruned Biomass Harvesting for Energetic Applications. *Energies*. 2019; 12(4):632. https://doi.org/10.3390/en12040632

Source: https://www.gospodarstwo-sadownicze.pl/w-zgodzie-z-natura

Pruned biomass bailings can easily be stored in bales on the field site in the open air at a low-cost. It is related to the fact that there is still much free space for air flow, natural drying takes place, leading to the decrease in moisture content to a level acceptable for energetic use.

Storage of apple pruned biomass in baling is an important part of the logistic chain and could include different options, like open air storage, under cover storage, storage tank, silo, storage with drying, etc. In terms of places, the storage could take place in the orchard, at the final consumer, but there is also an option of mobile pruning services offered to farmers. The use of apple pruned biomass for energetic purposes requires some energy input, manpower engagement, and investment in indispensable machinery.

Figure 12. Pruning-to-energy process



Source: The Influence of Apple Orchard Management on Energy Performance and Pruned Biomass Harvesting for Energetic Applications, 2019

The process includes the following stages: harvesting, baling, on-site storage, loading, storage, loading, and transportation to the final user. In the logistic chain of prunings-to-energy, a crucial issue is transportation.

The distance between the orchard and the final consumer, as well as the amount of pruned biomass to be transported, is of critical importance in the estimation of the total costs of the supply chain. It seems that for biomass utilization in the small and middle size boilers the distance should not exceed 50 km (preferably below 25 km).

It is important to highlight that apple pruned biomass baling should be done by machinery adapted to the type of tree and the total logistics costs of the whole chain including pruned biomass harvesting, storage, and transportation to the final consumer must be lower than the incomes from the biomass selling.

According to Dyjakon (2019), the cost estimation of the harvesting process in the apple orchard included purchasing cost, service life, machinery usage, while operating costs included fuel consumption and pruning biomass yield. A labor cost of €19.0 h−1 was assumed as an average value in the agricultural sector in the European Union (EU), although the cumulative labor cost of agriculture in Poland is ca. €6.0 h−1. This very conservative approach was applied to display a safe margin of the total costs on the farmer's side, as well as to allow a more realistic comparison of the results against the background of the European bioenergy market[19].

Figure 13. Estimation of the harvesting process in the apple orchard

Parameter	Unit	Tractor John Deere 5075 GV	Baler SIMPA Z279/1 Classic
Power	kW	54.0	-
Investment	€	37,000	15,000
Service life	yr	15	10
Trial work	$SMH \cdot yr^{-1}$	1500	500
Resale	%	20	28
Interest rate	%	7	7
Inflation rate	%	2	2
Taxes, insurance, and housing	%	1	1
Labor cost	$€ \cdot h^{-1}$	19	-
Fuel cost	$€ \cdot dm^{-3}$	1.3	-
Lubricant cost	$€ \cdot dm^{-3}$	5	5
Repair and maintenance factor *	%	80	50

SMH—scheduled machine hours (the operation time of the machinery (including delays)); * in accordance with Reference [11].

Source: The Influence of Apple Orchard Management on Energy Performance and Pruned Biomass Harvesting for Energetic Applications, 2019

It is important to highlight that the costs and pruning biomass potential in apple orchards depend also on other factors, such as orchards age, apple variety, density of plantings, harvested machine operation, experience of the workers, etc. As a result, different amounts of pruned biomass might be harvested by the machine set. The decision about the way to proceed with pruned residues should be supported by a case-specific analysis to make a right decision. The pruning harvesting for energetic purposes is strongly influenced by the management strategy in the apple orchard. Pruning harvesting can at least reduce the costs of orchard cleaning. With proper management, the income from biomass sale can be significantly higher, leading to a lowering of the total apple production costs. The orchard management is a critical parameter affecting energy recovery, as well as financial returns.

[19] Dyjakon A. The Influence of Apple Orchard Management on Energy Performance and Pruned Biomass Harvesting for Energetic Applications. *Energies*. 2019; 12(4):632. https://doi.org/10.3390/en12040632

According to research studies, the available collected biomass potential is an amount of 0.69 tDM·ha−1 per year. Pruned biomass analysis showed a moisture content of 45.1% in the fresh material, the ash content was 0.8% dry mass, and the lower heating value was 18.05 MJ·kg−1 dry mass. Total production cost, including all steps and avoided cost of mulching, was 74.7 €·t−1 dry mass. The net energy balance of this value chain was very positive, giving a value of ca. 12,000 MJ·ha−1 per year. This is why the yearly harvested pruned biomass may be considered a good energy source for local heating systems. For the agriculture region, it might be one of the potential solutions in the process of replacement of fossil fuels with renewables and for fostering improved energy efficiency in production processes. This way, biomass might be also a contributor to the renewable energy targets.

There is no additional statistical data on the use of apple prunnigs in the Mazovia region. According to information from producers cooperating with the cluster, most of them are sold for energy purposes. There are no composting plants in the region that would allow the use of this waste as a raw material for the production of natural fertilizers, reducing the consumption of artificial fertilizers used for production in orchards.

1.2.2 Biomass availability – apple pomace

In 2021, Poland produced 4,170,000 tons of apples and more than half of them is processed, generating a solid residue called apple pomace. On average, nearly 75% of apple fresh weight is supposed to be extracted as juice during juice production, and the leftover is collected as food waste, the so-called pomace.

Apple pomace is a left-over solid residue resulting from extraction of juice from apples in apple juice concentrate, cider, jams etc. that accounts for ~25% of total apple weight.

In Poland, about 65% of processed apples rely on juice pressing causing the residues, which the biggest part is apple pomace. The apples can also be processed into clear apple juice concentrate, cider, canned as fresh slices/cubes, baby foods, apple butter, jelly, vinegar etc.

Currently, apple pomace is mostly used as animal feed, but the price ranges from 430 to 550 EURO per tonne[20]. However, it is an unprocessed raw material derived from production waste, the value of which, after processing, may increase by using its potential. The apple pomace can be applied directly or after minimal processing as functional ingredients in various types of food products. For example, apple pomace can improve the dietary fiber content and health-promoting properties of bakery products, such as bread, sweet bakery products and brittle bakery food. Apple pomace can also be incorporated with extruded food and meat products to enhance their nutritional value. Additionally, the utilization of apple pomace in confectionery products and dairy food was found to have contributed to the product quality characteristics. Moreover, it can also be used as a part of the substrate for alcoholic beverage development and edible mushroom cultivation. Further potential applications as flavouring and stabilizing agents were also apparent. In addition, many functional bioactive compounds that are extracted from apple pomace, including pectin, phenol and fiber, can also be utilized in food products to improve the product quality and nutritional properties.

Considering the large volume of this by-product generated from the production and processing of juice, the commercial applications of pomace can create great economic impact, but it is important to highlight that is also characterized by high water content and a tendency to rot quickly, so as an unstable waste, apple pomace pose a high risk of biological contamination. Using it as a source of energy in agricultural biogas plants might be considered as an alternative and a safe and effective way to manage them.

On the other hand, however, apple production waste is characterized by a high content of biologically active components valuable for human and animal nutrition, such as vitamins and polyphenols.

[20] Average prices based on market offers (own calculations based on current seller offers)

Polyphenols are natural compounds with antioxidant activity, showing anti-inflammatory, antiviral and anticancer properties. They could be successfully recovered and used in food and feed production processes. The use of fruit and vegetable pomace for biogas production means that these components are irretrievably lost.

Taking into account that the costs for apple pomace waste management is very high, while the recovery rate is relatively low, the recovery should be done as close as possible to the production site. It is also motivated by the fact that composting of apple pomace creates secondary pollution due to greenhouse gasses production, as well as creates surfaces for human disease vectors to breed, and it has the potential to contaminate ground waters.

In Mazovia region, Apple processing plants are located in different parts region, with a concentration in the Grojec area. Examples of apple juice factories are:

1. Nasza Tłocznia - https://naszatlocznia.pl
2. Sad Sok - https://www.facebook.com/SadSokTlocznia/
3. Tłocznia Bankiewicz – www.soki-naturalne.eu
4. Naturalne Tłoczone - https://naturalnetloczone.pl
5. Royal Apple - https://royal-apple.com/kontakt/

1.3 Nutrient Availability

1.3.1 Nutrient availability – apple prunings

In terms of apple orchards, nutrients are located mostly in fruits leaves, fruits, roots and pruning wood. The practice of pruning can have an indirect impact on the nutrient distribution and overall health of an apple tree because by removing excess, dead, or diseased branches, pruning helps the apple tree to allocate its resources (including nutrients and water) more efficiently to the remaining branches and fruit, which can lead to healthier and more productive growth.

Part of the nutrients absorbed by trees during a vegetative season returns to the soil through fallen leaves, pruning wood or root death potentially could be available again for uptake. It is also important to highlight that proper pruning allows for better sunlight penetration and air circulation that can enhance photosynthesis, which in turn can impact the tree's ability to absorb and utilize nutrients effectively.

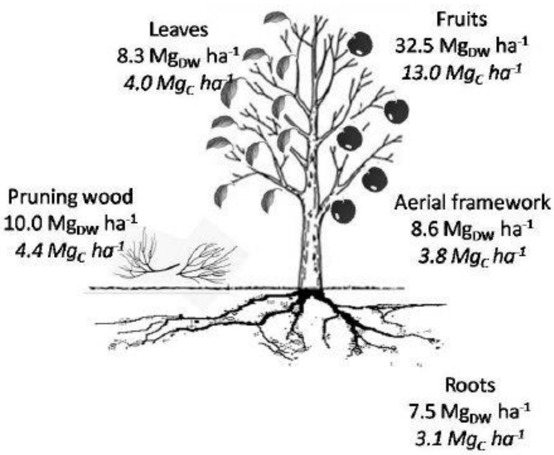
The nutritional content of apples primarily includes:

- Vitamins –source of vitamin C and B.
- Minerals - potassium (K) and smaller amounts of other minerals.
- Fiber - apples are known for their dietary fiber content, particularly in the skin.
- Water - high-water content.
- Calories: 95 calories in a medium-sized apple

According to GrowingFruit.org the most important nutrient is nitrogen (N). Young trees require about 0.1 pounds of actual nitrogen per year of age. Mature trees need 0.1 to 0.2 pounds of nitrogen per inch of trunk diameter measured at knee height. Phosphorus (P) and Potassium (K) are usually applied based on soil test results. In terms of the application, fertilizers are typically applied in early spring and again in early summer. Nutrients contained in fruits leave the ecosystem and often have to be replaced by fertilizers. Nutrients stored above and belowground in tree framework can also be considered as losses as they leave the system when trees are removed. Regular soil testing is recommended to tailor the fertilization needs accurately[21].

According to Scandellari[22], six year-old excavated trees had a total biomass 16.1 ± 0.8 Mg ha^{-1}, corresponding to 6.9 ± 0.4 Mg C ha^{-1}. The biomass of excavated trees was distributed 17% to branches and twigs, 26% to above grafting stem, 10% to below grafting stem, 32% to coarse roots and 15% to fine roots. Integrating biomass data relative to tree excavation and those reported in Table 1 we could estimate a cumulative (years 1-6) value of NPP of 67 Mg (in term of biomass) and 28 Mg (in term of C) (Scandellari et al, 2010).

Figure 14. Nutrients in apple trees



Source: Scandellari et al, Net primary productivity and partitioning of absorbed nutrients in field-grown apple trees, (2010)

Excessive or insufficient fertilizer addition in orchards affects growth, fruit yieldand quality or represents a source of environmental pollution. Under sustainable agriculture it is therefore necessary to determine the amounts of nutrients.

1.3.2 Nutrient availability – apple pomace

Apple pomace is a heterogeneous mixture consisting mainly of skin and flesh (95%), with a tiny proportion of seeds (2%–4%) and stems (1%). Apple pomace is a rich source of nutrients and phytochemicals, such as carbohydrates, vitamins and minerals. It consists of a high amount of carbohydrates, of which about 70% are simple sugars, have a high source of arabinose and rhamnose and contain from 10 to 12% glucose (dry weight basis), which is amain fuel source for

[21] growingfruit.org/t/fertilizing-fruit-trees/15376

[22] Scandellari, F., Ventura, M., Malaguti, D., Ceccon, C., Menarbin, G. and Tagliavini, M. (2010). *Net primary productivity and partitioning of absorbed nutrients in field-grown apple trees*. Acta Hortic. 868, 115-122, DOI: 10.17660/ActaHortic.2010.868.11

most tissues throughout human body. Besides carbohydrates, apple pomace is also a source of proteins.

Apple pomace is a rich source of many minerals, which are of interest from the human nutritional point of view. Potassium represents the main portion of the total mineral content of apple pomace and provides 20% of Recommended Dietary Allowances (RDA) after consumption of 100g of apple pomace. Sodium and phosphorus are the next most widespread minerals in apple pomace and provides respectively 13% and 11% of RDA.

Apple pomace is also a rich source of copper and zinc, both of which are essential for human well-being.

Figure 15. Proximate nutritious composition of apple pomace

Constituents	Composition (dry weight basis)	Constituents	Composition (dry weight basis)
Moisture (%)	3.90–10.80	**Alcohol-soluble fraction of carbohydrate**	
Protein (%)	2.94–5.67	Saccharose (%)	3.80–5.80
Total carbohydrate (%)	48.0–62.0	Glucose (%)	19.50–19.70
Fibre (%)	4.70–51.10	Fructose (%)	48.30
Insoluble fibre	36.50	Xylose, mannose and galactose (%)	1.20–4.40
Soluble fibre	14.60	L-malic acid (%)	2.60–3.20
Fat (ether extract, %)	1.20–3.90	Arabinose and rhamnose (%)	7.90–6.0
Pectin (%)	3.50–14.32	Glucooligosaccharides (%)	3.40–3.80
Ash (%)	0.50–6.10	Xylooligosaccharides (%)	3.0–3.70
Minerals		Arabinooligosaccharides (%)	0.20–0.40
Phosphorus (%)	0.07–0.076	Uronic acid (%)	2.70–3.40
Potassium (%)	0.43–0.95	**Alcohol-insoluble fraction of carbohydrate**	
Calcium (%)	0.06–0.10	Glucan (%)	41.90–42.90
Sodium (%)	0.20	Starch (%)	14.40–17.10
Magnesium (%)	0.02–0.36	Cellulose (%)	7.20–43.60
Copper (mg/kg)	1.10	Polysaccharides of xylose, mannose and galactose (%)	13.0–13.90
Zinc (mg/kg)	15.00	Polysaccharide of arabinose and rhamnose (%)	8.10–9.0
Manganese (mg/kg)	3.96–9.00	Acid detergent lignin (%)	15.20–20.40
Iron (mg/kg)	31.80–38.30	Uronic acid (%)	15.30

Source: Bhushan, et al., 2000

The variation of chemical profiling among apple pomace is controlled by variable factors viz. origin, variety, as well as type of processing. Apple pomace as a part of apple contain significant amounts of polyphenols. The apple pomace is big source of flavonoids (flavanols and flavanols), which consist of quercetin 3-O- rutinoside, quercetin 3-O-galactoside, quercetin 3-O-glucoside, quercetin 3-O-xyloside, quercetin 3-O-arabinoside and quercetin 3-O-rhamnosid. Apple pomace contains about 5% of seeds, which contain from 27.5 to 28% lipids, and could be a good source of oil. The oil from apple seeds can be obtained by cold-pressing or hot-extracting. Additionally apple seeds oil contains high levels of linoleic acid (49%) and other dominant fatty acids as oleic, palmitic and stearic acid.

Apple pomace contains many pro-health compounds, including bioactive phenolic compounds with antioxidant and anti-inflammation properties. It has great potential for conversing into edible products, as it is characterized by a high content of pro-health compounds like dietary fibre and many phytochemicals, including phenolics, like quercetin, catechin, phloretin/ phlorizin, gallic acid and chlorogenic acid, all of them can reduce chronic disease risk. Therefore apple pomace can be a potential source for health food preparations. Dry apple pomace is a natural concentrate of bioactive substances from the group of polyphenols.

In terms of innovative applications of nutrients, apple pomace could be incorporated into bakery products, meat products, confectionery and dairy products. It could enhance their nutritional value or act as a flavouring or stabilizing agent. The most common application of apple pomace in the food industry resides in their high antioxidant ingredients that are added as preservatives in addition to their redox properties that prevent many chronic diseases associated with oxidative stress. In terms of fresh apple pomace, it has high moisture content and is often susceptible to microbial degradation marketed often, therefore needs to be dehydrated during drying and then ground into powder.

1.4 Discussion of the Results

Apple trees require yearly prunings, which leaves a substantial amount of residues. This woody biomass could be a promising source of raw materials in the wood industry and could replace traditional wood assortments for bioenergy and industrial uses. Additionally, nutrients from the prunings could also be returned to the soil, by chipping the prunings and using it as a fertilizer. Due to their significant energy balance, it is also an economically justified source of energy for the local market because of its reasonable productivity, good energy balance, and positive economic outcomes. However, alternative paths of apple pruning valorization should be considered and further researched.

The apple juice production process results in solid residues, also known as apple pomace. This apple pomace is a rich source of nutrients, carbohydrates, vitamins and minerals. Due to its high content of biologically active components valuable for human and animal nutrition, it could be used as a functional ingredient in many types of food and feed. However, the pomace also has a high water content and a tendency to rot quickly, so it is important to treat it as soon as possible to mitigate the risk of biological contamination. These potential applications and the best course of action should be further researched.

1.5 Conclusions and Recommendations

1.5.1 Conclusions

In this report the availability of apple tree prunings and apple pomace has been analysed. These are important biomass resources in the Mazovia region. Mazovia is the largest apple producing region, good for almost half of the Polish production. Poland is the largest apple growing country in the EU.

Prunings

Annual pruning is required for the proper growth of the apple tree and for ensuring high apple production. Pruning generates woody residues with branches and leaves, which must be disposed of. In Mazovia, the theoretical potential is estimated at 50.000 ton (dry) per year. The technical availability will be close to that figure as collection is mostly well to organise in the field. Most prunings are currently baled and collected to serve as fuel for heating in wood boilers. Economic availability depends on fuel prices and costs of collection. Wood prices have been good the last few years, but costs depend highly on local orchard management and transport costs.

Apple pomace

Apple pomace is the left-over solid residue resulting from extraction of juice. In Mazovia, the theoretical potential is estimated at almost 250.000 ton (fresh) or some 150.000 ton (dry) per year. The technical availability will be close to that figure as the waste stream comes available in the factory where it can be easily collected. Most apple pomace are currently used as animal feed. Price ranges from 430 – 550 euro per ton (fresh material). New applications of apple pomace are being developed as part of this project. Several new products are mentioned in this report. Quality of the feedstock and biological contamination may be an issue for some high value applications.

Figure 16, apple biomass potential in Mazovia

Geographical area	production area	production rate	apple production	prunings	pomace
	ha	ton/ha/year	kton/year	kton/year (dry)	kton/year (dry)
Poland	161.948	25,12	4.068	112	305
Mazovia	69.816	28,21	1.970	48	148
Conversion factors					
Prunings	0,69	t(dm)/ha/year			
Apples processed	50%				
Pomace/processed apple	25%				
Pomace moisture content	40%				

Nutrients

For sustainable apple production good soil and proper nutrition is essential. Nitrogen (N) is important. Young trees require some 50-gram nitrogen per year of age. Phosphorus (P) and Potassium (K) are usually applied based on soil test results. Fertilisers are typically applied in early spring and again in early summer.

There should be potential for using biomass residues for nutrient recycling and soil improvement, but it is unclear how much this potential is already used in the region.

1.5.2 Recommendations

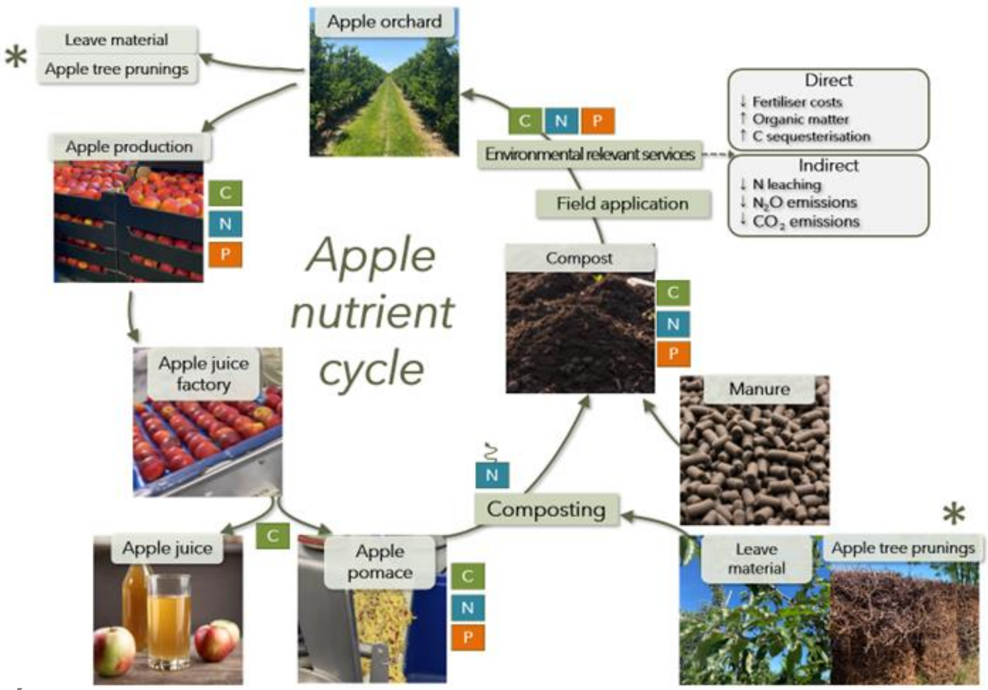
Biomass availability

- Share experience - within the Mazovia platform - in prunings collection, processing and storage systems.
- Share experience in apple pomace collection, processing and feed stock quality assurance for high value applications.
- Support the development of storage and production systems close to agricultural production, which will reduce production and storage costs, reduce the risk associated with the seasonality of production and have a positive impact on the local economy. This requires the involvement of public funds and attracting private investors.

Nutrients

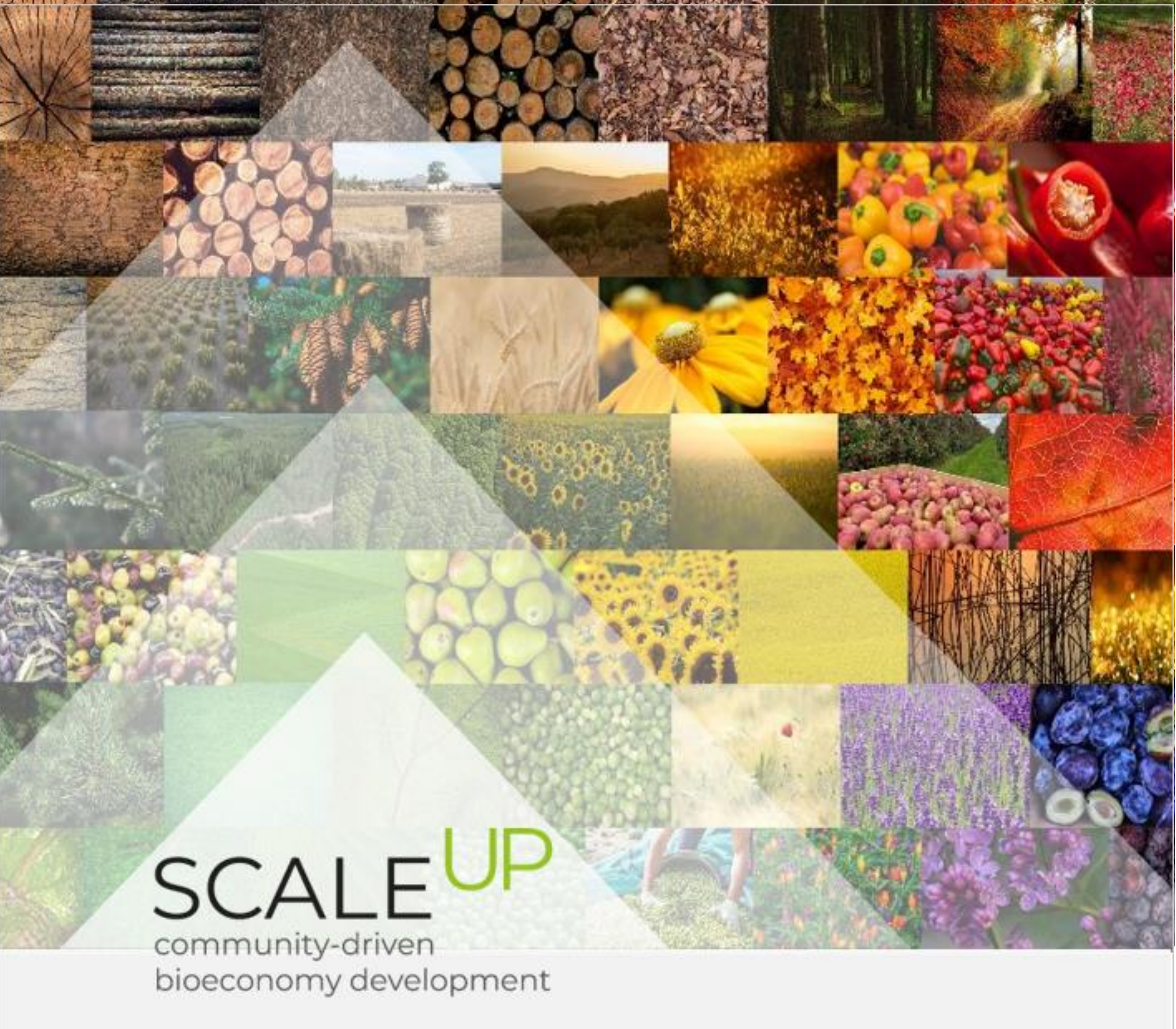
- Develop and share know-how on the production of compost from prunings with a mix of organic streams and the application of compost for nutrient supply and soil improvement for orchards. Assess the potential of nutrient recycling systems as shown in the following diagram.

Figure 17, Apple nutrient cycle, own image.



General

- Develop a bioresources regional strategy with proper support instruments for biobased production.
- Support cooperation between stakeholders (science, local government and entrepreneurs) to share experience and know-how and stimulate joint development on biomass production, nutrient recycling, biomass processing with high value products. Promote technical and business development.



Regional Biomass and Nutrient Availabilities in Strumica, North Macedonia

February 2024

SDEWES-Skopje

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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 12). 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.[23]

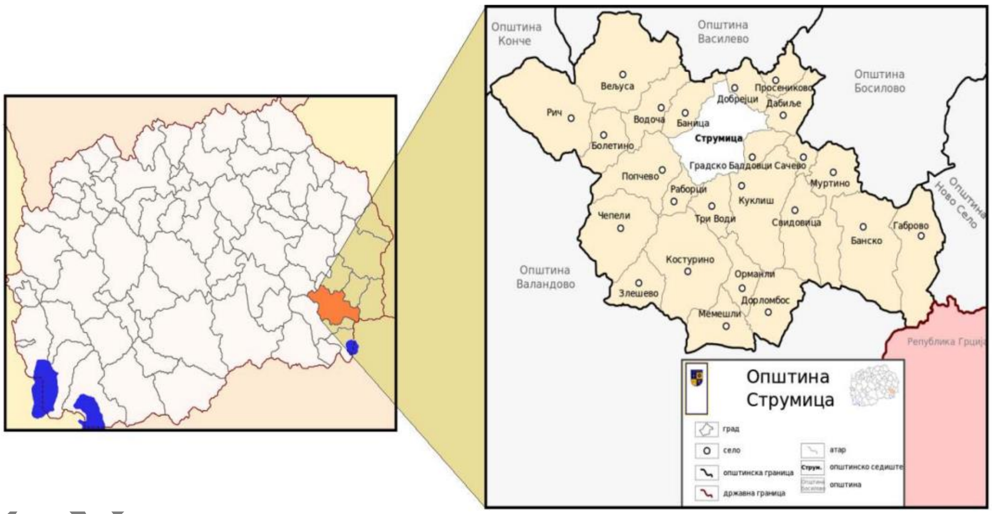

Figure 12: Geographical position of the municipality of Strumica

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

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

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 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.[24]

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)[25]. 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. [26]

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 23.

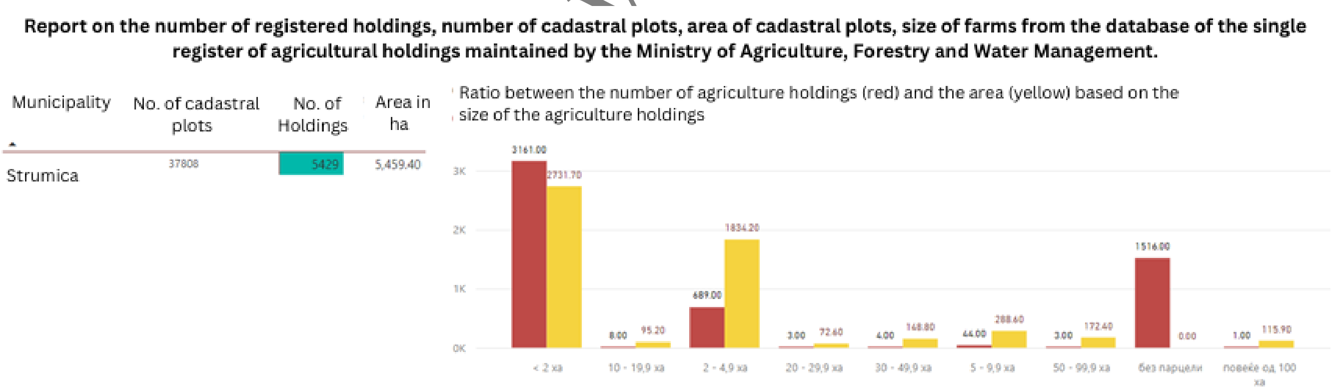

Figure 23: Number of registered agricultural holdings,

number and area of cadastral plots, size of farms in municipality of Strumica

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

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

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

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 34. It is a composite index that considers the interaction of three components exposure, sensitivity, and adaptive capacities to address associated effects or risks[27] 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.

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	0.636	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 34: 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.

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

- 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[28], 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.[29]

[28] 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.

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

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.

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 45 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.

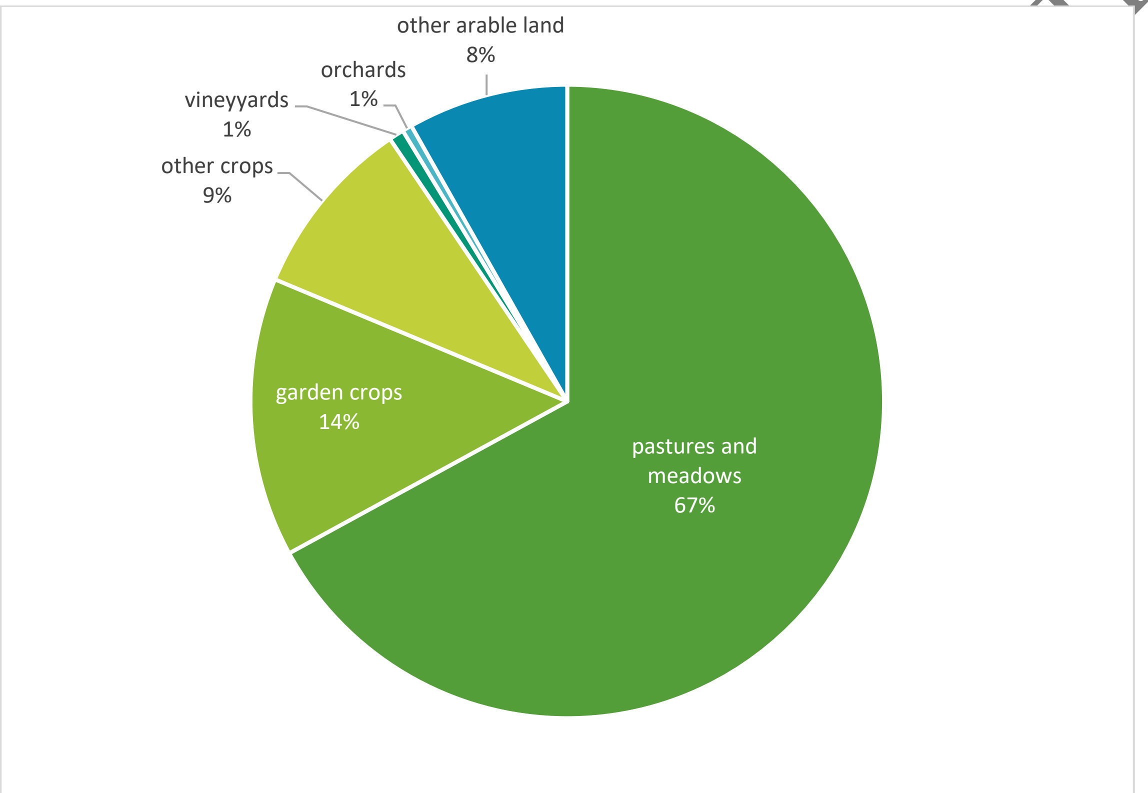


Figure 45: Agricultural area by category of use in hectares according to the NUTS 2013, for Strumica, 2022

Source: MAKStat database

The principal agricultural crops are shown on the **Figure 56**. 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.

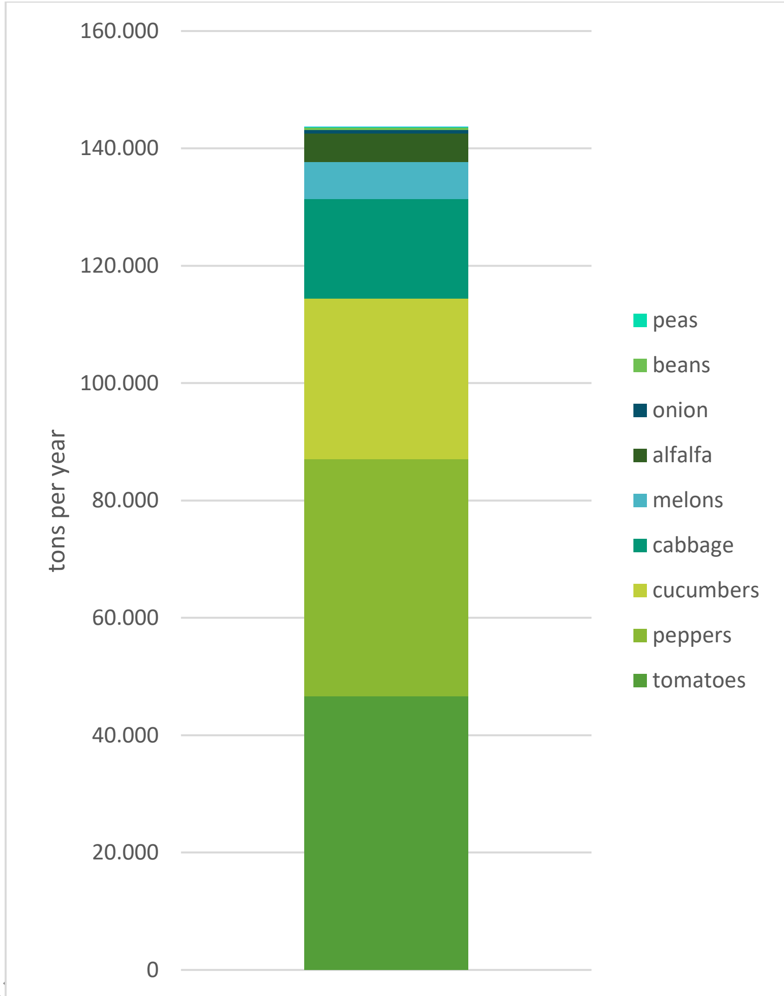


Figure 56: **Production of most important garden crops, for Strumica, 2022**

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.

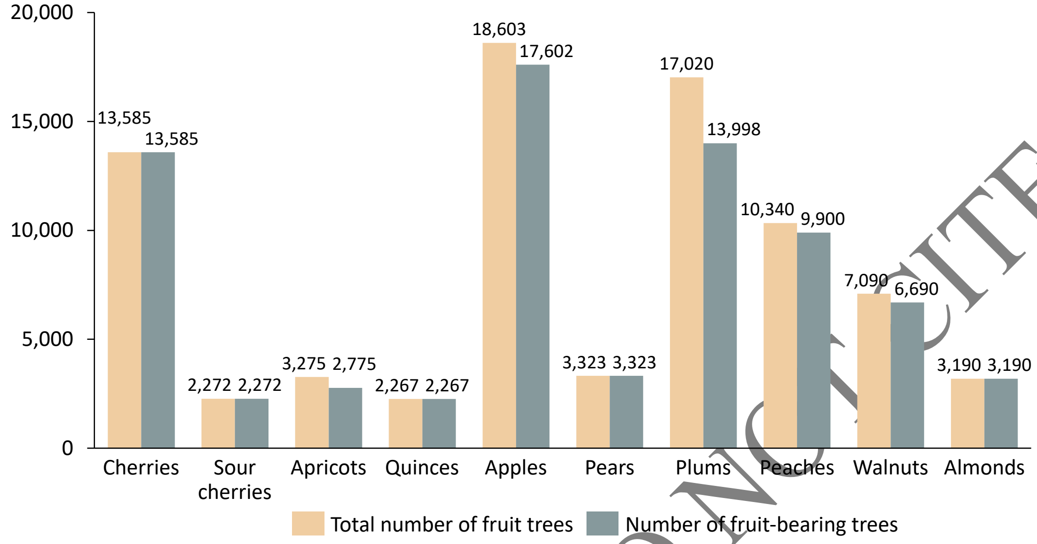


Figure 67: Number of fruit trees and fruit-bearing trees, according to the NUTS 2013, for Strumica, 2022

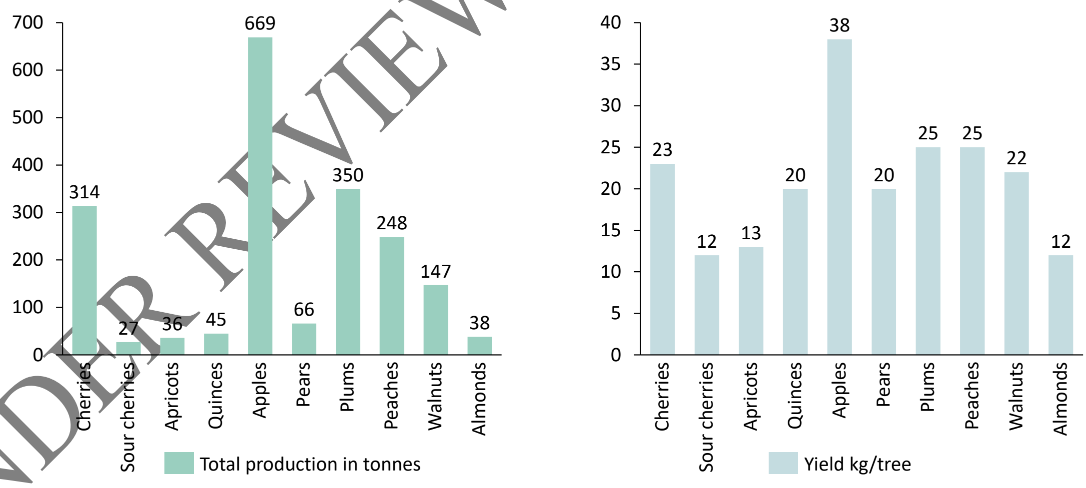


Figure 78: Production of fruit, according to the NUTS 2013, for Strumica, 2022

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.[30]

In addition to the agricultural residues, it is important to consider the forest residues as well. In Figure 89, 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.

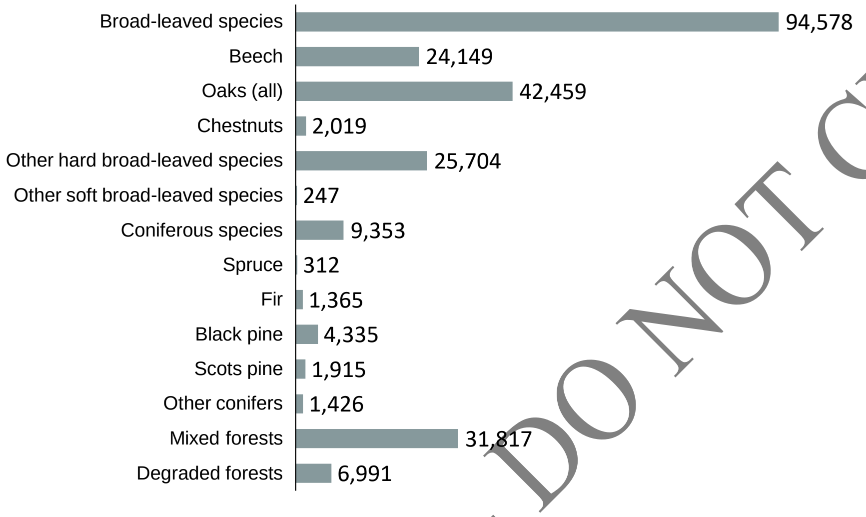
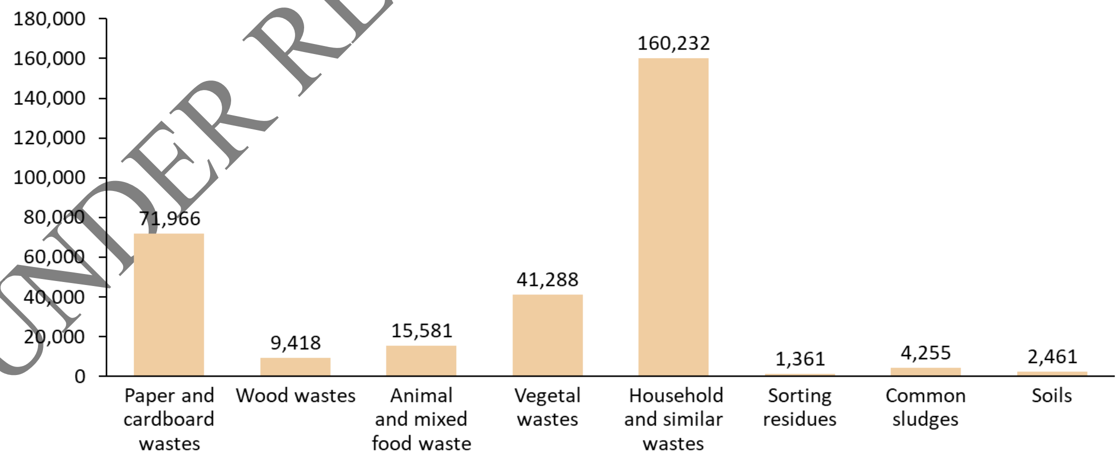


Figure 89: Forest area by type in South-east region, 2022 (in hectares)

Source: MAKStat database

Another waste stream that could be of potential use is the municipal biowaste from the households and commercial sector. Figure 910 represents the amount of waste by categories on national level, where is evitable that the households are producing most of the waste.



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

Figure 910: Amount of waste-by-waste categories, North Macedonia, 2020, in tonnes

Source: MAKStat database

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. [31] 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 3.

Table 3: 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 4 provides an overview of the biodegradable residues from agricultural crops as presented in the local environmental action plan of the municipality of Strumica.

Table 4: 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

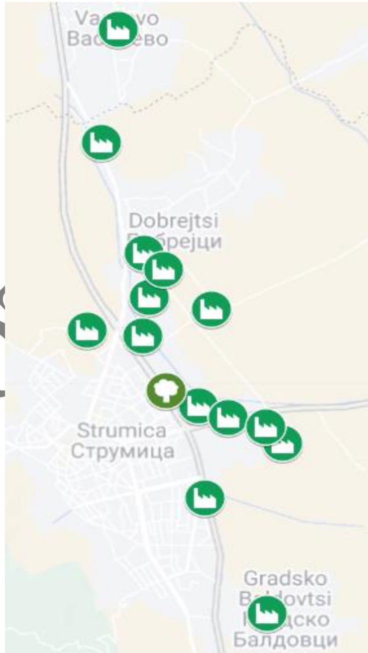
In the study the areas for agricultural crops are considerably lower than the MAK Stat database figures. In the MAK database the area for garden crops is more than twice as large (3.300 ha vs. 1.640 ha). The organic residues produced for garden crops (3.280 ton per year) are much lower than expected 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

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

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.

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.[32]

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

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, 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.).[33]

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. [34] 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.

[33] https://eastregion.mk/wp-content/uploads/2022/02/Анализа%20за%20состојба%20со%20пожетвени%20остатоци%20во%20Брегалнички%20регион.pdf
[34] https://www.sciencedirect.com/science/article/abs/pii/S0956053X17305846

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 (Table 4).

Table 5. 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 6). 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). [35]

Table 6. 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 ($CaCN_2$)	18-22%
Phosphorus fertilizers:	Superphosphate	16-18% P_2O_5
	Thomas phosphate flour (Thomas phosphate)	16-18% P_2O_5
	Triple superphosphate	42-48% P_2O_5
Potassium fertilizers:	Potassium sulfate	48-52% K_2O
	Potassium carbonate	60% K_2O
	Potassium chloride	40 and 60% K_2O
Calcium fertilizers:	Limestone	70-90% $CaCO_3$
	Unquenched lime	90-95% CaO
	Saturational manure	20-25% CaO + 15% organic matter

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

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. [36] 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.[37,38,39] (Figure 1011) 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.

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36 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.

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

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

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

Figure 1011. Different types of organic and mineral fertilizers

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 1112). 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 1112. 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 m3 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 1213).

Figure 1213. 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 1314).

Figure 1314. 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	Advocate for and implement policies that support the modernization of agriculture in the region. This could involve financial incentives, training programs, and infrastructure

Modernization	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.

Regional Biomass and Nutrient Availabilities in Upper Austria

February 2024

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1 Regional biomass and nutrient availabilities in Upper Austria

1.1 Introduction

1.1.1 Background

Upper Austria is a state in mid-North of Austria and an economic hotspot with different types of industries. The most important sectors are automotive, environmental engineering, chemistry, material processing such as metals, plastics, paper, and wood. Additionally, (bio-) energy and the food industry also contribute to the Upper Austrian economy. [40]

Austrian food production generates between 13.5 billion euros and 20 billion euros annually, consists of 3,500 companies (250 of which are counted as large-scale food production - companies with 50 or more employees and/or over 250 million euros in sales) and employs 70,000 people. The 250 large companies turn over between 90 and 95% of the goods. The food and beverage industry can be divided into the following sectors (in alphabetical order):

- Baked goods
- Beer
- Delicatessen/Spices
- Fats/Oils
- Meat
- Vegetable and fruit processing
- Beverages
- Milk/Dairy
- Frozen foods
- Sugar/Sweets

1.1.2 Scope

Food waste arises along the entire value chain - agriculture, production, trade, gastronomy, and households. Many projects already deal with the two ends of a food value chain - production in the field and waste in households.

In this project we would like to focus on by-products in food production.

A study "Waste Avoidance in Austrian Food Production" surveyed companies with a market share of 22% and then extrapolated the figures for Austria. From this it can be concluded that in Austria 1,338,000 t (+/-1%) of organic by-products are generated in food production.[41].

In total, 121,800 tonnes (+/- 6%) of avoidable food waste are generated in food production in Upper Austria every year. This value was collected in a survey of large-scale productions, which turn over between 90% and 95% of all goods. This value is calculated based on the member statistics of the Chamber of Commerce Food Industry Association[42].

The graph shows that almost half of all avoidable food waste is generated in the bakery sector (51,700 tonnes +/-12%). 35,000 tonnes of this are bread and bakery products that food retailers return to producers as part of free returns. In beer breweries within the production process, 5,700 t of avoidable biowaste is generated, according to this study[42].

[40] Land Oberösterreich - Betriebsansiedlung (land-oberoesterreich.gv.at)
[41] www.fabbiogas.eu,
[42] Abfallvermeidung in der österreichischen Lebensmittelproduktion, Österreichisches Ökologie-Institut. Wien, 2017

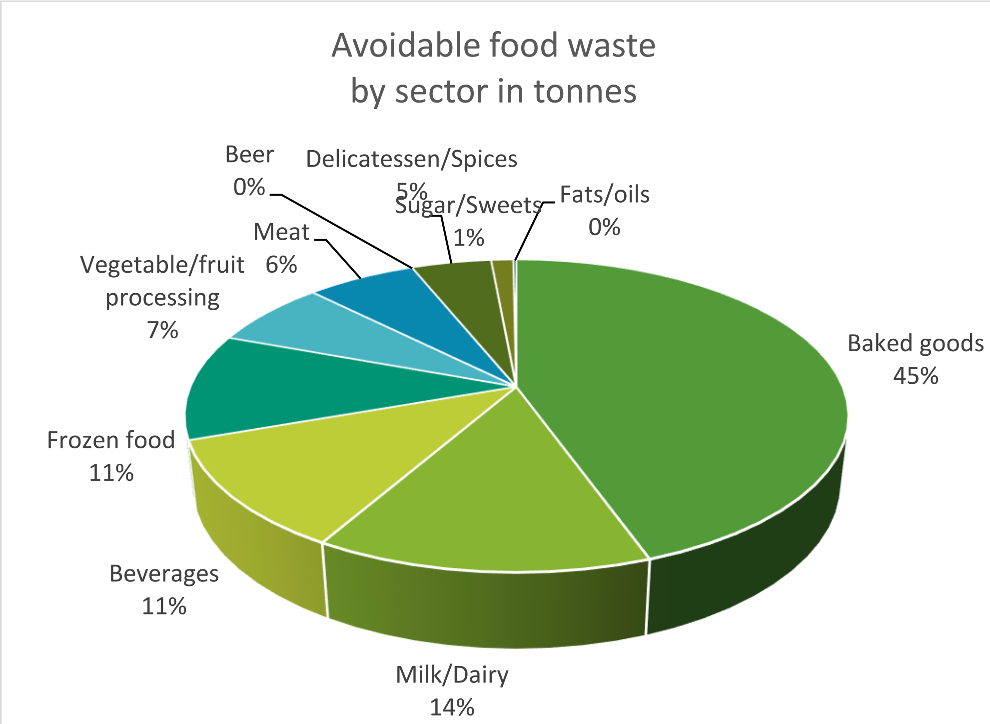

Figure 115: Avoidable food waste by sector in tonnes[42]

Bakeries and the baked goods industry is one of the largest food industries in the food sector in Upper Austria. The food produced here and, more specifically the food waste, is of great importance for Upper Austria and will therefore be examined more closely in the SCALE-UP project. The good cooperation with the bakery sector also makes it possible that the results of the project are given great attention and are included in future decisions in the sector as well as in the individual companies.

With 324 breweries in 2021, Austria has one of the highest brewery densities in the world and 67 breweries[43] in Upper Austria. 118 of these are so-called microbreweries with an annual beer output of up to 1,000 hectolitres. Most of the beer is sold through normal food retailers, with only around 17 per cent of total consumption being consumed in restaurants. In terms of annual beer consumption, Austria ranks second behind the Czech Republic but ahead of Germany and Poland[44].

The distinction between avoidable food waste and non-avoidable organic materials here is very important and can be defined as follows:

- non-avoidable organic by-products/residues/wastes that are generated during food production and are not suitable for human consumption (e.g. bones, blood, slaughterhouse waste, sour whey, pomace, ...). These must be disposed of, recycled, or further processed accordingly.
- Preventable food waste such as pre-packaged products, overstocked food, returned goods or edible raw products that are waste and must be disposed of. Returned goods are products that are transported back to the producer by the retailer when they are not sold and are offset.

The reasons and causes for food losses in production are manifold and range from the manufacturing process, cleaning, quality assurance measures to overstocking and overproduction as well as returns, transport damage or foreign bodies in the product.

43 https://brautopo.webnode.at/oberoesterreich/
44 https://de.statista.com/themen/4398/alkoholkonsum-der-oesterreicher/#topicOverview

The most frequently cited reason for the generation of avoidable food waste is the manufacturing process, at 44%. All other causes were mentioned in roughly equal proportions [45]. For this reason, we will also take a closer look at the manufacturing processes within the framework of the SCALE UP project.

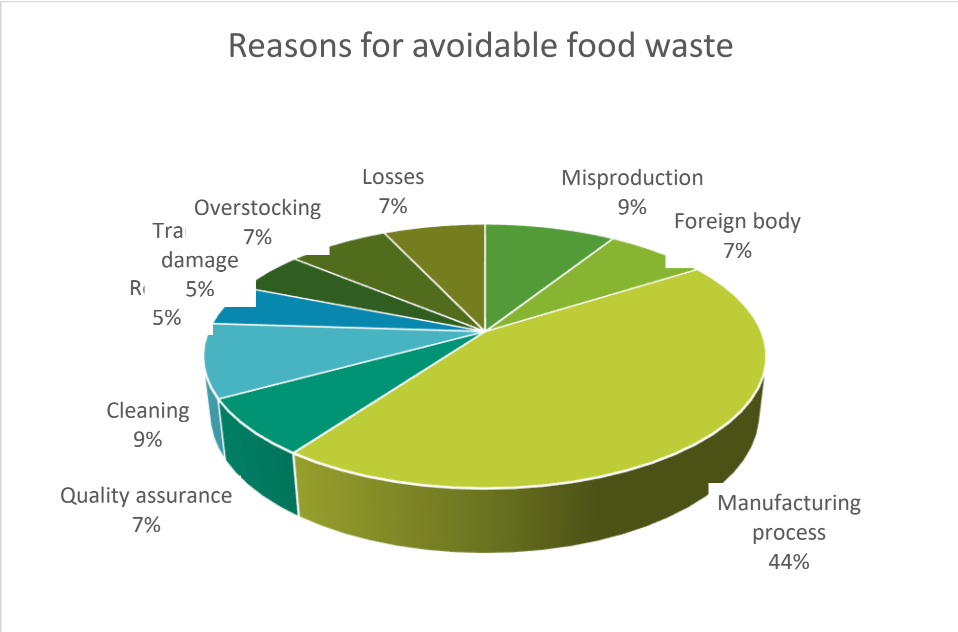

Figure 216: Reasons for avoidable food waste[42]

Are nutrients a constraint in the sustainable harvesting of biomass reducing its availability?

Nutrients from food manufacturing byproducts can be both beneficial and detrimental to sustainable biomass harvest, depending on several factors, including the type of byproducts, their quantity, and how they are managed. Here are some important considerations:

Beneficial aspects:

a. Fertilizing effect: Some byproducts, such as compost from food waste, can act as a natural fertilizer and increase soil fertility. This can promote the growth of biomass crops.
b. Circular economy: the use of by-products from food production in agriculture can be part of a sustainable circular system in which resources are used efficiently.
c. Waste reduction: The use of food by-products in biomass production can help reduce waste and provide environmental benefits.

Hindering aspects:

a. Competition for resources: if the use of food byproducts in biomass production competes with the use of these byproducts for animal feed or other purposes, this could affect availability.
b. Quality of byproducts: The quality and composition of food byproducts can vary, and some could contain contaminants or undesirable substances that impede biomass crop growth.
c. Transportation and storage: transportation and storage of byproducts may incur costs and energy consumption, which may affect environmental sustainability.

[45] Abfallvermeidung in der österreichischen Lebensmittelproduktion, Österreichisches Ökologie-Institut. Wien, 2017

d. Overuse: overuse of food byproducts in biomass production could reduce the availability of these resources in the long term and have negative impacts on food production.

Overall, the impact of food byproducts on sustainable biomass harvest depends on careful planning and management. An integrated approach that considers circular economy and waste minimization can help maximize the benefits and minimize the drawbacks. It is important to consider the local context and specific circumstances to make the best possible decisions regarding the use of food byproducts in biomass production.

Is it possible to use part of the biomass as compost of fertiliser?

Currently, the by-products of food production in Upper Austria or residues of production end up to a very large extent in composting plants, in sewage treatment plants or in biogas plants and are subsequently applied to the fields as fertiliser. However, a lot of energy is lost in the process. The goal is not only to use the nutrients as fertiliser, but to put the residues to a higher-value use.

Are there any innovative applications of nutrients?

In Upper Austria there are various innovative applications for the recycling of nutrients from food waste. As already mentioned, a large part of the residues and thus nutrients from food production in Upper Austria are reused in biogas plants or composting plants or used as feed for farm animals in agriculture. Unfortunately, there are no concrete figures on how high this share is.

In the medium to small-scale sector, there are numerous initiatives, innovations, and ideas on how nutrients from food waste residues can be recycled to a higher value. Some innovative examples:

- The use of food waste to produce bio-fertilisers: Through special processes such as drying and fermentation, the nutrients can be extracted from the waste and processed into high-quality fertilisers.
- Using food waste to produce insect protein. Insects such as mealworms or the larvae of the soldier fly can be fed with the waste and produce high quality protein that can be used as feed for livestock, etc.
- There are also projects in which food waste is used to produce bioplastics. Through special processes, the organic components of the waste can be converted into biodegradable plastics.

1.2 Biomass Availability

Before going into greater details about the availability of the chosen streams for this report, it is interesting to look at all biomass streams that can be observed in Austria. The figure below shows a variety of different streams, including imported biomass in red but also agricultural streams in dark green, forestry-related streams in brown and particularly interesting for nutrient recycling, residual materials & by-products for recycling in light orange. The graphic is an interesting overview to keep in mind as this report particularly dives into agricultural use and the related streams.

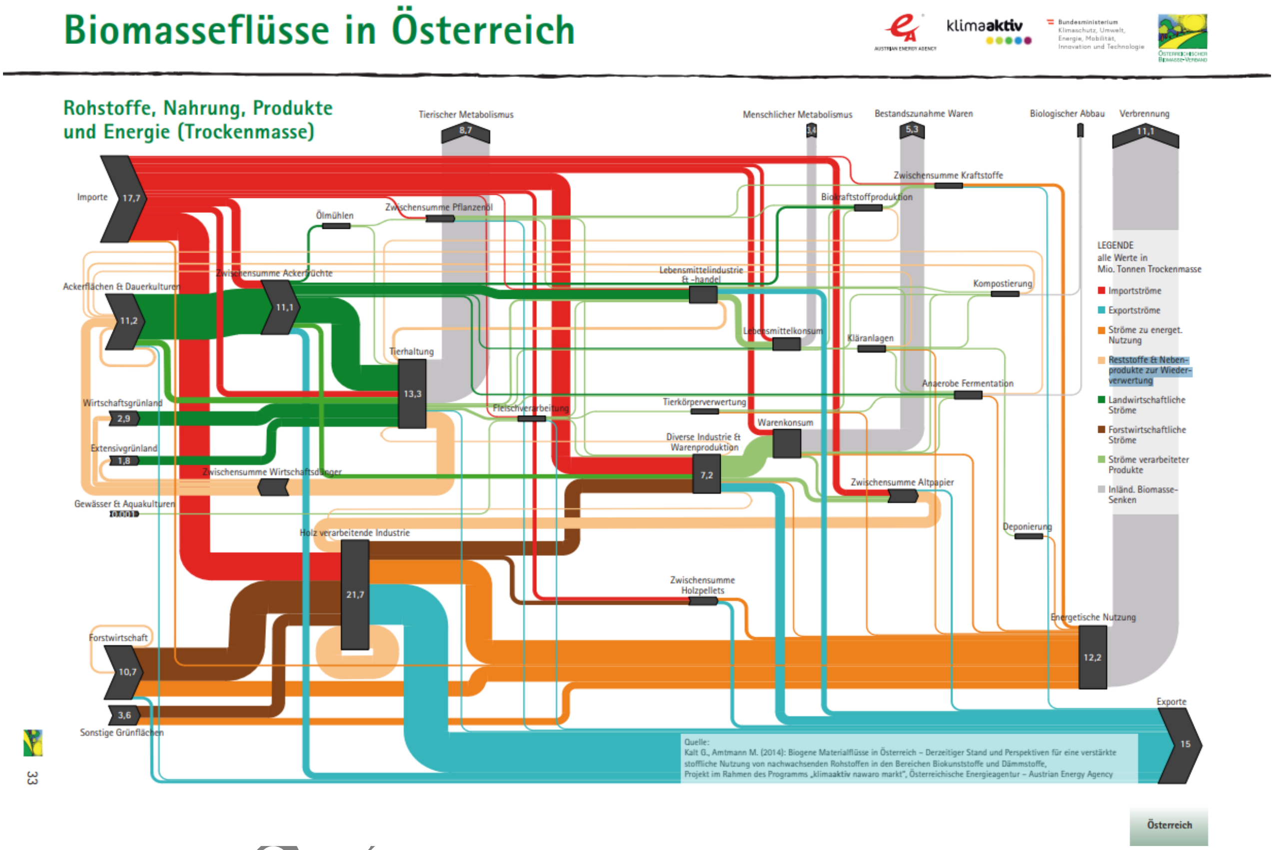

Figure 3: Biomass streams in Austria[46]

[46] Bioenergie Atlas Österreich. Österreichischer Biomasse-Verband, Wien, 2023.

1.2.1 Biomass availability feedstock 1 – Side products of beer production

Before getting into detail about all the different side streams that occur and to what extent, it makes sense to take a brief look at the overall beer production process and at what point different side streams occur specifically.

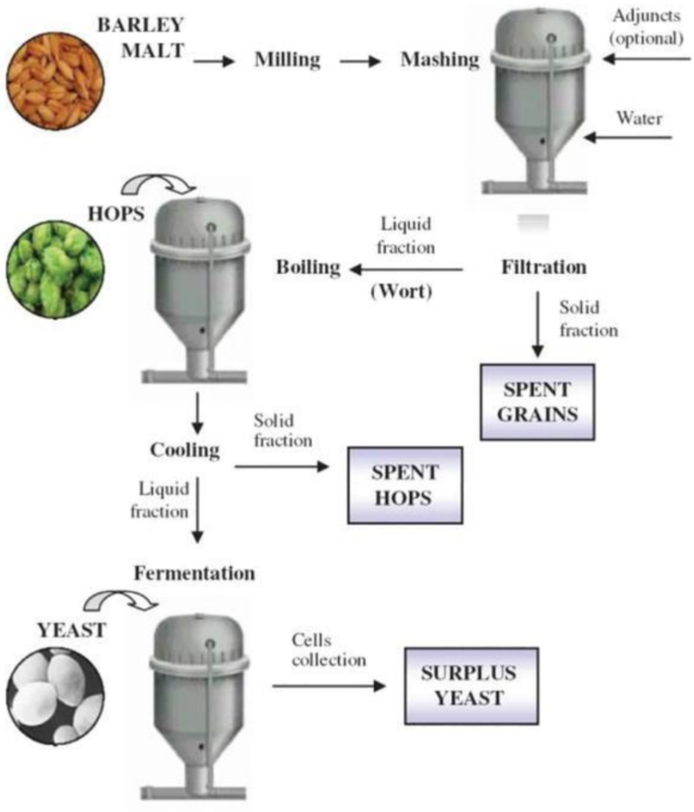

Figure 4: Beer production process and related side streams occurring during the process[47]

In February 2012, a questionnaire survey of the Austrian brewing industry was carried out by the Federal Environment Agency. The responses cover around 82% of the Austrian market and show that around 17.4 kg of spent malt is produced per hectolitre of beer[48]. In 2020, 2,8 million hectolitres of beer were produced in Upper Austria[49]. This results in a generation of the waste type SN 11404 "spent grains" of about 151,400 tons. A similar figure of 170,000 tons is obtained for the generation of spent grains using the information from KEPPLINGER & ZANKER (2004)[50] that about 20 kg of wet spent grains are generated per hectolitre of beer.

According to evaluations of eBilanzen (data as of February 2012), about 21 tons of SN 11405 "spent hops" were treated as input of waste treatment plants in 2010. It is assumed that this corresponds to the generation of this waste[48].

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[47] Shiomi, Naofumi (2018). Current Topics on Superfoods. ISBN: 978-1-78923-209-7

[48] Reisinger, H., Domenig, M., Thaler, P. & Lampert, C. (2012). Rückstände aus der Nahrungs- und Genussmittelproduktion. Materialien zur Abfallwirtschaft. Umweltbundesamt. Report REP-0403, Wien, 2012

[49] Statistische Daten über die österreichische Brauwirtschaft. Verband der Brauereien Österreichs, Wien, 2021.

[50] Kepplinger, W., & Zanker, G. (2004). Die Verwertung von Biertrebern im Brauereiverbund. in *DepoTech* (S. 189-196). Verl. Glückauf.

A percentage representation of the organic waste and residues produced by an Austrian brewery is shown in Figure 3. At 78.2%, brewer's spent grains represent the largest share of production-specific waste in terms of volume and are the most energy-rich fraction due to their chemical composition (HERFELLNER ET AL. 2006)[51].

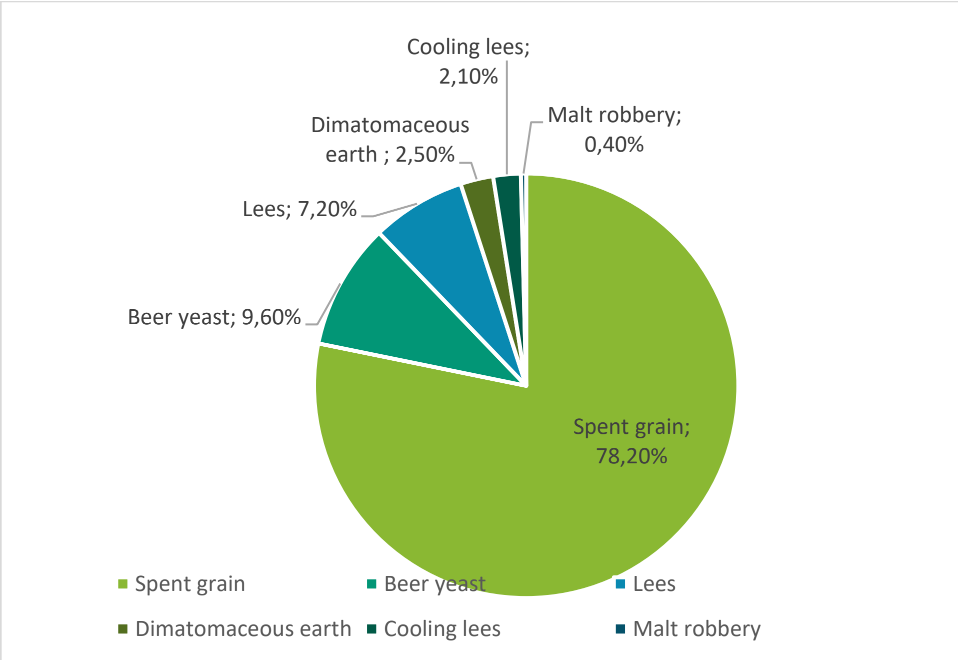

Figure 5: Example of the distribution of waste volumes in an Austrian brewery[51]

In 2004, a total of about 150,000 t of spent malt, malt kernels and malt dust were produced, yeast and yeast-like residues about 12,000 t. In the BAWP 2006, these wastes are assigned to the new waste code of the Waste Catalogue Ordinance, number 921. Almost the entire volume of biogenic residues from the breweries is passed on to the animal feed industry or to agriculture. The revenues achieved here are quite low. In 2004, only about 300 t were landfilled[52].

According to FNR (2006), the following biogenic residues are produced per hectoliter of beer: - 20 kg spent grains, - 2.4 kg yeast and tank bottoms, - 2.4 kg trub, - 0.5 kg kieselguhr (sludge), - 0.1 kg malt dust. This information corresponds to the questionnaire evaluation from 2012, where 12 breweries (82% of the Austrian market) were surveyed. They stated that around 17.4 kg of malt spent grain is produced per hectoliter of beer[48]. Spent grains represent by far the largest proportion of biogenic residues in terms of volume and are thus the relevant substrate of a large-scale biogas plant. For the sake of completeness, however, the forms of utilization of yeast, tank bottoms, diatomaceous earth and wastewater are also described.

[51] Bärnthaler, J. Bergmann, H., Drosg, B., Hornbachner, D., Kirchmayr, R., Konrad, G. & Resch, Ch. (2008). Energiesysteme der Zukunft. Technologie, Logistik und Wirtschaftlichkeit von Biogas-Großanlagen auf Basis industrieller biogener Abfälle. Endbericht. Projektnummer 812785.

[52] LEBENSMINISTERIUM (2006a): Bundesabfallwirtschaftsplan 2006; ISBN 3-902 010-70-3; URL: http://www.bundesabfallwirtschaftsplan.at/

Table 1: Production, raw materials, and utilisable waste materials at Brau Union[52]

Year: 2005	Amount	Brau Union	Österreich
Produktion			
Bier	[hl]	5.071.740	8.785.000
Rohstoffe			
Malz	[t]	80.777	139.920
Rohfrucht	[t]	940	1.628
Hopfen	[t]	32	56
Summe	**[t]**	**81.749**	**141.604**
Verwertbare Altstoffe			
Trebern	[t]	80.132	138.802
Trockentrebern	[t]	0	0
Malzstaub	[t]	151	262
Hefe/Geläger	[t]	6.013	10.416
Summe	**[t]**	**86.296**	**149.480**

Spent grain (Treber)

As can be seen from various sources, the spent grain content per hectoliter of beer is between 17.4 and 20 kg and accounts for around 80% of the total waste generated by breweries. According to feedback from the Austrian beer industry[48], BSG is utilised for following:

- 4 % as food,
- 93 % as animal feed and
- 3 % as input for biogas production

An example of five breweries that participated in the data collection indicated that they use their spent grains as animal feed in agriculture. The annual volumes of spent grains produced range from 450 t to 18,095 t per site. The revenues obtained range between 7.80 and 12 €/t[48,51]. This also corresponds to the information provided by the first Styrian spent grains distributor, which indicates a revenue of about 10 €/t[53].

The advantages of using spent grains as feed are:

- Higher basic feed performance due to higher dry matter intake
- Low metabolic load due to rumen-stable protein
- Health-promoting and milk-producing

[53] Erster Steirischer Trebervertrieb (2007). Zusammensetzung und Analyse der getrockneten Bierhefe. www.treber.at

- Economic efficiency

As a result, spent grains are used as feed for dairy cows, cattle for fattening and pigs. Furthermore, brewer's grains are successfully used for feeding game, sheep and horses[53]. The high content of essential amino acids, especially lysine, gives brewer's yeast a very good amino acid supplement to fattening rations. Fresh brewer's yeast is also a valuable supplementary feed in every fattening ration because of its high mineral and vitamin content[54].

In principle, this makes brewers' grain a very nutritious option for animal feed. However, it is difficult to digest, so it is only used in moderation. Alternative uses, e.g. as a substrate for mushroom cultivation, would therefore make sense. Small quantities could also be used in flours and to produce baked goods. The achievable prices are estimated at 5 - 10 euro cents. This corresponds to 5 to 10 times the proceeds from the current disposal method[51], but is considerably lower than the proceeds from animal feed utilisation[48].

Good brewers' grains smell like bread, but only have a short shelf life as mould forms after just a few days. Leitgeb, 2001[55], describes an emergency solution: fresh spent grains can be stored under water for a few days, but this produces mainly lactic acid. However, ensiling is more favourable.

Due to the material composition, spent grains are in theory suitable for composting. However, due to long residence times and considerable emission problems, composting is not practical. At present, the utilization of spent grains as animal feed is largely assured and economically the best option if possible.

The material utilization of spent grains in the building materials or baked goods industry is also possible. Heineken's spent grains fractionation process is another possibility for recycling spent grains. In this process, the fractions fibres (husks), proteins and liquid are separated from each other and recycled individually. In addition to the provision of thermal energy during the combustion of the fibres, economic viability is also to be achieved through the sale of spent grains protein. However, the market prices for this are based on those of soybean meal, which is available at low cost on the world market. The higher production costs for spent grains protein cannot be covered by this [51].

The disposal or recycling of organic residues is an increasing problem for breweries due to high disposal costs and fluctuations in potential sales markets. Rising transport and energy costs as well as the high energy content of organic brewery waste make energy recovery options for brewery residues increasingly interesting[51].

According to verbal statements, a large proportion of brewer's grains are processed in biogas plants, especially by smaller breweries. Unfortunately, no exact figures could be obtained. Different sources of organic wastes and by-products for co-digestion show their approximate biogas yields of yeast and yeast sludge from breweries of 400 – 800 m3 per ton organic solids[56].

Table 2: Substance data of spent grains[57]

Dry matter content DS (in mass%)	Organic dry matter content (in % of DS)	N (in % of DS)	P (in % of DS)	Gas yield (in m^3/t DS)
25	66-95	4,5	0,65	468

[54] Südtreber (2023). Gesund&wirtschaftlich füttern mit GVO-freien Produkten
[55] Leitgeb, r. (2006). Einsatz von instrudriellen Nebenprodukten in der Rinderfütterlung. 2. Viehwirtschaftliche Fachtagung BAL Gumpenstein
[56] Braun, R. & Wellinger, A. (2003). Potential of Co-digestion. IEA Bioenergy. Task 37 – Energy from Biogas and Landfill Gas.
[57] ARCHEA Service GmbH - ein 100% Tochterunternehmen der ARCHEA Biogas N.V., Eindhoven (NL)

Furthermore, spent grains can be separated into a fibre-rich, a water-rich and a protein-rich fraction. The individual parts can then be further processed according to their properties. The first fraction can be used in paper production, the second as a substrate for growing mushrooms and the third as fish feed[48].

Yeast and trub (Hefe, Geläger)

Yeast is sold to feed producers at a price of approx. 7 €/t. The Obermurtaler Brauereigenossenschaft recycles its tank bottoms (267.3 t/a) partly in composting and partly as animal feed. According to the brewery cooperative, this results in annual transport costs of about €10,000. Brewery #24 utilizes about 2,250 t/a of tank bottom yeast as animal feed and in a biogas plant. The sales price for tank bottom yeast was given as 1.50 €/t. Another future utilization possibility of yeast is the coating of e.g., tablets. This is currently used mainly in the pharmaceutical industry. The material has advantageous properties, such as complete suspend ability in water and low permeability of oxygen. Another possible application is as an additive in seasonings, e.g., soup seasoning, etc., and as a substrate for mushroom cultivation beds[51].

Table 3: Substance data of yeast (DS = dry substance) [57]

Substance	Dry matter content DS (in mass%)	Organic dry matter content (in % of DS)	N (in % of DS)	P (in % of DS)	Gas yield (in m^3/t DS)
Yeast	10	92	723	62	67
Yeast, pressed	25	92	660	62	152
Yeast dried	90	92	610	61	505

Dimatomaceous earth (Kieselgur)

Diatomaceous earth is a naturally occurring mineral raw material used as a filter aid. Diatomaceous earth as a residual material is currently composted, which causes costs in the amount of about 50 to 60 €/t. The Obermurtaler Brauereigenossenschaft incurs annual removal costs of around 8,000 € for 110.5 t of diatomaceous earth, i.e., around 72 €/t[51].

Wastewater (Abwasser)

Within a study from 2007 the amount of wastewater in breweries was analysed. One brewery generated about 36.8 t of wastewater containing yeast and beer residues in 2006, which was discharged into the sewer. Information on the composition of the wastewater (e.g., TS content) is not available. Other breweries have their own biogas plant in which the wastewater is fermented. The daily gas yield is about 140 m³. A combined heat and power plant (CHP), which was installed for electricity generation and heat utilization, had to be taken out of operation due to technical problems. The gas utilization was rebuilt, and the biogas is now used directly via a combi burner[51].

1.2.2 Biomass availability feedstock 2 - Side and waste streams bakery products

In this sector, 90% of the market is shared by commercial bakers and 10% by industrial companies. It also includes the flour milling, baking agent and pasta industries. In production, a surplus of 1.5% to 2% is common to meet certain deliveries[58].

A distinction must be made here between by-products that are generated in the manufacturing process during production and finished bakery products that are left over in sales as scrap goods. By-products of production are mainly dough types[58].

210,000 tonnes of bread and baked goods end up as waste in households, retail, and food production in our country every year. This amount corresponds to one fifth of avoidable food waste in Austria. In comparison, the people living here consume between 490,000 and 650,000 tonnes of bread and pastries every year.

Figure 6: Avoidable bread and bakery waste along the value chain in Austria. Translations: Households (purple), Supermarkets (ocher), Production (dark blue), Gastronomy, unknown (light blue) (Source: Pulswerk GmbH)[588]

In bakeries alone, around 52,000 tonnes of bread and pastries end up as waste every year. These are often so-called free returns from supermarkets: this mainly refers to bread and pastries that the bakeries first deliver to the supermarket in the form of chilled dough pieces and then receive back as baked goods that could not be sold. The bakeries credit the supermarkets for the quantity returned, so the supermarkets do not suffer any financial losses, disposal problems or risks[59]. Especially weather and seasonal factors influence the quantity of returned goods[58].

In addition to the free returns that go back to the bakeries, 13,000 tonnes of bread and pastries remain in the supermarkets every year[59].

Table 5 shows the average shares of recycling routes for used baked goods from 44 Austrian bakeries. Only a very small portion of avoidable food waste ends up in residual waste (> 0.3%)[59].

[58] Hietler, P., Hopfner, C. & Pladerer, C. (2017). Abfallvermeidung in der österreichischen Lebensmittel-produktion. Österreichisches Ökologie-Institut.

[59] Hietler, P., Hopfner, C. & Pladerer, C. (2021). Brot ist kostbar! Ohne Mist! Handlungsanleitung zur Reduktion von vermeidbaren Brot- und Backwarenabfällen entlang der Wertschöpfungskette. Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie

Table 5: Recycling routes for used bakery products from 44 Austrian bakeries[48]

Recycling route	Shares in %
Feeding	86,6
Internal utilization (e.g. breadcrumbs)	3,3
Social Institutions	3,3
Biogas Production	4,8
Composting	1,8
Residual Waste (waste incineration plant or MBT)	0,01
Other Utilization (e.g. alcohol production)	0,03

By-products generated in manufacturing process.

Within this report we focus on by-products (dough) that are generated in the manufacturing process in bakeries and industry. Based on the reports of a well-known bakery producer, the waste dough production amounts to 3.5% of the bakery production[48]. If this percentage is applied to the total baked goods produced in Austria of about 599,000 tons (STATISTIK AUSTRIA 2010), this results in an annual generation for SN 11111 "Dough" of about 21,000 tons[48].

Dough comes from [48]

- Industries producing baked goods (bread industry) and pasta,
- commercial bakeries and pastry shops,
- private bakeries and pastry shops,
- food retailers with associated bakeries that bake semi-finished products and offer them "fresh from the oven".

A study in Switzerland allocated different sources of losses. As the situation and culture in Switzerland is similar, the amount can be assumed as equal in Upper Austria[60]:

Cereals and bakery products:

- The losses in the production of small rolls (gate to gate) in very large baking plants amount to an annual average of 4 %, based on the final product dry matter (confidential).
- In biscuit production, losses of 6.1 % to 16 % occur, depending on the product and the process used, in relation to the quantity produced. The greatest losses are generated by the cutting process for biscuits, where a large bar is first produced and then cut up (confidential information from a large manufacturer).

Finished products:

- The losses incurred in the production of fresh pasta also depend on the type of product and range from 3.75 % to a maximum of 34 % (confidential information from an SME).

[60] Baier, U., Mosberger, L., Gröbly, D., Buchli, J. & Müller, C. (2016). Organische Verluste aus der Lebensmittelindustrie in der Schweiz. Massenflussanalyse nach Branchen. Ursachen / Verwertung. Wissenschaftlicher Schlussbericht ZHAW.

Ideas on how dough waste can be recycled:

- Returning products (re-work)
  In many cases, surplus or faultless goods that have been removed from the production process can be returned to it. Bakeries refer to this as "re-work". A certain proportion of dough pieces or finished baked goods can be reused in production. Many bakeries produce sourdough or a so-called cooked piece from old bread. Sliced and toasted bread from the previous day is finely ground and mixed with water. This mixture is combined with sourdough and flour to form a dough. Processing into breadcrumbs or bread cubes is another option. In this way, waste can be channelled into the highest added value and reprocessed into food[59]. According to verbal information from an Upper Austrian SME, the proportion of dough pieces reworked in this company is between 80 and 90%.

- Processing raw materials
  If bakeries have unsaleable bread leftovers in the production process, these can be processed into other products through suitable co-operations. There are many examples of this, such as the use of old bakery products as a raw material for "bread beer" or the distillation of gin from old bread, but also the production of "bread crisps " [59].

- Waste dough is particularly suitable for utilisation in biogas plants.
  Reisinger, H. et al (2012)[48] assume, that more than half of the annual amount of overproduced dough that cannot be re-worked into production, is used in biogas plants.

Table 6: Substance data of old bread[57]

Substance	Dry matter content DS (in mass%)	Organic dry matter content (in % of DS)	N (in % of DS)	P (in % of DS)	Gas yield (in m^3/t DS)
Old bread	65	97	760	53	479

1.3 Nutrient Availability

1.3.1 Nutrient availability nutrient 1

The following tables show relevant nutrient contents in the spent grains of beer production from different sources:

Spent grain:

Table 7: Source - Biertreber (suedtreber.de); Composition and analysis of spent grains[61]

Composition and analysis of brewer's grains/spent grains:			
		Fresh	**Silaged**
Dry matter (in %)		21,8 - 24,7	23,6 - 27,1
Nutrients	Crude protein	22,5 - 27,5	22,3 - 26,3
	Crude fat	5,5 - 9,5	6,6 - 10,8
	Crude fiber	16,2 - 21,2	17,6 - 22,4
	Crude ash	3,8 - 6,2	3,7 - 6,7
	Nitrogen-free extracts	40,0 - 47,0	37,3 - 45,7
	Starch		7,9 - 9,2
	Sugar		1,3 - 1,6
	Calcium	0,27 - 0,49	0,20 - 0,46
	Phosphor	0,57 - 0,77	0,43 - 0,73
	Sodium	0,10 - 0,90	0,23 - 0,45
	Magnesium	0,17 - 0,27	0,10 - 0,34

[61] Biertreber (2023) https://suedtreber.de/biertreber (Date: 28th of Aug. 2023)

Table 8: Crude nutrient content of spent grain[62]

Crude nutrient content of spent grain:		
Crude nutrient	**g/kg**	**dry matter %**
Crude protein	521	52,1
Crude fat	16	1,6
Crude fibre	25	2,5
Raw ash	81	8,1
N-free extractives	357	35,7
Sugar	13	13

Table 9: Minerals and trace elements in spent grain [54]

		Frisch	Siliert
		von – bis	von – bis
Trockensubstanz (in %)		21,8 – 24,7	23,6 – 27,1
Nährstoffe (in % der TS)	Rohprotein	22,5 – 27,5	22,3 – 26,3
	Rohfett	5,5 – 9,5	6,6 – 10,8
	Rohfaser	16,2 – 21,2	17,6 – 22,4
	Rohasche	3,8 – 6,2	3,7 – 6,7
	N-freie Extraktstoffe	40,0 – 47,0	37,3 – 45,7
	Stärke		7,9 – 9,2
	Zucker		1,3 – 1,6
Mineralstoffe (in % der TS)	Calcium	0,27 – 0,49	0,20 – 0,46
	Phosphor	0,57 – 0,77	0,43 – 0,73
	Natrium	0,10 – 0,90	0,23 – 0,45
	Magnesium	0,17 – 0,27	0,10 – 0,34

62 Erster Steirischer Trebervertrieb (2023). Zusammensetzung und Analyse der getrockneten Bierhefe. www.treber.at

Table 10: Trace elements, amino acids, vitamins and fatty acids from brewer's grains[54]

Spurenelemente (in mg je kg TS)		Aminosäuren (in % der TS)		Vitamine (je kg TS)		Fettsäuren (in % des Fettes)
Eisen	190	Lysin	1,1	Vitamin B1	1,26 mg	8:0
Zink	85	Methionin	0,6	Vitamin B2	0,91 mg	10:0
Mangan	50	Cystin	0,5	Vitamin B6	0,62 mg	12:0
Kupfer	14	Asparaginsäure	1,4	Vitamin B12	38,90 mcg	14:0
Kobalt	0,18	Threonin	0,9	Folsäure	0,07 mg	16:0 (Palamitins.)
Selen	0,10	Serin	0,8	Nicotinsäure	38,90 mg	18:0 (Stearins.)
		Glutaminsäure	4,3	Ca-d-pant.	3,03 mg	18:1 (Ölsäure)
		Prolin	2,0	Biotin	140,00 mcg	18:2 (Linolsäure)
		Glycin	0,9	Vitamin E	25,70 mg	18:3 (Linolens.)
		Alanin	1,0			20:0
		Valin	1,3			22:0
		Isoleucin	0,9			22:1
		Leucin	1,6			24:0
		Thyrosin	0,7			Rest
		Phenylalanin	1,1			
		Histidin	0,5			
		Arginin	1,2			

Table 11: Feed value of spent grains according to DLG feed value tables and latest studies [54]

Futterwert von Biertreber lt. DLG-Futterwerttabellen:

ME/MJ	NEL/MJ	XP g	UDP g	nXP g	RNB g
11,2	6,7	249	97	185	+ 10

nach neuesten Untersuchungen wird der Futterwert von Biertreber wie folgt bewertet:

ME/MJ	NEL/MJ	XP g	UDP g	nXP g	RNB g
11,4	6,8	260	159	229	+ 5

Table 12: Raw material and energy content per kg dry matter of spent grains compared to selected protein feeds and cereals.

Tabelle 1: Rohnährstoff- und Energiegehalte je kg Trockenmasse von Biertrebersilage im Vergleich zu ausgewählten Eiweißfuttermitteln und Getreide
(Quellen: DLG 1997, 2001, 2009, 2011, LfL Gruber Tabelle 2014, Spiekers 2009)

Futtermittel	TM	XF	XL	XS	XP	nXP	RNB	UDP	NEL
	g	g	g	g	g	g	g	%	MJ
Biertreber, frisch	240	178	82	49	253	185	+11	40	6,4
Biertreber, siliert	247	160	88	17	249	188	+10	40	6,7
Biertreber, getrocknet	900	170	68	42	259	198	+10	45	6,2
Sojaextraktionsschrot	880	68	14	69	500	291	+34	30	8,6
Rapsextraktionsschrot	880	143	21	0	392	254	+22	35	7,1
Weizen/Gersten-schlempe, getrocknet	940	74	27	27	372	266	+17	40	7,4
Weizen	880	29	13	662	138	172	-5	20	8,5
Ackerbohnen	880	89	10	422	298	195	+15	15	8,6
Erbsen	880	67	9	478	251	187	+10	15	8,5

Abkürzungen: TM = Trockenmasse; XA = Rohasche; XF = Rohfaser; XS = Stärke; XP = Rohprotein; nXP = nutzbares Rohprotein; RNB = Ruminale Stickstoffbilanz; UDP = unabbaubares Rohprotein (Durchflussprotein, engl. undegraded protein); NEL = Nettoenergie-Laktation; ME = Umsetzbare Energie (engl. Metabolisable energy); MJ = Mega Joule

Brewer's grains are a valuable, high-protein feed (Futtermittel) with high levels of nXP (usable crude protein) and UDP (undegradable crude protein). In terms of energy concentration, they are positioned between basic and concentrated feeds and have a medium energy concentration compared to concentrated feeds. Brewer's grains can be described as a high-fiber feed. Their use in the feeding of ruminants, taking into account their specific protein properties, and can make a significant contribution to a sufficient protein supply.

Yeast

The table shows the nutrient content of brewer's yeast. Analysed by a company that sells brewer's yeast for feeding to livestock[57].

Table 13: Minerals and trace elements in yeast [52]

Element	Unit	Amount
Ca	g	3,3
P	g	33
Mg	g	2,6
K	g	24
Na	g	2,44
Fe	mg	560
Mn	mg	59
Zn	mg	92
Cu	mg	64
Mo	mg	1,25
Co	mg	0,4
Fe	mg	2,15
Se	mg	0,11

1.3.2 Nutrient availability nutrient 2

Following table contains an overview of the composition of macronutrients in different bread types.

Table14: Macronutrient content [% per 100 g] in common bakery products [63].

Macronutrient	Bread type		
Content in [%]	**Wheat roll/bun**	**Bread**	**Whole-grain bread**
Water	29,5	43,7	38,8
Carbohydrates	55,5	41	43
Protein	8,7	6,9	7,3
Fiber	3	6,2	8,1
Fat	1,9	1,1	1,2
Vitamins & Minerals	1,4	1,1	1,6

Doughs:

No nutrient contents could be determined for dough pieces resulting from production. However, as the nutrient content should not change because of processing and baking, the nutrient values of stale bread can be used.

Old bread:

Bread that did not go on sale or was left over during the sale (best-before date exceeded, sorted out as food) is currently mainly fed to animals or processed into gas in the biogas plant. Only hygienic bread may be fed (e.g., no mouldy bread).

Scrap bread has a high sodium content. 1 kg of old bread in the ration reduces the need for the need for cattle salt by 10 g. Limiting factors in the feeding of dairy cows are the high starch content and the lack of structural effect.

[63] LandschafftLeben. https://www.landschafftleben.at/lebensmittel/brot/gesundheit (Seen: 10.11.2023)

Table 15: Comparison of ingredients per kg dry matter of stale bread[64]

2. Inhaltsstoffe pro kg Trockenmasse von Altbrot im Vergleich (ZIFO 2014)

	Altbrot	Gerste	Weizen
Trockenmasse [g/kg FM]	650	880	880
Rohprotein [g]	123	125	137
nXP [g]	175	165	170
UDP [%]	10,0	25,0	20,0
Lysin [g]	3,3	4,43	3,35
Methionin [g]	1,8	2,02	1,78
Energie [MJ NEL]	9,40	8,21	8,53
Energie [MJ ME]	14,44	13,00	13,40
Stärke und Zucker [g]	702	627	707
Zucker [g]	60,0	25,0	31,8
Rohfett [g]	30,0	25,0	20,0
Rohfaser [g]	14,0	50,0	30,0
Rohasche [g]	28,0	2,3	1,7
Kalzium [g]	0,9	0,7	0,7
Phosphor [g]	2,5	4,0	3,8
Natrium [g]	4,1	0,3	0,2
Kalium [g]	5,0	5,0	5,0

64 Schuster, H., Moosmeyer, M. & Rauch, P. (2014). Futtermittelblatt Rind Altbrot. LfL Tiernährung.

Table 16: Nutrient content of feed materials[65]

Quelle: StoffBilV vom 14.12.2017, Tabelle 4; fachlich erweitert durch Bayerische Landesanstalt für Landwirtschaft (LfL) - Basisdaten, Stand: November 2018

TS = Trockensubstanz; **RP**- Rohprotein; **FM** = Frischmasse

Einzelfuttermittel	Produktart und Erläuterungen	RP-Gehalt	TS-Gehalt	Nährstoffgehalt				
				N	P	P_2O_5	K	K_2O
		[% in TM]	[%]	[kg/dt FM]				
Einzelfuttermittel allgemein								
Ackerbohne	Korn	30	86	4,10	0,52	1,19	1,16	1,39
Altbrot		15	65	1,56	0,07	0,16	0,33	0,40
Apfeltrester		8	22	0,29	0,04	0,09	0,15	0,18
Backabfälle		12	88	1,70	0,23	0,53	0,88	1,06
Bierhefe	flüssig	53	10	0,84	0,11	0,25	0,15	0,18
Biertreber	siliert	25	25	1,00	0,15	0,34	0,02	0,02

1.4 Discussion of the Results

Concerning the availability of biomass in the two chosen streams, a few statements can be made. Firstly, though breweries overall make up a small share of food waste in Austria, the density of breweries still makes them an interesting branch to investigate further. With a variety of different waste material comes a variety of use. The most financially beneficial and logistically doable repurposing is still animal feed.

Looking at the bigger stream of by- and waste products of bakeries, we observe that only an incredibly small percentage is wasted. Even when just looking at excess dough produced, there are several alternatives that include re-working the overproduced material back into the initial process, turning them into raw material in a different production line or using them in biogas plants producing biogas and biofertilizer.

Breweries create several kinds of biomass. The decision was made to look more closely at two of them: spent grain and yeast. Both are nutrient-heavy biomass streams, with spent grain specifically being heavy in protein. This connects directly to its use in animal feed, but also makes it a resource that needs to be used wisely as to not overfeed in terms of protein. With yeast, phosphorus and potassium stand out as macro minerals. These two are both relevant for humans as well as crops as in the latter, they contribute heavily to the growth of the plants.

For dough, data were used from studies on old bread. Here we can see that nutrient value is lower than in brewery waste-products. It should be noted that the nutrients apply to finished baked goods that are deemed “old”. Not to dough prior to processing.

65 Grunert, M. (2020). Nährstoffgehalte von Einzelfuttermitteln. Landwirtschaft/Pflanzenbau. (10.11.2023: https://www.landwirtschaft.sachsen.de/download/Tab_33_Naehrstgeh_Einzelfutterm_2020_06_05.pdf)

1.5 Conclusions and Recommendations

1.5.1 Conclusions

The decision of why these two streams were investigated becomes apparent when looking at them side by side. Bread and baked goods stand out in terms of amount, there is significantly more bread available as a waste stream. The following table provides an overview of available biomass streams as well as an approximation for the price per ton of the specific streams:

Table 17: Biomass potential and applications

	Biomass in tons	Percentage used in feed	Price per ton
Spent grains	150k-170k	93%	€ 7,8 - € 12
Yeast	12k	unknown	€ 7
Bread	210k	86%	Not publicly available
Dough	21k	Unfit for use in animal feed	Not publicly available

For bread and dough, there are existing contracts between bakeries/supermarkets and feed producers. However, arrangements are not published and the price per tonne is unknown.

There is no indication that the available amount of biomass is insufficient, still, with increased biomass demand or market shifts to other routes, this can change. Close monitoring remains necessary.

Residues can be utilized well for animal feed or biogas production. For dough, however, reworking, either in the same or a different process, are considered better options.

For nutrient recycling, the following routes exist and are applied depending on product quality and availability of conversion systems in the area.

1. The residues are used for animal feed; animals produce meat and dairy products; manure is digested producing biogas and the digestate is upgraded to bio-fertiliser and nutrients are returned to the field.
2. The residues are used as co-digestion material producing biogas and bio-fertiliser and nutrients are returned to the field.
3. The residues are composted, and nutrients are returned to the field.

1.5.2 Recommendations

Two major points stand out that are equally important and closely connected. Firstly, we recommend looking more deeply into logistics. Creating reliable transportation for the incurred bio waste is crucial to ensure a deliberate use of as much material as possible, the closing of loops and the reduction of waste under the principle of repurposing.

Secondly, we see a huge opportunity in connecting production processes. What can be considered biomass in one process can be a raw material in another. A very easy example is that leftover dough can be used to make bread chips. This is still thinking within the same industry. Better is that this thinking is extended to distilleries, biogas plants, sewage plants and other stakeholders. Here, the SCALE-UP project and its platforms offer a good starting point for inter-sectoral thinking outside of one's own industry.

Overall, the way bakeries are handling their side streams and the minimal amount of food that is eventually declared waste, can be taken as an example for other sectors. Processes have been designed efficiently and while there is room for improvement, little biomass is left unused. Biomass availability is stable, and the use has been well organised through process optimization.

For nutrient recycling, financial considerations are dominant. This does not guarantee the best ecological way nutrients are used. If residues can directly be used for bioproducts or materials, this should be preferred as it saves crops, land use and nutrients. Only when this is no longer possible, they should be used for composting of biogas production. This **cascadic use** of resources can be both an interesting starting point for researchers in terms of biomass stream optimization as well as policies and laws that have proven in the past to vastly expedite the speed at which change is implemented.

community-driven
bioeconomy development

Regional Biomass and Nutrient Availabilities

Study on the availability of biomass for the bio-based building value chain in the French Atlantic Arc

February 2024

Sylvie GUILLO and Jean-Luc LAFARGUE

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1. Regional biomass and nutrient availabilities in the French Atlantic Arc

1. Introduction

1.1 Background

The French Atlantic Arc is composed of 4 regions in the Western of France: Brittany, Normandy, Pays de la Loire and New-Aquitaine regions. It is the field of intervention of the Association of the Chambers of Agriculture of the Atlantic Area (AC3A), an association created in 1993 by 27 local chambers of agriculture. The chambers of agriculture were willing to work on common agricultural issues in this geographical area at the European level. Now 4 regional chambers of agriculture - one per administrative region - are involved in the SCALE-UP project.

Agriculture in the Atlantic Arc covers an area of 89,656 km^2. It has many characteristics in common from one region to another: the influence of the oceanic climate and the proximity of the sea have shaped the typology of farms that are very much linked to cattle breeding, particularly because of the importance of the bocage and marsh areas.

These regions face strong demographic pressure due to their proximity to the Atlantic coast and the English Channel.

Environmental issues are also critical. These regions are fully affected by the impacts of climate change, with a rise in temperature and a reduction in water resources, which until now had spared these regions with high rainfall.

Agriculture in a few key figures (RGA 2020)[66] :

- 144,000 farms and 187,000 farmers.
- Predominance of livestock farming: more than 2/3 of the farms are primarily engaged in livestock production.
- Arable crops represent between 32 and 39% of the agricultural area. But these areas are constantly growing.

[66] Source: agricultural census (RGA) 2020.

Number of farms and share of livestock farming in the French Atlantic Arc		
REGION	**NUMBER OF FARMS**	**SHARE OF LIVESTOCK FARMING**
Brittany	26 347	80%
New-Aquitaine	64 200	31%
Normandy	26 510	56%
Pays de la Loire	26 409	70%

Source : RGA 2020.

The agricultural orientation of these regions is changing and evolving towards a decrease in livestock production: the main reasons for the disengagement of farmers from livestock production are working time constraints and the high drudgery of work, combined with unprofitable meat prices. In addition to this, the reduction in meat consumption recommended by the Intergovernmental Panel on Climate Change (IPCC) to cope with climate change, the context is moving towards an increase in crop production in these four regions.

This context is favourable to the development of fibre plants in these regions, especially as these crops offer important advantages for future climate challenges. This issue will be addressed in the next chapters.

1.2 Scope of the study

We have chosen to focus on the development of four fibre plants linked to the resources available in the rural areas of the Atlantic Arc:

- Straw
- Hemp
- Miscanthus
- Flax

These plants have primary uses such as livestock breeding, human food or animal feed, but their uses are diversifying, particularly for industrial purposes (chemicals, textiles, construction).

Following contact with stakeholders in the fibre plant sector, we have chosen to work on the use of these plants as bio-based construction materials, which is a major issue in the decarbonisation of the building sector.

Bio-based materials are materials derived entirely or partially from renewable organic matter (biomass)[67]. The nature of these bio-based materials is diverse: wood, cellulose wadding, recycled textiles, cereal husks, cork, thatch, meadow grass, etc.

[67] Terminology standard NF-EN 16575 of October 2014: "*Biobased materials are materials derived entirely or partially from living biomass such as wood, hemp, rapeseed, miscanthus, straw, flax shives, among others*".

These fibres can be used as raw materials for bio-based building materials in varying proportions. The standard defining bio-based materials does not specify a minimum content of biomass raw materials in the final material.

In 2018 with the ELAN[68] law, the French government is promoting bio-based materials by clearly advocating the use of renewable materials and including environmental performance as one of the main issues for buildings. This has resulted in an environmental regulation for new buildings called "RE2020", which makes it compulsory to calculate the carbon impact of all new buildings from 1st January 2022. Life-cycle analysis over 50 years is becoming a central element in both new construction and renovation.

The building sector accounts for 30% of France's CO_2 emissions, including the manufacture of materials, construction and housing[69]. Life Cycle Analysis of buildings from the E+/C- experiment[70] shows that 70%[71] of greenhouse gases come from construction materials and equipment. To reduce the sector's carbon footprint, it is therefore essential to limit emissions from these materials.

Biobased materials made from **renewable and local raw materials (wood, flax, hemp, straw, etc.**) capture carbon during construction and throughout the building's lifespan. They are likely to become essential for the construction and renovation sector, which will have to adapt to these new regulations.

It should be noted that the building sector is also working on reuse, which will become compulsory under the EPR (Extended Producer Responsibility) for the building industry, which comes into force in 2023 (law no. 2020-105 of 10/02/20 on the fight against waste and the circular economy). According to the French Building Federation, building waste accounts for 46 million tonnes every year in France.

2. Biomass availability

The latest available data on areas planted with fibre plants (flax, hemp, miscanthus) show varying situations in the French Atlantic Arc. The data from Common Agricultural Policy (CAP) declarations show an overall favourable trend over the last 13 years.

Areas planted with fibre plants (in hectares) in the French Atlantic Arc

REGION	2010	2020	2022	Trend
Brittany	191 ha	882 ha	1,500 ha	↗
New-Aquitaine	535 ha	1,052 ha	1,558 ha	↗
Normandy	34,367 ha	86,499 ha	76,483 ha	→
Pays de la Loire	1,019 ha	5,003 ha	5,159 ha	↗
TOTAL	**36,112 ha**	**93,436 ha**	**84,700 ha**	↗

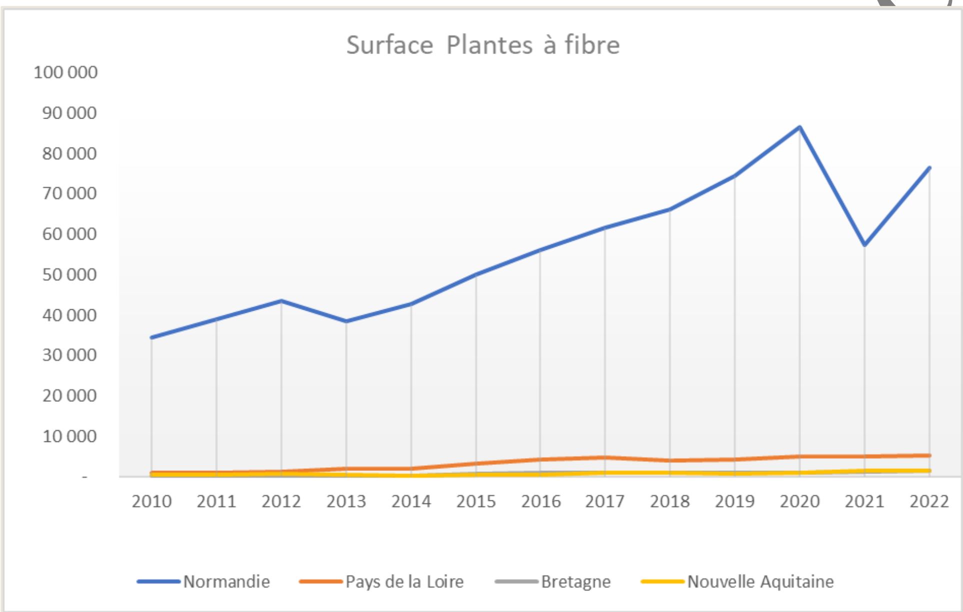
[68] Loi ELAN: évolution du logement, de l'aménagement et du numérique (ELAN law: evolution of housing, land use planning and digital).
[69] Source: Hélène Lenormand, "*Growing thermal insulation: an overview of materials available in France*", 2022.
[70] The E+/C- experiment is a tool that has been used to calculate a building's energy balance and assess its greenhouse gas emissions throughout its lifecycle. This experiment, which was launched in 2017, served as a basis for the RE2020. https://www.cerema.fr/fr/actualites/batiment-cerema-experimentation-e-c-energie-carbone. This experiment has become an E+/C- label.
[71] Source Cerema : https://publications.cerema.fr/webdcdc/pti-essentiel/impact-carbone-batiment/

Source : CAP declarations.

The increase in surface area has been exponential: +57% in 13 years, thanks in particular to the Normandy region and the growth in demand for fibre flax.

The latest figures from the graphic parcel register (Registre parcellaire graphique – RPG*)* of 2022 show that this increase is continuing steadily throughout the Atlantic Arc, under the influence of local stakeholders*.* The New Aquitaine region, despite being the largest in France, is the region with the less surface area planted with fibre plants.

Evolution of the surface area planted with fibre plants in the French Atlantic Arc (from 2010 to 2022)



Source : RPG 2022.

2.1 Availability of straw

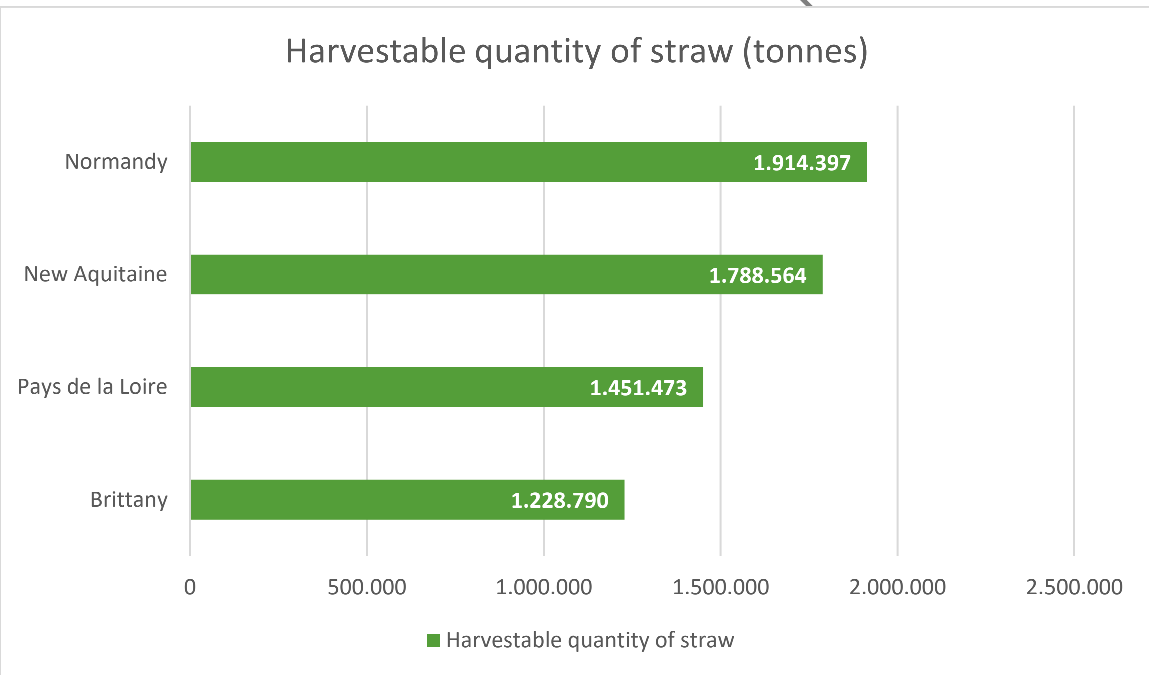
Straw is a residue from the harvesting of cereals for animal feed or human consumption (bread, dough, etc.). There are several types of cereal, but wheat is the most widespread crop in Western France, and for the moment it is the only one described in the professional rules for straw construction.

© Chamber of Agriculture of Vendée

Using data from FranceAgriMer (public administrative establishment in charge of collecting and analysing economic data of the agricultural sector), we have established the quantities of straw harvested[72] in the Atlantic regions as an average over 4 years (2018/ 2019/ 2020/ 2021) to avoid variations in harvesting due to weather conditions and in relation to areas sown.

Breakdown per region of cereal crop surfaces in 2022 in the French Atlantic Arc	
Brittany	433,858 ha
New-Aquitaine	742,756 ha
Normandy	592,645 ha
Pays de la Loire	521,532 ha

Normandy is the region with the highest straw production (average theoretical yield over 4 years).

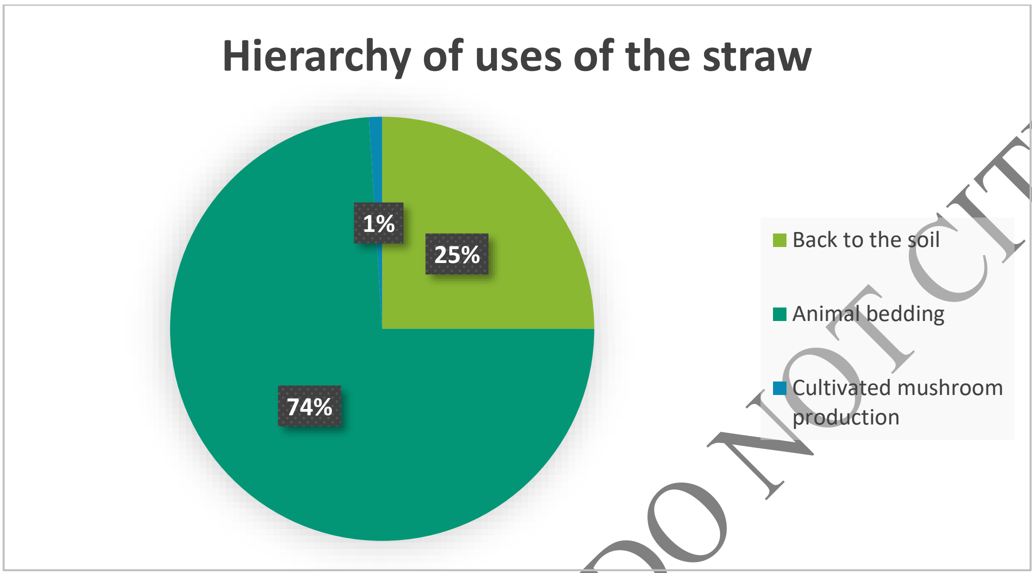


Source: FranceAgriMer - average quantity over 4 years (2018/2021)

Almost 6.383 million tonnes of straw are harvested in the French Atlantic Arc region. The main use for this by-product is as animal bedding. Some farmers leave the straw on site after the wheat harvest. This practice is difficult to quantify, and varies greatly from region to region, from livestock farming to arable farming - some farmers even consider this practice to be "wasteful". FranceAgriMer

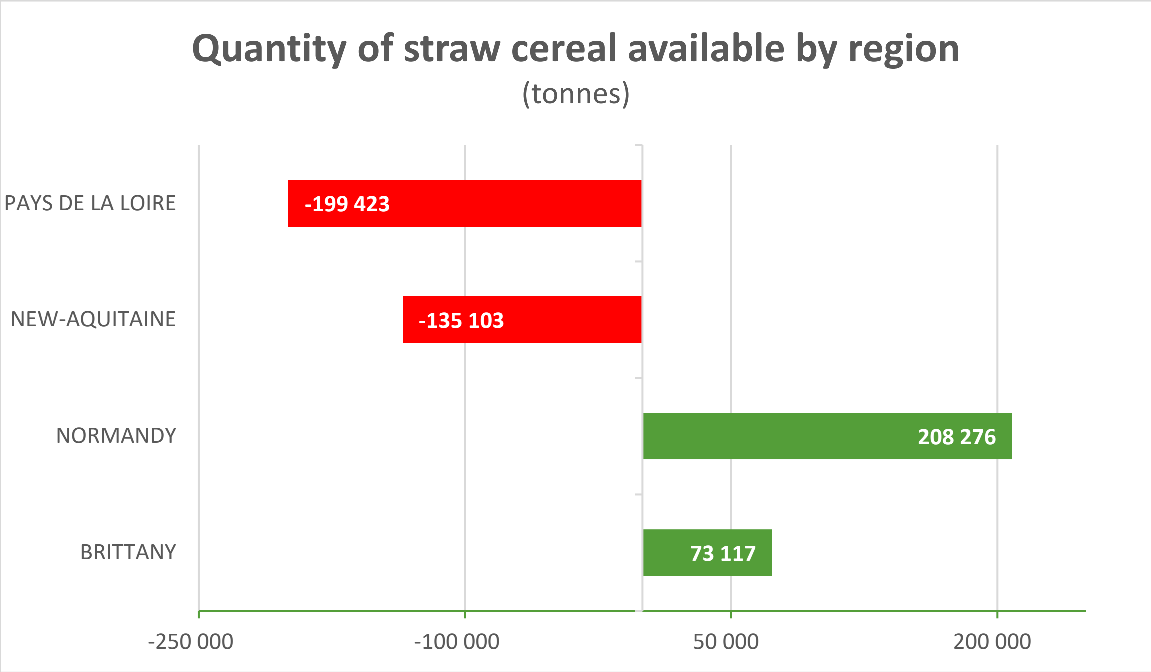
[72] Quantities exported from the field. Excluded from this table are the quantities of unharvested straw left on the ground. This return to the soil is used as fertiliser to improve the agronomic quality of the soil.

nevertheless worked on estimations regarding the primary uses of straw (graph below), including the use of straw as an agronomic input to soil. It also includes cultivated mushroom production, as in some regions, straw is used for mushroom production. The Pays de la Loire region is one of the regions with the largest production of cultivated mushrooms.



Source: FranceAgriMer - average over 4 years - Uses in the French Atlantic Arc

Once the conventional uses of the straw are fulfilled, the availability of straw for other purposes varies from one region to another. It depends on production volumes and local uses. In New-Aquitaine and Pays de la Loire, for example, straw cereals, including wheat, are used for livestock farming, which is very common in these regions. Straw shortages are compensated for by straw imports between regions of France, or even from neighbouring countries. For example, some counties in the New-Aquitaine region have a shortage in straw production and need to import straw from Spain. These import/export flows are not known in terms of volume.



Source: FranceAgriMer - average over 4 years

The quantities of straw available are not linked with the number of livestock in the region, as shown in the table below.

Number of livestock by Large Bovine Unit equivalent[73] in the French Atlantic Arc	
Brittany	5,129,166
New-Aquitaine	3,002,934
Normandy	2,350,000
Pays de la Loire	3,544,500

Source: RGA 2020.

Brittany is the region with the highest livestock numbers in LBU equivalent, followed by Pays de la Loire. However, Brittany has a surplus of straw, as does Normandy.

There are several reasons for this. Both Brittany and Normandy have a majority of dairy cattle. However, dairy farms have opted for slurry systems rather than straw-covered areas to comply with standards.

In contrast, beef cattle farms - which are much more common in the Pays de la Loire and New-Aquitaine regions - are on straw pastures. In addition, grazing is practised for longer periods in Normandy and Brittany, due to weather conditions that are more favourable for grass growth, particularly in summer.

[73] The herd includes all animals in Large Bovine Unit (LBU) equivalent: cattle, pigs, poultry, goats, sheep, etc.

Other livestock reared in buildings (poultry, pigs) are either on slatted floors, or use very little straw and therefore do not have a significant impact on straw use. These livestock are very present in the Brittany region, which is the leading region for pigs (56% of French livestock), and for poultry.

2.2 Availability of Hemp

Agricultural hemp is an annual plant in the *Cannabinaceae* family. Only *cannabis sativa* - with a low THC content (< 0.2%) - is grown. Hemp is subject to strict regulations and only certified seed is authorised. The use of self-grown hemp is strictly prohibited, as it may increase THC levels. Before harvesting, checks are carried out on 30% of crops to verify THC levels.

Originally from Central Asia, hemp has been cultivated for 8,000 years, mainly for its textile fibre. Its surface area shrank considerably with the emergence of competing fibres such as cotton and synthetic fibres in the 20th century. However, in recent years, with the development of uses for hemp, production has risen again. In 2022, the areas planted with hemp in France were 21,700 ha, compared with 12,000 ha in 2015. France leads the European hemp production with 50% of the planted surface area.

To assess the availability of hemp biomass, it is important to be familiar with all the possible uses. Knowing how to make the most of the whole plant, even the hemp dust, is key in the profitability of this crop. Hemp has many uses, both for food and non-food purposes:

The many uses of the hemp

Part of the hemp	% of the plant weight	Distribution of uses
Seed	10%	Harvested in September. 84% for feed (bird and fish) 15% for human consumption including protein and oil 1% for cosmetic
Chenevotte	44%	48% for animal bedding 28% for aggregate 22% for horticultural mulching 2% other
Fibre	24%	50% for fine paper 29% for insulation in building 10% plasturgy 10% textile 1% other
Flower[74]		Harvested in August for CBD and other molecules.
Dust	22%	57% for compost 33% for energy 10% other

Source: Interchanvre.

[74] We will not be dealing with hemp flower harvested for CBD - this is a very specific sector.

Hempseed is used as animal feed for birds and as fishing bait. Hempseed oil, produced by crushing hempseed, is of high nutritional quality (rich in omega 3, fibre and protein). The oil is also used in cosmetics.

The hemp stalk is made up of fibres that surround the chenevotte. The fibres, obtained by defibrating the stalk, are used in a wide range of applications (fine paper, insulation, automotive plastics, window profiles, textiles). The chenevotte, which is the wood of the plant, is highly absorbent, making it ideal for bedding and mulching. It is also used in construction and makes good compost at the end of its lifespan.

The dust or fines have a high absorbency and are rich in carbon. It is used as an organic amendment or bedding for cattle. After compression, it is used as fuel in industrial boilers.

The surface area planted with hemp in the Atlantic Arc was **4,668 ha** in 2022 broken down as follows:

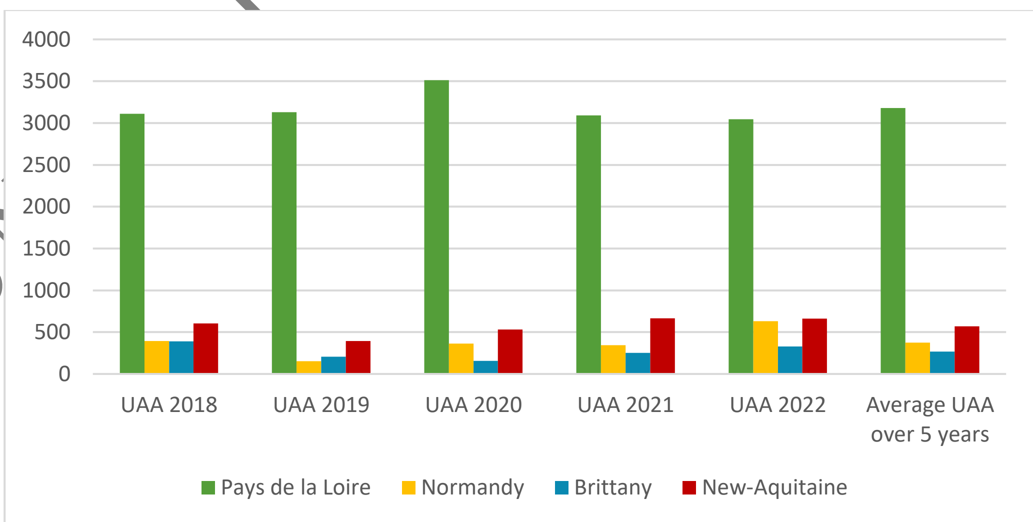
Breakdown of hemp surfaces declared for the 2022 CAP in the Atlantic Arc	
Brittany	329 ha
New-Aquitaine	661 ha
Normandy	631 ha
Pays de la Loire	3,047 ha

Source: Graphic plot register (RPG) 2022, Regional Chamber of Agriculture of New-Aquitaine.

The Pays de la Loire region concentrates the largest number of hectares in the west of France (65% of the area studied). This is largely due to the dynamism of the stakeholders in the Pays de la Loire region, particularly the CAVAC (agricultural cooperative for hemp production), which is located in Vendée and has been involved in hemp production and the manufacture of bio-based insulation materials for over 15 years.

The Hemp-It cooperative produces hemp seed. It is located in Maine-et-Loire, and contributes to this dynamism. However, the figure below does not consider Hemp-It surfaces as they deal with hemp seed and not fibre hemp.

Evolution of hemp surfaces by region over the last 5 years (2018-2022)



Source: CAP declarations.

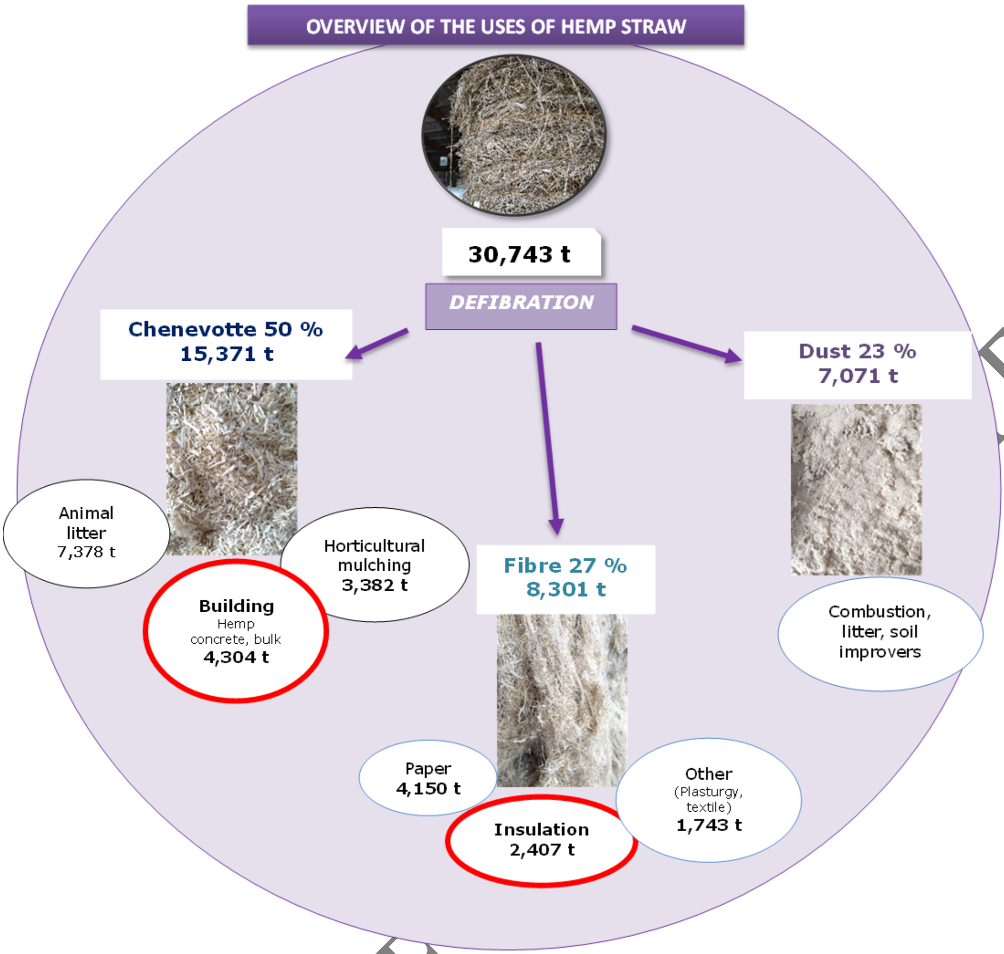
The assessment of hemp production in the graph above has been made based on hectares of fibre hemp declared to the CAP, using average yields: 1 tonne of dry matter for hempseed and 7 tonnes of dry matter for hemp straw. An average over the last 5 years has been calculated to show the trend (and avoid annual variations due to particular circumstances such as the weather), however the graph shows there have not been any major variations in the surface areas over this period.

The table below assessed the yield of seed and the yield of straw from the hemp production in the Atlantic Arc, using the average surface area calculated over the 5 years (2018-2022) and the theoretical production per hectare assessed as follows: yield of 1 tonne of dry matter per hectare for hempseed, and yield of 7 tonnes of dray matter per hectare for hemp straw.

Theoretical hemp production in the Atlantic Arc (for the 4 regions, excluding CBD)	
Average hemp surface	4,392 hectares
Estimated hempseed yield	4,392 tonnes
Estimated straw yield	30,743 tonnes

Source: RPG, average 2018-2022.

Driven by demand for bio-based materials and the dynamism of the local stakeholders involved, hemp production is expected to increase over the next 3 years. Hemp-based building materials come from hemp straw. Based on the data from FranceAgriMer, it has been possible to estimate production volumes in 2022 for the Atlantic Arc and their various markets. It is estimated that **6,711 tonnes of hemp** produced in the Atlantic Arc were processed for the building market and transformed into hemp concrete or insulation. This amount has been calculated based on the average hemp surface of 4,392 hectares.



2.3 Availability of miscanthus

Miscanthus is a perennial rhizomatous grass of the C4 type[75] , which contributes to its high productivity. *Miscanthus x giganteus,* the only species grown in France, is triploid and therefore sterile, and its rhizome is non-tracking. These two characteristics ensure that the plant is non-invasive. Miscanthus is a perennial plant planted for at least 20 years. From the 2nd year of cultivation, no maintenance (weeding, inputs) is required: no weeding, no nitrogen inputs, no plant protection treatments.

© Chamber of Agriculture of New-Aquitaine

[75] It has a C4-type photosynthetic metabolism. C4 plants use the C4 carbon fixation pathway to increase their photosynthetic efficiency by reducing or eliminating photorespiration.

© Chamber of agriculture of Eure-et-Loir

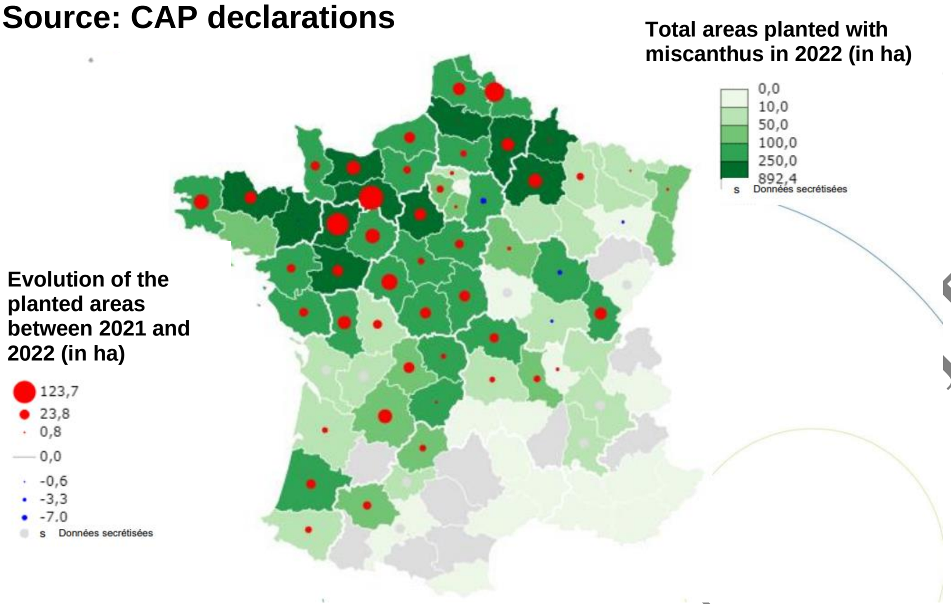
The miscanthus sector is still in its early stages in France, with few local stakeholders handling large volumes. Most of these stakeholders are members of the France Miscanthus association. Novabiom is the leading miscanthus planter, while Lamont Colin énergies is France's largest miscanthus producer. Biomis G3, an association created in 2013, brings together producers, manufacturers (Calcia cement, PSA, Addiplast, etc.) and local authorities. Biomis G3 aims to develop industrial markets for miscanthus. It is particularly interested in sustainable building and bioplastics. Its role is to bring together manufacturers and local authorities around the miscanthus use and to explore the possibility of setting up integrated local supply chains.

In 2023, a total of 11,000 hectares had been planted nationwide, with an annual increase of 18% over the last five years[76]. Several sources of data were used to assess the available biomass: FranceAgriMer, CAP declarations and a study by the France Miscanthus Association[77].

[76] The miscanthus sector in France - France Miscanthus - February 2023
[77] https://france-miscanthus.org/le-miscanthus-en-chiffres/

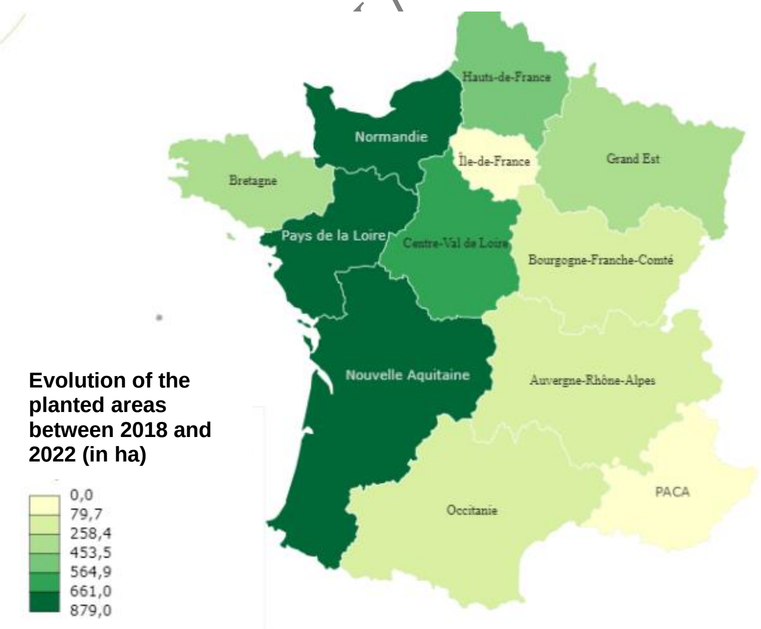
Location of miscanthus planted areas in 2020.

Source: CAP declarations



Source: France Miscanthus

The north-west of France accounts for most of the area planted according to 2022 sources.



Source: France Miscanthus

The Atlantic Arc is the area in which surfaces planted with miscanthus increased the most between 2018 and 2022, particularly in Pays de la Loire, Normandy and New-Aquitaine regions.

Growth in miscanthus planted areas between 2018 and 2022		
REGION	**SURFACE (2022)**	**INCREASE**
Brittany	914 ha	+ 334 ha
New-Aquitaine	882 ha	+ 666 ha
Normandy	1,259 ha	+ 676 ha
Pays de la Loire	1,812 ha	+ 883 ha

Source: RPG 2022.

This production has grown strongly in recent years. With an area of 6,400 hectares in 2019 and an average yield of 12.73 tonnes of dry matter per hectare in the growing phase (from the 4th year of age, the yield is lower in previous years), the French production is estimated at 57,440 tonnes in 2019.

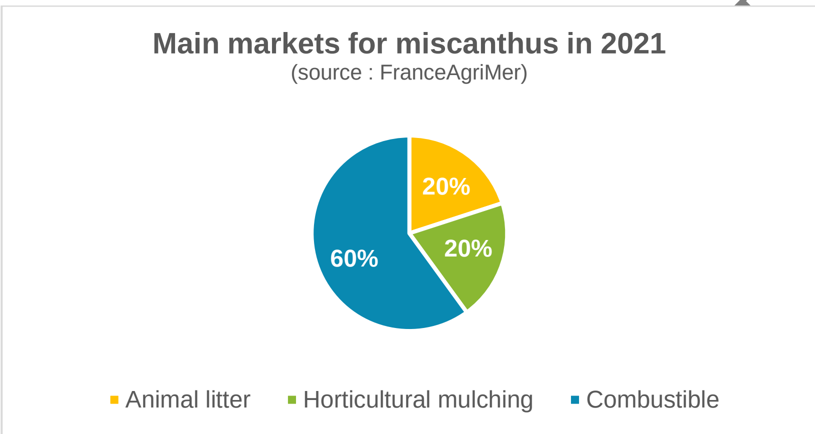
Projections have been made for the years 2020 to 2023, based on historical and newly planted areas, and assuming that the average growing yield remains at 12.7 tonnes/ha. The health situation and the slowdown in activity due to the coronavirus in spring 2020 have slowed development. As a result, production is expected to rise, but at a slightly slower pace than forecast: 79,000 tonnes in 2022, and possibly 88,000 tonnes in 2023.

Miscanthus has many diverse uses. In addition to conventional uses such as mulching, bedding, heating and cattle rumination, there are more innovative markets such as bioplastics and sustainable building, which are still underdeveloped.

Miscanthus markets		
AGRICULTURE	**Animal litter**	Interesting for its absorbing properties, miscanthus is used as animal litter in three markets: poultry, cattle and horse. Miscanthus litter is available in several forms: crushed, granulated, re-emitted granules or flour.
	Horticultural mulching	Primarily used by local authorities, private individuals and farmers (mainly horticulturists and winegrowers) for its absorbing and insulating properties that preserves soil moisture and act as a thermal insulator for plants.
	Rumination	The use of miscanthus to help cattle rumination has been under development for several years, notably by the Lamont-Colin farm, which has largely developed this niche market. Miscanthus has no nutritional value, though it helps cattle rumination.
ENERGY PRODUCTION	**Combustible**	Miscanthus is an alternative to coal or wood. For instance, it is used in the furnaces of alfalfa dehydration plants. It is a renewable energy source, with the advantage of being produced close to the plants. It has the same calorific value as wood. Miscanthus can also be used in boilers.

	Biofuel	The Futurol 2nd generation biofuel project, launched in 2008, incorporates several potential biomass sources, including miscanthus. In early 2020, the Futurol project process was bought by Croatian oil company INA.
BUILDING	**Bio-based concrete**	The cement manufacturer Alkern is currently developing concrete blocks made from miscanthus.
OTHER EXPERIMENTAL USES	**Bioplastics**	Miscanthus has for several years been the subject of studies and projects to explore its use as a polymer compound. The first markets are in the automotive sector, but projects are still in their early stages. Indeed, a tonne of micronized miscanthus is sold for around 600 € to 700 € per tonne.

Source: FranceAgriMer[78].



2.4 Availability of flax

Sown in March, the flax is harvested in July and pressed in August-September. It is stored on farms and processed in scutching plants throughout the year. It is therefore available all year round (except for the holiday period, generally in August). Flax seeds are first sown, generally between March and April, and the plant reaches maturity 100 days later. In June, the plant flowers. Then comes the harvesting stage:

- **Removal**: in July, when all the flowers have disappeared and the stem is hard, it can be harvested and left on the ground to dry.
- **Harvesting**: the seeds on the straw are harvested using a hulling machine.
- **Retting**: this stage consists of separating the textile fibre from the woody part of the flax stalk. The flax growers turn the stalks over to homogenise the whole.

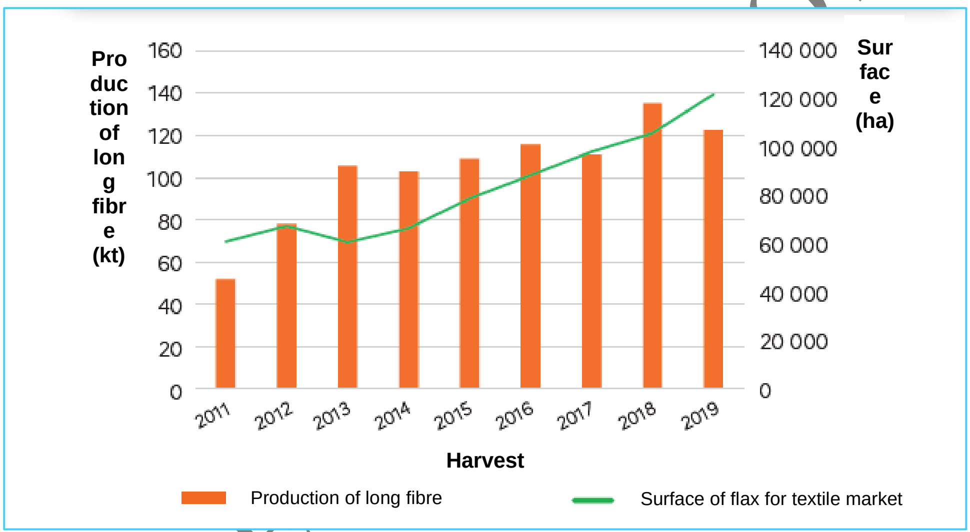
[78] Study on price formation in the French miscanthus production secto

- **Scutching**: this consists of separating the flax fibre from the wood in the stalk. This produces long fibres called flax fibre and short fibres called tow.
- **Combing**: The fibre is then combed to produce fibre ribbons which are sent to the spinning mill.

France is the world's leading producer of flax, accounting for 75% of global production. The production is concentrated in the north-west of France, with most flax grown on the coast between France and the Netherlands, mainly in Normandy (60% of the area cultivated in 2020) and Hauts-de-France (35%) regions*.* Flax is grown by 8,200 producers.

The surface area planted with flax in France has increased by a quarter since 2021. Most of the flax produced in France (over 90%) is exported to Asia, especially China, to be spun and re-exported to Europe[79]*.*

<ins>Growth in French fibre flax surface area and long fibre production</ins>



Source: FranceAgrimer – Sector sheet, January 2021

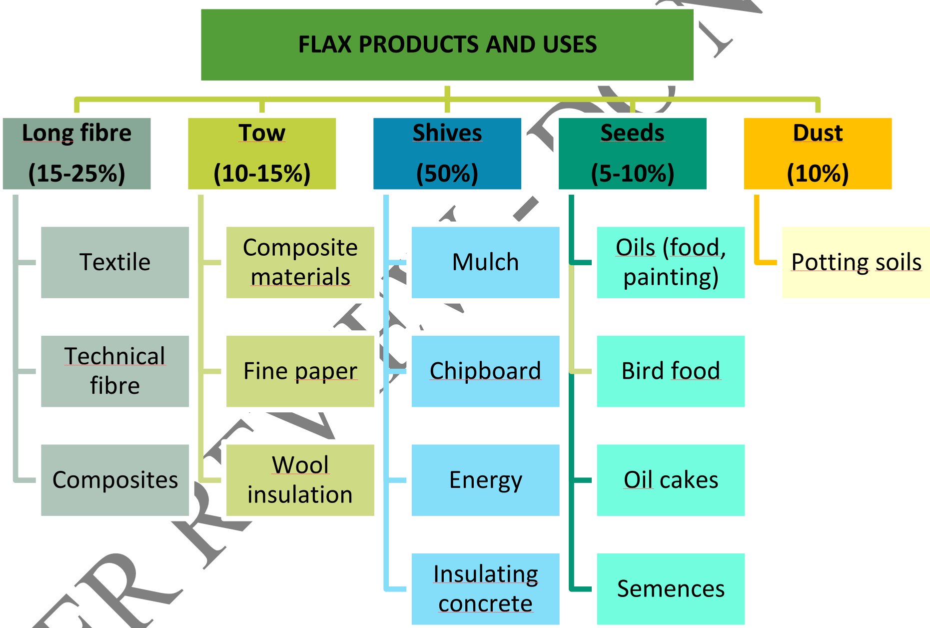
Normandy accounts for almost 2/3 of French fibre flax production. The region has planted 85,256 ha in 2020, representing around 656,000 tonnes of flax straw (527,900 tonnes on 73,315 ha in 2019 - 63% of French production). The surface area planted with flax is growing steadily, doubling between 2000 and 2020 in Normandy. Investments over the last two years confirm this trend for the years to come, driven by new stakeholders in Normandy: new scutching plants from the Depesteele group in the Vexin and the scutching cooperative of North of Caen *(*new subsidiaries from the Neubourg scutching cooperative and Teillage Lamerant scutching cooperative).

[79] Source: Regional Chamber of Agriculture of Normandy, Assessment of resources available for construction in Normandy, May 2022.

Breakdown per region of flax surfaces in the Atlantic Arc in 2022	
Brittany	257 ha
New-Aquitaine	15 ha
Normandy	74,593 ha
Pays de la Loire	300 ha

Source: FranceAgriMer.

Flax is generally grown for its fibres, but it offers a wide range of products (long fibres, tow, shives, seeds, dust) that can be used for a wide range of purposes. The diagram below shows the various markets for fibre flax. In most cases, the biomass from the crop has to go through two transformation processes before being used. Co-products such as tow and flax shives are very interesting for the manufacture of technical materials, including those used in construction.



Source: Regional Chamber of Agriculture of Normandy.

Main markets for flax	
Textile	Although flax fibres account for just 0.3% of the textile fibres produced worldwide, the sector remains by far the largest market for them, absorbing 95% of long fibres and 70% of tow.
Non-wovens	It is a market for flax tow for around 15% of its volume.
Composite materials	The emergence of these new applications is largely the result of innovation by SMEs. They also offer great potential for industrial sectors that are particularly demanding when it comes to the properties of materials, such as the marine, aeronautical and rail sectors.
Fine paper	Flax-based papers are light, strong and high quality. They can be used for a variety of purposes (publishing papers, graphic papers).
Animal bedding and horticultural mulching	Thanks to their honeycomb structure, flax shives have a great capacity to absorb water and retain it over the long term.
Energy	Some shives are used for energy purposes. Their calorific value is comparable to that of wood (4 kWh/kg) – for a lower cost of access – and their moisture content is low (10 to 12%). Clearly, 2.5 kg of shives are equivalent to 1 litre of fuel oil.
Oil	Known for its drying and polymerisation properties, linseed oil is used on its own or mixed with other oils, resins and solvents. Flax leaves can also be used to make cosmetic and pharmaceutical products.
Sustainable building	The company De Sutter in Normandy recovers almost all of the shives in the Seine-Maritime and Eure regions to produce particleboard.
Chemicals	Development of the chemicals sector by the Prevcarb company. An integrated biorefinery is under development in Normandy. The idea is to deconstruct shives to produce lignin, cellulose and hemicellulose. Each of these materials will have its own market.

3. Availability of nutrients

To assess the availability of nutrients for the four biomass streams studied, and develop their sustainable use in the building industry, it is important to consider their environmental benefits and the hierarchy of their uses:

- **Straw** is a co-product of food production and is used primarily to meet the needs of livestock. Increasing the use of straw in the building sector will not lead to dedicated crops being grown for this purpose, and consequently will not increase the need for nutrients.
- **Hemp** requires no fertiliser or plant protection products, and its deep root system improves soil structure, leading to higher yields for the following crop. Hemp cultivation is part of a plot rotation system (a 5-year period must elapse between two crops of hemp), therefore it does not compete with food production.
- **Miscanthus** requires no fertiliser or plant protection products and is suitable for cultivation on difficult soils.
- **Flax** does not require much fertiliser, and part of the flax biomass that can be used in the building sector is flax shives, which are a co-product of flax production for the textile industry. Therefore, it is possible to develop its use in the building sector without using dedicated crops, and therefore without increasing the need for nutrients.

Nutrient needs and availability as well as environmental benefits are presented in the sections below.

3.1 Nutrient needs and availability for straw

Straw is a co-product of wheat growing. The nutrients used are primarily to boost wheat yields, not straw. This is one of the crops we have the most control over in terms of technical itineraries, as wheat has been grown in almost every region of France for a long time. Interventions vary according to the stage of development of the wheat:

- at tillering stage between December and February, herbicides can be used on wheat crops;
- between February and April for the growing period, fertilisation is applied (3 nitrogen inputs);
- fungicides (powdery mildew, foot rot, septoria, yellow rust, fusarium and brown rust) are used between February and June;
- growth regulators are used between March and April, and insecticides between May and June;
- the grain develops between July and August and is then harvested.

Nutritional needs vary according to the variety of wheat grown and the expected yields.

Nutrient needs for wheat

Biomass	Yield	N kg/ha	P_2O_5 kg/ha	P kg/ha	K_2O kg/ha	K kg/ha	SO_3 kg/ha	S kg/ha	MgO kg/ha	Mg kg/ha
Grain	80 q/ha	144	52	23	40	33	27	11	10	6
Straw	4 t/ha	26	7	3	50	41	5	2	3	2

This crop requires the use of inputs and treatments involving the use of plant protection products. Trials on the use of straw from organically grown cereals for construction were inconclusive in terms of quality. In fact, this straw contains more weeds, which are a constraint for this use. These weeds present a double risk as a potential source of moisture and possible food for pests or moulds.

Straw is sometimes used as a soil improver. It essentially contains potassium, followed by phosphorus, magnesium and calcium in lesser proportions. Straw provides approximately per tonne:

- Nitrogen (N): 7-7.5 units
- Phosphorus (P): 1-2 units
- Potassium (K): 12-14 units
- Magnesium (Mg): 1 unit
- Calcium oxide (CaO): 4-5 units

The nitrogen measured in the straw is not available to crops, as the straw even mobilises the residual nitrogen in the soil for its degradation. The nitrogen availability coefficient is therefore zero. Depending on the nature of the soil, it may be advisable to bury the straw, particularly for its potassium content. Straw is also sought after for the carbon (C/N around 100-120) it can bring back to the soil.

The importance of straw as a soil improver depends on the cropping systems in the area. Pure cereal growers need it to feed their soil, which is why they return straw to the soil. But the other cover crops returned to the soil can also compensate. The overall rotation practised on the farm can also vary this practice from one year to the next.

Withdrawing straw for use as a building material is therefore not an agronomic problem if it is compensated by other inputs. When properly integrated into a farming system with crop rotation, straw resources are available without the need to use mineral nitrogen to compensate.

3.2 Nutrient needs and availability for hemp

Growing hemp is simplified by the absence of disease and pests. Hemp has a high level of genotypic diversity. It doesn't require any plant protection products, thanks to its covering power. It's a "zero-phyto" crop. Hemp has the advantage of having a low nitrogen requirement, as the plant can fetch fertilisers on its own, thanks in particular to its deep roots, which also give it the advantage of requiring little water - which means the plant is highly resistant to drought.

Advantages of the hemp:

- absence of diseases and pests: a "zero-phyto" plant;
- low nitrogen requirement: 0 to 100 u/ha;
- deep roots: low water requirements (except for sowing) and well-tilled soils;
- covering power: no herbicides and clean soils.

Nevertheless, care must be taken at the sowing stage, which takes place from mid-April to early May, to give hemp every chance of developing properly. Hemp is a spring crop with a relatively short growing cycle (between 120 and 150 days). It fits in well with a diversified crop rotation based on autumn crops (hemp, wheat, spring barley/rapeseed, wheat, maize, hemp) and allows the soil to be freed up quickly. It can be planted in between crops cultivation and diversifies soils, leaving them clean and well-tilled for subsequent crops thanks to its taproot. Practical experience has shown that cereal yields after hemp were improved[80] .

Growing hemp absorbs 15 t of CO_2, the equivalent of one hectare of forest.

[80] Guide de culture du Chanvre - Terres Inovia - 2020 - www.terresinovia.fr

3.3 Nutrient needs and availability for miscanthus

Miscanthus plantations need weeding in the first year but are maintenance-free from the 2nd year onwards and can be grown for 20 years. It is planted in May. It can be removed at any time. It is harvested in March-April and can be stored in bulk. In the current state of French production, no diseases or pests are detrimental to it, and it requires little or no fertilisation[81].

Miscanthus provides many ecosystem services. Miscanthus cultivation offers catchment capacity in polluted areas and creates attractive wildlife cover, particularly for small game. It can therefore be planted in catchment areas or hunting grounds. The crop does not require any fertiliser and is particularly suitable for use in water catchment areas. Its dense root system improves soil structure and encourages infiltration, helping to combat run-off and erosion. It also acts as a nitrate filter and absorbs heavy metals. The permanent cover provided by miscanthus reduces the formation of gullies.

Finally, the high height of miscanthus provides an effective barrier to wind erosion while limiting the contamination of plant protection products by air. The higher the miscanthus planting density, the more effective the positive barrier effects. Planting strips of miscanthus between agricultural plots therefore helps to reduce the effects of erosion and soil degradation, particularly in arable farming areas. The cultivation of miscanthus is therefore seen as a necessary "no-treatment zone" between plots of land and homes, to act as a buffer zone to prevent plant protection products reaching people by air.

Miscanthus can be used in a variety of ways. Dual-use projects for miscanthus have already been set up in Alsace in certain counties where miscanthus is planted in highly polluted catchment areas and plays a role in regulating this pollution. At the same time, the miscanthus harvested each year is used to fuel a local boiler room that provides energy for the local authority.

3.4 Nutrient needs and availability for flax

Flax is a non-irrigated crop that follows a long crop rotation cycle (6-7 years), which increases crop biodiversity on farms and prevents the spread of disease. It acts as a carbon sink, retaining 3.7 tonnes of CO_2 per hectare[82]. Flax is fast-growing and can be grown in poor soils. It is also environmentally friendly, requiring little nitrogen input. The latest research by the Arvalis institute indicates a requirement of 12 kg of nitrogen/ha for the production of one tonne of unthreshed retted flax. Nitrogen is applied at sowing time.

Weeds should be controlled from the start of the flax cycle. Crop rotation and tillage mean that weeds can be controlled as little as possible. In this sense, flax is an agronomically interesting crop.

Finally, pest control is increasingly being achieved through products that use natural mechanisms to combat crop pests. Several biocontrol products are currently being tested and approved for use on flax by the Arvalis institute.

[81] Miscanthus cultivation technical sheet – Chamber of Agriculture of the Landes
[82] Source : Terre de Lin.

4. The relevance of fibre plants to enhance sustainability in the building sector

4.1. The assets of straw

A local production

Given that cereals are grown throughout the Atlantic Arc, straw is supplied regionally and even at local scale, therefore it does not require important transport - and therefore carbon emissions. According to Luc Floissac[83], 50% of straw supplies come from a source less than 10 km away, 40% between 10 and 50 km and 10% more than 50 km away. However, this figure needs to be put into perspective. Self-builders are still very active in straw construction, but with the development of straw construction by companies and craftsmen, supply distances are likely to be greater. Nevertheless, supplies are expected to remain mainly regional, as transport costs are an important factor in the profitability of straw-based construction.

Recognised professional standards

Straw as a bio-based material for the building market has been organised for several years to ensure its development. For over 10 years, professionals have been publishing professional rules for building with straw. This regulatory framework has enabled straw to gain recognition from the building industry and insurers alike. The ten-year construction guarantee is therefore guaranteed for all straw construction.

A ”carbon sink” material

When straw is used as a soil improver, 85% of the carbon is released into the atmosphere in the form of CO_2. If it is used as a bio-based material in building, the CO_2 captured during the farming process will be stored in the building throughout its lifespan. Straw has a reference lifespan of 50 years, even if older straw buildings exist and show no signs of deterioration. This temporary storage of CO_2 can be quantified in the Life Cycle Assessment (LCA) of straw as being beneficial for the climate[84] since this CO_2 does not end up in the atmosphere. The use of straw is therefore one of the possible ways of reducing CO_2 and does not contribute to the greenhouse effect. The calculation proposed to assess the reduction in CO_2 emissions is based on the quantity of carbon biomass contained in the product and its lifespan. For an average lifespan of 50 years, the reduction[85] is of -14 kg CO_2 equivalent/m² (Fiche de Déclaration Environnementale et Sanitaire (FDES) – Environmental and Health Declaration Sheet)[86]. An FDES is a standardised document that presents the results of a product's LCA as well as health information with a view to calculating the building's environmental and health performance for its sustainable design. It is valid for 5 years.

This lower carbon impact should be seen in the context of the replacement of 'conventional' insulation materials, such as glass or rock wool, which have a high carbon impact. Furthermore, its high-performance insulating properties mean that it saves energy in terms of the buidling’s consumption and therefore reduces CO_2 emissions.

[83] Luc Floissac, La construction en paille, collection *Techniques de PRO*, terre vivante, 2012.
[84] G. DEROUBAIX et al, *Cycles de vie des produits à base de bois et séquestration du carbone*, FCBA, 2012.
[85] Source RFCP (Réseau Français de la Construction Paille) - 2019: https://rfcp.fr/wp-content/uploads/2019/10/Livret-vert.pdf
[86] Source RFCP - FDES collective - July 2022 - verified by INIES. INIES is the national reference database for environmental and health data on construction products and equipment**.** INIES provides Environmental and Health Declaration Sheets: https://www.inies.fr/

Little or no processing

The straw used for construction requires little processing before use. The only constraint on construction is the size of the straw bale. Otherwise, it can be used as is. Straw is the insulation material that requires the least grey energy[87].

Other qualities of straw

These environmental properties are in addition to its thermal insulation and soundproofing qualities, which promote healthy indoor air quality.

The end-of-life of straw insulation material

During deconstruction, the straw can be easily dismantled and separated from the other elements. There are two possible end-of-life options:

- **Composting**: straw is a natural material that can easily be composted in a suitable centre.
- **Recycling**: straw can also be recycled as a soil improver by farmers.

[87] Grey energy, or embodied energy, is the quantity of energy consumed during the life cycle of a material or product: production, extraction, transformation, manufacture, transport, use, maintenance and finally recycling, with the notable exception of use.

4.2. The assets of hemp

Hemp can be used in many different ways in the building sector:

- Hemp concrete or hemp mortar[88] is made from hemp chips and combined with a mineral binder (lime) and water.
- Hemp wool is used to insulate attics, partitions and floors.
- Hemp felt is made from hemp fibres impregnated with sodium carbonate. It is used to insulate floors, partitions and wooden structures.
- Hemp can also be used to complement other materials such as wood. Hemp concrete can be used to protect a timber frame thanks to its fire-retardant properties.

Hemp-based materials offer a number of advantages:

- As a building material, hemp offers excellent thermal insulation both in winter and in summer.
- In terms of sound insulation, it acts as a sound absorber, reducing ambient noise.
- Combined with the breathable properties of the walls, the natural ventilation provided by hemp regulates humidity by maintaining an optimum hygrometry level in the house. It absorbs excess humidity in the air and releases it when the air is too dry.
- It also offers good fire resistance. Tests have shown that after 3 hours and 30 minutes at temperatures in excess of 1100°C, the unexposed side does not exceed 90°C.
- Hemp cultivation requires less water and pesticides than other traditional building materials, making it an attractive option from an environmental point of view. And because the plant is grown without pesticides, it emits no VOCs (volatile organic compounds).
- Economically, hemp-based materials are currently more expensive on the market. But in practice, a study by Cérema has shown that the thermal performance of hemp concrete can save up to 70% on heating costs.

[88] The difference lies mainly in the use: hemp concretes are used for all applications (roofs, walls and floors), while mortars are used for rendering.

4.3. The assets of miscanthus

A recent study carried out by Nobatek in the New-Aquitaine region explored the potential of miscanthus as a lightweight earth construction material, and compared it with the conventional materials: chenevotte and wheat straw. The raw materials tested were as follows:

- For hemp: hemp shives prepared for hemp concrete.
- For miscanthus: ground miscanthus for agricultural mulching, undusted.
- For straw: shredded material for rodent bedding, long fibres (5, 10 cm).
- The mixtures made in constant mass proportion are as follows: fibre 21%, soil 35%, water 44%.

BIOMASS	HEMP SHIVES	MISCANTHUS	STRAW
Pictures			
Handling	Excellent Good wrap Non-elastic material Fibre length < 1cm Easy moulding	Medium Medium wrap Non-elastic material Fibre length 1-3 cm Medium moulding	Low Difficult to wrap (silica) Highly elastic material Fibre length 3-10 cm Difficult moulding (size of fibres, elasticity)
Fibre density	150 kg/m³	190 kg/m³	135 kg/m³
Dry consistency	Excellent Very clean material	Medium Dust seems to affect cohesion	Good Adhesion that seems to fail when wet is resolved when dry
Compression	Compressible materials. There is no breaking strength; the material becomes denser as a function of the force applied. Straw is also highly elastic.		
Thermal conductivity λ = the capacity of a material to conduct heat: for the same thickness of insulation, the lower the λ, the greater its thermal resistance and the better its performance.	= 0.090 W/m².K λ	= 0.067 W/m².K λ	= 0.061 W/m².K
Ways to improve	Already optimised	Dust removal Finer grinding Sorting Defibration	Shorter calibrated cut Press drying

Source: NOBATEK, Exploratory study on plant fibres for lightweight earth, M.LOUVARD, May 2023.

These comparative tests show that there are good opportunities for using miscanthus in bio-based construction materials, but there is still progress to be made in processing the raw material, particularly in dust removal, grinding and defibration. the lack of professional rules for miscanthus building materials is also an obstacle.

4.4 The assets of flax

Particleboard[89]

Flax shives are used in the manufacture of agglomerated particleboard because of their low density (120 kg/m3 unpacked) due to their honeycomb structure. In this application, shives provide materials with:

- high fire-retardant properties: this unique characteristic means that flax panel is used as a major component in fire doors. Even though it is lighter than particleboard, it has better fire-retardant qualities.
- good sound insulation: this property is particularly interesting for the manufacture of doors and partitions.
- flexibility and high resistance to torsion: because flax shives are lighter and longer (between 10 and 20 mm long, with a cross-section of around 2 mm) than wood fibres, flax panels are more flexible and more resistant to torsion than traditional particleboard.

In Normandy, stakeholders are looking to make the most of by-products such as flax shives, and work is underway on the insurability of flax-based materials.

[89] Source: sanopan.com – society De sutter.

5. Development forecasts for bio-based materials in building

The "*technical plant fibres in materials*" market overview assessed the volumes produced by origin of plant fibres in France in 2017:

Bio-based product	Origin	Volume produced
Flexible insulation	Hemp, flax and rice straw	7,200 t/year
Filler insulation	Cereal straw	4,600 t/year
Plant-based concrete	Hemp straw (mainly), flax straw or rape straw	40,000 t/year

These volumes have increased - the market study estimated in 2017 that biobased insulation would see annual market growth of 10% by 2025/2035, thanks in particular to the incentive regulations introduced by the French government.

In this report makes an attempt to evaluate the volumes potentially produced in 2022 and the development forecasts for the 4 regions of the Atlantic Arc, sector by sector, since the dynamics are not the same from one sector to another.

5.1 The current market for straw-bale construction

© Chamber of agriculture of Marne

Straw construction can be used for all types of building, from detached houses to multi-storey buildings and industrial or commercial buildings.

Around 6,000 buildings are constructed in France using straw, and 500 new constructions are recorded every year[90], representing a steady increase of 8% in the number of buildings. The French sector is the most dynamic in Europe.

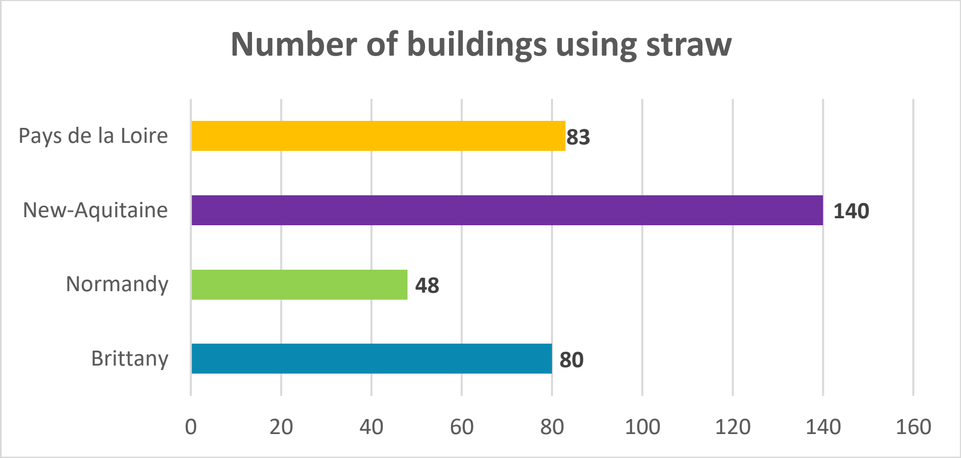
The development of straw-bale construction depends to a large extent on the presence of agricultural businesses that can supply straw and craftsmen who have mastered construction techniques.

The professional rules for straw construction introduced by the RFCP[91] in 2012 have led to recognition of the straw sector in the construction industry. They serve as a basis for passing on the

[90] RFCP Green Paper - 2019
[91] https://www.rfcp.fr/les-regles-professionnelles/

technical know-how of straw construction to professionals through pro-straw training courses that guarantee access to standard insurance scales.

In the Atlantic Arc region, 351 buildings have been constructed using straw[92] according to the straw construction panorama.



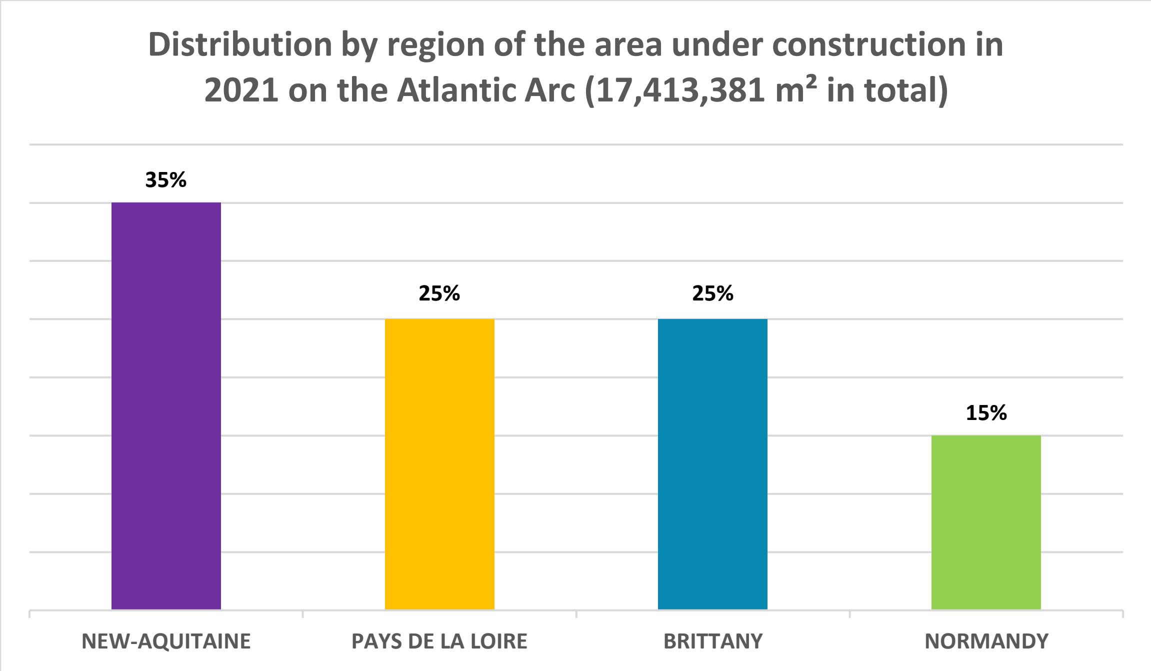
Building with straw is originally a militant and individual initiative, but the interest of local public authorities is growing as they look for sustainable options in public procurement for new buildings. are beginning to be sensitive to the issue of sustainable development in the construction of their buildings and are opting for sustainable building. For the moment, mainly schools are being built using straw. Public procurement is a real accelerator in the development of construction using bio-based materials.

High school of Aizenay in Vendée (Pays de la Loire, France) built with wood and straw insulation - © Regional Council of the Pays de la Loire

Other sectors are clearly keen to develop construction using bio-based materials. In Normandy, the Union sociale pour l'Habitat (Social Union for Housing) has set its target to build all its new projects using bio-based materials by 2025/2026. Straw is one of the materials chosen to meet this target.

[92] Source : http://www.constructionpaille.fr/panorama/

The availability of straw in the Atlantic Arc should be compared with potential construction needs. According to Sitadel[93] in 2021, 110,000 homes are under construction in the French Atlantic Arc. If we add other buildings, we arrive at 17,413,381 m² under construction.



The average straw requirement for insulation varies depending on the building: a 100 m² house requires around 6 to 9 tonnes of straw, while non-residential buildings require around 20 kg per m² [94]. Housing accounts for 55% of the surface area under construction and other buildings for 45% in the Atlantic Arc. Based on 2021 data, it is possible to compare the surface areas under construction with the quantities of straw needed for straw insulation.

93 https://www.statistiques.developpement-durable.gouv.fr/

94 Source: Céréma and Collectif Paille Armoricain

The table below shows the data for each type of building, and therefore the theoretical straw needs for building in 2021.

Type of building under construction	Homes	Non-residential buildings
Quantity of straw required in T/m².	0,09	0,02
Surface area under construction in m² in 2021	9,812,600	7,600,781
Tonnage of straw required for 100% of buildings constructed with straw (TMS)[95]	883,134 t	152,016
Tonnage of straw required for 10% straw buildings (TMS)	88,313	15,202
Tonnage of straw required for 1% straw buildings (TMS)	8,831	1,520

For 1% of homes built with straw, 8,831 tonnes of straw are needed. This corresponds to the 2,944 ha of wheat needed to supply this tonnage. This figure should be compared with the 2 million 300 ha sown in 2021, therefore 0.1% of the land area.

Currently, according to RFCP data, the annual increase in the number of straw buildings is 8%, which for the Atlantic Arc represents **29 more buildings per year**, including 23 homes. Assuming a house surface area of 100 m², around **270 tonnes of straw** would have been used for housing construction in 2021. This represents only 90 ha for the whole of the Atlantic Arc.

These figures are expected to rise as a consequence of new regulations, interest from social housing stakeholders and straw-based construction innovations led by local stakeholders.

Even though, overall, the four regions of the Atlantic Arc have a straw deficit (estimating a return to the soil at 25% of the volumes of straw produced), the tonnages of straw required appear low in relation to the tonnage of straw harvested in the regions.

© Chamber of agriculture of Hautes-Alpes

[95] TMS: tonne of dry matter

Furthermore, the uses of straw in the building sector are likely to rise and diversify as a consequence of agricultural developments, and in particular the sharp fall in cattle numbers. National beef production fell by 7.3% between 2021 and 2022, and forecasts are even lower for 2023. In some regions of the Atlantic Arc, the decline in livestock numbers is very sharp, and has been a trend for more than 10 years: in New Aquitaine, between 2010 and 2020, livestock numbers - all categories combined - fell by 12%.

REGION	NEW-AQUITAINE	PAYS DE LA LOIRE	BRITTANY	NORMANDY
Number of LUs - 2010/2020	- 12,2 %	- 4,7 %	- 5,5 %	- 6 %

This decline has two consequences: a reduced need for straw for bedding, and an increase in the area under crops that can be sown to cereals and therefore provide straw. However, this increase remains limited to 2% more cereal surface area over the same period (2010/2020)[96].

[96] Source: RGA 2010 & 2020

5.2 Development forecasts for miscanthus in the building market

The development forecasts for plant-based solutions in the building sector offer further opportunities for miscanthus. At present, although miscanthus is used in a variety of ways in the building industry, it is only used as a filling material and not as a load-bearing element. For miscanthus as for the other fibre plants, there are currently two opposing market strategies: "low tech" processes and semi-industrial processes. Some stakeholders opt for the low-tech process, which takes longer to install but is more attractively priced because the agricultural material undergoes little processing, while others prefer blocks or panels, which are more processed products that are expensive but easier to transport and install. The development forecasts for miscanthus are still at the experimental stage and are therefore difficult to quantify. The construction market is assumed to account for 10% of miscanthus markets.

5.3 Development forecasts for hemp in the building market

Hemp has great potential for development in the building market, thanks to its ecological properties and its advantages in terms of sustainability. But demand for hemp is also evolving positively, driven by regulatory changes in the construction sector. Above all, the dynamism of the industry's stakeholders is significantly boosting its development forecasts.

In the Atlantic Arc, the CAVAC cooperative group in Vendée is the biggest actor, both collecting and processing hemp. The cooperative collects 14,000 tonnes of hemp straw from its members, which is then defibred and processed into insulating panels at its CAVAC biomatériaux subsidiary. CAVAC biomatériaux is building a new plant in 2023, with the aim of tripling the area planted with hemp by 2025, from 2,000 ha to 6,000 ha, to meet the demand. In Pays de la Loire, there are two other producers' associations: Chanvre Paysans, which tends to work in short circuits, and the association of hemp producers in Sarthe, whose producers now supply CAVAC. There are no hemp mills in Brittany. However, there are producer associations such as "Lin et Chanvre en Bretagne" and "Bretagne Chanvre Développement". There are no hemp growers in New-Aquitaine either. Associations of hemp producers, "Lo Sanabao" and "Chanvre Mellois", tend to work in short circuits. Their markets are essentially self-builders and/or a network of trained local craftsmen. « Les Chanvres de l'Atlantique », located in Geours de Maremme (Landes), mainly processes hemp seed.

In Normandy, from 2008 to 2019, an average of 40 Normandy producers have been growing hemp every year on 350 ha, mainly for Agrochanvre in Barenton. Agrochanvre also collects hemp from neighbouring regions, for a total of 600 ha and 2,500 tonnes of straw per year[97]. In the same time, the textile industry is developing in Normandy, which will put several thousand tonnes of chenevotte on the market. This could destabilise existing industries: as this chenevotte is a waste product for the textile flax industry, it is likely to be sold at a lower price than hemp fibre.

Nevertheless, the development forecasts for hemp in the construction industry are promising. Taking into account the ambitions of existing stakeholders, the area under hemp should increase from **4,668 ha to 8,800 ha** by 2025, giving a theoretical production available for construction of 13,500 T, broken down into 8,700 T for hemp concrete and 4,800 T for insulation.

[97] Source : Regional Chamber of Agriculture of Normandy.

5.4 Development forecasts for flax use in the building market

Currently, the use of flax in buildings in mainly from short fibre, up to an amount of 11,000 tonnes in 2020, only produced in Normandy. The production of bricks made from flax shives is a market being explored by a number of French manufacturers, including the cooperative Depestele in Normandy. Research is ongoing on concrete block from flax shives. The first is a load-bearing block made from cement, sand, lime, shives and water. It has the same function as a conventional breeze block, but also provides initial insulation. The second insulating block is made from shives, lime, water and additives to reduce the drying time.

No matter what the harvesting conditions, the woody residues of the plant have a certain stability, unlike fibre. Flax is used in the same way as traditional insulation materials. However, it has a much greater heat storage capacity. It takes four times longer for heat to penetrate flax insulation. Flax shives are also excellent sound insulators. The qualities of flax shives are recognised by construction professionals, but the value of this material remains low and is currently a niche market because of the absence of professional rules (and therefore of insurance).

In this report, to assess development forecasts of flax for bio-based building, we chose to keep only the tonnage of short flax fibre used in Normandy (11,000 tonnes). It is the only region producing these fibres in the Atlantic Arc.

5.5 Summary

In the Atlantic Arc, the theoretical volumes of biobased materials produced in 2022 were initially calculated on the basis of the agricultural areas planted and declared to the CAP and the theoretical average yields per crop.

Then, based on the tonnages of fibre plants available, we estimated the proportion potentially used in construction using theoretical percentages.

Theoretical use of biomass produced in 2022	Straw	Hemp	Miscanthus	Flax fibre
UAA planted	2,290,791 ha	4,668 ha	4,867 ha	75,165 ha
Tonne of dry matter theoretically harvested	6,383,000 t	32,676 t	61,957 t	578,770 t
Use in building	270 t	6,711 t	6,200 t	11,000 t

These tonnages are relatively low compared with the conventional materials used in construction. We are still in a niche market. Biobased materials account for 10% of the construction market, and are mainly wood-based.

5.6 Growth assumptions for the bio-based building market

Driven by the RE2020 regulations, the bio-based materials market is enjoying sustained growth of around 10% a year. Industry professionals estimate that demand will double between now and 2025, driven by the new rules, but also by the massification of supply, which makes these materials more accessible. We have chosen three working assumptions*:*

- Assumption 1: Current growth: 10%.
- Assumption 2: medium progression: 25%.
- Assumption 3: strong growth: 50%.

Estimated volume produced in France based on the 3 assumptions:

Type of bio-based materials	Volume produced in 2017	Estimated volume in 2023	Volume in 2025 Assumption 1 + 10 %	Volume in 2025 Assumption 2 + 25 %
Flexible insulation (hemp straw, flax and rice)	7,200 t/year	7,493 t/year	8,242 t/year	9,366 t/year
Filling insulation (cereal straw)	4,600 t/year	4,787 t/year	5,266 t/year	5,984 t/year
Plant-based concrete (hemp, flax or rapeseed)	40,000 t/year	41,626 t/year	45,789 t/year	52,033 t/year

By applying these assumptions to the Atlantic Arc data, we obtain the data listed in the table below, according to biomass. This projection is applied in a linear pattern whatever the feedstock, even if the dynamics are not the same for miscanthus and flax.

Availability of biomass for construction	Straw	Hemp	Miscanthus	Flax
Assumed tonnage for 2022	270 t	6,711 t	6,200 t	11,000 t
Surface area	90 ha	4 392 ha	477 ha	1,570 ha
For construction: **+10**	297 t	7,382 t	6,820 t	12,100 t
Equivalent UAA required	99 ha	4,831 ha	525 ha	1,727 ha
For construction: **+25**	338 t	8,389 t	7,750 t	13,750 t
Equivalent UAA required	113 ha	5,490 ha	596 ha	1,963 ha
For construction: **+50**	405 t	10,067 t	9,300 t	16,500 t
Equivalent UAA required	135 ha	6,588 ha	716 ha	2,355 ha

This projection is applied in a similar way for all the biomass streams, but it will not apply in the same way depending on the organisation of the sector, the region - some stakeholders being more ambitious - and whether it is a co-product or a dedicated plant.

6. Conclusions and recommendations

6.1 Conclusions

The aim of this study is to gain a better understanding of the biomass available on the market for bio-based building materials. The aim is also to verify whether this market represents an opportunity for agriculture or whether, on the contrary, it competes with other markets for agricultural production, particularly for human consumption.

The use of bio-based materials in the building industry is clearly on the increase, if not exponential. There are a number of reasons for this, not least the regulatory context, with the effective application of the RE 2020 directive in the building sector and the regulation on zero carbon emissions by 2050. Bio-based materials from fibre plants have very interesting physical properties, particularly with regard to thermal heat, guaranteeing recognised comfort and resistance. Certain regions are also developing “wood-bio-based materials pacts” (Pactes bois-biosourcés) to facilitate the development of the use of these materials. The presence in the regions of stakeholders involved in a dynamic industry - from production to the marketing of finished products - both locally and on the regional or even national market, is also an asset for the development of this market.

However, the advantages of these materials are hampered by a highly restrictive regulatory framework in terms of insurance, with the principle of "one material, one use, one standard". Even though certain sectors, and straw in particular, have developed professional rules that are now recognised, this is one of the main obstacles to the development of bio-based materials.

Other blocking factors include a lack of knowledge about these materials on the part of professionals and the general public. Economic factors (high prices) and regulatory factors (building insurance criteria, standardisation of materials) are slowing down the development of bio-based products and providing little incentive for innovation.

Uneven capacities across the Atlantic Arc

The first lesson to be learned from this biomass study is the wide disparity in availability between the regions of the Atlantic Arc. This territorial disparity is linked to the presence of stakeholders with processing and distribution facilities in the regions concerned. Straw is the more evenly distributed fibre plant across the Atlantic Arc.

Normandy is a leader in fibre flax production, particularly for textiles, while also having a strong presence in hemp. The production is boosted by the strong presence of flax-scutching companies and flax mills. Textiles dominate the market, but the recycling of flax co-products is making strong progress, with a direct impact on bio-based materials for the building sector. The company Agrochanvre promotes hemp production in the region and neighbouring departments through sourcing with local producers. There are currently no downstream stakeholders in the region offering straw, but this is one of SCALE-UP project’s objectives with the support of the solution “Atelier du biosourcé” in Normandy, which aims at setting up a place to gather bio-based building solutions and promote their use for building, including straw-based solutions.

Pays de la Loire is the leading region for hemp production in the Atlantic Arc. In contrast, Brittany, historically a land of flax and hemp, will have few areas planted with flax, hemp and miscanthus by 2022. The same is true of New Aquitaine, despite its size. The CAVAC cooperative invested in hemp processing and the production of bio-based building materials 15 years ago. This explains the growing presence of hemp surfaces in the region. There are also two associations of hemp producers who are more focused on selling through short distribution channels. Straw stakeholders are also well represented in Pays de la Loire: Profibre (linked to CAVAC since 2022), Isol'En Paille, and soon COPANO (the second selected innovator in our region), which is working on an innovative straw panel solution.

In New-Aquitaine, there are no industrial stakeholders in the manufacture of bio-based materials. Instead, there are organisations of farmers working in short circuits, such as Chanvre Mellois. The New-Aquitaine region is supporting the development of very localised industries in rural areas, with a focus on experimentation and links upstream and downstream in the industry. In this way, the preliminary study of markets and the upstream testing of products enable hemp to be grown by groups of farmers.

*"*SCIC IELO paille*"* is a cooperative that promotes short circuits and the local economy. Based in the Vienne region of France, its aim is to develop this straw production throughout France, while maintaining strong ethical values by working with the local economy. It promotes a spreading model that aims to bringing production closer to where projects are built. The stated aim is that "chopped straw should not be transported more than 250 km from the wheat production field to the carpenter's workshop or the building site where it will be used".

Uneven availability of resources

Straw is widely distributed throughout the Atlantic Arc and can therefore be used directly without the need for extensive logistics. This resource has a number of technical qualities and assets that make it available to meet the sustainable building objectives of the RE 2020. It can be used immediately: being a by-product of cereal production, it does not require any changes to the crop rotation or the acquisition of technical production know-how. Farmers already grow cereals and have a good command of the crop. There remains, however, a real fear on the production side that the straw construction sector will compete with the need for straw for the animal sector or for returning to the soil. The quantities of straw needed for construction are small in relation to production and do not seem capable of destabilising the livestock market. Furthermore, the structural trend towards a decline in livestock farming, combined with an increase in the area under cereal crops, means that there is likely to be greater availability of the resource without destabilising other agricultural production. A certain vigilance is however needed due to climate change, as weather conditions can make straw rare in certain seasons - as is the case for the 2024 harvest, where heavy autumn rain delayed or even prevented winter cereal sowing. This vigilance is not the only obstacle to the development of straw. Just as there must be a market potential and a commitment on the part of professional craftsmen, the prescription of public contracts and the training of professionals are all levers that will enable the straw market to develop.

Regarding **miscanthus***,* Marie Rondin's recent study "*On the trail of a new sector in the building industry: miscanthus*" shows the real opportunities for miscanthus in the construction industry. Miscanthus is a perennial crop whose biomass, once processed, offers excellent insulation and strength properties. With a 20-year production life, low water consumption and no need for phytosanitary treatment during the growing phase, this crop is becoming established in France, particularly in the Atlantic Arc regions, where it is growing rapidly. The miscanthus is a plant that can easily be established in areas where environmental issues are at stake (for instance polluted soils), and can be used to diversify conventional production. Construction and the supply of bio-based materials from miscanthus is a very interesting area for development because miscanthus can be planted in all types of lands, enabling local supplies with a low carbon footprint.

Hemp is developing rapidly in the Atlantic Arc, with an assured increase in the area under cultivation this year. However, this easy-to-produce plant has experienced difficulties, mainly due to unstable markets and a complex harvest. This is making some growers more cautious, as they need to be sure of a market to sell their production. This type of production also requires all the by-products - including dust - to be used if it is to be profitable.

Flax: Flax is mainly grown for the textile industry, which is very demanding and profitable for the sector. This situation does not encourage the development of flax shives, which are used for construction. There are operators in the Normandy and Hauts de France regions. Production is highly concentrated, which could encourage the massification of resources around co-products (shives and tow).

6.2 Recommendations

Increasing the number of these fibre plants is of both environmental and agronomic interest, with development forecasts for crop diversity and markets for farms in the Atlantic Arc. This development will depend on several factors that are worth working on:

- **Developing demand, in particular by mobilising stakeholders**

It is important to provide a political framework and to motivate regional elected representatives and agricultural leaders. Synergies could make it possible to mobilise existing economic stakeholders, in particular the cooperatives with a strong presence in Brittany and New Aquitaine. The cooperative model is an asset that can reassure producers. The development of demand will also require the removal of a barrier to the use of bio-based materials, among which the price, which is still too high. It is by mass-processing, linked to the industrialisation of the supply, that economies of scale will be achieved to bring competitive prices to the market.

To ensure that the use of biobased materials by building professionals really takes off, awareness-raising campaigns can be used to reach craftsmen and companies who are not part of the biobased materials network. The regional bio-based materials associations (FB², ARPE, Collectif biosourcés Pays de la Loire and ODEYS) are make significant efforts to demystify and educate the public about the use of all bio-based materials, with numerous conferences and tools: directories of professionals, a call for expressions of interest to help local authorities move towards biobased construction, and so on. Similarly, the national industry associations are heavily involved, offering a wide range of tools to promote the use of biobased materials (training courses for professionals, purchasing guide for public procurement).

As a complement to these actions, the SCALE-UP project can extend this influence on a small scale by supporting the two winning companies in the SCALE UP project in cooperation with craft unions and local structures.

The actions of the public authorities, and in particular of the 4 regions which have all adopted a regional plan in favour of the bioeconomy, are important. It is regrettable, however, that under national subsidies such as Ma Prim'Rénov, additional subsidies are not granted for the use of bio-sourced materials.

- **Adapting the offer**

The straw industry is innovating in terms of the type of straw packaging available. At present, straw is used in the form of 36 or 22 cm bales, but other products are emerging, such as blown straw developed by IELO Paille and straw panels designed by COPANO. It is these innovative techniques that the SCALE-UP project can support in developing the use of straw in construction in Pays de la Loire, with the support of COPANO, and in Normandy, with the setting up of the "Atelier du biosourcé" (bio-based workshop). These new forms of packaging mean that straw can be used in a wider range of ways, particularly for renovation.

The miscanthus sector needs to be structured more around sustainable materials, and links with the straw and hemp sectors seem necessary for exchanges on the technical nature of materials, their uses and markets. Hemp and flax have already entered an industrial transformation process, but there is still room for innovation in terms of processes, end-products, etc.

➢ **Securing farm supply**

The development of local supply chains will inevitably come from downstream and from a precise demand in terms of volume, price and with a production contract to which farms are committed. Farms need to be reassured.

These fibre plants have a number of advantages: they diversify crop rotation, are inexpensive to produce, can adapt to climate change, have low water requirements, and for certain crops and certain areas can be the basis for PES (Payment for Environmental Services) contracts.

However, it is important to study precisely how much land should be planted on each farm to avoid over-specialisation, a return to monoculture or too much substitution for food crops. It is up to each region to strike the right balance between the potential for food production and soil diversification. The bioeconomy approach makes it possible to develop innovative sectors that make sense for the local economy while preserving the environment.

The study shows that the market economy governs the development of these sectors: it is demand that will develop the supply of production and not the other way round. Farmers are interested in these products as soon as they are assured of an outlet.

➢ **Massification of the supply of bio-based products to be competitive**

The sector has a challenge to seize: a commitment to production purchase prices that is compatible with a guaranteed income for farms, while guaranteeing an attractive price on the materials market: this challenge involves massifying the supply and therefore reducing processing costs.

It is also possible to work on models for pooling processing and logistics tools to amortise collection costs and invest in relevant collective tools that will enable development to be stepped up on a local scale while achieving economies of scale.

Not all sectors will be affected. Straw does not undergo a major industrialisation process. It is part of a local development rationale for local markets, even if the raw product is easily transportable.

➢ **Creating links between producers, building professionals, local players, users and specifiers**

Public funding is also an important factor, and the networking of relevant stakeholders in the value chain ensures that the initiatives undertaken are sustainable.

The development of these sectors, which have the common characteristic of being firmly rooted in local areas, is an asset for agriculture and the development of rural areas. These plants also have environmental assets that make them attractive for the sustainable building industry.

References

All references used in this report are available in the SCALE-UP deliverable T2.4 “Information package” available online: https://www.scaleup-bioeconomy.eu/.

Regional Biomass and Nutrient Availabilities in Andalusia, Spain

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Abbreviations

A	Andújar
AR	Ash Rejection
CC	Cover Crop
CEC	Cation Exchangeable Capacity
COMP	Composted
EOP	Extracted olive pomace
Ha	Hectare
km	kilometres
ktoe	Thousand tonnes of oil equivalent
Mha	Megahectare
MJ	Megajoule
MSW	Municipal Solid Waste
Mt yr-1	Metric Tonne Per Year
MW	Megawatt
NCOMP	Not Composted
O	Olvera
OL	Olive leaves
OM	Olive Mill
OMWW	Oil mill wastewater
OTP	Olive tree pruning biomass
P	Phosphorus
R	Reja
SA	Stables Aggregates
t	Tonne
T	Tobazo
TC	Total C
TN	Total N
toe	Tonne of oil equivalent
WHC	Water Holding Capacity

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1 Regional biomass and nutrient availabilities in Andalusia

1.1 Introduction

1.1.1 Background

Andalusia is a region located in the southwest of Europe with an area of more than 87,000 km² (ca. 9Mha) and 940 km of coastal area. The agricultural area represents about 4.4 Mha and the forestry area is about 4.6 Mha. This makes it the fourth-largest region in the European Union in terms of surface area and the most populated region in Spain, with some 8,400,000 inhabitants. Andalusia has historically been an agricultural region, in comparison with the rest of Spain and the rest of Europe. The primary sector constitutes an important source of employment due to the link between people and environment, as 51% of the population lives in rural areas where resources are mainly produced.

With around 350,000 farmers (Dawson, 2022) and 5,400 agro-industrial businesses (S3P T&BD, s.f.), Andalusia ranks second in Europe for agricultural production, accounting for about 23% of all agri-food jobs in Spain.

In terms of agricultural biomass, there is substantial potential for biomass (extensive areas of olive groves, fruit, and vegetables in the region). Specifically, (CIRCE, 2016)*:*

- Considering only agriculture, biomass production reaches 8 million tons a year, highlighting sectors such as olive groves (29%), horticulture (18%), wheat straw (13%), and corn straw (5%).
- The biomass potential amounts to 3,955 ktoe[98], of which 1,322 is agricultural waste, 77 ktoe is livestock waste,1,023 industrial waste, 322 forestry waste, 620 ktoe from energy crops and 591 ktoe is from urban waste.
- Other interesting waste streams include paper and pulp, sewage sludge, plastics, and MSW (waste).
- Horticultural and forestry waste streams have less sophisticated conversion alternatives available in Andalusia.

Olive farming is mostly found in the Mediterranean basin, and it adds significant socioeconomic benefit to the communities where it is cultivated. Andalusia is leader in the sector (Caracterización del sector agrario y pesquero de Andalucía., 2022)*:*

- Area: 1.64 million hectares in 2022 (60% of the national area, 32% of the EU area, and 13% of the world area). Between 2018 and 2022 it has increased by 2.7%.
- Holdings: 165,431 holdings where the predominant crop is olive groves.
- Production: 6.56 million tonnes of olives (2020/21). Between the 2016/17 and 2020/21 campaigns, production has increased by 13.7%.

[98] ktoe: 1 ktoe = 1000 toe. Toe: Tonne(s) of oil equivalent, is a normalized unit of energy. By convention, it represents the estimated quantity of energy that may be produced from one tonne of crude oil. It is a standardized unit with a net calorific value of 41,868 kilojoules/kg.

1.1.2 Scope

Spain is the world leader in surface area, manufacturing, and international commerce. Spanish olive oil production accounts for 70% of EU totals and 45% of global production (Blasco, 2023). The sector is not only of undeniable economic importance, but also has important social, environmental, and territorial implications. More than 350,000 farmers are engaged in olive growing, the sector supports some 15,000 jobs in the industry (Dawson, 2022).

Olive groves are grown in 15 of the 17 autonomous communities. The surface area of olive groves in Spain is 2.75 million hectares, of which 2.55 million are used for oil mills (93% of the total olive groves), with Andalusia producing the most, with 1.67 million hectares. (The olive tree: Spain's treasure, 2022).

Table 1 shows the distribution of the olive grove area in Andalusia in 2022:

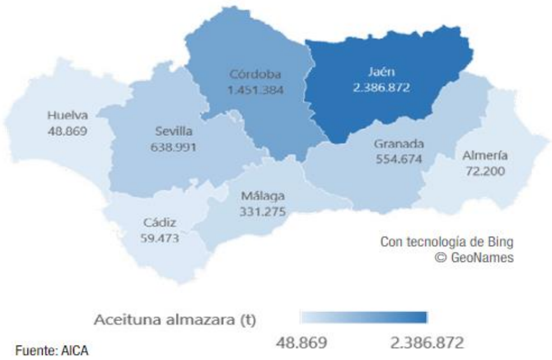
Table 1: Distribution of olive grove area in Andalusia *(Caracterización del sector agrario y pesquero de Andalucía., 2022)*.

Province	Surface (Ha)	%
Jaen	582,114	35.5
Cordoba	374,703	22.9
Seville	255,610	15.6
Granada	200,089	12.2
Malaga	140,084	8.5
Huelva	34,362	2.1
Cadiz	33,402	2.0
Almeria	19,262	1.2
Andalusia	1,639,627	100.0

According to data from the 2020/2021 campaign, Andalusia produced 6.56 million tonnes of olives, with 42.3% harvested in the province of Jaen, 24.8% in Cordoba, and 14.8% in Seville. Between the 2016/17 and 2020/21 campaigns, the percentage of production devoted to olives for oil mills averaged 92.6%, while that dedicated to olives for table consumption was 7.4%. (Caracterización del sector agrario y pesquero de Andalucía., 2022)

The following image shows the provincial distribution of the average production (t) of olives from oil mill (image A) and table olives (image B) for the 2016/17 to 2020/21 campaigns.

A



B

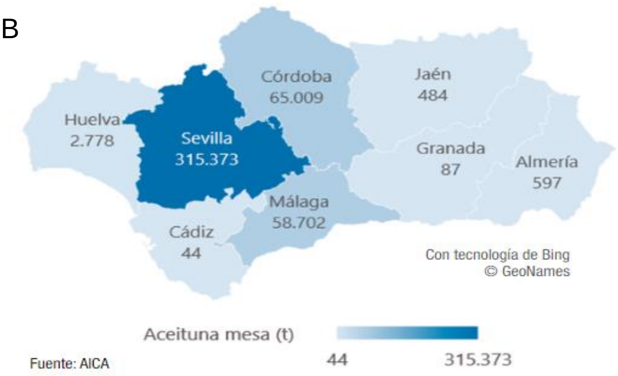


Figure 1: Average production of olives for oil mill and table olives (2016/17-2020/21) *(Caracterización del sector agrario y pesquero de Andalucía., 2022)*.

The total value of olive oil and olive production amounted to 3,468 million euros in Andalusia in 2021, of which 2,212 million euros (63.8%) corresponded to olive oil, while the remaining 1,256 million euros (36.2%) were olives. Olives include table olives (11.3%) and mill olives processed by industries (24.9%) (Caracterización del sector agrario y pesquero de Andalucía., 2022).

Systems of olive cultivation:

There are 3 main systems of olive cultivation:

- Traditional: traditional olive groves consist of spaced rows of huge, centuries-old olive trees, which are mainly established on steep slopes where it is difficult to mechanise the work. This type of agriculture has a major drawback in that productivity is typically limited due to the low number of olive trees per hectare. On the other hand, traditionally, harvesting is done by hand, a model that is changing as the rural world becomes more professionalized.
- The intensive olive grove: this type of plantation allows an increase in the density of olive groves per hectare and practically all the tasks are mechanised. The yields improve considerably due to the use of irrigation systems and mechanised harvesting.
- Superintensive olive grove: the olive trees are arranged in the form of a hedge in this type of plantation. The superintensive olive grove has had an unprecedented increase in recent years because it allows a high level of mechanisation and rapid entry into production. However, this type of crop is highly dependent on the water conditions of the soil (if it is rainfed, production is considerably reduced).

Table 2 shows the different characteristics of the different production systems.

Table 2: Characteristics of different production systems in Spain *(Pérez, 2023)*.

Characteristics of different production systems.			
Type of olive grove	Density (olive trees/ha)	Area (%)	Production (kg olives/ha)
Traditional	< 140	51	7 000
Intensive	141-1000	46	10 000
Superintensive	>1001	3	12 000

The most common production systems in Spain are traditional (51%), followed by intensive (46%). Intensive systems require a higher initial investment since the number of trees per hectare is higher than in traditional systems. However, intensification makes it possible to increase productivity while lowering unit production costs, resulting in a shorter payback period: 7 years in superintensive versus 13 years in traditional plantations (Pérez, 2023).

Specifically, in Andalusia, 81.3% of the olive grove area is classified as traditional, 13.6% as intensive, and 2.5% as superintensive based on planting density. The following figure (Figure 2) compares the trend of the different production systems in Spain and in Andalusia (Caracterización del sector agrario y pesquero de Andalucía., 2022).

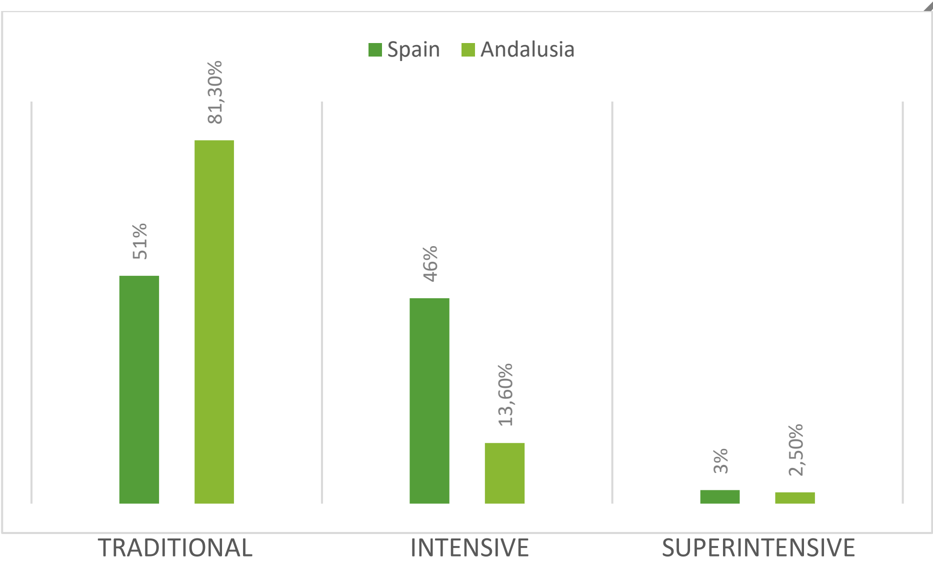


Figure 2: Comparison of the different production systems. Source: Own elaboration.

1.2 Biomass Availability

1.2.1 Location of olive biomass

In Andalusia, more than 8.7 million tonnes of biomass resources are generated each year from agriculture, of which 2.5 million tonnes correspond to the olive sector (Caracterización del sector agrario y pesquero de Andalucía., 2022).

Regarding the olive oil value chain, biomass is found in three different locations or phases (Table 3): Agricultural (Olive Farmland), olive oil mill, and Olive-Pomace or oil extraction plant (Contreras, Romero, Moya, & Castro, 2020). The biomass potential of the olive industry in Andalusia can be calculated as 2.5 Mt per year in agriculture, 4.2 Mt per year in olive-oil mills (Caracterización del sector agrario y pesquero de Andalucía., 2022) and 1,6 Mt per year in pomace olive oil extraction businesses (Polonio, Villanueva, & Gómez-Limón, 2022) (Table 3).

Table 3: Biomass potential of the olive grove sector in Andalusia (t/year)

Phase	By-product	Biomass (t/year)
Agricultural (Olive Farmland)	Pruning residues (wood, branches, and leaves)	2,548,258
Olive-Oil Mill*	Olive Pomace	4,212,348
	Stone	
	Olive mill leaves	
Olive-Pomace or oil extraction plant	Stone	1,592,716
	Extracted pomace	

1. Olive Farmland “Biomass from pruning”: Every year, biomass from pruning is created in the agricultural fields; historically, the unproductive branches from each tree are removed biennially to facilitate fruit collection during the next crop. This procedure generates a considerable amount of biomass, which must be removed from the fields as quickly as possible to prevent the spread of plant pests.

2. Olive-Oil Mill “Biomass from olive mills”: Other types of biomasses can be found in olive mills, where olives are transported to make olive oil. First, olives are cleaned in the mill, where a blowing machine separates leaves and short thin branches (olive mill leaves). The crushed olives are then centrifuged to generate olive oil and olive pomace.
   In some small mills, the conventional hydraulic pressing separation technology is still employed, although in most cases, continuous centrifugation systems are used. Two types of olive pomace are produced depending on the function of the decanter used for centrifugation:
   2.1 Two-phase pomace (from the two-phase decanter): The by-product is Olive Pomace (“Alperujo”). “Alperujo” is a very wet semi-solid substance (water content between 65-70%). Its composition is made up of a liquid residue (“Alpechín”) and a solid residue (pomace) (Muñoz, 2011).
   2.2 Three-phase pomace (from three-phase decanter): The by-product is pomace (“Orujo”). Pomace is a wet solid, with a water content of around 45%. The pomace consists of a combination of skin, pulp, stone, and fatty residue (Muñoz, 2011).

   Figure 3 shows each of the systems and the associated by-products:

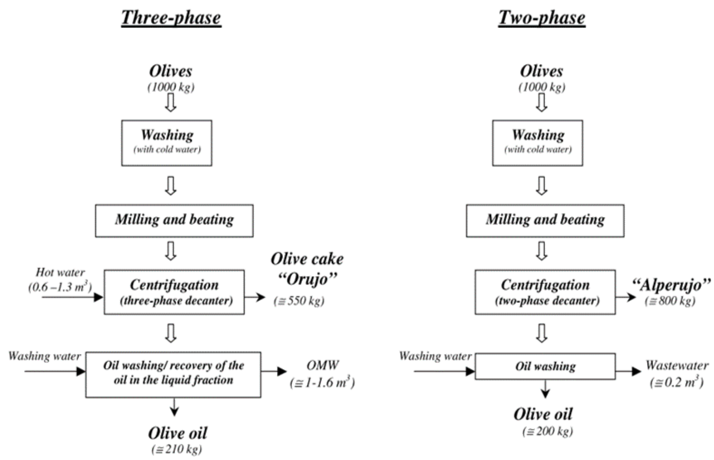


Figure 3: Comparison of the three and two-phase centrifugation systems for olive oil extraction *(Alburquerque J. , Gonzálvez, García, & Cegarra, 2004)*.

Almost all Spanish mills (99%) utilize a two-phase decanter to separate the oily paste into two phases (oil phase and pomace) without adding water. This reduces the generation of wastewater and, therefore, the pollutant load compared to three-phase decanter pulps and the traditional pressing method.

However, others insignificant methods of processing olive oil exist as well. For example, destoning the olives before grinding them is one such method. Although its effects on the quality of olive oil are still unknown, this may support the future valorisation of olive stones and seeds. Recently, an innovative two-phase decanter (multiphase decanter) containing wastewater, oil (8–12%), and olive pulp was introduced to the market. It produces both a dehydrated peel and a unique semi-solid pitted olive cake, known as "pate" or "pate olive cake" (Contreras, Romero, Moya, & Castro, 2020).

3. Olive-Pomace or oil extraction plant: To extract the remaining oil that is still present in the pomaces, they are often sent to pomace extraction factories. Technical hexane, a combination of alkanes, is the most often employed solvent in this solid-liquid extraction technique used in these facilities to extract residual oil. Crude pomace oil and an extracted pomace by-product are the results of this method. To obtain olive pomace oil, crude pomace oils are delivered to oil refinery facilities (García-Martín et al., 2020).

Figure 4 summarises the different processing schemes and by-products obtained in the production of olive oil:

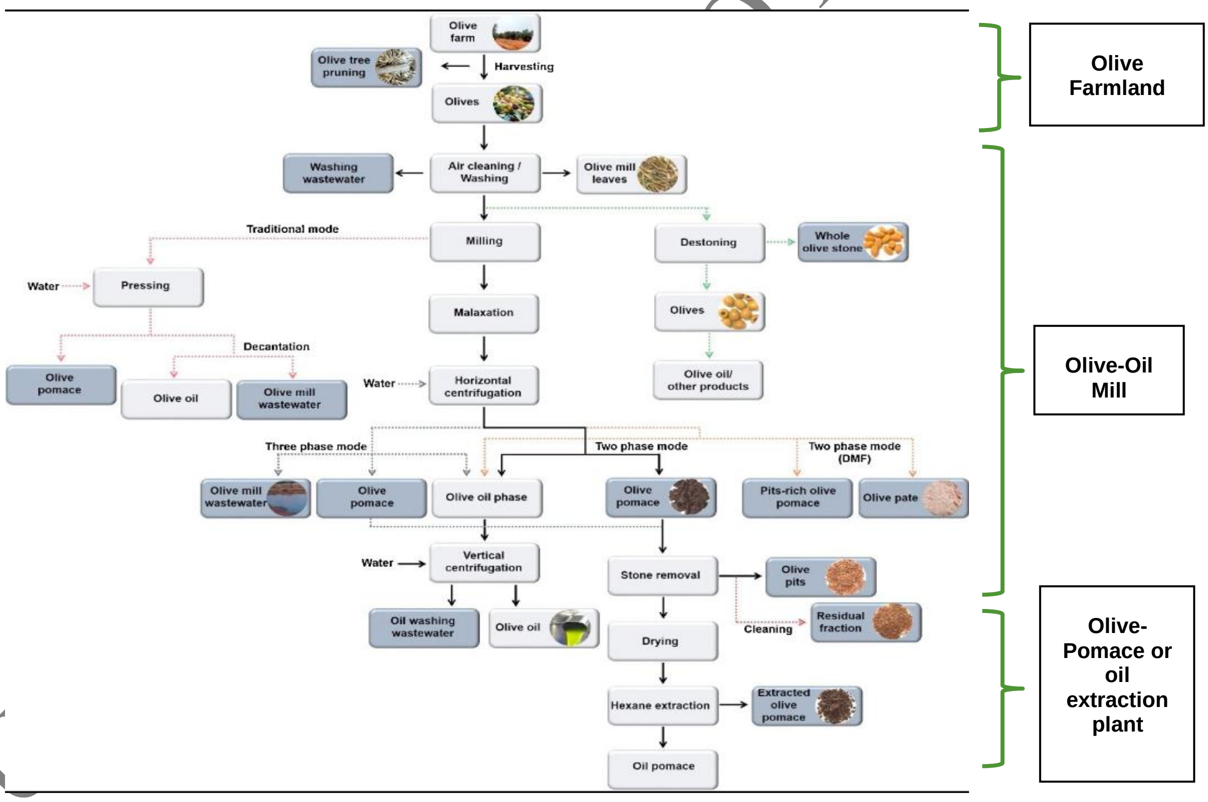


Figure 4: Simplified processing schemes for olive oil production and by-products produced *(Contreras, Romero, Moya, & Castro, 2020)*

The most important by-products derived from the olive value chain can be defined as follows (Polonio, Villanueva, & Gómez-Limón, 2022)*:*

1. Olive Leaves that is a mixture of leaves and small branches from the prunings of olive trees as well as the harvesting and cleaning of olives before oil extraction from olives. Olive leaves are generally used for direct combustion, animal feed (fresh), or pellet manufacturing. About half of the farmers eliminate the prunings by controlled burning in the field that produces CO_2, and particulate emissions and poses a potential fire risk. A potential and important use of pruning is to protect the soil and improve soil quality.
2. Olive Stone: Olive stone is a lignocellulosic substance that contains significant levels of protein, phenolic chemicals, cellulose, and hemicellulose. It is one of the most important solid by-products generated from olive oil production.
3. Olive pomace is the primary byproduct of the oil extraction process, known as the two-phase technique, which is utilized in almost all olive mills in Spain. This residue represents about 80% of olive weight and consists of olive skin, pulp, seed, and fragments of stones, as well as a small amount of residual oil, between 1% and 3%, depending on the process conditions and olive variety. It is a highly polluting waste due to the elevated organic matter and phenolics content, as well as difficult to dispose of since it has a high moisture content of 60-80% (Manzanares, et al., 2017). Of the two main by-products of the olive oil extraction company, 40 kg of olive pomace are produced for every 100 kg of olives (very variable depending on technique). (Berbel & Posadillo, 2018).
4. Currently, the most common method for treating olive pomace is to dry it and extract it using hexane to recover any residual oil, which is then sold as pomace olive oil following chemical refinement. Extracted olive pomace: the final solid residue generated in pomace olive oil extracting industries after pomace oil recovery, extracted olive pomace, usually has ~ 10% moisture and contains residues of pulp, seeds, skins, and stones (Manzanares, et al., 2017). The quantity of stone in extracted olive pomace is determined by the upstream extraction operations, since some stones are typically removed during the milling or pomace olive oil extraction process. .
5. Olive oil mill wastewater is a by-product of the three-phase processes of olive oil extraction from olives. This black liquid effluent has a high concentration of phenolic chemicals from the vegetative water of the olive fruit, the water used for washing and treatment, and a portion of the olive pulp and waste oil (Ben Sassi, Boularbah, Jaouad, Walker, & Boussaid, 2006). Some research has demonstrated the possibility of treating this wastewater through different processes such as composting, use as fertiliser, and for microbial growth that will reduce its toxicity and produce a reusable stream of treated water.

Table 4 shows, for each of the by-products obtained in the olive oil industry, the main intrinsic characteristics of the by-product that are important for the valorization process, the current valorization options and the economic value of the by-products (University of Jaén (UJA), Olive Tree Institute (IO), Ankara University (AU), Olive Research Institute (ORI), & Direction Générale de la Production Agricole (DGPA), 2018).

Table 4: Olive oil industry by-products generated in different stages of the value chain.

	OLIVE LEAVES	OLIVE STONE	OLIVE POMACE (2-PHASES)	OLIVE POMACE (3-PHASES)	OLIVE OIL MILL-WASTEWATER (3-PHASES)
Location	Olive grove	Olive mill	Olive mill	Olive mill	Olive mill
Production Rate	2.5-3.0 t/ha	90-100 kg/t of olives	650-750 kg/t of olives	550 kg/t of olives	650-1200 L/t of olives
Ash content (%,ar)	3-5	0.5-2	2-5	2-5	-
Moisture, (%,ar)	15-20	30-35	65-70	45-50	55-70
Lower Heating Value (MJ/kg)	16-18	17-19	16-18	16-18	-
Selling price (€/kg)	Free	0.08 (wet)	Disposal Fee	Disposal fee	-
Current valori-sation	None (burn at the field)	Sell to biomass produc-ers (at low price)	Extractor com-panies	Extractor companies	Fertilizer (in some cases)

1.2.2 Use of olive by-products

In Andalusia, olive by-products are often used as a source of energy. It is used less frequently to produce compost and animal feed, and less frequently to produce products with significant added value (Table 5).

Table 5: Use of olive by-products (*Berbel, Gutiérrez-Martín, & La Cal, Valorización de los subproductos de la cadena del aceite de oliva, 2018*).

Use of olive by-products		Percentage
Energy generation	Electricity generation	47.00%
	Thermal energy	33.00%
Composting or direct field application		14.30%
Waste		0.70%
Animal feed		5.00%

Due to their composition and characteristics, the by-products generated by olive cultivation and its associated industries can be vaporized in different applications.

Energy

Due to this biomass potential, Andalusia has developed a map of resources and facilities that encompasses two applications in one tool: the biomass potential in Andalusia and the biomass facilities in Andalusia.

The tool has functionalities common to both, such as information by municipality, where a single search shows all the information regarding potential and existing facilities in a selected municipality; and specific functionalities for each application, such as the search for biomass in a given quantity and the search for facilities in a given location.

Biomass Potential in Andalusia gathers updated and extended information on the potential of this energy resource, analysing sectors not previously studied and updating biomass production ratios as a consequence of the application of the information obtained in the biomass field. Currently, there is no official register of biomass production that collects, for each of the producing sectors, the quantities of biomass generated. This means that the estimation of its potential requires the availability and handling of reliable and contrasted information, as well as calculation methods capable of evaluating it as closely as possible (Agencia Andaluza de la Energía (AAE), 2022).

The figure (Figure 5) below shows that biomass potential is predominant throughout the province of Jaen, where potential values are between 5,001-10,000 (toe/ha) and 10,001-15,000 (toe/ha). For the rest of Andalusia, biomass potential is mostly concentrated in the southern area of Seville and Cordoba, with predominant values between 5,001-10,000(toe/ha). (Agencia Andaluza de la Energía (AAE), 2022).

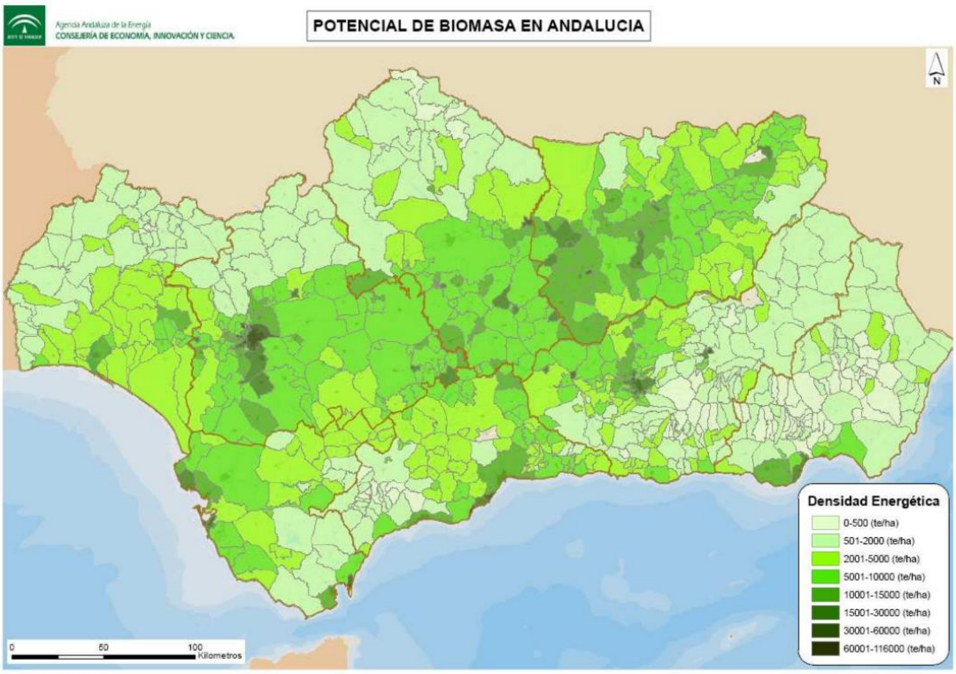


Figure 5: Biomass Potential in Andalusia *(Agencia Andaluza de la Energía., 2020)*.

The map of biomass installations in Andalusia, shows all the installations that use biomass as fuel for electrical or thermal use, or that generate fuel from biomass, such as biofuel and pellet factories. For the first time, information that until now was dispersed in different registers and applications, is unified in one tool. The information on this map is updated periodically and highlights the possibility of being able to consult in each municipality the installations for thermal use with biomass, for all sectors, classifying the information according to the type of equipment; being of great use to both installation companies and biomass distributors (Agencia Andaluza de la Energía (AAE), 2022).

The following table (Table 6) shows the evolution of biomass applications for electricity capacity in Andalusia:

Table 6: Annual evolution of biogas and biomass electricity generation in Andalusia (MW) *(Consejería de Política Industrial y Energía, 2022)*

ANDALUSIA	2014	2015	2016	2017	2018	2019	2020	2021
Biogas electricity generation	29.82	29.82	30.75	30.75	31.53	33.45	33.45	33.45
Biomass electricity generation	257.48	257.48	257 .48	257.48	227.98	273.98	273.98	273.98
TOTAL	6114.58	6119.34	6123.42	6124.66	6103.91	7215.81	8103.4	8940.82

Table 6 shows that in 2021, 33 MW or 0.4% of renewable energy in Andalusia came from biogas and 274 MW or 3% came from biomass electricity generation.

Biofuels

Olive by-products are often used as a source of energy. However, other potential uses are possible, such as their transformation into bioethanol for use as advanced biofuel. Biofuels are classified as environmentally friendly and renewable energy sources obtained from biowaste. In this sense, as lignocellulose-derived biomass materials, olive tree pruning biomass (OTPB), olive leaves (OL), and extracted olive pomace (EOP) residues contain a certain proportion of carbohydrate polymers and lignin that could be converted into fermentable sugars and other valuable molecules, which could then function as precursors for high value-added products such as biofuels (Table 7)

Table 7: Chemical characterization of olive tree pruning biomass, olive leaves, and extracted olive pomace. Results are expressed as g/100g raw material oven dry weight (Manzanares, et al., 2017).

Composition (%, dry matter)	OTPB	OL	EOP
Cellulose	21.6 ± 0.2	9.3 ± 0.4	10.1 ± 0.5
Hemicellulose	14.5 ± 0.2	9.5 ± 0.2	11.3 ± 0.8
Xylose	10.2 ± 0.0	4.5 ± 0.1	10.3 ± 0.6
Galactose	2.2 ± 0.0	2.0 ± 0.1	1.0 ± 0.1
Arabinose	3.2 ± 0.2	4.0 ± 0.4	1.1 ± 0.2
Mannose	0.6 ± 0.1	0.3 ± 0.0	0.3 ± 0.1
Acid-insoluble lignin	15.4 ± 0.4	15.1 ± 0.5	20.1 ± 1.5
Acid-soluble lignin	2.3 ± 0.1	2.6 ± 0.2	1.8 ± 0.2
Extractives	28.6 ± 1.3	45.2 ± 1.5	48.8 ± 1.2
Glucose	7.3 ± 0.1	7.1 ± 0.1	8.0 ± 0.5
Phenolics[1]	2.9 ± 0.0	4.4 ± 0.2	6.1 ± 0.1
Ash	3.9 ± 0.6	8.3 ± 0.2	9.1 ± 0.5
Elemental			
Nitrogen	0.5 ± 0.1	1.3 ± 0.1	1.7 ± 0.1
Carbon	45.9 ± 0.3	49.4 ± 0.3	48.3 ± 0.4
Hydrogen	6.3 ± 0.1	6.8 ± 0.2	6.1 ± 0.0
Sulfur	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0

[1] Expressed as gallic acid equivalents (GAE).

High-added value compounds

On the other hand, olive biomass as a source of bioactive chemicals is a top focus in practical research in this area. The research conducted by (Galanakis & Kotsiou, 2017) explains the various methods for recovering bioactive components from olive oil and processing olive byproducts, as well as a complete approach for ensuring the process's sustainability.

Wastewater from mills is a rich source of bioactive compounds and natural phenols such as hydroxytyrosol, tyrosol, and oleuropein. These phenols are active ultraviolet filters used in cosmetics (Galanakis C. M., 2017). The most widely used technique consists of carrying out a pretreatment of the initial material and the subsequent conversion of oleuropein into hydroxytyrosol, prior to the extraction of phenols with a solvent and/or other technologies.

The separation and purification of these high-added value compounds could open the door to future research, given the inhibitory effect that phenolic compounds can have on sugar fermentation. The removal of these compounds from the aqueous extract could also favour the production of ethanol from the glucose present in the extractive fraction, thus increasing the production of biogas or bioethanol (Manzanares, et al., 2017).

Table 8: Chemical Composition of oil mill wastewater (OMWW) from a 3-phase extraction process *(Alburquerque J. , Gonzálvez, García, & Cegarra, 2004)*.

Parameters	OMMW	Wet Olive Pomace	Composts
pH	4–6	5–7	50–10
Dry matter (%)	6–7	50–71	
Water (%)	83	70	20
BOD (g/L)	35–110		
COD (g/L)	40–220		
EC (dS/m)	5–12	1–5	2–7.3
Organic matter (g/kg)	46–62	840–980	260–900
TOC (g/kg)	34–40	490–540	110–580
TN (g/kg)	0.60–2.10	7–19	11–54
C/N	52–54	28–73	9–36
p (g/kg)	0.15–0.30	0.7–2.2	1–30
K (g/kg)	2–9	7–30	6–44
Na (g/kg)	0.1–0.4	0.5–1.6	2–41
Ca (g/kg)	0.20–0.6	1.5–9	7–72
Mg (g/kg)	0.04–0.22	0.7–4	1–57
Fe (mgkg)	18–120	80–1470	100–410
Cu (mg/kg)	1.5–6	12–29	1.5–80
Mn (mg/kg)	1–12	5–39	13–130
Zn (mg/kg)	2.4–12	10–37	38–138
Phenols (%)	1–11	0.5–2.4	0.1–4

Table 8 indicates that phenolic compounds are present in higher concentrations in oil mill wastewater (OMMW) than in wet olive pomace and compost. It is possible due to the hydrophilic nature of these compounds that allows them to be soluble in the aqueous fraction and less soluble in the oily (hydrophobic) phase.

Because of its high content of phenolic compounds (10,650 mg/L), strong disagreeable odor, high concentration of fats, oil, and grease (FOG), and high organic loading (COD and BOD5), oil mill wastewater has a reddish-black appearance. About 400 times more organic material is present in this effluent than in regular home wastewater. Oil mill wastewater also has an electrical conductivity (EC) range between 5.5 and 12.0 dS/m, a pH between 4 and 5, and a high content of polyphenols (Khdair & Abu-Rumman, 2020).

Animal feed and human nutrition

Moreover, there are other medium-value uses of olive biomass, such as animal feed, in which case the most widely used by-product is olive pomace. The study carried out by (Zabetakis & Nasopoulou, 2013) of the available evidence on the use of olive by-products as feed in aquaculture and livestock concluded that, in both cases, olive pomace consumption low 12% of intake does not affect growth and improves the fatty acid profile in both meat and milk. In ruminants with a diet with a pomace content below 10 % of total intake, a reduction in feed cost is achieved and milk composition is improved (with no negative effect on milk production).

Finally, reference is made to the by-products of the olive oil chain as a functional feed supplement to improve human nutrition. As mentioned above, the consumption of olive pomace improves the fatty acid profile of both meat and milk by decreasing the composition of saturated acids and increasing unsaturated acids. In addition, a common finding is that the fat and solids content of milk, as well as its yield, increase on a diet containing olive pomace.

Biorefinery or bioindustry

Biorefineries are defined as structures where biomass conversion processes take place to produce chemicals, fuels, energy, and high-value-added products from biomass. In rural areas with a high density of agricultural and agro-industrial wastes, such as olive crop areas and related industries, an integrated biorefinery process based on lignocellulosic feedstock is particularly attractive.

To determine the feasibility of biorefineries, an important question to address is to analyse what kind of products can be obtained, distinguishing between "tractor" and "gregarious" products.

- Tractor products:

  Tractor products are those which justify the collection and transport of biomass in the first instance, and which justify the industrial investment for its subsequent management:

  - Primary tractor products: Products for direct consumption or subjected to a first transformation.
  - Secondary tractor products: Products from the valorisation of by-products generated in the production of primary tractor products.

- Gregarious products:

  Products obtained from the same biomass that are processed to obtain tractor bioproducts, but which do not in themselves justify the total investment necessary for their management: collection, transport and logistics, storage, processing plant, etc (Quintela & Pinilla, 2019).

Table 9 summarises a classification of the tractor and gregarious bioproducts that can be obtained from olive trees in Andalusia. Bioproducts of particular interest are highlighted in bold.

Table 9: Main tractor and gregarious bioproducts from an agricultural olive biorefinery in Andalusia *(Quintela & Pinilla, 2019)*.

BIOMASS	BIOPRODUCTS
Olive tree	PRIMARY TRACTOR PRODUCTS: **Olive oil** SECONDARY TRACTOR PRODUCTS: **Olive pomace oil** **Bioenergy (biofuels, heat and electricity)** GREGARIOUS PRODUCTS: Sterols, Triterpene alcohols, Aliphatic alcohols, Waxes, Saturated aliphatic hydrocarbons **Squalene** Tocopherols **Phenolic compounds** (hydroxytyrosol, oleuropein, oleocanthal) **Triterpenic compounds** (maslinic acid, oleanolic acid, ursolic acid...) Fermentable carbohydrates Lignin, cellulose, and hemicellulose Proteins and amino acids Organic acids

1.3 Nutrient Availability

1.3.1 Nutrient requirements

The olive tree is adapted to the Mediterranean climate, characterised by hot, dry summers with low rainfall and high inter- and intra-annual variability. This adaptation means that it is not particularly demanding in terms of water and nutrients. However, intensification of olive orchard management entails increased use of fertilizers, especially nitrogen, phosphorus, and potassium.

The nutrient requirements of the olive tree are as follows:

- Micronutrients: those which the plant needs in smaller quantities (Iron, Aluminium, Boron, Chlorine, Nickel, Chlorine, Sodium, Cobalt, Manganese, Zinc, Fluorine, Copper, Molybdenum and Selenium).
- Macronutrients: which are extracted in larger quantities (Potassium, Nitrogen, Calcium, Phosphorus, Sulphur, and Magnesium).

Most of these nutrients are absorbed through the roots, although most organs (leaves, fruit, trunk, etc.) are capable of absorbing nutrients in ionic form when they are in solution. The aim of fertilisation is to supplement with the essential elements that the olive grove needs and not to add to the soil or the tree all the elements that the tree needs, as many of them are found in the soil in adequate quantities. These quantities differ from one soil to another for various reasons (previous treatments, cultivation techniques, etc.), and the requirements vary with the age of the olive grove, its productive characteristics, etc. It is, therefore, necessary to determine the nutritional needs of the olive grove and to predict the amount of fertiliser required annually to achieve optimum productivity, which depends on several factors:

1. Knowledge of the available nutrient content and diagnosis of toxicities caused by excess salts (sodium, chlorine, and boron).

2. Foliar analysis: This consists of the chemical analysis of a sample of leaves from the tree. It allows the detection of low nutrient levels before the onset of harmful deficiencies.

Table 10 shows an interpretation of nutrient levels in olive leaves expressed in dry matter.

Table 10:Interpretation of nutrient levels in olive leaves expressed in dry *(López Clemente, 2021)*.

Element	Deficient	Appropriate	Toxic
Nitrogen (%)	1.4	1.5-2.0	-
Phosphorus (%)	0.05	0.1 -0.3	-
Potassium (%)	0.4	> 0.8	-
Calcium (%)	0.3	>1	-
Magnesium (%)	0.08	> 0.1	-
Manganese (ppm)	-	> 20	-
Zinc (ppm)	-	> 10	-
Copper (ppm)	-	> 4	-
Sodium(%)	-	-	> 0.2
Chlorine (%)	-	-	> 0.5
Boron (ppm)	14	19-150	185

The nutritional needs of the olive grove are lower than those of other crops, it can produce fruit even in adverse conditions for other crops, and it has nutrient reserve organs that are easily reusable (reserves contained in old stems and leaves) (López Clemente, 2021).

1.3.2 Olive fertilisation

Some of the alternative soil management practices are spontaneous or cultivated cover crops (CC) along the inter-rows of olive trees which prove to be an effective tool to reduce erosion, run-off, and loss of soil fertility. Most olive growers use spontaneous vegetation because of the economic savings on seeds. In 2018, 92% of the Spanish olive grove areas with some form of CC had spontaneous CC, sometimes combined with pruning residue cover crops, which are long-lasting, protect the soil and improve soil fertility. However, the continued use of the same CC produces a change in the ruderal flora. CC have a significant role in increasing soil organic matter and nutrients (Rodríguez-Lizana, Repullo Ruibérriz de Torres, Carbonell-Bojollo, Moreno-García, & Ordóñez-Fernández, 2020).

In general, the nutrient absorption capacity through the leaves is relatively low, which is why foliar fertilisation is recommended, as there is experimental evidence that, in rainfed olive groves, foliar fertilisation is a very effective system for supplying nutrients. Foliar application of fertilisers is therefore indicated in those cases where the application of immobilised or blocked nutrients with limited availability in the soil is required or when conditions may lead to a loss of these nutrients (Hidalgo, Leyva, Hidalgo, Pérez, & Vega, 2020)

In irrigated olive groves, the usual way of applying fertilisers is by fertigation; however, foliar fertilisation is a complement to this technique and allows correcting the demand for nutrients at certain specific times.

Not all nutrients are well absorbed by the leaves of the olive tree. Nitrogen (N), Sodium (Na), and potassium (K) are very well absorbed, and phosphorus (P) has a very acceptable absorption. However, the high uptake of sodium (Na) and chlorine (Cl), which is negative for the olive tree, must also be considered. Foliar uptake rate of Calcium (Ca), and Iron (Fe) is very low, a nutrient deficiency that must be corrected by soil inputs or fertigation (Table 11).

Table 11: Absorption of nutrients through the olive leaf *(Hidalgo, Leyva, Hidalgo, Pérez, & Vega, 2020)*.

Foliar absorption	Nutrient element
Very high	Sodium (Na), Potassium (K) and Nitrogen (N)
High	Phosphorus (P), Chlorine (Cl), and Sulphur (S)
Low	Magnesium (Mg), Zinc (Zn), Copper (Cu), Manganese (Mn), Molybdenum (Mo) and Boron (B)
Very low	Iron (Fe) and Calcium (Ca)

Other factors that participate in the absorption of nutrients through the olive leaf are:

- Application at times of high ambient humidity or at night improves nutrient uptake by keeping the leaf surface moist for longer.
- High temperatures and low relative humidity: reduced uptake due to evaporation of water and formation of salts from the respective fertilisers on the leaf surface.
- Reducing the fertiliser concentrations in the treatment mixture and increasing the number of applications per year leads to better results.

1.3.3 Nutrient recycling

Olive orchard sustainability may benefit from the recycling of trimmed orchard material, olive pomace, and olive mill effluent, as well as the use of recycled wastewater for irrigation. However, there is a risk of environmental damage.

- Olive-tree pruning is a lignocellulose substance that consists mostly of cellulose, hemicellulose, and lignin. The literature contains very little information about the elemental composition. Nonetheless, some authors point out that elemental composition of the olive-pruning debris is: 44-46% C, 6% H, 47% N, and 0% S. When pruning residues are incinerated, almost all of their N content is volatilised (P and K would remain mostly available). However, when pruning residues are shredded, an amount of N is retained on the farm that would be available in the medium to long term (due to the relatively low decomposition rate of pruning residues) (Liétor Gallego, García Ruiz, & Domouso De Agar, 2023).

- The rate of decomposition of olive leaves is relatively slow due to their high lignin and polyphenol content and their high carbon: nitrogen ratio, i.e. the availability of these nutrients will be medium to long term.

- About 30.000 t of olive stones are produced annually by the olive table business (Khdair & Abu-Rumman, 2020). As a lignocellulose material, its main components are cellulose, hemicellulose, and lignin (García-Martín et al., 2020). Owing to its elevated lignin concentration, it was purportedly appropriate for thermal application. Compared to other lignocellulose materials, olive stones were discovered to offer a great potential as solid biofuel for combustion.

  However, it has also been suggested that it can be used as a source of fermentable sugars, antioxidants, and other lignocellulose materials. Environmental pollution will be substantially reduced if olive stones can produce added-value products from thermochemical and biochemical perspectives.

Sulfur can hardly be found in olive stones in terms of elemental makeup. Chlorine and copper stand out among the several trace elements that are present, with concentrations ranging from 90 mg/kg to 435 mg/kg and from 0.6 mg/kg to 2.3 mg/kg, respectively. Ash levels are frequently lower than 2% (wt.). Olive stone ash mostly contains the inorganic components Al_2O_3, CaO, Fe_2O_3, K_2O, MgO, and SiO_2 (García-Martín et al., 2020).

- For years, olive mill wastewater application was tested under field conditions as an organic amendment. Many times, the results concerning the raise of plant growth, crop yields, and enhancement of soil fertility were promising, while in some other cases phytotoxicity problems, groundwater contamination, decreased soil porosity, as well as enhanced electrical conductivity, salinity, increased soil acidity and decreased N mineralization rate occurred (Chatzistathis & Koutsos, 2017).

- Recycling of olive mill pomace through composting could be a strategy for providing some ecological services to olive oil groves. Figure 6 shows the C, N and P cycling of fruits harvested in olive oil farming when olive mill pomace is composted and applied to olive oil groves.

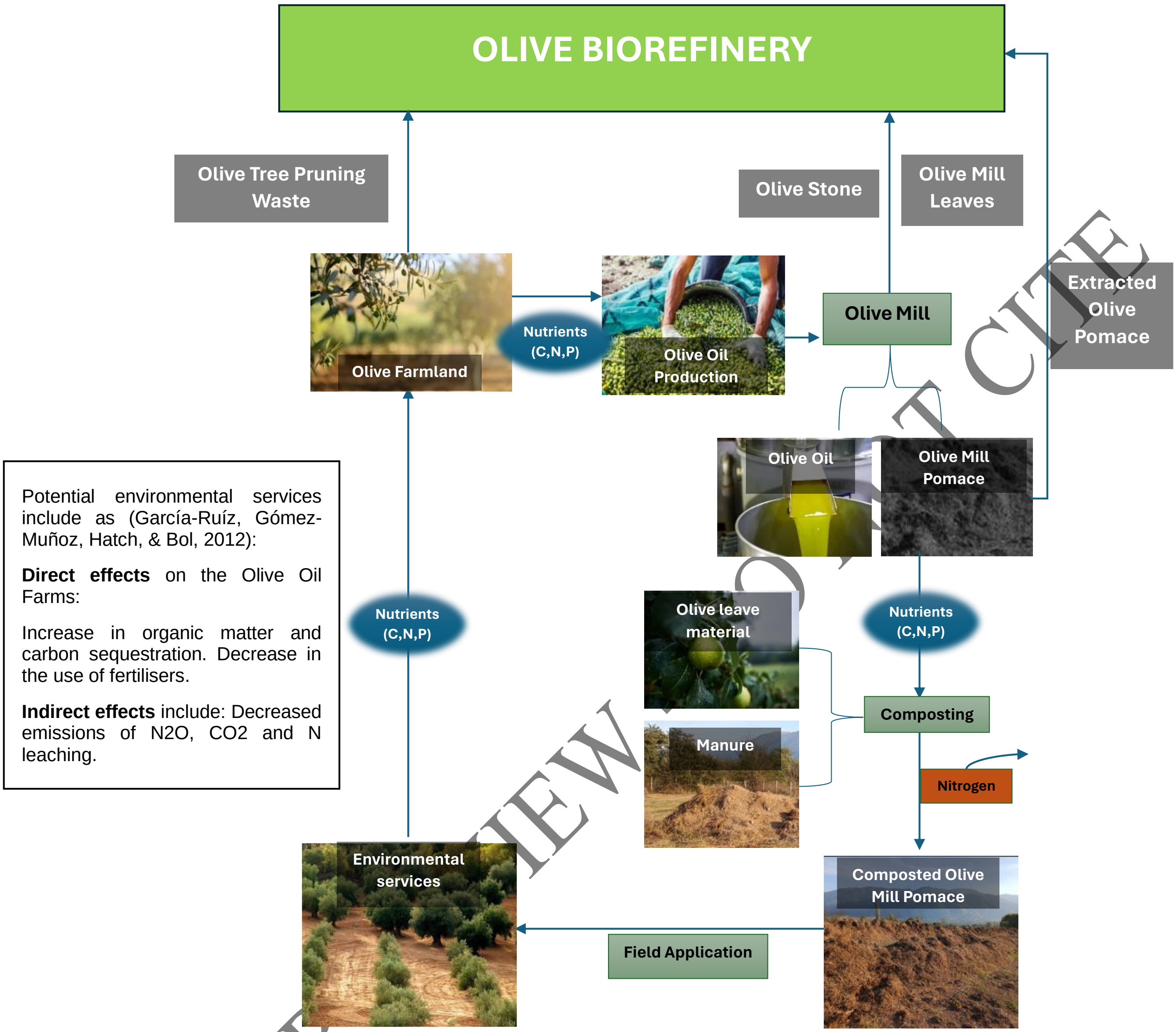


Figure 6: Fate of C, N, and P of the fruit harvested in the olive oil farming when olive mill pomace is composted and applied to the olive oil groves. Source: Own elaboration

Firstly, composting olive mill pomace reduces most of the potential environmental pollution problems related to the disposal of approximately 4 million tonnes of olive mill pomace produced in Andalusia over a relatively short period (3 months). On the other hand, most of the nutrients (especially nitrogen, phosphorus, and potassium) harvested with the yield, are contained in the olive mill pomace, and therefore after composting and application to olive oil groves help to recycle these nutrients, reducing the need for chemical fertilisers. The estimates show that between one to two-thirds of the Andalusian olive, oil groves could be fertilised annually with the olive mill pomace produced in Andalusia after composting, with a subsequent reduction of about 25 – 60% in chemical fertilisers. In addition, the main beneficiary of the economic and environmental profits of composting olive mill pomace and application to olive oil groves is the farmer (García-Ruíz, Gómez-Muñoz, Hatch, & Bol, 2012).

Table 12 shows an analysis of different properties of olive receiving (COMP) or not (NCOMP) composted olive mill pomace at four Andalusian olive oil mills (Olvera (O), Reja (R), Tobazo (T) and Andújar (A)) (García-Ruíz, Gómez-Muñoz, Hatch, & Bol, 2012).

The addition of olive mill pomace compost improves each of the measured parameters, indicating an improvement in the quality of soil qualities for cultivation without the use of chemical fertilisers.

Table 12:Analysis of different properties of olive farms receiving (COMP) or not (NCOMP) composted olive pomace from olive oil mills *(García-Ruíz, Gómez-Muñoz, Hatch, & Bol, 2012)*.

Site		WHC (%)	SA (%)	CEC (meq100 g^{-1})	LOI (%)	TC (%)	TN (%)	Available P (μg P g^{-1})
O	COMP	26.3 ± 0.81^{a}	51.8 ± 2.0^{a}	22.2 ± 1.22^{a}	3.95 ± 0.95^{a}	2.29 ± 0.39^{a}	0.25 ± 0.04^{a}	10.6 ± 0.04^{a}
	NCOMP	22.3 ± 0.3^{b}	34.0 ± 1.6^{b}	20.8 ± 0.21^{b}	3.45 ± 0.85^{a}	2.00 ± 0.49^{a}	0.27 ± 0.03^{a}	9.3 ± 0.03^{a}
R	COMP	21.8 ± 1.3^{a}	57.9 ± 1.8^{a}	25.3 ± 3.83^{a}	8.34 ± 3.67^{a}	4.84 ± 1.90^{a}	0.29 ± 0.03^{a}	30.3 ± 0.03^{a}
	NCOMP	20.5 ± 1.7^{b}	37.1 ± 0.9^{b}	18.6 ± 0.27^{b}	3.96 ± 1.09^{b}	2.30 ± 0.57^{b}	0.23 ± 0.02^{a}	11.5 ± 0.02^{b}
T	COMP	23.6 ± 0.5^{a}	56.7 ± 0.2^{a}	21.1 ± 3.46^{a}	6.31 ± 2.22^{a}	3.66 ± 1.15^{a}	0.25 ± 0.08^{a}	6.9 ± 0.01^{a}
	NCOMP	20.5 ± 0.8^{b}	22.6 ± 0.6^{b}	15.4 ± 2.06^{b}	2.39 ± 0.62^{b}	1.39 ± 0.32^{b}	0.10 ± 0.02^{b}	7.6 ± 0.02^{a}
A	COMP	30.2 ± 0.5^{a}	23.9 ± 1.0^{a}	23.3 ± 6.9^{a}	16.1 ± 3.49^{a}	8.49 ± 2.11^{a}	0.74 ± 0.33^{a}	57.4 ± 0.33^{a}
	NCOMP	28.7 ± 1.3^{a}	23.7 ± 1.5^{a}	10.6 ± 1.2^{b}	1.88 ± 0.41^{b}	1.09 ± 0.21^{b}	0.05 ± 0.02^{b}	3.57 ± 0.02^{b}

Water holding capacity (WHC), soil stables aggregates (SA), cation exchangeable capacity (CEC), organic matter (LOI), total Carbon (TC), total Nitrogen (TN), and available Phosphate.

1.4 Discussion of the Result

To sum up:

- In Andalusia, the olive industry is regarded as both a vital component of the region's cultural legacy and a strategic driver of job and revenue growth.
- Olive oil manufacturing and olive pruning produce massive waste streams.
- Nutraceuticals, bioenergy and biofertilizers, biobased materials, food and feed additives, and other new value-added and commercially viable ingredients and products could be created from these olive waste and by-products.
- Olive mill pomace is primarily composted and then applied back to the farm by olive growers to recycle nutrients taken after harvest.

1.5 Conclusions

Most of the biomass derived from olive groves in the EU Mediterranean basin are produced in Spain, accounting for around 51% of pruning residues, 72% of leaves, olive stones, and extracted pomace, 81% of olive pomace and 28% of wastewater. (Galán-Martín, et al., 2022).

Figure 7 shows by-products obtained from olive orchards and olive mills:

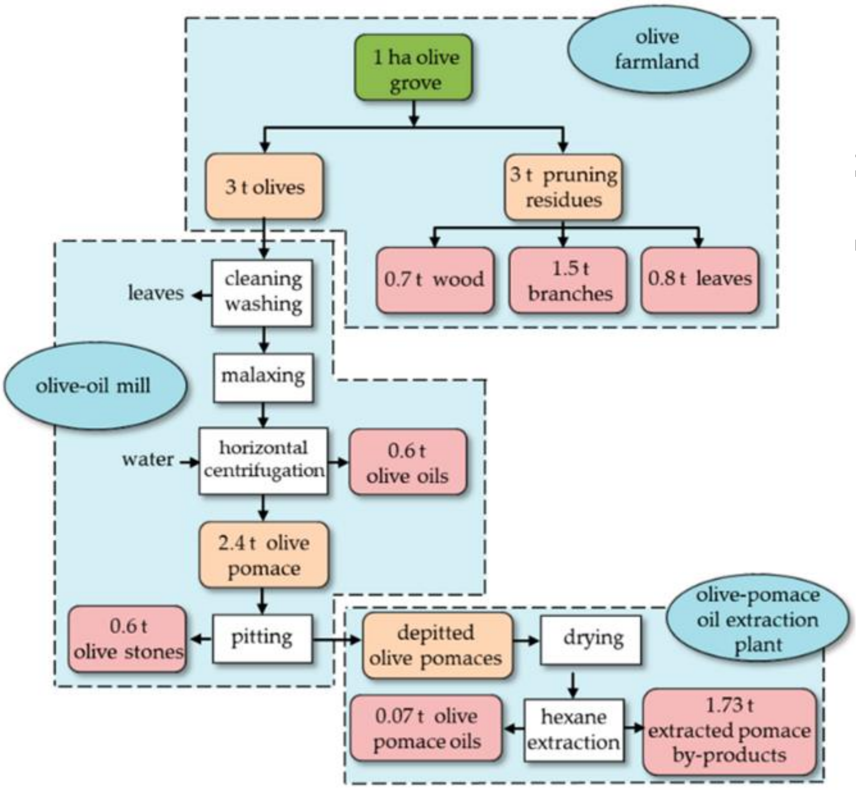


Figure 7: By-products obtained from olive orchards and olive mills *(García-Martín et al., 2020)*

Table 13 shows the biomass potential in Andalusia based on the data provided in Figure 7 "By-products obtained from olive orchards and olive mills" and the estimated distribution of olive grove in Andalusia.

Table 13:Olive-derived biomass potential in Andalusia.

		Tonnes (t)							
Region	Distribution (ha olive grove)	Olives	Pruning Residues	Leaves	Olive Oils	Olive Stones	Olive Pomace	Olive Pomace Oils	Extracted Pomace By-Products
-	1.0	3.0	3.0	0.8	0.6	0.6	2.4	0.07	1.73
Andalusia	1,639,627	4,918,881	4,918,881	1,311,701.6	983,776.2	983,776.2	3,935,104.8	114,773.89	2,836,554.71
		Metric Tonne (Mt)							
Andalusia	1,639,627	4.9	4.9	1.3	1.0	1.0	3.9	0.1	2.8

Olive grove and their industry associated involve distinct procedures, like cutting branches and wood from pruning, removing leaves, washing olives, grinding, pounding, and extracting the oil. As a result, huge quantities of by-products are generated (stones, leaves, pomace...). Particularly, olive pomace (OP) causes environmental problems, and one way that has been found to manage its negative impact is its use as a soil fertility improver. Studies such as (Alaoui, El Ghadraoui, Tanji, Harrach, & Farah, 2023) indicate that while improving soil structure, they do not modify soil pH and salinity and simultaneously increase organic matter and plant nutrient availability. Moreover, it has been demonstrated that the incorporation of these organic residues into the soil improves the structural stability index of the aggregates and facilitates the aggregation of soil particles, which is especially important in soils with low levels of organic carbon (Figure 8).

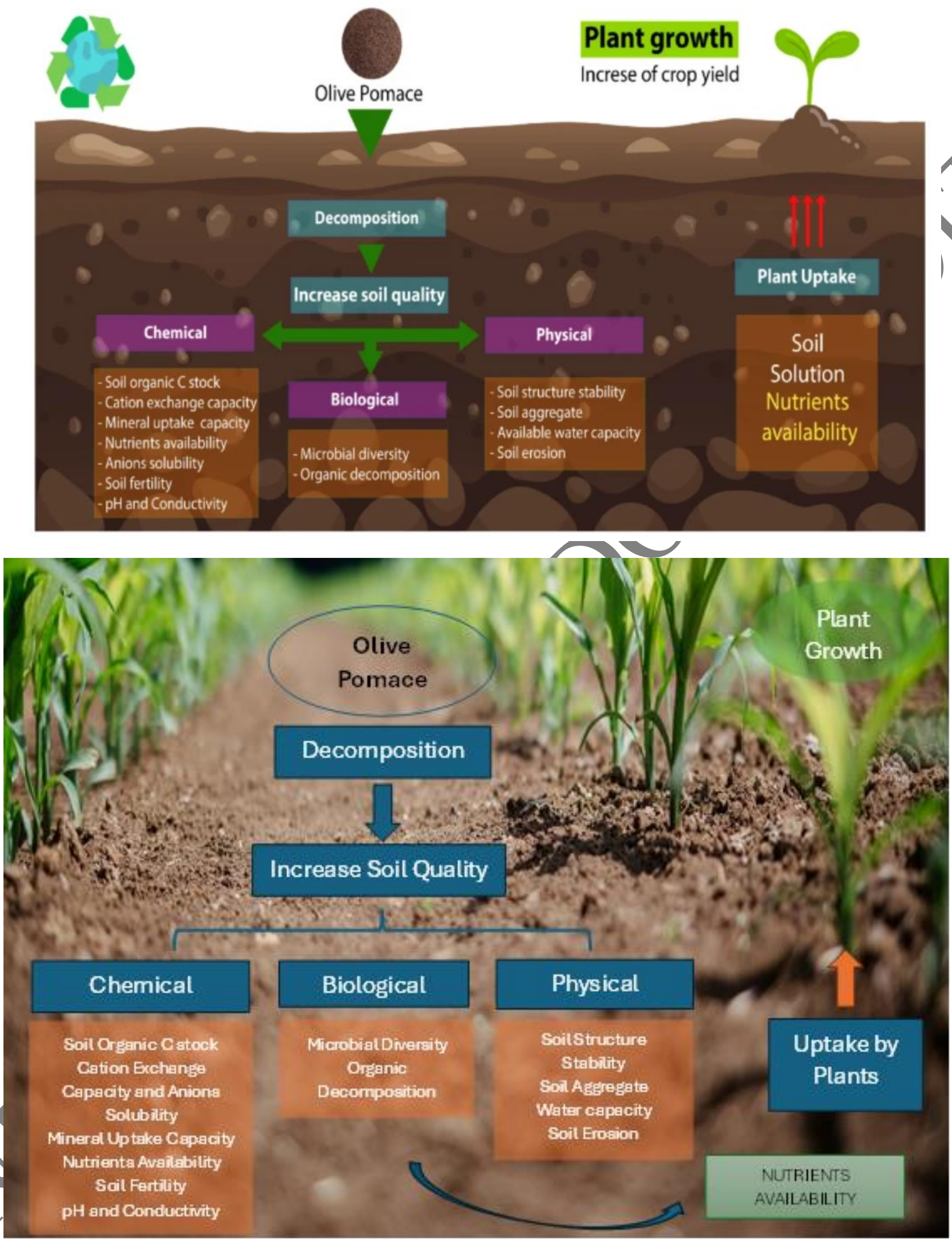


Figure 8: Olive pomace as a sustainable bio-fertiliser *(Alaoui, El Ghadraoui, Tanji, Harrach, & Farah, 2023)*.

Traditionally, pruning waste has been burned without any purpose. But for the past few years, this method has been coupled with ground deposition and shredding as an organic input. Firewood is either consumed by the farmers themselves or marketed without much-added value. Industrial by-products such as the stone or pomace have also traditionally been used as fuels for thermal purposes and the leaf has been used as livestock feed or for compost production together with fatty and wet pomace and residues from livestock farms (Berbel, Gutiérrez-Martín, & La Cal, Valorización de los subproductos de la cadena del aceite de oliva, 2018).

However, it can be shown that olive grove biomass has been used mostly for energy, to a smaller amount for animal feed and compost production, and very seldom for obtaining products with higher added value. Current research focuses on biomass as a way to obtain high-value-added products, such as bioethanol as a second-generation fuel or bioplastics, among others.

A biorefinery integrated process based on lignocellulosic feedstock is particularly appealing in rural regions with large levels of agricultural and agro-industrial waste, such as olive crop areas and associated businesses. More than 70% of all olive waste produced in Spain is accumulated in the Andalusian area, which includes the municipalities of Jaen, Cordoba, and Seville. As a result, the valorization of these wastes is interesting from a social and environmental perspective.

1.6 Recommendations

Recommendations to improve biomass availability and nutrient recycling in the olive sector in Andalusia are:

- Improve regulatory cohesion at regional, national, and European level.
- Create business plans for regionally suitable biobased solutions.
- Provide training on regulations for public administration, private enterprise, and citizens.
- Develop incentives for companies that work with bioactive products.
- Promote research. Innovative bio-based products demand intensive R&D work. Public-private research consortia should be encouraged in this regard.
- Engage stakeholders with experience in bioproduct uses, in de biorefinery design.
- Promote communication and exchange of experience and know-how between research and value chain actors.
- Promote SME-engagement. Bioeconomy companies in the region are often of low to medium size, with limited financial resources.

For the SCALE-UP- project and the multi-actor platform it is recommended:

- To strengthen and continue the innovation support programme for bio-based solutions. These are in line with key policy objectives, the European Green Deal, the EU Bioeconomy Strategy, the EU's long-term vision for rural areas, and the EU Rural Pact and Action Plan.
- To strengthen and continue the training program addressing nutrient recycling, primary producer integration into value chains, digitalization, efficient infrastructures and logistics, social innovation, governance, and trade-off strategies.
- To enhancing dialogue and cooperation among actors in the value chain.
- To address in the support and training programme the regulatory developments regarding by-products and end-of-waste status (see below).

B*y-products and and-of-waste status*

The industrial biomass category includes organic waste generated in the agri-food, fishing, and forestry industries. Most of the by-products generated by these industries should not be considered waste, since they usually have an alternative use in the market as raw materials that find applications in other industries or sectors.

This can be considered the main obstacle, since in the new bioeconomy framework, for many of these biomasses to be reused in other circuits (e.g., food or pharmaceutical), they must reach the end of waste status. Some of these biomasses have already begun the process of achieving this status. According to the "Law 7/2022 of 8 April on waste and contaminated soils for a circular economy[99] a substance or object that results from a production process and whose purpose is not the production of that substance or object is considered as a by-product and not as waste when the following conditions are met:

- There is no doubt that the substance or object is meant for future usage.
- The substance or object can be used directly without further processing other than normal industrial practice.
- The material or item is created as an intrinsic element of a manufacturing process. The further use complies with all relevant product requirements, as well as with the protection of human health and the environment, without causing overall adverse impacts on human health or the environment.

[99] Law 7/2022 of 8 April on waste and contaminated soils for a circular economy.

For a substance or object to be considered as a by-product, these conditions must be fulfilled simultaneously, i.e. only if every one of them is met will it be a by-product, otherwise the applicable legal regime will necessarily be that of waste (Agencia Andaluza de la Energía., 2020).

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SCALE UP
community-driven
bioeconomy development

Sustainability Screening – Biofuel Region, SE

March 2024

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EXECUTIVE SUMMARY

This report has been produced as part of the SCALE-UP project funded by the Horizon Europe research and innovation programme. The aim of this project is to support the development of small-scale bioeconomy solutions in rural areas across Europe. The aim of this study is to raise awareness of the ecological limits in the northern part of Sweden, based on three resources: water, soil and biodiversity. The report provides an overview of water resources management, land and soil resources management, and biodiversity management profiles in Sweden, focusing on Biofuel Region, the Swedish partner in the SCALE-UP project. BioFuel region corresponds to the four most northern counties in Sweden, Norrbotten, Västerbotten, Västernorrland and Jämtland

Water: Northern Sweden boasts stable water conditions, with approximately 40 rivers and creeks forming part of its hydrology. Governance is overseen by five water districts, each managed by a County Administrative Board, responsible for implementing the EU Water Framework Directive. The region is significant for hydropower production, with 80% of Sweden's hydropower generated here. However, re-examination of hydropower installations is underway due to EU regulations and concerns about energy security.

Soil: Sweden's land area comprises mainly forest land, with 68% covered by forests. The Forestry Act regulates forest management, emphasizing sustainability and biodiversity conservation. Forest land is predominantly owned by individual owners, private companies, and the state. The forest industry plays a vital role in Sweden's economy, ranking as the second-largest exporter of pulp, paper, and sawn wood products.

Biodiversity: Sweden's biodiversity is shaped by its post-ice age colonization, resulting in relatively few endemic species. Implementation of EU Nature Directives is managed by various sector authorities, ensuring the conservation of habitats and species. Recent government initiatives focus on reviewing forest policies to balance environmental and production goals while promoting sustainable forestry practices.

Finally, this large territory is fully aware and affected by the impacts of climate change, primarily with rising temperatures causing forest fires and insect attacks in summer and making the period of frozen soils shorter in winter, limiting the harvest season. It is extremely important to continue with a comprehensive approach to natural resource management, balancing economic interests with environmental sustainability and biodiversity conservation including water, soil and biodiversity.

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Abbreviations

CEC	**Cation Exchange Capacity**
DOC	**Dissolved Organic Carbon**
EQS	**Environmental Quality Standards**
EEA	**European Environment Agency**
EU	**European Union**
MW	**Megawatts**
RBD	**River Basin District**
RBMP	**River Basin Management Plan**
SEK	**Swedish Krona**
SFA	**Swedish Forest Agency**
SOC	**Soil Organic Carbon**
SOM	**Soil Organic Matter**
TWh	**Terawatts per hour**
WEI+	**Water Exploitation Index plus**
WFD	**Water Framework Directive**
WISE	**Water Information System for Europe**

1 Resource management profiles (by BFR)

1.1 Water resources management profile

The hydrology in northern Sweden is connected to the catchment areas of approximately 40 rivers and creeks. In total Sweden has approximately 120 main catchment areas (see **Error! Reference source not found.**). Northern Sweden has relatively stable water conditions with good availability and relatively small variations. The catchment areas located in the BioFuel Region (i.e. the area contemplated in the SCALE-UP project and in this study) are the ones labelled 1-42, 114 and 116 in **Error! Reference source not found.** (with the latter two flowing into Norway).

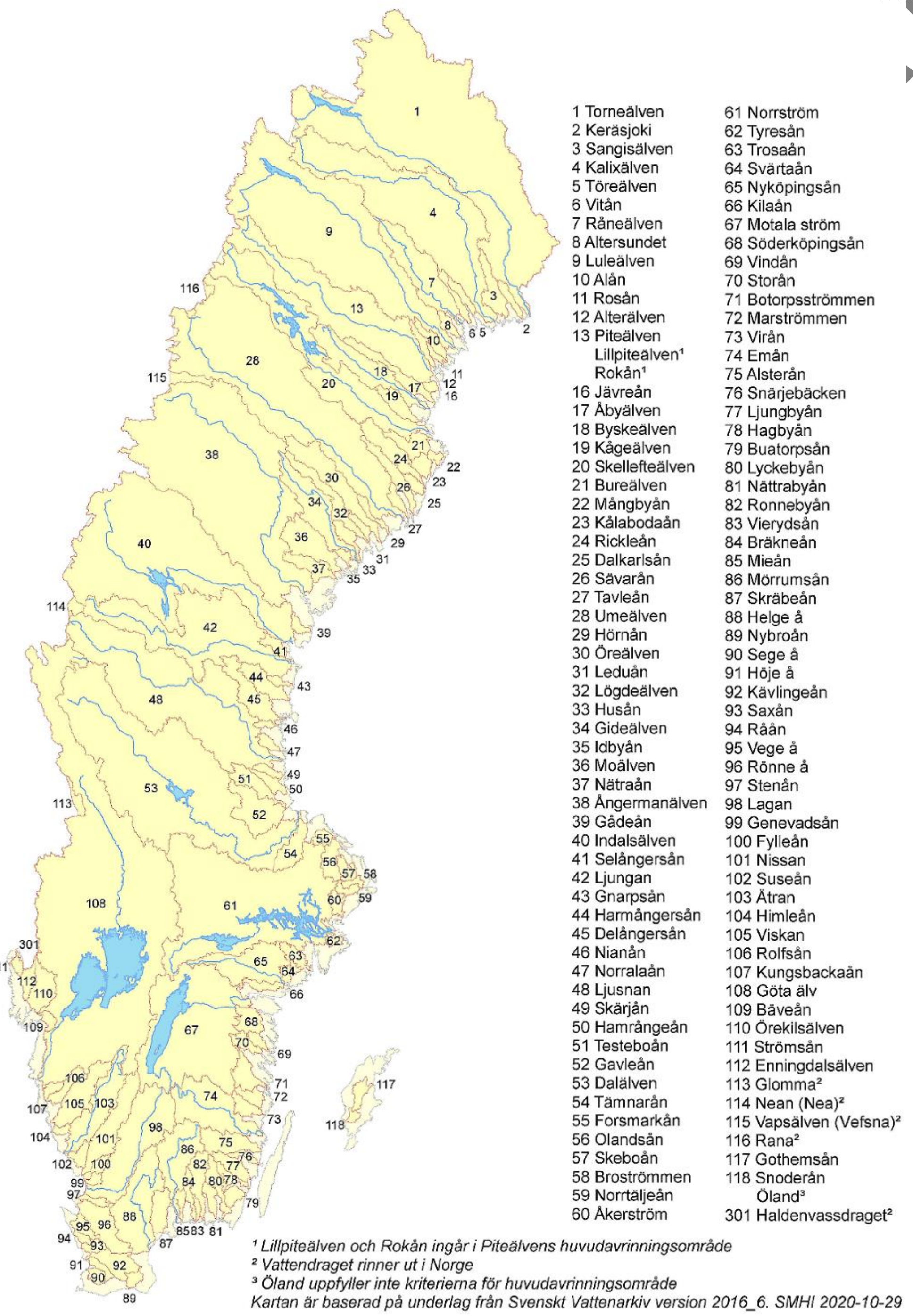

Figure 17 Catchment areas in Sweden. Source: SMHI, 2022.

Governance and regulations

In Sweden, the water authorities' mission is to implement the EU Water Framework Directive. Sweden is divided into five different water districts, based on the borders of the major sea basins and catchment areas, which means that the 21 counties and 290 muni-cipalities can be a part of more than one district.

In each water district one of the county administrative boards is appointed by the government to act as water district authority:

- The County Administrative Board of Norrbotten is the Water Authority of the Bothnian Bay Water District
- The County Administrative Board of Västernorrland is the Water Authority of the Bothnian Sea Water District
- The County Administrative Board of Västmanland is the Water Authority of the North Baltic Sea Water District
- The County Administrative Board of Kalmar is the Water Authority of the South Baltic Sea Water District
- The County Administrative Board of Västra Götaland is the Water Authority in the Skagerrak and Kattegat Water District.

Each water district authority has an office which prepares cases for the water delegation, coordinates the county administrative boards producing documentation, and collaborates with affected parties at all levels from local to international level. The five water authorities must manage the quality of the water environment. This means, among other things, that Swedish water authorities:

- Produce and revise the management plan and programme of measures for each RBD
- Decide on environmental quality standards (EQS)
- Coordinate water management work within the districts
- Collaborate nationally, regionally and locally with interested parties in water management
- Submit information to the Maritime and Water Authority for further reporting to the European Commission

The role of hydropower and energy security

There are roughly 2,000 hydropower plants in Sweden, with a total installed output of approximately 16,300 Megawatts (MW). During a year with normal water inflow the hydropower produces around 65 TWh. That is approximately 30 percent more than the electricity consumption of the entire Swedish industry per year. Sweden has four so called “National Rivers “that are protected from further expansion of hydropower. All of them are situated in the area of BioFuel Region. Two of them are not affected by hydropower (Torne River and Kalix River), while the other two are (Vindel River and Pite River). The power plants located in the BioFuel Region account for 80 percent of hydropower production in Sweden.

In January 2019, the Swedish government tasked the Swedish Agency for Marine and Water Management, the Energy Agency and Svenska Kraftnät (the country’s electricity network operator) with the task of producing a proposal to re-examine hydropower in the country. The plan was submitted to the government in October 2019. In the summer of 2020, the government announced its decision. According to provisions in the regulation on water activities, work on re-examination began in February 2022 and is expected to last for 20 years. The need for the re-examination arose from the fact that hydropower was expanded long before the entry into the EU and the laws concerning water in the EU affects the hydropower installations. The government has announced in autumn 2022 that they want to pause the work. This is due to, among other things, the war in Ukraine and the discussion about security of supply. The extra time is primarily needed to analyse how much the re-examinations/reconsiderations may risk affecting the capacity of the electricity system to ensure energy security.

Soil moisture on productive forest land

The hydrologic influence on soil moisture classes shows that only 5.5 percent of the productive forest land in the BioFuel Region area (Norrland) is classified as dry (Table 7), the corresponding number for Sweden in total is 6.22 percent.

Table 7 - Percentage distribution and areas of different soil moisture classes on productive forest land in Sweden.

Code Designation*	Norrland		Svealand		Götaland		Hela landet	
	(%)	(Milj. ha)	(%)	(Milj. ha)	(%)	(Milj. ha)	(%)	(Milj. ha)
Dry Soil	5.50	0.68	6.88	0.36	7.37	0.36	6.22	1.41
Mesic soil	59.58	7.43	59.27	3.10	57.66	2.84	59.09	13.37
Mesic-moist soil	33.14	4.13	32.58	1.70	31.96	1.58	32.75	7.41
Moist soil	1.74	0.22	1.27	0.066	2.85	0.14	1.87	0.42
Wet soil	0.04	0.005	0.01	0.001	0.17	0.008	0.06	0.014
Total	100	12.47	100	5.23	100	4.93	100	22.63

Source: Data from the Swedish Forest Soil Inventory 1993-2002. (Norrland= Northern Sweden) The soil moisture class reflects the average conditions during the growing season.

**** Code Designation Description***

Dry soil: The groundwater level is estimated to be deeper than 2m below the soil surface.
Mesic soil: The groundwater level is estimated to be at 1-2 m depth.
Mesic-moist soil: The groundwater level is estimated to be at less than 1 m depth.
Moist soil: The groundwater level is estimated to be at less than 1 m depth. It is usually visible in hollows within the sample plot.
Wet soil: Groundwater forms permanent pools of water at the soil surface.

1.2 Land and soil resources management profile

Sweden's land area is 410,000 square kilometres or 41 million hectares. Of that area, 68 percent is forest land and 7 percent agricultural land. The built-up and landscaped (bebygd och anlagd mark) land does not make up more than 3 percent of Sweden's total land area. Open marshes and other open land with and without vegetation and glaciers account for 22 percent.

Of Sweden's total forest land area, almost 69% is made up of moraine and in Norrland (Northern Sweden) the share is 75% (see Table 8).

Table 8 - Percentage distribution and areas of different land uses in Sweden.

	Norrland		Svealand		Götaland		Whole country	
	(%)	(Milj. ha)	(%)	(Milj. ha)	(%)	(Milj. ha)	(%)	(Milj. ha)
Productive forest land	**75.42**	12.47	84.11	5.23	82.72	4.94	78.82	22.64
Pasture land	0.09	0.015	1.16	0.072	6.12	0.37	1.58	0.45
Mires	20.76	3.43	11.06	0.69	4.88	0.29	15.36	4.41
Rock	1.81	0.30	3.51	0.22	6.28	0.37	3.10	0.89
Subalpine woodland	1.75	0.29	0.14	0.009	0	0	1.04	0.30
Other climate impediment	0.17	0.029	0.03	0.002	0	0	0.11	0.030
Total	100	16.53	100	6.22	100	5.97	100	28.72

Source: Data from the Swedish Forest Soil Inventory 1993-2002.

National regulation concerning forest land

The Forestry Act expresses the demands society has on you as a forest owner. The law states that the forest is a renewable resource that must be managed so that it sustainably provides a good return. At the same time, you must take into account the cultural environment, reindeer husbandry and other interests. In short the legislation regulates:

- Establishing new forest: New forest must be established after felling.
- Notification of felling: Regeneration felling of at least 0.5 hectares must be notified to the Swedish Forest Agency no later than six weeks in advance.

- Natural and cultural environment conservation: Forest biodiversity must be preserved. It is therefore important to take this into account in all forestry operations. At the same time, other interests, such as the cultural environment and outdoor recreation, must be considered.
- Reindeer husbandry: If you have land where reindeer husbandry may be conducted, you must take reindeer husbandry into account
- Mountainous forest: In montane forests, you must apply for a permit to harvest for regeneration.
- Measures against insects: Insect pests reproduce in unbarked fresh coniferous wood. Insect damage must be prevented by taking care of the amount of damaged spruce and pine forest that exceeds 5 cubic metres of forest within one hectare

Ownership of forest land

The largest area of productive forest land in 2020 was owned by the group of individual owners consisting of natural persons, estates and unlisted companies. These own just under half (48 percent) of the area declared as productive forest land. The second-largest share (25 percent) is owned by private limited companies, followed by state owned companies (12 percent) and the state (8 percent). Other private owners and other public owners hold the remaining 6 and 1 per cent productive forest land, respectively. The development of these shares during the period 1999 to 2020 was relatively stable, with only slight changes. In 2020, almost half of the productive forest land in Sweden was owned by 310,749 private persons (SFA, n.d.)

The economic importance of the forest industry

Sweden is the world's fourth largest combined exporter of pulp, paper and sawn wood products (2022). The export value in 2022 was 186 billion SEK (2021: 157 billion). About 82 percent of the production of Sweden’s forestry sector is exported. Investments in the sector in 2022 amounted to SEK 15.8 billion (2021: SEK 12.1 billion) (Skogs Industrierna, 2024).

Pulp, paper and sawn timber comes second place when comparing important export goods for Sweden, 186 billion SEK. In the following table from Statistics Sweden, the timber part is missing.

Sweden‘s 10 most important export goods in 2022, Source: SCB, 2023.

Export goods	**Billion SEK**
Vehicles	243
Mineral oils	160
Medical and pharmaceutical products	139
Nonelectric machines and devices	109
Paper, pulp and goods made of paper	103
Electric Machines and devices	93
Iron and Steel	93
Machines for specific industries	74
Telecom, radio, television sets	73
Power-generating machines	63

1.3 Biodiversity management profile

Late colonization after the ice age has resulted in very few endemic species being found in Sweden compared to older geographical regions (SLU, 2020).

Implementation of the EU Nature Directives in Sweden

It is primarily the responsibility of the relevant sector authorities to ensure that the provisions of the EU Birds and Habitats Directives are transposed into Swedish legislation. The authorities concerned, primarily the Swedish Environmental Protection Agency, the Swedish Forest Agency, the Swedish Board of Agriculture and the Swedish Board of Fisheries, must therefore ensure the appropriate formulation, implementation and enforcement of regulations within their area of responsibility. Primarily, this refers to the relevant provisions of the Species Protection Ordinance and the Hunting Ordinance, where the articles of the Directives have been incorporated.

Currently, some such implementing regulations are found in the statute books of the authorities mentioned. The provisions of Swedish legislation that derive from the EU Nature Directives and that this handbook deals with concern a variety of societal activities. This means that it is not only the most directly responsible sector authorities and authorities such as the county administrative boards and the environmental courts that must be aware of- and apply the provisions. The country's municipalities are responsible for several issues relating to protected species. One example is planning matters, which can have a direct impact on the interests safeguarded by the Species Protection Ordinance and the Hunting Ordinance.

It is therefore important for the municipalities to know the purpose and content of the ordinances. In connection with Sweden's membership of the EU, species protection was clarified in Swedish legislation. The Habitats Directive's species protection was the guiding principle when it was introduced in the Species Protection Ordinance. As a result, birds were subject to the same regulations as the species listed in Annex 4 of the Habitats Directive. Both the Habitats and Birds Directives are minimum directives, which means that the individual Member States can introduce more far-reaching provisions, such as in the Species Protection Regulation, where the protection of birds is slightly strengthened compared to the Birds Directive (Naturvårdsverket, 2009).

New investigation announced by the Swedish government.

On the 7th of February the Swedish government announced a new investigation called “A robust forest policy that sees the forest as a resource"

A special investigator will carry out a review of the national forest policy given the development since the forest policy reform in 1993, including policy development within the EU, as well as consider measures for long-term sustainable and competitive forestry that strengthens economic freedom and the willingness to invest.

The task also includes making proposals for effective, simple and well-functioning supervision of forestry and a more effective way to work with the national environmental goals that concerns the forest. The aim is to develop a future expedient forest policy that promotes long-term sustainable competitive forestry, increased forest growth and long-term increased access to sustainable forest biomass in order to fully contribute to climate change and jobs and growth throughout the country. The equal forest policy goals - the environmental goal and the production goal – remains (Regeringskansliet, 2024).

Biodiversity on forest land

To measure forest biodiversity on an area of 28 million hectares is difficult and is therefore often done by measuring important structures for biodiversity such as the amount of dead wood and, old trees, amount of broadleaves and snags. In 1993 the Swedish Forestry Act was revised, and two targets were incorporated: a production target and an environmental target. The intention, according to the preparatory work, was that these two goals would be equal. In order to follow up on the revised law the National Forest Survey now has 30 years of data to analyse and it is clear that all the above-mentioned important structures have increased, as have the areas of formally and voluntary protected forest land. *(Skogsdata 2014 with theme on (Biological diversity, Skogsdata 2019 with theme on from 2014, Forest structures, Skogsdata 2020 with theme on from 2019, Dead wood, Skogsdata 2022 on the theme from 2020, The formally protected forest from 2022)*

2 Methodology for the appraisal of available capacity of the regional ecosystem (by Ecologic Institute)

The text in this chapter is strongly based on the description of the methodology for the BE-Rural Sustainability Screening presented in Anzaldúa et al. (2022), with only minor adaptations that resulted from the implementation of the approach in SCALE-UP.

2.1 Water data and indicators

To run the sustainability screening of surface and groundwater bodies potentially relevant to the BioFuel Region in Sweden, the authors of this report have reviewed the data reported in the 2nd River Basin Management Plans (RMBPs) of the Bothnian Sea and the Bothnian Bay River Basin Districts published in 2016 (data from the 3rd reporting cycle was not yet available on the WISE Database at the time of the analysis). The benefits of tapping on this reporting process is that it includes well-defined indicators like the status of water bodies in each RBD as well as data on significant pressures and impacts on them. Further, these data are official, largely available, accessible, and updated periodically (every six years). Authorities in charge of developing a regional bioeconomy strategy would generally be expected to have good access to the entity in charge of developing the River Basin Management Plan (i.e. the River Basin Authority), and so could theoretically consult it if necessary.

2.1.1 Description of the data / definition of the indicators employed

Data reviewed for this part of the screening included the reported ecological and chemical status of rivers and lakes as well as the quantitative and chemical status of groundwater bodies in the two RBDs that roughly coincide territorially with the BioFuel Region. These data give indications on water quality in the two river basins according to the five status classes defined in the WFD. These are: high (generally understood as undisturbed), good (with slight disturbance), moderate (with moderate disturbance), poor (with major alterations), and bad (with severe alterations) (EC, 2003). Further, data on significant pressures and significant impacts on the water bodies in the river basin districts are used to indicate the burden of specific pressure and impact types on water ecosystems in the regions based on the number and percentage of water bodies subject to them. Significant pressures are defined as the pressures that underpin an impact which in turn may be causing the water body to fail to reach at least the good status class (EEA, 2018).

All data described above were accessed on 05.06.2023 from the WISE WFD data viewer (Tableau dashboard) hosted on the European Environment Agency's (EEA) website[100].

Table 9 - Indicators used for the water component of the sustainability screening

Category	Indicator Family	Indicator	Spatial level	Unit of measure	Comments/Reference
Water	Water quality	Status of water bodies according to the EU Water Framework Directive	River Basin District	Number of water bodies in high, good, moderate, poor, bad or unknown status	WISE WFD Data Viewer[101] Disaggregated data for ecological and chemical status of surface water bodies; quantitative and chemical status of groundwater bodies, per River Basin District

[100] https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd
[101] WISE WFD Data Viewer (https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd)

	Burden on water bodies	Significant pressures on water bodies	River Basin District	No. and % of water bodies under significant pressures per pressure type	WISE WFD Data Viewer
	Burden on water bodies	Significant impacts on water bodies	River Basin District	No. and % of water bodies under significant impacts per impact type	WISE WFD Data Viewer

Source: Anzaldúa et al., 2022.

To determine which status class a certain water body falls into, WFD assessments evaluate the *ecological* and *chemical* status of surface waters (i.e. rivers and lakes) and the *quantitative* and *chemical* status of groundwater bodies. Ecological status refers to *"an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters".* It covers assessments of biological (e.g. presence and diversity of flora and fauna), physico-chemical (e.g. temperature and oxygen content) and hydromorphological criteria (e.g. river continuity) (EC, 2003; BMUB/UBA, 2016). The chemical status of a surface water body is determined by comparing its level of concentration of pollutants against pre-determined Environmental Quality Standards (EQS) established in the WFD (concretely in Annex IX and Article 16(7)) and in other relevant Community legislation. These standards are set for specific water pollutants and their acceptable concentration levels.

In the case of groundwater bodies, chemical status is determined on the basis of a set of conditions laid out in Annex V of the WFD which cover pollutant concentrations and saline discharges. Additionally, the water body's quantitative status is included in the WFD assessments, defined as "*an expression of the degree to which a body of groundwater is affected by direct and indirect abstractions"*. This gives indication on groundwater volume, a relevant parameter to evaluate hydrological regime (BMUB/UBA, 2016).

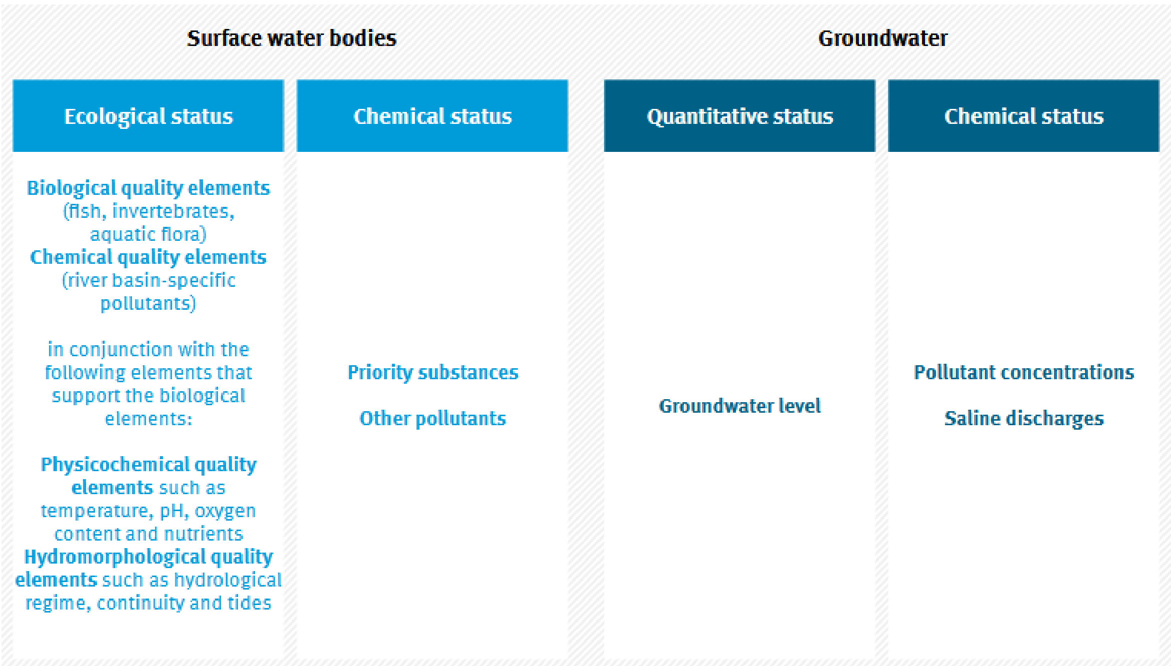

Figure 18 - Overview of surface water body and groundwater status assessment criteria, as per the Water Framework Directive. Source: BMUB/UBA, 2016.

In the case of surface water bodies, the WFD objective is not only that they reach good status, but that quality does not deteriorate in the future (EC, 2003), which is relevant in the context of the development of bioeconomy value chains.

2.1.2 Methodology applied

The authors of this report have followed the approach described in Anzaldúa et al. (2022) to valorise the data from the WFD reporting described in the previous sub-section that allows for an appraisal that is non-resource intensive (based on reliable, publicly available and accessible data) yet capable of providing a rough overview of the state of the BioFuel Region's waters. This is in line with the rationale of this sustainability screening, which aims to enable stakeholders with limited financial resources and/or expertise in the field to consider ecological limits in a structured manner when exploring bioeconomy activities. The preferred option for this part of the assessment would have been to supplement the WFD data with a water quantity balance indicator like the Water Exploitation Index plus (WEI+) developed by the EEA and its partners. That indicator compares the total fresh water used in a country per year against the renewable freshwater resources (groundwater and surface water) it has available in the same period. This could have strengthened the water quantity element in the screening. However, the calculation of the WEI+ at regional level is currently not conducted or foreseen by its developers, and it would entail a disproportionately large effort that falls beyond the scope of this task in SCALE-UP. For these reasons, the reported data from the WFD process has been employed exclusively within the following methodology.

The overall apportionment of rivers, lakes and groundwater bodies in the BioFuel Region according to their WFD status classification can be used to set the baseline for the sustainability screening. It provides initial insight on the situation in the demarcation as regards "ensuring access to good quality water in sufficient quantity", "ensuring the good status of all water bodies", "promoting the sustainable use of water based on the long-term protection of available water resources" and "ensuring a balance between abstraction and recharge of groundwater, with the aim of achieving good status of groundwater bodies", all explicit aims of the WFD that are aligned with the consideration of ecological limits. Further, the data on significant impacts and pressures affecting the water bodies in the river basins are useful as they can point towards specific problems (e.g. nutrient pollution) and the types of activities that may be causing them (e.g. discharge of untreated wastewater, agriculture).

As a first step, the approach used for this element of the screening entails calculating what proportion of the total number of surface water bodies located in the RBD is reported as failing to achieve Good Ecological Status/Good Chemical Status or for which conditions are unknown. Similarly for groundwater bodies, the proportion is calculated of those who are reported as failing to achieve Good Chemical Status/Good Quantitative Status or for which conditions are unknown. The resulting ratios are then compared to the respective EU proportions, which are used as (arbitrary) thresholds. According to the latest assessment published by the EEA in 2018, "around 40% of surface waters (rivers, lakes and transitional and coastal waters) are in good ecological status or potential, and only 38% are in good chemical status" (EEA, 2018). Accordingly, "good chemical status has been achieved for 74% of the groundwater area, while 89% of the area achieved good quantitative status" (EEA, 2018). Using these markers, the following step is to rank the current conditions of the BioFuel Region using an ordinal risk rating (high, moderate, low) based on the distance of the result of each indicator to the EU level results. On this basis, the thresholds and ordinal ranking convention suggested by the authors of this report are as shown in Table 10 and Table 11.

Table 10 - Proposed thresholds for the water section of the sustainability screening

Water body type	Status category	2018 EU-level assessment results (proportion of water bodies achieving good status)	Proposed thresholds for the sustainability screening		
			High concern	Moderate concern	Low concern
Surface water bodies	Ecological status	~40%	0-40%	41-89%	90-100%
	Chemical Status	38%	0-38%	39-89%	90-100%
Groundwater bodies	Chemical status	74%	0-74%	75-89%	90-100%
	Quantitative status	89%	0-89%	-	90-100%

Source: Anzaldúa et al., 2022.

Table 11 - Ordinal ranking convention for the water section of the sustainability screening

Ordinal ranking for water resources		Chemical status		
		High concern	Moderate concern	Low concern
Ecological or Quantitative status	High concern			
	Moderate concern			
	Low concern			

Source: Anzaldúa et al., 2022.

This initial appraisal based on the thresholds shown above is then supplemented with a review of the reported data on the types of significant pressures and impacts on surface and groundwater bodies. In this case percentage values are already given, and so this step in the screening simply entails the listing of the reported pressures and impacts and the identification of those which are more frequently reported. From here, the screening team can seek potential correlations between the most reported pressure types and the most reported impact types (e.g. diffuse sources causing nutrient pollution).

The final step in the approach is to draft a note describing the share of water bodies failing to reach good status and formulating preliminary statements on the types of bioeconomy activities that could be considered, those that should be considered with reserve, and those that should be avoided.

These initial statements are used to frame the discussion of the group of stakeholders involved in the development of the bioeconomy value chains in focus in the SCALE-UP project.

2.1.3 Data uncertainties

The data resulting from the assessments reported in the WISE Database are subject to the limitations of the scientific and methodological approaches used by their authors. It thus must be considered that the official assessments are based on estimates, include assumptions, and will therefore carry a margin of error.

An important limitation bound to the implementation of the sustainability screening is that the WFD data used refer to the RBDs of the Bothnian Bay and the Bothnian Sea, whose territorial boundaries do not coincide entirely with those of the BioFuel Region. A future iteration of this exercise by the local stakeholders could increase the resolution of the screening of water resources by tapping on additional information sources, like higher resolution data for the specific territorial demarcation of the BioFuel Region, if they become available.

Lastly, another issue to consider is the data currently available on WISE is from 2016, while more updated assessments are already available at the time of writing of this document. These come as part of the 3rd cycle of river basin management planning (2022-2027), but are not yet reflected on the WISE Database hosted by the EEA. Here as well, such sources could be considered by the stakeholders performing the sustainability screening to avoid overlooking any relevant recent developments.

2.1.4 Methodological uncertainties

The proposed methodology for the water section used in this application of the sustainability screening is straight-forward and accessible, yet it must be used with care and, where possible, should incorporate higher resolution data evaluated by thematic experts. As previously mentioned, the thresholds set in this case have been the proportions, at EU-level, of water bodies that fail to achieve good status or for which conditions have been reported as unknown. This has been a pragmatic, yet easy to challenge way of defining a benchmark for the BioFuel Region. Conditions and context in other European RBDs may be significantly distinct to those in Northern Sweden, and thus a more appropriate reference point could be defined in those cases. For this, the authors envision the contributions and guidance from the team of local and foreign experts as briefly described in Section 3.2 of Anzaldúa et al., 2022. Optimally, these thematic experts should know the regional context well and thus be in a good position to guide the setting of such thresholds. Beyond this, the simplicity of the necessary calculations and the fact that the data on significant pressures and impacts are used without further computation and compared in relative terms within the RBD limit the possibility of additional accuracy or uncertainty issues emerging.

2.2 Soil data and indicators

2.2.1 Description of the data / definition of the indicators employed

The selected indicators for vulnerability to soil depletion are closely interrelated and refer specifically to soil erosion **by water**. These are:

- Estimated mean soil erosion rate (in $t\ ha^{-1}\ a^{-1}$)
- Share (%) of area under severe erosion (>10 $t\ ha^{-1}\ a^{-1}$)

In broad terms, soil erosion describes the process through which land surface (soil or geological material) is worn away (e.g. through physical forces like water or wind) and transported from one point of the earth surface to be deposited somewhere else (Eurostat, 2020). The above-mentioned indicators describe particularly the amount of soil (in t) per unit of land surface (in ha) that is relocated by water per year.

Variations of these indicators can be calculated by considering different combinations of land cover classification groups, such as *all land*[102] and *agricultural land*[103]. As shown in Figure 19, at EU level in 2016, about three quarters of soil loss occurred in agricultural areas and natural grasslands, while the remaining quarter occurred in forests and semi natural areas (Eurostat, 2020). Therefore, since it is the type of land cover that is most vulnerable to erosion, the present sustainability screening will consider in first line the above-mentioned indicators specifically for agricultural areas and natural grasslands. This scope of the indicators is also in line with the two sub-indicators for soil erosion considered by the Joint Research Centre European Soil Data Centre (JRC ESDAC). Moreover, both the *mean erosion rate for agricultural land* and the *share of agricultural area under severe erosion* are part of the EU Common Agriculture Policy (CAP) context indicator 42 (CCI42) for the period 2014-2020.

Figure 19 Share of land cover and soil loss across the EU-27 in 2016[104]

Source: JRC, Eurostat

The data has been extracted from EUROSTAT, specifically the dataset "Estimated soil erosion by water, by erosion level, land cover and NUTS 3 regions (source: JRC) (aei_pr_soiler)". For determining the baseline in the sustainability screening, we have selected the latest available data, i.e. for 2016.

Mean soil erosion rate, which undergirds both selected indicators, is considered useful because it provides a solid baseline to estimate the actual erosion rate in the regions (Panagos et al., 2015). This indicator is based on the latest Revised Universal Soil Loss Equation of 2015 (RUSLE2015), specifically adapted for the European context (see Panagos et al., 2015), which is a model that takes into account various aspects, including two dynamic factors, namely the cover-management[105] and policy support practices[106] (both related to human activities) (Panagos et al., 2020).

[102] This refers to all potentially erosive-prone land (in simplified terms), specifically to CORINE Land Cover classification groups: Agricultural areas (2), forest and semi natural areas (3) excluding beaches, dunes, sand plains (3.3.1), bare rock (3.3.2), glaciers and perpetual snow (3.3.5). These, as well as other classes, are excluded because they are not subject to soil erosion.

[103] This refers only to agricultural land (agricultural cropland as well as grassland in simplified terms), specifically to CORINE Land Cover classification groups: Agricultural Areas (2) and Natural Grasslands (321)

[104] Excluding not erosion-prone land (e.g. beaches, dunes, etc.). Forest and natural areas exclude also natural grasslands, which are evaluated together with agricultural areas.

[105] Known as the c-factor, it has a non-arable component, which includes changes in land cover and remote sensing data on vegetation density, as well as an arable component, which includes Eurostat data on crops, cover crops, tillage and plant residues.

[106] Known as the p-factor, it reflects the effects of supporting policies in estimating the mean erosion rate by including data reported by member states on Good Agricultural Environmental Conditions (GAEC) according to the CAP, specifically contour farming, as well data from LUCAS Earth observation on stone walls and grass margins.

The estimated mean soil erosion rate value obtained through the RUSLE2015 model refers to water erosion only, but it is considered to be the most relevant at least in terms of policy action at EU level, due to the relative predominance of water erosion over other types of erosion. Furthermore, it offers the important advantage of providing a viable estimation for erosion vulnerability at a relatively small geographic scale, i.e. the local or regional level. This can serve as an important tool for monitoring the effect of local and regional policy support strategies of good environmental practices (Panagos et al., 2015, 2020, and Eurostat, 2020).

2.2.2 Methodology applied

The near-universal indicators available to track soil vulnerability are related to either erosion or the decline in soil organic carbon (SOC)/soil organic matter (SOM) (Karlen & Rice, 2015). However, there are major data gaps regarding to SOC/SOM and data is currently only available at national level. According to Panagos et al. (2020), soil organic carbon does not change so quickly and therefore is not so sensitive to human influence on short term. Therefore, they recommend using just a sole indicator for monitoring impact of policies: "estimated mean soil erosion rate" (by water), which they calculate using the RUSLE2015 model. For our purposes, we have complemented the *mean soil erosion rate* indicator, with the *share of agricultural area under severe erosion* in order to gain a comprehensive picture of soil erosion in a region.

Soil erosion is considered generally as a sort of proxy indicator of soil degradation, which in turn is the most relevant component of land degradation at EU level (EC, 2018). However, not all types of bio-based activities have a direct effect on erosion, but rather primary production of biomass. Nonetheless, as these are currently the most widespread bioeconomy activities in rural areas, we will consider their impact on soil degradation, and therefore on soil erosion, to be the most relevant one for this assessment.

The indicators for vulnerability to soil degradation were selected, on one hand, due to the limited number of soil indicators available at the required regional scale. On the other hand, the RUSLE2015 model used for this data also represents the current state-of-the-art methodology for calculating soil erosion. These aspects are crucial, since the choice of indicators needs to be: a) acceptable to experts, b) routinely and widely measured, and c) have a currency with the broader population to achieve global acceptance and impact (Stockmann et al., 2015). In order to carry out the screening of soil vulnerability, a number of datasets need to be accessed. As mentioned above, these data can be accessed via Eurostat.

In terms of processing the erosion data, it is important to consider that the overall erosion rate changes across geographic areas, meaning the vulnerability/risk is not necessarily evenly distributed. In cases where the mean soil erosion rate exceeds the 10 t ha^{-1} a^{-1}, erosion is considered severe and activities that can generate, or are associated with a high erosion impact should be strongly discouraged. Erosion rates between 5 and 10 t ha^{-1} a^{-1} are considered moderate, requiring some attention towards practices that have a high impact on erosion, but with less urgency. However, it is relevant to take a look not only at the mean erosion rate for the area itself, but also at its spatial distribution, which is roughly reflected on the indicator of share of (agricultural) area under severe erosion.

2.2.3 Data uncertainties

The data used is produced from an empirical computer model (RUSLE2015) and produces estimates. Hence, there are several uncertainties related to the figures if compared to data collected on the ground. However, the purpose of the model is to generate data for a large spatial scale taken into account human intervention, which is not possible to do only through empirical measurements. That being said, like every model, assumptions have to be made and there is an intrinsic level of uncertainty. Specifically related to the RUSLE methodology, Benavidez et al. (2018) critically reviewed the RUSLE methodology, upon which RUSLE2015 is based, and identified following main limitations:

- its regional applicability to regions that have different climate regimes and land cover conditions than the ones considered (in the original RUSLE for the USA, in RUSLE 2015 for Europe)

- uncertainties associated generally with soil erosion models, such as their inability to capture the complex interactions involved in soil loss, as well as the low availability of long-term reliable data and the lack of validation through observational data of soil erosion, among others.
- issues with input data and validation of results,
- its limited scope, which considers only soil loss through sheet (overland flow) and rill erosion, thus excluding other types of erosion which may be relevant in some areas, e.g. gully erosion and channel erosion, to name a few. Moreover, it also excludes wind erosion.

A further factor of uncertainty in the data is the fact that the RUSLE model is calculated using mean precipitation data over multiple years and a large territorial scale (in this case Europe). Thus, it fails to account the changes in rainfall intensity, which are highly relevant for determining water erosion accurately. This is the case not only considering the seasonality of rainfall, but also its distribution across the continent (Panagos et al., 2020). Another important uncertainty identified by Panagos et al. (2020) is the lack of georeferenced data for annual crops and soil conservation practices in the field at a continental level, which has had to be estimated from statistical data.

Nonetheless, when considered best available estimates, the mean soil erosion values generated through the application of RUSLE2015 model offer a very suitable basis for assessing vulnerability to soil loss in general terms, even if the generated absolute values are to be taken with caution (Benavidez et al., 2018).

2.2.4 Methodological uncertainties

Among the most relevant uncertainties regarding the application of the sustainability screening in terms of soil vulnerability are the selection of the threshold against which the severity of erosion is evaluated and the selection of the land cover types that will be considered.

Regarding the threshold of 10 t ha^{-1} a^{-1} for severe erosion, it is important to mention that this was obtained directly from the dataset that was used[107]. However, it is still an arbitrary value which can be adapted. For instance, some sources like Panagos et al. (2015, 2020), who were involved in the generation of the data for the JRC ESDAC, consider severe erosion to be above 11 t ha^{-1} a^{-1}. In this regard, we have also decided to stick to the lower value described in the Eurostat dataset because it is more conservative and, as such, more suitable for an initial (and indicative) sustainability screening like the one we are proposing.

The selection of land cover types presents another area for potential uncertainty. Choosing between “all lands” and “agricultural lands” can have considerable implications for interpreting the data. For example, it is possible that the mean soil erosion rate is 5 t ha^{-1} a^{-1} (moderate erosion) in one land cover type, but lower in the other. This would have an effect on the assessment, which would present any potential concerns about erosion and steps that should be taken. As such, it is important to have solid grounding for the choice of dataset. The ultimate decision whether to consider all lands (including forests) is arbitrary and lays with the group performing the sustainability screening. Particularly when that decision is based on considerations of the economic relevance of forestry related industries in the region rather than on the actual share of the area that is covered with forest (it should be high to justify their inclusion), the values of soil erosion (for all lands) shall be taken with some reservations. This is because these values tend to be lower than the value for agricultural land and can create the impression that vulnerability to erosion is lower than it actually is. However, due to the indicative (and non-exhaustive) nature of the present sustainability screening, this uncertainty is not especially relevant for cases such as the BioFuel Region, which has a high proportion of forest land and where both values (for all lands and agricultural land with natural grassland) are low (see section 4.1).

[107] See metadata of the used dataset at https://ec.europa.eu/eurostat/cache/metadata/en/aei_pr_soiler_esms.htm

2.3 Biodiversity data and indicators

2.3.1 Description of the data / definition of the indicators employed

Unlike for water- and soil-related risks, there are no reliable indices or standardized metrics to operationalize and compare risks to biodiversity at the regional level and in an integrated manner. Biodiversity is intricate and multifaceted, spanning genetic, species, and ecosystem diversity across various regions. Attempting to consolidate this diversity into a singular index may oversimplify it, leading to the loss of crucial information (Ledger et.al 2023; Brown & Williams 2016). Instead, biodiversity risks in a given region could be uncovered by considering the status of all species known to inhabit the region under scrutiny on a one-by-one basis, without trying to synthesize their collective status in a single index. Accordingly, our methodology suggests screening for biodiversity risks of a region by taking stock of its species of flora, fauna and fungi present in the demarcation and considering their conservation status. The Red List of Threatened Species of *the International Union for Conservation of Nature* (IUCN) is a globally recognized system for classifying the conservation status of species[108]. It is structured along the following risk categories (IUCN 2001, 2003):

(1) Critically Endangered (CR): This is the highest risk category assigned by the IUCN Red List for wild species. Species in this category are facing an extremely high risk of extinction in the wild.
(2) Endangered (EN): Species in this category are facing a high risk of extinction in the wild.
(3) Vulnerable (VU): Species in this category are facing risks of extinction in the wild.
(4) Near Threatened (NT): Species in this category are close to qualifying for, or are likely to qualify for, a threatened category soon.
(5) Least Concern (LC): Species in this category have been evaluated but do not qualify for any other category. They are widespread and abundant in the wild.
(6) Data Deficient (DD): A category applied to species when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution or population status.
(7) Not Evaluated (NE): A category applied to species that have not yet been evaluated against the criteria.

Data description

Data on the risk category of each species found in the SCALE-UP regions is accessed through the online database of the IUCN Red List website. The IUCN Red List serves as a comprehensive repository of information, offering insights into the present extinction risk faced by assessed animal, fungus, and plant species. In 2000, IUCN consolidated assessments from the 1996 IUCN Red List of Threatened Animals and The World List of Threatened Trees, integrating them into the IUCN Red List website with its interactive database, currently encompassing assessments for over 150.300 species. Since 2014, assessors of species have been mandated to furnish supporting details for all submitted assessments. Among the recorded details are the species' (1) IUCN Red List category, (2) distribution map, (3) habitat and ecology, (4) threats and (5) conservation actions. The assessment of these dimensions is elaborated below:

(1) The IUCN Red List category: The IUCN Red List categories (CR, EN, VU, NT, LC, DD, NE) are determined through the evaluation of taxa against five quantitative criteria (a-e), each grounded in biological indicators of population threat:

[108] The International Union for Conservation of Nature (IUCN) is a global environmental organization that was founded on October 5, 1948. It is the world's oldest and largest global environmental network. The IUCN works to address conservation and sustainability issues by assessing the conservation status of species, promoting sustainable development practices, and providing guidance and expertise on environmental policy and action. The IUCN also plays a crucial role in influencing international environmental policies and fostering collaboration among governments, NGOs, and the private sector to promote conservation efforts worldwide (IUCN 2018).

a. Population Size Reduction: This criterion evaluates the past, present, or projected reduction in the size of a taxon's population. It considers the percentage reduction over a specific time frame, with different thresholds indicating different threat levels.
b. Geographic Range Size and Fragmentation: This criterion assesses the size and fragmentation of a taxon's geographic range. Factors such as few locations, decline, or fluctuations in range size contribute to the evaluation.
c. Small and Declining Population Size and Fragmentation: This criterion focuses on taxa with small and declining populations, considering factors like population size, fragmentation, fluctuations, or the presence of few subpopulations.
d. Very Small Population or Very Restricted Distribution: This criterion addresses taxa with extremely small populations or limited distributions. It assesses whether the taxon is at risk due to its small population size or restricted geographic range.
e. Quantitative Analysis of Extinction Risk: This criterion involves a quantitative analysis, such as Population Viability Analysis, to estimate the extinction risk of a taxon. It considers various factors influencing population dynamics and extinction risk.

While listing requires meeting only one criterion, assessors are encouraged to consider multiple criteria based on available data. Quantitative thresholds of the IUCN Red List categories were developed through wide consultation and are set at levels judged to be appropriate, generating informative threat categories spanning the range of extinction probabilities. To ensure adaptability, the system permits the incorporation of inference, suspicion, and projection when confronted with limited information.

(2) The distribution map: The IUCN Red List distribution map serves as a reference for the taxon's occurrence in form of georeferenced data and geographic maps. This data is available for 82% of the assessed species (>123.600) and is based on the species' habitat, which is linked to land cover- and elevation maps. The indicated area marks the species extent of occurrence, which is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred, or projected sites of present occurrence of a species, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of species, such as large areas of obviously unsuitable habitat. For a detailed explanation of the mapping methodology, please refer to the *Mapping Standards and Data Quality for the IUCN Red List Spatial Data* (IUCN 2021).

(3) Habitat and Ecology: The IUCN classifies the specific habitats that a species depends on for its survival. These habitats are categorized into three broad systems: terrestrial, marine, and freshwater. A species may inhabit one or more of these systems, and so the possible permutations result in seven categories of natural systems. Beyond these seven system categories, the IUCN offers a more nuanced classification system for habitats, comprising 18 different classes at level 1 (e.g., forest, wetlands, grassland, etc.), and 106 more specific classes listed at level 2 (e.g., Forest – Subtropical/tropical moist lowland, Wetlands (inland) – Permanent inland deltas; Grassland - Temperate) (IUCNa n.d.). For SCALE-UP’s sustainability screening, the IUCN classification of the seven systems is sufficient to refine the search while not excluding relevant habitats. The EU Habitats Directive, in contrast, distinguishes 25 habitat types that are considered threatened and require active and recurring conservation action. The Directive demands member states to take measures to maintain or restore these natural habitats and wild species. If data on these became accessible in the future, it could be used in future iterations of the sustainability screening to supplement the results that using the IUCN classification yields.

(4) Threats: The IUCN database encompasses various general threats that can negatively impact a species. Direct threats denote immediate human activities or processes impacting, currently impacting, or potentially affecting the taxon's status, such as unsustainable fishing, logging, agriculture, and housing developments. Direct threats are synonymous with sources of stress and proximate pressures. Assessors are urged to specify the threats that prompted the taxon's listing at the most granular level feasible within this hierarchical classification of drivers. These threats could be historical, ongoing, or anticipated within a timeframe of three generations or ten years. These generalized threat categories encompass residential and commercial development, agriculture and aquaculture, energy production and mining, transportation and service corridors, biological resource use, human intrusion and disturbances, natural system modifications, invasive and other problematic species, genes and diseases, pollution, geological events, and climate change and severe weather. Beneath each general threat, more specific threats are detailed. Please refer to the IUCN Red List's website[109] for a detailed list of all threats, including explanations.

(5) Conservation Actions: The IUCN database contains conservation action needs for each species, providing detailed information on the current conservation efforts and recommended actions for protecting the taxon. It includes general conservation actions such as research & monitoring, land/water protection, management, and education. Specific conservation actions are listed under each general action, along with a description of the current conservation status and recommended actions to protect the taxon. A hierarchical structure of conservation action categories (see the IUCN Red List's website[110]) indicates the most urgent and significant actions needed for the species, along with definitions, examples, and guidance notes on using the scheme. Assessors are encouraged to be realistic and selective in choosing the most important actions that can be achieved within the next five years, informed by the conservation actions already in place.

Note: the IUCN Red List and the EU Habitats Directive

Both, the EU's Habitats Directive and the IUCN Red List aim to preserve biodiversity, but they employ distinct methods and standards for evaluating conservation status. The Habitats Directive is centered on preserving natural habitats and wild species of flora and fauna within the EU, mandating that member states establish Special Areas of Conservation for habitats and species listed in its annexes. The Directive categorizes conservation status into three groups: favorable, unfavorable-inadequate, and unfavorable-bad. This classification system of habitats and species is based on how far they are from the defined 'favorable' conservation status, not their proximity to extinction (Sundseth 2015).

Conversely, the IUCN Red List is a worldwide evaluation of the conservation status of species, categorizing them according to their extinction risk. The Red List employs a set of five rule-based criteria to assign species to a risk category (see above). However, there are inconsistencies and weak agreement between the conservation status assessments of the Habitats Directive and the IUCN Red List. These inconsistencies can be significant, and correlations can vary greatly between taxonomic groups. Specifically, the Red List assessment tends to be more pessimistic than the Directive's Annex (Moser et.al 2016). Amos (2021), on the other hand, has found strong correlations between the two classifications systems for plants, while recognizing the Red List's quicker reaction to changes in the conservation status.

In summary, while both the Habitats Directive and the IUCN Red List aim to protect and

[109] See here: https://www.iucnredlist.org/resources/threat-classification-scheme
[110] Ibid.

conserve biodiversity, they use different methodologies and criteria to assess conservation status, leading to discrepancies in their assessments. However, they can complement each other in providing a comprehensive view of the conservation status of species and habitats at both the European and global levels (IUCN 2010).

2.3.2 Methodology applied

The methodology aims to derive a list of species which would require special consideration (e.g. close monitoring and safeguarding) in the context of implementing bioeconomy activities. To generate this list, the search function of the interactive IUCN database is used following five steps:

(1) Scope of Assessment: Selection of Europe as the scope of assessment to evaluate the conservation status of the European population rather than the global population. This approach ensures that species are identified as threatened based on their status in Europe, irrespective of their global abundance.

(2) Geographical Delineation: Utilization of the interactive map of the IUCN database to draw a polygon that exceeds the region of interest. Exceeding the regions ensures that the entire region is covered, as it is not possible to draw a polygon exactly matching the boundaries of the region. Moreover, a larger polygon also respects the uncertainty of delineating a species area of extent, since the actual area of extent is possibly more fluid than its statically indicated geolocations. Consequently, the larger polygon minimizes the risk of excluding any relevant species for which geolocations are registered just minimally outside of the regions' administrative boundaries, but which could inhabit parts of the region in the future. There is no rule of thumb for a correct distance between polygon boundary and region boundary.

(3) Species Selection: Limiting of the search results to endangered and critically endangered species to focus on those facing the most severe risks.

(4) Habitat Selection: selection of all habitats to ensure the full coverage of habitat types present in the geographical delineation defined in step 2.

(5) Threat Selection: Selection of threats associated with the respective regional bioeconomy and/or value chain to refine the search results to species likely to be impacted by them.

By following these steps, a targeted list of species is derived, focusing on species facing significant risks within the context of the regional bioeconomy strategy or value chain being explored, aligning with the specific conservation and bioeconomic priorities of the region.

2.3.3 Data and methodological uncertainties

It is important to acknowledge certain limitations and uncertainties associated with the data and methodologies used:

(1) Inaccurate representation of relevant area: The IUCN database allows for the interactive drawing of a map for a regional assessment. However, this drawn map might not accurately represent the area directly relevant to the bioeconomy strategy or value chain being explored. Since the selected polygon is larger than the actual bioregion, the assessment risks to include species that are not relevant to the bioregion and the bioeconomic strategy of the region.

(2) Lack of local habitat differentiation: The spread of species is indicated as its extent of occurrence without differentiating between habitats at the local level. This means that certain species might solely inhabit very particular habitats within the indicated extent of occurrence. An endangered amphibious species, for instance, might have an area of extent covering an entire country. However, it will only be found in very rare habitats within this area of extent (e.g., pond with very specific qualities). Accordingly, a regional assessment as outlined here (e.g., at the municipal level) might list certain species that do not occur in the assessed regions due to a lack of suitable habitats on the local level.

(3) Potential oversights in conservation status: Using Europe as a scope of assessment might hide any problematic conservation status of a species at the global or at the local level.
(4) Outdated data: The IUCN aims to have the category of every species re-evaluated at least every ten years and aims to update the list every two years (IUCNb n.d.). Nevertheless, the data might be outdated, which could lead to inaccuracies in the assessment of biodiversity risks. For this screening carried out for Northern Sweden, 30 percent of the data was older than 5 years, the most dated ones being from 2016.
(5) Incomplete data: The data might be incomplete, which could limit the comprehensiveness of the assessment.
(6) Limited species coverage: It is estimated that the world hosts about 8,7 million species (Sweetlove, 2011). As of now, more than 150.300 species (16.120 in Europe) have been assessed for the Red List, leaving large data gaps at the global level.
(7) Taxonomic standards: The taxon being assessed must follow the taxonomic standards used for the IUCN Red List. Any deviation from these standards could lead to inaccuracies in the assessment.

The Swedish Species Information Centre at the Swedish University of Agricultural Sciences is responsible for the IUCN Red List assessments in Sweden. They do not collect data in nature, except in rare cases, instead they use what is available, e.g. from authorities' environmental monitoring programs and the like. Some examples of data sources used as basis for the Red List assessments in 2020 were:

- Environmental monitoring, e.g. test fishing, benthic fauna surveys,
- Butterfly monitoring, bird surveys
- Hunting and fishing statistics
- National Forest Inventory, e.g. proportion of dead wood and older forests
- The Swedish Board of Agriculture's figures for the area of grassland and semi-natural pastures (measures of change in important habitats)
- Citizen Science via Artportalen
- Research on the environmental requirements and ecology of species

As previously mentioned in section 1.3 the predominant monitoring of biodiversity in forests are made based on the inventory, by the Swedish NFI, of important structures.

3 Potential ecological burden of regionally relevant bioeconomic activities

Note: the “Global Overview” sections in this chapter were produced based on a review of available and accessible scientific literature on the impacts of bioeconomy activities on water, land and soil, biodiversity, and other environmental dimensions. Quotes associating such activities (or elements thereof) with positive and negative effects on the said environmental dimensions were collected manually from the scientific studies and then fed to ChatGPT 3.5/4 for structuring and synthesis into flowing text.[111] The resulting text was then thoroughly reviewed and adjusted manually to ensure fidelity with the source documents.

[111] Quotes fed to ChatGPT were sorted by topic and kept in quotation marks, including their correct in-text citation. Prompts and feedback were provided to the system to synthesize the information maintaining the style, using the right scientific references, and improving by avoiding repetition, not leaving any of the provided information out, and highlighting agreements, disagreements and complementarities among quotes.

3.1 Bioeconomic activity selected for the screening

The activity selected for review in this chapter is primarily forestry, in general, and the extraction of logging residues that follows clear cutting, in particular. Logging residues consist of branches and the top of the tree.

Being one of the primary wood producers in the EU, Sweden is recognized as a key contributor to the European bioeconomy, supplying significant forest biomass (Eggers et al., 2020). Nowadays, forestry plays a significant role not only in providing timber and pulpwood but also in contributing to biomass for bioenergy –including materials like branches and tops, saw dust and bark– as well as in starting to explore production of biochemicals and biopolymers. In Northern Sweden, there is a potential to increase the currently low extraction rates of logging residues. The current low extraction rates are mainly resulting from greater transport distances to end users. However, rising demand for biomass, e.g., as a renewable alternative for fossil fuels, also raises concerns regarding the environmental impact of the associated value chains and possible effects on the provision of ecosystem services.

The global overviews pinpoint some problematic issues that can arise concerning water, soil and biodiversity when extracting or processing forest biomass. Results come from academic studies carried out in several countries and include some management systems or practices that are not being used in Sweden, for example whole tree extraction and root extraction. The relevance of including them in this report is to collect reference points to provide a wider picture of the documented effects of specific activities and management practices on the three environmental dimensions considered in the sustainability screening, putting into perspective the current frameworks and practices in Northern Sweden (which are described in the sub-sections titled “The situation in Northern Sweden”).

3.2 Overview, management practices and potential burden on the resources examined

3.2.1 Potential burden on water resources

Global overview (by Ecologic Institute)

Depending on the techniques employed, extraction and processing of forest biomass such as timber, and of forestry residues such as stumps, tops and branches slash, and bark can significantly impact water resources. At first instance, where no preventive measures during extraction are undertaken, water quality can be affected by soil disturbance and increased runoff, potentially carrying sediments and nutrients into water bodies. In Sweden, for this reason, the Forestry Act requires to leave zones near creaks and lakes undisturbed. Harvesting is mainly carried out in winter, when the land is frozen, to avoid compaction and damage to the soil. Approximately 50 percent of the tops and branches are used to pave the forest roads to minimize the risk for soil damage. If forest residues are harvested, approximately 30 percent is left in the forest to prevent nutrient depletion and habitat deterioration. Tree stumps consist of approximately one fifth of the tree and were previously harvested to a limited extent in Sweden. Due to both technical, economic and ecological reasons, stump extraction is not performed in Swedish forestry today.

Similarly, if the scale of manufacturing/processing operations and their wastewater management practices do not account for ecological boundaries, the processing of forest biomass into materials and products can affect water resources by abstraction and pollution pressures. This is meant to be safeguarded by the legal frameworks in place (e.g. environmental permitting procedures and environmental protection legislation).

Water Quality: Log extraction can impact water quality through increased runoff and leaching of nutrients, dissolved organic carbon (DOC), and particles that metals (Hg, Al, Pd, Cd, Zn, Fe) are attached to (Ranius et al., 2018). In particular, increased nutrient emission is observed but only after stump extraction (not practiced in Sweden see 3.1), possibly leading to eutrophication of water bodies and thereby potentially affecting aquatic life and water resources for human use. The resultant effects are variable and highly site specific (ibid.). However, it is not clear whether increased nutrient concentrations have these impacts at landscape scale (ibid.).

In acid sensitive areas, clear-cutting –as forestry management practice– and slash extraction is found to increase the risk of loss of base cations. The biomass removal can result in soil and surface water acidification as well as increased concentrations of Al (Ranius et al., 2018). As a possible solution, ash recycling may be used (Titus et al., 2021). Other practices carried out e.g. in Finland to reduce the risk of aquatic systems becoming acidified include not leaving harvested biomass adjacent to water bodies (ibid.). Similarly, the UK restricts the deposition of fresh harvest residues in trenches formed by mounding for restocking at sites with high risk of acidification of water ecosystems (ibid.).

Water Consumption: Biomass residues can be extracted not only for biofuel purposes but also to produce materials, such as biopolymers or bio-source chemicals. As such, tannins, aromatic chemicals contained in bark, can be extracted for commercial purposes. However, the conventional methods for tannin extraction require chemicals, and a significant amount of energy and water resources (Faye et al., 2021). In the referenced study, the outcomes for yield, energy, and water usage across the entire extraction process revealed that the stages of tannin extraction and tannin isolation are the most energy-intensive, accounting for 23% and 72% of the total energy consumption, respectively (ibid.).

To reduce energy and water consumption, ultrasound-assisted treatment and recycling of the extract solution can be introduced into the tannin extraction process. This method allows for the most significant energy and water reductions across the whole process –41% and 49%, respectively– while increasing the tannin yield by 13% compared to the control extraction method (ibid.).

The situation in Northern Sweden (by BFR)

Under the Swedish environmental quality objective „Only Natural Acidification“, it states: "The acidifying effects of deposition and land use should not exceed the limit of what soil and water can tolerate. The deposition of acidifying substances should also not increase the corrosion rate in soil-based technical materials, water distribution systems, archaeological artifacts, and rock carvings."

The number of acidified lakes has decreased, but in the follow-up in 2013, it was assessed that the set goals for 2020 will not be achieved with existing policy instruments. It was noted, among other things, that the acidification load from forestry is increasing as a result of increased extraction of wood fuels while ash return has not increased at a corresponding rate. A large part of the soil and surface water acidification originates from the combustion of fossil fuels and deposition of acidifying nitrogen and sulfur compounds.

However, all forest growth also contributes to soil acidification as trees, during their uptake of nutrients in the form of cations (positively charged ions), release hydrogen ions in exchange, which have an acidifying effect. If the trees are not harvested but allowed to die and decompose on site in the forest, this effect is neutralized. However, when trees are harvested, it results in soil acidification. Soil acidification caused by forest growth has increased as forest growth has increased in the country, and now with wood fuel as a new sought-after assortment, it increases further as more biomass is harvested.

The harvested biomass, in the form of branches and to some extent stumps, is also more nutrient-dense than stem wood (compare with Figure 20).

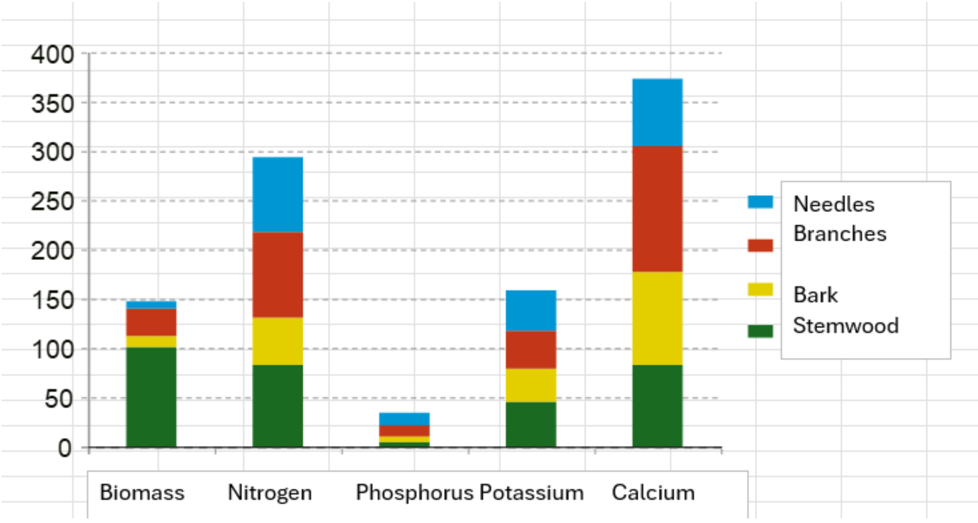

Figure 20 - Biomass (ton/ha) and nutrient (kg/ha) distribution in a 139-year-old spruce stand in Västerbotten with a standing timber volume of 278 m3sk. Source: Nykvist, N. (1974)

While the deposition of acidifying sulphur compounds has decreased significantly and recovery from acidification has been observed in soil and surface water, there is concern that increased growth and increased harvesting intensity will slow down the rate of recovery. Therefore, general advice in the Forestry Act states that the extraction of wood fuels should be compensated by returning ash to forest soil. Support for this is found in research showing that base saturation and pH decrease in forest soil after wood fuel extraction, with the greatest differences in the humus layer. The effect also manifests in soil water with higher hydrogen ion levels and lower concentrations of base cations. Ash addition has been shown to compensate for and thus counteract this. However, empirical studies showing that ash return to forest soil in moderate doses (the Forestry Board's general advice states that a maximum of 3 tons per hectare is applied per 10-year period and 6 tons per hectare per rotation) affects the quality of runoff water and thus the acidification situation in surface waters are lacking. There are therefore differing opinions on the need for ash return to counteract surface water acidification after wood fuel harvesting. Future research will have to show the way (Egnell, 2014).

3.2.2 Potential burden on soil resources

Global overview (by Ecologic Institute)

Forest biomass extraction practices that do not adequately account for environmental effects can impact soil by altering its structure, moisture retention and aeration; decreasing soil fertility by depleting nutrient capital, removing cations and gradually acidifying soil, or through soil disturbance, including erosion, soil displacement, compaction, and rutting; potentially reducing soil productivity.

Nutrient Depletion: The extraction of forestry biomass residues can lead to a decrease in soil nutrients. Specifically, whole-tree harvesting has been found to result in the export of nutrient elements at a rate 2 to 4 times greater than that of stem-only harvesting (Ranius et al., 2018) (not practiced in Sweden se 3.1). Biomass residues, when left to decompose in the forest, contribute to the cycling of nutrients, enhancing soil fertility. Their removal might therefore reduce the availability of essential nutrients like nitrogen and phosphorus, which are vital for the growth of biomass production (Ranius et al., 2018). Consequently, the nitrogen stocks are depleted at the ecosystem level. Stump harvesting in certain areas in northern Europe and America can, on the other hand has been shown to reduce emissions of carbon dioxide, nitrous oxide and methane in the short term, not affect the timber production of the next forest rotation and reduce the infection rate of root rot (Persson and Egnell, 2018).

Mitigating nutrient depletion from areas can be achieved through retaining forest biomass on grounds with restricted rooting space (such as shallow or stony soils) or on soils with diminished nutrient supply per soil unit (like sandy soils). This can be further enhanced by tailoring the rates of nutrient extraction according to the trees species present and by reducing the extraction of ground litter and forest floor materials (Titus et al., 2021). In the UK, for instance, it is recommended to postpone the removal of forest biomass until needle shedding after a drying period since needs account for half to two-thirds of the total nutrients in all the biomass (ibid.). The UK also sets a maximum retention threshold which amounts to 50-66% of total harvest residues (ibid.). Additionally, Scandinavian countries with geographical conditions akin to Sweden´s establish certain rules for retaining forest biomass. In Finland, the removal of all dead trees with a diameter exceeding 10 cm is prohibited. Meanwhile, in Norway, there are restrictions on the harvesting of both standing live and dead trees, along with a prohibition on removing dead wood lying on the ground that has been there for more than five years (ibid.). To mitigate nutrient depletion biomass harvesting guidelines, as part of broader sustainable forest management practices, should help alleviate public concerns about protecting environmental and social values, build trust in forest management and governance processes and help forest managers meet marketplace standards for sustainability (ibid.)

Soil Sensitivity and Soil Cation Exchange Capacity (CEC): CEC determines soils´ ability to retain cation nutrients (e.g., NH_4-N, K, Ca, Mg). Logging residue extraction frequently leads to the depletion of base cation stocks, which is especially evident in the reduction of base cation stocks at an ecosystem scale, the decrease of exchangeable base cation content in soils, and the diminished levels of base cations in runoff water (Ranius et al., 2018). Overall, base cation loss leads to soil acidification.

Several US guidelines on residue harvesting link soil CEC to site suitability for forest biomass harvesting. In particular, in Mississippi, suitability for forest biomass harvesting with CEC ranges from slightly limiting (>10 cmol kg^{-1}), to moderately limiting (5–10 cmol kg^{-1}), to very limiting (<5 cmol kg^{-1}) (Titus et al., 2021). Alternatively, in the UK the emphasis is placed on the "acid-base status" of the underlying soil type when assessing site sensitivity to forest biomass removal. Soils characterized by high acidity and low base status are categorized as "high-risk" due to the potential deficiency in base cation nutrients (ibid.).

Soil Sensitivity and Soil Organic Matter (SOM): SOM encompasses all organic components in the soil and is essential for maintaining soil structure, fertility, and water-holding capacity. Forest biomass harvesting potential is considered to various degrees limited at sites where soil has low SOM, i.e., 10% and less, according to the different US guidelines (Titus et al., 2021). At the same time, organic soils, which contain high levels of SOM, are not suitable for forest biomass harvesting either, especially in areas like ombrotrophic peats where rain is the primary nutrient source and, consequently, fertility remains low, regardless of CEC (ibid.).

Compensatory measures to restore the site´s characteristics include extending the rotation period before the final harvesting of stands, which helps to boost the total organic matter accumulated over the course of a rotation (ibid.).

Physical Soil Quality: The use of heavy machinery to harvest and transport logging residues usually results in increased soil disturbance. It can damage vegetation cover, compact the soil, reducing its porosity and air spaces, cause soil erosion and increase the number of water-filled local depressions (Ranius et al., 2018; Solberg et al., 2005; Titus et al., 2021; Wielgolaski et al., 2005). The potential damage for physical soil quality from the use of machinery is found to be larger for stump extraction (not practiced in Sweden see 3.1) than for slash harvesting. Meanwhile, some studies show that slash harvest mostly leads to increase in soil temperature (Ranuis et al., 2018).

To reduce erosion, soil compaction, or rutting, it is a commonly recommended practice to conduct harvesting activities only when soils are either dry or frozen, limiting the number or frequency of entries into the area, and keeping harvest residues on skid trails and across the entire harvesting site (Titus et al., 2021). Moreover, in Finland, harvesting should be modified to reduce rutting if the following size is exceeded: >10-cm depth for >5% of the rut length on the site (ibid.). Then, Finland also identifies areas that are deemed unsuitable for the removal of harvesting residues, such as dry (xeric) upland site types (ibid.).

Soil Organic Carbon (SOC): there are initial adverse impacts of logging residue extraction on carbon storage that are, however, temporary, and carbon stocks are largely replenished over the span of decades (Ranuis et al., 2018). In particular, empirical findings from northern coniferous forests indicate that stump extraction has minimal and temporary impacts on carbon stocks and respiration rates (Eggers et al., 2020; Ranuis et al., 2018; Titus et al., 2021).

Adopting modified forest management practices, such as fertilization and extending rotation periods, could offset carbon losses due to logging residue extraction, potentially leading to a quicker restoration of carbon stores to levels comparable to those achieved with stem-only harvesting (Ranuis et al., 2018).

The situation in Northern Sweden (by BFR)

Track formation and soil compaction

All driving within stands increases the risk of track formation and soil compaction. Soil compaction can lead to altered conditions in the root environment for future forest generations, which in the worst case can result in reduced growth (Skinner et al., 1989; Dyck and Mees, red.; Wästerlund, 1994; Hakkila, 1989).

Track formation is partly an aesthetic problem but can also damage ancient remains and create conditions for the transport of finer materials and water-soluble organic compounds to surrounding watercourses. In addition, the forest fuel assortment entails additional driving in connection harvesting and terrain transport of the forest residues.

Considering that we are also moving towards warmer and wetter winters where periods of frost become increasingly rare in the country, there is reason to take this problem seriously.

Ash recycling

The short-term growth effects of forest biomass harvesting, as described earlier, are likely primarily due to the nitrogen harvested with the forest biomass, thus withheld from the new forest generation or the remaining stand during thinning and clearing. If logging residues are not removed after final felling, it is a common practice to wait for 2-3 years for the branches to start decomposing before afforestation. When logging residues have been removed afforestation can start the same year resulting. The extra years can compensate for some of the losses in growth depending on the extraction. The results also show that growth reduction can be eliminated by compensating for the additional nitrogen uptake with nitrogen fertilization. Since there is no nitrogen in wood ash, no short-term positive effect of wood ash on forest production can therefore be expected, provided that the ash itself does not affect nitrogen availability in any way. It appears that experiments with ash recycling yield similar production responses as older liming experiments, where growth is stimulated on sites with a lower carbon stock relative to the nitrogen stock in the humus layer, known as the carbon-nitrogen ratio. The threshold value lies around ratios of 30. Liming or ash recycling on forest sites with carbon-nitrogen ratios well above 30 in the humus layer tends to result in growth reduction, while production increases on sites with values well below 30. On sites with values around 30, there is often no effect observed at all. Figure 21 displays results from several field experiments with ash recycling, where 1-6 tons of ash have been applied to young or juvenile forests across the country, which reinforces this picture. The carbon-nitrogen ratio is not typically available information in a stand register, so the relationship between the carbon-nitrogen ratio and soil fertility (site index) can be utilized. The threshold value for site index appears to be around 24, meaning that better site qualities may be positively affected by ash recycling, while poorer site qualities may react negatively.

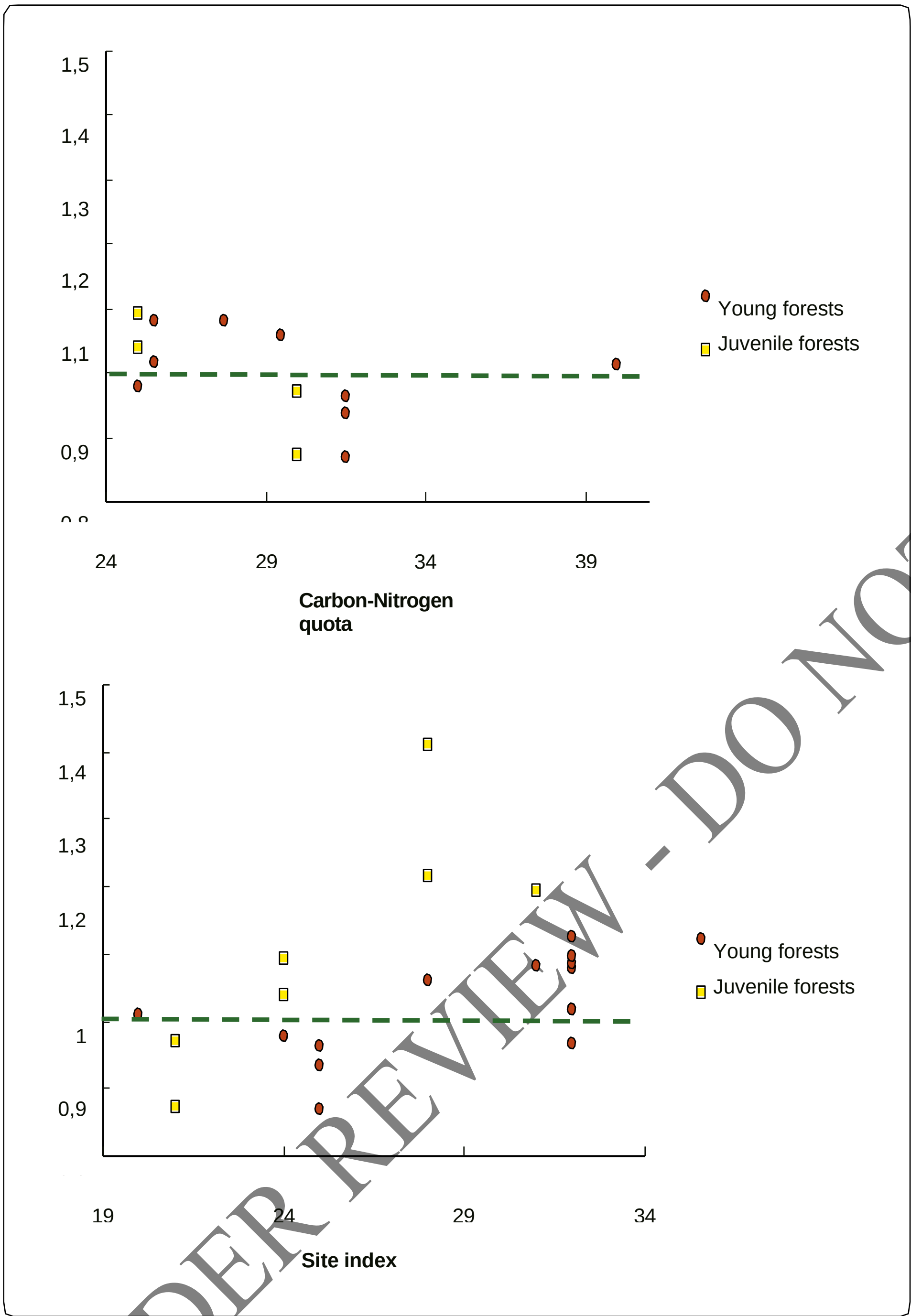

Figure 21 - Results from field experiments in Sweden. Relative growth for young forest and juvenile forests after ash recycling (applied doses of 1-6 tons per hectare). Source: Data from field trials compiled by the author, Gustaf Egnell.

The need to compensate for nutrient losses caused by air pollution and/or forest biomass harvesting with ash or other nitrogen-free products has been debated for a long time, and in many cases, the conclusion is that it is unnecessary from a forest production perspective on mainland soils (Sikström et al., 2001).

However, there are soils where wood ash has a known and significant effect on forest production – namely on forest soils defined as peatlands with an organic soil layer that is 30 cm or thicker. Many of these soils have been drained in the past to stimulate forest production. Forest production on these soils is primarily limited by low potassium and phosphorus availability. Adding wood ash to such soils can significantly increase production (Silverberg and Hotanen, 1989; Egnell, 2014).

3.2.3 Potential burden on biodiversity

Global overview (by Ecologic Institute)

Habitat Structure and Quality: Removing logging residues from forests can disrupt the habitats of various species (Titus et al., 2021). For instance, deadwood and leaf litter provide essential habitats for insects and microorganisms, especially those adapted to the abundant sun-exposed dead wood created by large-scale disturbances. In particular, in Swedish managed forests, 53% of the dead wood-dependent species (beetles such as Carabids, fungi, and lichens) were detected on slash or stumps (Ranius et al., 2018). Even though slash and stumps occur in high abundance, some of the species inhabiting these substrates are regarded as rare or declining, which typically means they occur in very low densities. For species occurring in low densities in abundant habitats, it is extremely hard to estimate their distribution area or other aspects relevant to determining their red-list status (ibid.). In such a way, slash and stump harvesting (not practiced in Sweden see 3.1) can negatively affect their populations at the landscape level but rather in a short-term perspective only (ibid.). As compensatory measure to restore desired habitat characteristics, creation of high stumps as well as retention of other biomass types (pre-existing downed wood, the forest floor, and roots) are recommended for harvest residue removal (Titus et al., 2021). Still, it is to point out that the majority of landscape-level populations, including endangered and rare species, are mostly found in other types of deadwoods and are not impacted by the harvesting of logging residues (Ranius et al., 2018).

Population State: Slash extraction is found to negatively affect the population density of game species or the condition of individuals that rely on these logging residues for sustenance (Ranius et al., 2018). This is especially relevant in case of extracting pine or broadleaf slash instead of spruce (ibid). For reindeers, the connection between logging residues extraction and the food availability is less evident (ibid.), although the former is likely to reduce grazing potential in Northern Sweden (Eggers et al., 2020). The most important biotope for reindeer herding is open pine forests with abundance of soil and tree lichens, and extraction of logging residues is not practiced in that kind of forests in Sweden. Finally, in some cases, slash extraction was found to have impact on plant species composition up to 20 years after logging. Nonetheless, these results are highly variable and depend on differences in soil types, nutrient availability, and the degree of soil disturbance (Ranius et al., 2018).

Stand Structure's Vertical Heterogeneity: In a study modelling different management scenarios in Northern Sweden, increasing woody biofuel extraction was found to negatively affect mature broadleaf-rich forest and old forests in both biofuel extraction settings applied (business-as-usual, representing current practices, and bioeconomy, with intensified biomass extraction options) (Eggers et al., 2020). However, careful management planning is thought to allow for increasing woody biofuel extraction with small losses in biodiversity and ecosystem services, up to a certain point (ibid.).

A probable approach for preserving biodiversity while increasing woody biofuel extraction is harvesting biomass during dense early thinning phases. The concept is currently under exploration and is not yet technically or economically viable. It may eventually allow for an earlier acquisition of bioenergy, and concurrently preserve the forest´s vertical structural heterogeneity, which is advantageous for biodiversity (Eggers et al., 2020). This opportunity is especially relevant for Northern Sweden since this region possesses a considerable potential to increase extraction rates of primary woody biomass, currently low due to the greater transport distances, as mentioned earlier.

Lastly, it should be noted that according to (Ranius et al., 2018), while studies of species populations at the forest stand scale are valuable, evaluating the potential of maintaining species populations viable requires an understanding of the dynamics at landscape level.

The situation in Northern Sweden (by BFR)

Conservation of biodiversity has been high on The literature reviewed indicates that the agenda for many years and is manifested for forests by being directly addressed in two of the Swedish environmental quality objectives, namely “Living Forests” and “A Rich Plant and Animal Life”. Additionally, activities on forest land may indirectly affect surrounding surface waters, hence “Living Lakes and Watercourses” may also be impacted by forest biomass extraction and ash recycling.

The introduction of forest biomass assortment, as the third largest assortment alongside pulpwood and timber, has so far primarily led to increased harvesting intensity where more and more of the tree biomass is harvested during logging, along with some ash recycling activities. Now, there is increasing discussion about the need to also increase biomass production in our forests, for example through nutrient supplementation, fast-growing tree species and clones, shorter rotation times, denser stands, drainage, ash on forested peatlands, etc. As the relevant level to assess effects on biodiversity is at the landscape level, it is important to understand that it is the combined effect of increased harvesting, more intensive production systems, and potential ash compensation at the landscape level that should be considered, not each activity separately. However, this cannot be done simply, which is why much of what is presented here is based on studies of the effects of one or a few action groups at a time. The focus here is also on forest biomass extraction and ash recycling, which have the potential to affect biodiversity by:

- Reducing the amount of deadwood available for wood-dependent species to live in or on.
- Affecting the conservation considerations during logging, as the "new" assortment of forest biomass is also to be harvested.
- Formerly economically uninteresting trees and species with conservation values now becoming economically interesting for harvesting.
- Forest biomass can act as a death trap for insects when transported away, as freshly exposed logging residues act as trap material and attract wood-dependent insects from surrounding areas.
- The protective and shaded environments provided by logging residues decrease.
- Removal of forest biomass affects the forest floor and humus layer, which may have effects on the composition of species in the soil.
- Increased soil damage as logging residues cannot be used as substrates for forestry machinery or in stump harvesting, which can lead to increased flows of fine soil particles and organic compounds into surface waters, affecting biological life.
- Ash recycling may directly or indirectly affect fauna, flora, and fungi in the soil and surrounding watercourses.

In managed forests, a large part of the trees are harvested and removed to become timber or pulpwood, wood that previously formed an important basis for much of the forest's species diversity. Increasingly, significant portions of logging residues are now also harvested as forest biomass, and in a growing market, there is now also increased interest in harvesting stumps.

The prerequisite for all forest-dwelling species is the presence of trees and other vegetation. Some of the forest-dwelling species obtain their energy supply through photosynthesis. All other species are part of various food chains that either start from the decomposition of wood and other dead material or, to a lesser extent, from grazing on living plants. Dead leaves, branches, and dead wood are therefore a necessary energy source for the multitude of species and a prerequisite for high biodiversity in forests. There are approximately at least 10-15,000 species living in forest soil and a similar number predominantly living above ground. Nearly 7,000 forest-dwelling species are entirely dependent on various qualities of dead wood.

This knowledge formed the basis for the previous sub-goal under “Living Forests”, regarding enhanced biodiversity, which formulated that the amount of dead wood, the area of older deciduous-rich forests, and old forests should be preserved and strengthened by 2010 in the following ways: The amount of hard dead wood has increased by at least 40% throughout the country and significantly more in areas where biodiversity is particularly threatened.

Forestry now routinely leaves dead trees in the forest, and the amount of dead wood is gradually increasing. It is important that the increased interest in forest biomass assortment does not drastically change this development. The increased demand for forest biomass also makes it important to understand differences in quality between different types of wood.

Generally, coarse dead wood (diameter > 10 cm) harbors greater species richness than finer dead wood. This is due, among other factors, to the fact that coarser wood is a more heterogeneous habitat that can accommodate more species, and that coarse wood takes longer to break down, thus providing a more stable microclimate, which benefits certain species.

However, studies of the biodiversity on equal volume or area of coarse and fine dead wood show no significant differences (Kruys, N. and Jonsson, B. G., 1999).

However, it is important to distinguish between the number of species and which species actually occur on different diameters of dead wood. Some species occur only on branches, while others occur only on coarse wood. A compilation of 3,600 red-listed species dependent on wood showed that most of these were dependent on stem wood, while only a smaller proportion depended on branch wood.

Additionally, finer wood is continuously added to our forests throughout much of the rotation period and in large quantities during harvesting. For example, in carbon balance calculations in forest landscapes, it is estimated that spruce loses 10% of its needle biomass and 2% of its branch biomass annually. The corresponding figures for pine are 25% and 5%, while the supply of coarse dead wood initially requires trees to grow and then is delivered randomly in connection with pests, storms, fires, or logging (primarily stumps).

This reasoning suggests that biodiversity, from a substrate perspective, can withstand quite extensive removal of logging residues from our common coniferous trees, while there is reason to be more cautious with the removal of logging residues from rarer tree species such as our noble hardwoods, especially oak, where a large number of rare wood-dependent insects utilize branch wood. In cases where rare wood in the landscape is used as forest biomass, the negative effect may further increase if rare insect species have time to lay their eggs in the forest biomass before it is chipped and burned. Forest biomass thus acts as a trap for rare species. To avoid or reduce this problem, based on knowledge of wood-dwelling insect ecology, it has been proposed that:

- Forest biomass from rare tree species in the landscape is removed before they have a chance to be colonized by insects during spring and early summer.
- Forest biomass from rare tree species in the landscape, which has been stored during the insects' flight period in spring and early summer, is stored for an additional year so that some of the trapped insects have time to hatch.
- Less valuable logging residues from coniferous trees are, if possible, used as cover over logging residues from rare tree species in the landscape.
- If there is no cover with coniferous logging residues, the topmost, most sun-exposed forest biomass is left in piles with logging residues from rare tree species in the landscape remaining.

These recommendations have been supported by subsequent research, where the highest number of beetle species and individuals have utilized the top layer in piles of oak logging residues. Furthermore, a comparison between logging residues from different tree species shows that the number of beetle species of wood-dwelling beetles is approximately equal for spruce, birch, aspen, and oak, while the number of red-listed species is higher for hardwoods.

Notably the commercial trees in BioFuel Region consists of pine, spruce and birch. Nobel hardwoods cannot grow in the northern part of Sweden (Egnell, 2014).

4 Screening results and recommendations

4.1 Overview

Resources screened		Ordinal Baseline Rating	Forestry (and forest biomass extraction) Management Practices	
Category	**Sub-Category**		**Potentially beneficial to the baseline status**	**Potentially detrimental to the baseline status**
Water	**Surface water bodies**		- Ash recycling - Restoration of surface water bodies (reverting hydromorphological alterations) - Placing harvest residues away from affected aquatic ecosystems - High-water-efficiency processes of production (e.g. for biochemicals)	- Combustion of fossil fuels and deposition of acidifying nitrogen and sulfur compounds leading/contributing to soil and surface water acidification - Clear-cutting, intensive slash extraction, and any other biomass management/extraction practices leads to increased runoff, leaching of nutrients, and ultimately water acidification or eutrophication - Abstraction of large volumes of water for the operation of new, large-scale production processes
	Groundwater bodies			
Land & Soil Resources	-		- Retaining forest biomass on vulnerable grounds - Extract logging residues from suitable spruce dominated stands, following recommendations from the SFA.	- Overextraction of forest biomass leading to nutrient- and base cation stock depletion
Biodiversity	**Endangered Species**	6	- Leaving high stumps, snags and coarse woody debris - Continued high environmental consideration in practical forestry - Retaining diverse biotopes, biomass types and deadwood	- Overextraction of deadwood and leaf litter (deteriorating habitats for insects and microorganisms)
	Critically Endangered Species	4		

4.2 Recommendations

According to the reported data for the second cycle of implementation of the WFD in Sweden, water resources (concretely, surface water bodies) are an area of concern in the Bothnian Bay and Bothnian Sea River Basins. Diffuse pollution (concretely, atmospheric deposition) is recurrent throughout and affects all rivers and lakes in the region. Further, habitat alterations that result from changes in morphology are also a significantly recurrent impact on rivers in the region, with alterations driven by changes in hydrology following. Any initiatives, including economic activities and management practices that facilitate or promote the restoration of the affected rivers should thus be favored. The reexamination of hydropower taking place at national level is one such example. In contrast, new changes in hydrology and morphology that result in habitat alterations where this is not yet an issue should be avoided. Overall, the scale and placement of any economic activities that could have substantial negative impacts on river and lake ecology should be planned very carefully to ensure that progress attained so far in meeting regulatory targets is not lost and instead continues to expand.

With forestry already being a central pillar of the regional economy in Northern Sweden, and with the increasing relevance of biofuel as a source to ensure energy security, it is also increasingly important to continue to employ biomass management practices that are known to favor water quality and avoid those associated with detrimental effects on water resources. Practices such as ash recycling and the placement of harvest residues far from already affected aquatic ecosystems are two such examples. Additionally, the production of materials from biomass residues, such as birch bark, necessitates attention to water and energy consumption, with innovative methods for the extraction process of valuable chemicals (e.g., tannins) providing options for efficiency improvements. Further, acidification has been identified as a recurrent impact on the region's waters. Regional experts link this with the combustion of fossil fuels and deposition of acidifying nitrogen and sulfur compounds. While this may not be directly related to forestry activities, it is important to avoid forestry management practices that have been associated with acidification in the past, to avoid aggravating the situation.

As regards groundwater bodies, no significant impacts have been identified so far. It is important that any expansion of existing economic activities, and/or development of new ones, is planned thoroughly and located smartly to avoid the exacerbation of existing pressures on currently affected aquifers as well as the affectation of others, especially as climate change sets on.

Recommendations to prevent potential burden on soil resources and long-term productivity

On land and soil resources, the implications for biomass production and forest productivity are particularly pronounced on less fertile sites. Current strategies to retain a proportion of logging residues can mitigate nutrient loss and, hence, support soil productivity. The planned extraction of logging residues on primarily spruce dominated relatively fertile forest land in northern Sweden has a potential to strengthen the bioeconomy. The present regulation regarding the extraction of forest residues, considering ecological restrictions according to the Swedish Forest Agency's recommendations,ensures that land and soil resources are managed properly.

While protected areas and low exploitation levels have resulted in favorable status of most species and habitats in the alpine region, only about 20 percent of species and 40 percent of habitats in Sweden achieve the overall aim of the EU Habitats Directive. Most species that do not achieve the overall aim are associated with agricultural land. (Naturvårdsverket, 2020). Biodiversity in Northern Sweden faces threats from increased biomass extraction, with potential negative impacts on habitat diversity and the availability of deadwood, crucial for many species´ survival. Since the new forestry act was implemented 1993 the amount of coarse wood debris has continued to increase. The species associated with the removal of logging residues are not equally endangered since this substrate is delivered as litter throughout the lifespan of the stand, 80-120 years.

Before approval of final felling operations in Sweden, a comprehensive plan to prevent potential negative environmental impact will be reviewed and monitored by the Forest Agency. Removal of stem wood does not pose a threat to long term productivity of forests but removal of logging residues can be problematic on poor soil as most of the nitrogen is found in the needles. Logging residues are removed only from relatively fertile spruce dominated forests and is not recommended in pine dominated forests on poor forest land. To prevent negative impact of removal, it is recommended to leave the logging residues in the forest during one season to dry and to drop as much as possible of the nutrient rich needles. To prevent soil damage, spruce dominated stands are normally harvested during winter on frozen soils and it is recommended that 30-40 percent of the branches are left in base roads for forest machines to drive on.

During a rotation period, thinning operations are carried out once or twice and final felling is carried out after approximately 100 years, removing most of the valuable stem wood. During these 100 years' time, nutrients are recycled when needles and twigs continuously litter from the trees. Litter is decomposed and nutrient is reused by the trees. Logging residues are only extracted once every 100 years after final felling and then removing approximately 60 – 70 percent of the residues.

If logging residues are not removed after final felling, it is a common practice to wait for 2-3 years for the branches to start decomposing before afforestation. When residues have been removed, afforestation can start the same year resulting in a higher rate of tree seedling survival and increased forest increment.

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SCALE UP
community-driven
bioeconomy development

Sustainability Screening – Mazovia, PL

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PU	Public	x
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EXECUTIVE SUMMARY

This report has been elaborated as part of the SCALE-UP project funded by the Horizon Europe research and innovation programme. The aim of this project is to support the development of small-scale bioeconomy solutions in rural areas across Europe.

The main objective of this study is to raise awareness of the ecological limits in the Mazovia region (*województwo mazowieckie*) in Poland, based on three resources: water, soil and biodiversity. The bioeconomy is by definition the economy of bioresources (from agriculture, forestry, aquaculture and biowaste), therefore of the living. It is essential to design bioeconomy sustainably, and that its development takes into account the potential impact on the environment. Furthermore, in the current context of fighting against climate change and environmental degradation, bioeconomy activities that provide environmental benefits (water quality, preservation of biodiversity, etc.) must be sought and encouraged.

Mazovia region is one of the six focal regions for the SCALE-UP project and is characterized by high industry diversification, low unemployment and high economic development speed and young and well qualified staff. It is also one of the most internally diverse areas in Poland, showing high internal diversification in science, research, education, industry and infrastructure. Agriculture is one of the most important sectors in the Mazovia and it is characterized by very fertile soils enabling a thriving development of agricultural economy with usable agricultural land covering about 65% of the area. The role of horticulture – especially apple production – is significant, as Poland is the largest producer of apples in Europe and almost half the country's production of apples is concentrated in the Mazovia region. Additionally, Mazovia region is one of the most populated areas in Poland, where renewable water resources play a key role in providing drinking water to residents.

Having in mind that Mazovia region is affected by the impacts of climate change, rising temperatures and significant pressure on water resources, soils and biodiversity, this report is therefore aimed at project leaders and stakeholders in the bioeconomy willing to develop an activity, to enable them to integrate these environmental considerations into the development of their product or service.

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1 Resource management profiles

1.1 Water resources management profile

Poland counts with a modest volume of renewable water resources every year, one of the lowest in Europe. The average water resources in Poland are approximately 60 billion m3 and in dry seasons this level may drop below 40 billion m3. In comparison, France, Sweden and Germany have water resources (in absolute values) of respectively: 206 billion m3, 196 billion m3, 188 billion m3. Surface water in Poland is characterized by high temporal and territorial variability, which causes periodic excesses and deficits of water in rivers (Environment 2023, GUS Statistics Poland Warszawa 2023).

The country's multi- annual average river discharge for years 2000-2022 was 56 km^3, (Environment 2023, GUS Statistics Poland Warszawa 2023). Considering Poland's current population of 38.5 million, this amounts to ca. 1,600 m3 of water resources available per capita per year (compared to a global average of ca. 6,500 m3 and a European average of ca. 4,500 m3). Poland also has one of the lowest water retention rates in Europe, of only ca. 6%. This rate is the ratio of the current, total capacity of the water in retention reservoirs (ca. 4 km3) and the multi-annual average river discharge mentioned above. In many European countries this rate exceeds 12%.

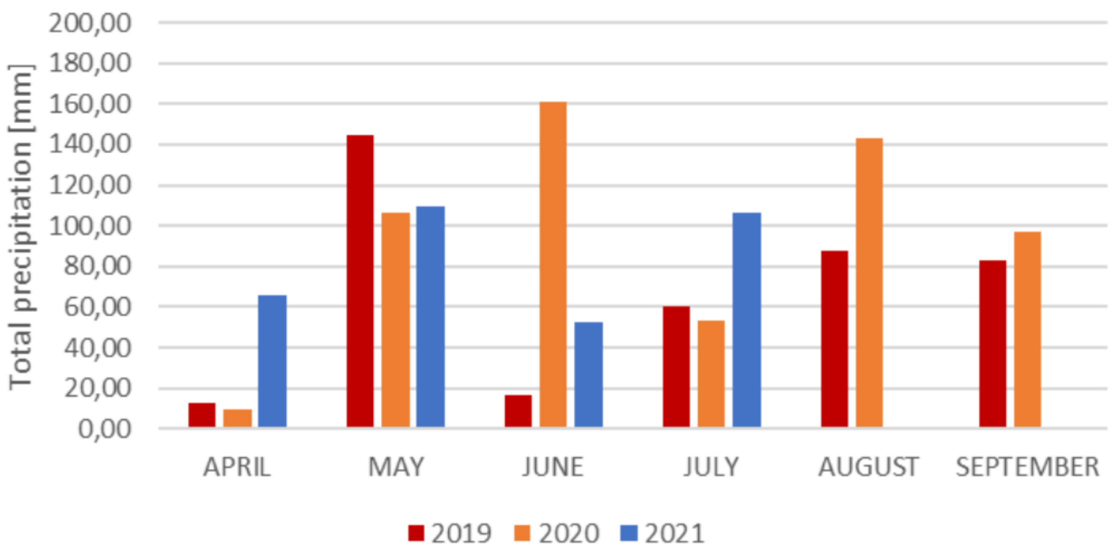

Figure 22 - Average sum of monthly precipitation over the Mazovian voivodeship. Source: Institute of Geodesy and Cartography, igik.edu.pl 2023

As shown in the figures below, the total water abstraction in Poland is 9385,4 m3, and is roughly distributed as follows: industry (69%), agriculture (9%), and municipal economy (22%) (GUS 2023).

Wykres 3. **Pobór wody na potrzeby gospodarki narodowej i ludności**
Chart 3. Water withdrawal for the needs of the national economy and population

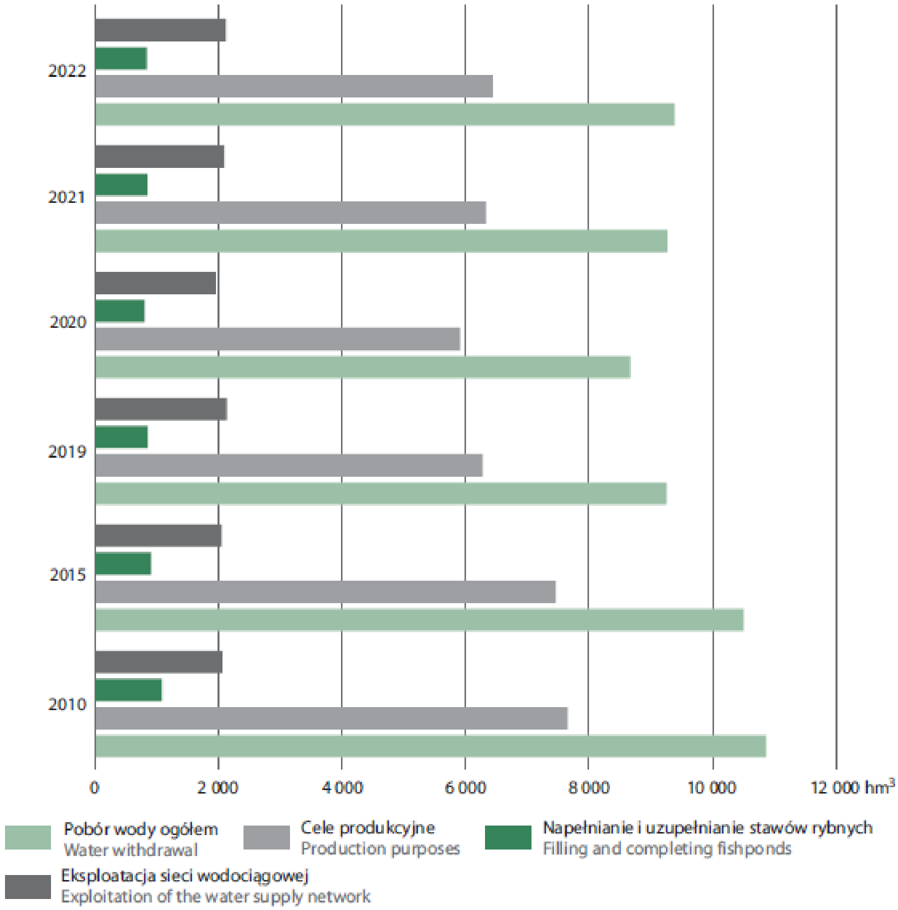

Figure 23 - Water withdrawal for the needs of the national economy and population. Source: Environment 2023, GUS Statistics Poland Warszawa 2023

Tabela 3. **Pobór wody na potrzeby gospodarki narodowej i ludności według źródeł poboru**
Table 3. Water withdrawal for the needs of the national economy and population by sources of withdrawal

Wyszczególnienie Specification	2010	2015	2019	2020	2021	2022
	w hektometrach sześciennych in cubic hectometers					
Ogółem Total	10 866,4	10 502,6	9 253,6	8 666,3	9 267,1	9 385,4
Wody powierzchniowe Surface waters	9 172,6	8 770,2	7 439,9	6 900,8	7 484,7	7 586,0
Wody podziemne Underground waters	1 625,2	1 677,3	1 772,1	1 720,2	1 738,3	1 761,0
Wody z odwadniania zakładów górniczych oraz obiektów budowlanych (użyte do produkcji) Water from mine and building constructions drainage (used for production)	68,6	55,2	44,2	45,3	44,1	38,4

Figure 24 - Water withdrawal for the needs of the national economy and population by source. Source: Environment 2023,GUS Statistics Poland Warszawa 2023

A large share of industrial water use is employed for cooling turbine condensers in thermal power plants. While this type of use does not result in a significant volumetric difference between input and effluent water at the plant level, it does have important implications on water quality (e.g. due to thermal pollution). As regards the agriculture sector, while irrigation often represents an important share of agricultural water use in other countries, Polish agriculture is based entirely on rainfall (Majewski, 2015).

Mazovia is the most populated area in Poland (14 percent of the country's population) and mainly abstracts water resources from rivers such as the Vistula, Bug and Narew to supply drinking water to its residents. There are numerous water reservoirs in the region that are used to irrigate farmlands and produce electricity. Some of these reservoirs, such as Lake Zegrze, also serve recreational and tourism functions. Currently, access to exact numbers regarding the volume of water resources in Poland and Mazovia is limited.

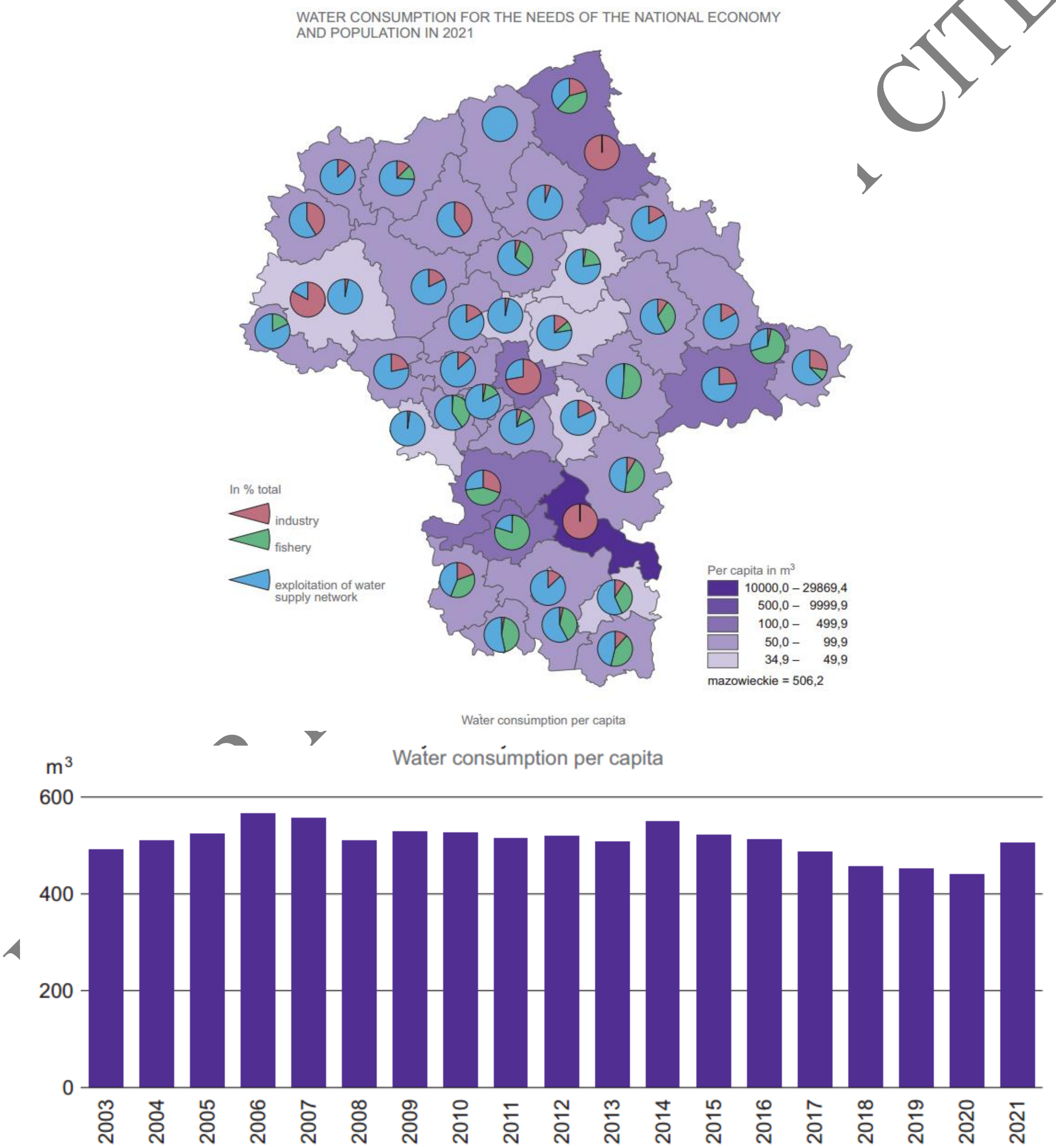

Figure 25 - Water Consumption per capita and per sector in Mazovia. Source: Statistical Office in Warszawa, 2022.

In relation to data from the Statistical Yearbook of Mazowieckie Voivodship (Mazovia region), in terms of the population connected to wastewater treatment plants in 2021 in Mazovia, there are considerable differences (see figure below), as urban population is widely connected to these kind of plants while people living in rural areas do not have it accessible in such extension.

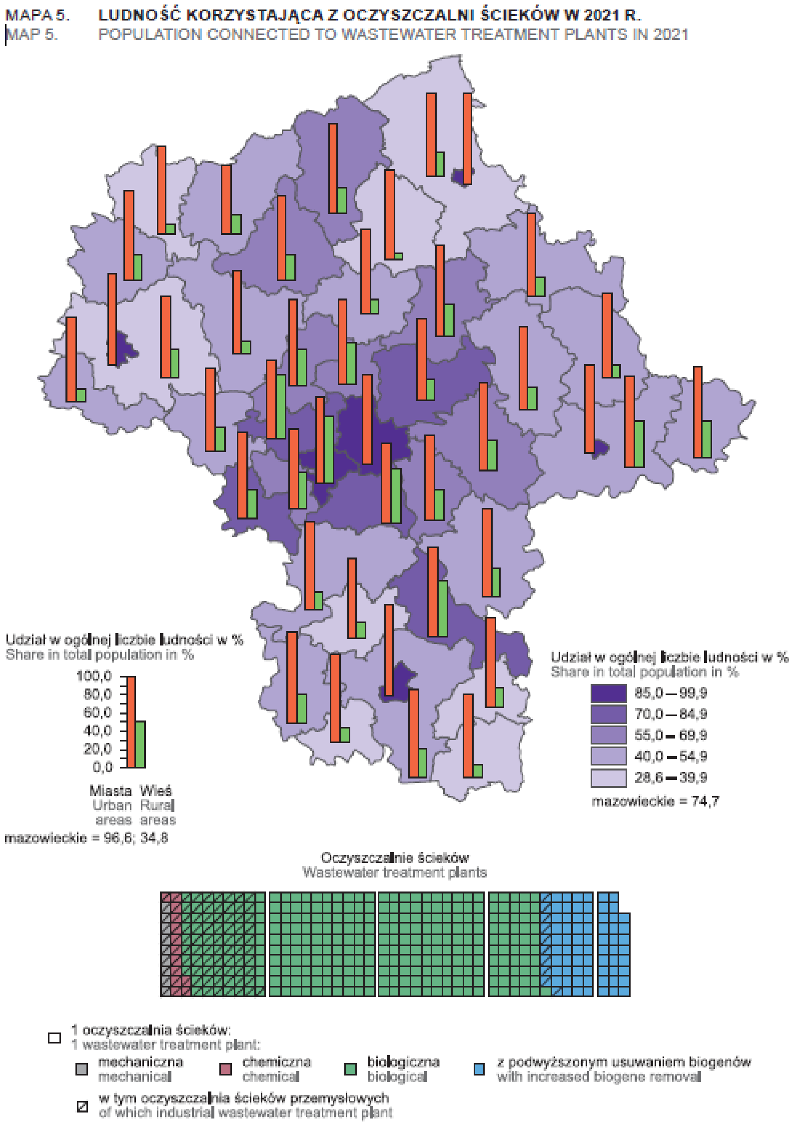

Figure 26 - Population connected to wastewater treatment plants in 2021 in Mazovia region. Source: Statistical Yearbook of Mazowieckie Voivodship

Water management in Poland involves multiple stakeholders and hierarchical structures responsible for overseeing various aspects of water resource utilization and protection. At the national level, the National Water Agency (Gospodarstwo Wody Polskie), along with the Ministry of Environment, plays a pivotal role. The National Water Agency supervises key entities such as the National Board for Water Management and Regional Water Management Boards. It holds ownership rights over state-owned waters and administers water use fees and taxes. Additionally, it oversees the preparation and implementation of River Basin Management Plans, Flood Risk Management Plans, and the National Programme for Urban Wastewater Treatment. The Ministry of Environment, on the other hand, is tasked with adopting the National Environmental Policy and overseeing institutions like the Chief Inspectorate of Environmental Protection (Główny Inspektorat Ochrony Środowiska) and the

National Fund of Environmental Protection and Water Management (Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej).

At the regional level, the Regional Water Management Boards (RWMBs) take charge of water management within their respective demarcations. They undertake various activities including identifying pressures on water resources and assessing their impacts; developing terms of water use, conducting economic analyses, and preparing flood studies and protection plans. RWMBs also coordinate flood and drought protection efforts and approve tariffs for municipal water supply and sanitation services. Furthermore, they issue consents for water use and provide opinions on draft regulation pertaining to water supply and sanitation. Voivodeship-level institutions are tasked with implementing and enforcing national water policies at the regional level, issuing permits for investments and monitoring water quality, while counties play a limited supervisory role over water companies.

At the local level, authorities collaborate with regional and national authorities to protect drinking water sources and implement measures outlined in River Basin Management Plans, Flood Risk Management Plans, and the National Programme for Urban Wastewater Treatment. Local authorities also oversee companies responsible for water supply and wastewater treatment within their jurisdictions. The delineation of responsibilities among national, regional, and local entities aims to establish a structured approach to water management in Poland, which is meant to facilitate effective resource utilization and environmental protection across different administrative levels.

Challenges related to water resource management in Mazovia include more extreme and shifting seasonal fluctuations and the associated droughts and floods that can cause difficulties in access to water, especially during periods when it is most needed.

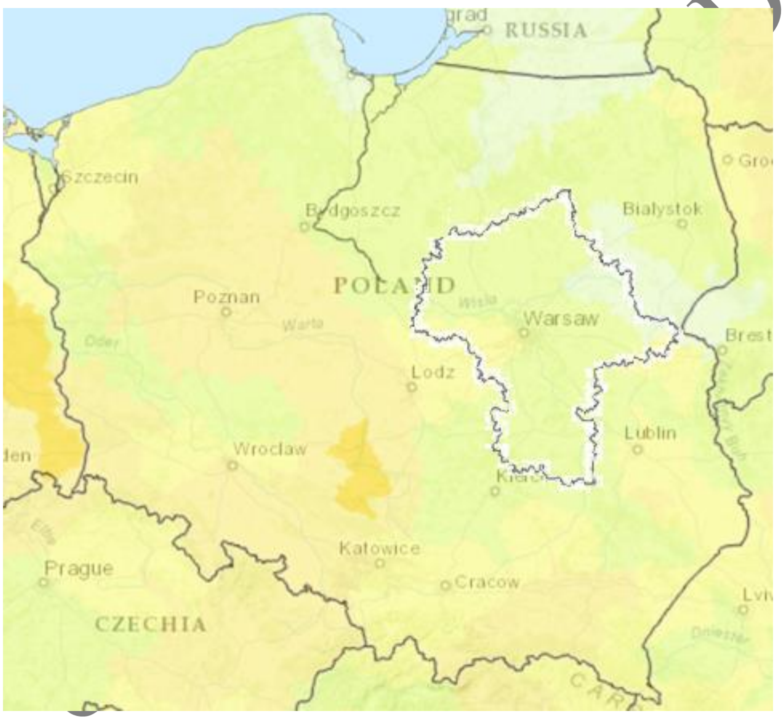

Figure 27 - Water scarcity risk in Poland and Mazovia. Source: WWF Risk Filter Suite, 2023, riskfilter.org/water/explore/map

Additionally, recent years have seen an increase in the amount of pollutants in water (Kuziemska et al., 2021), which poses a threat to the quality and safety of drinking water and the health of aquatic ecosystems. The density of water supply and sanitation networks in Mazovia is very poor (see Figure 28).

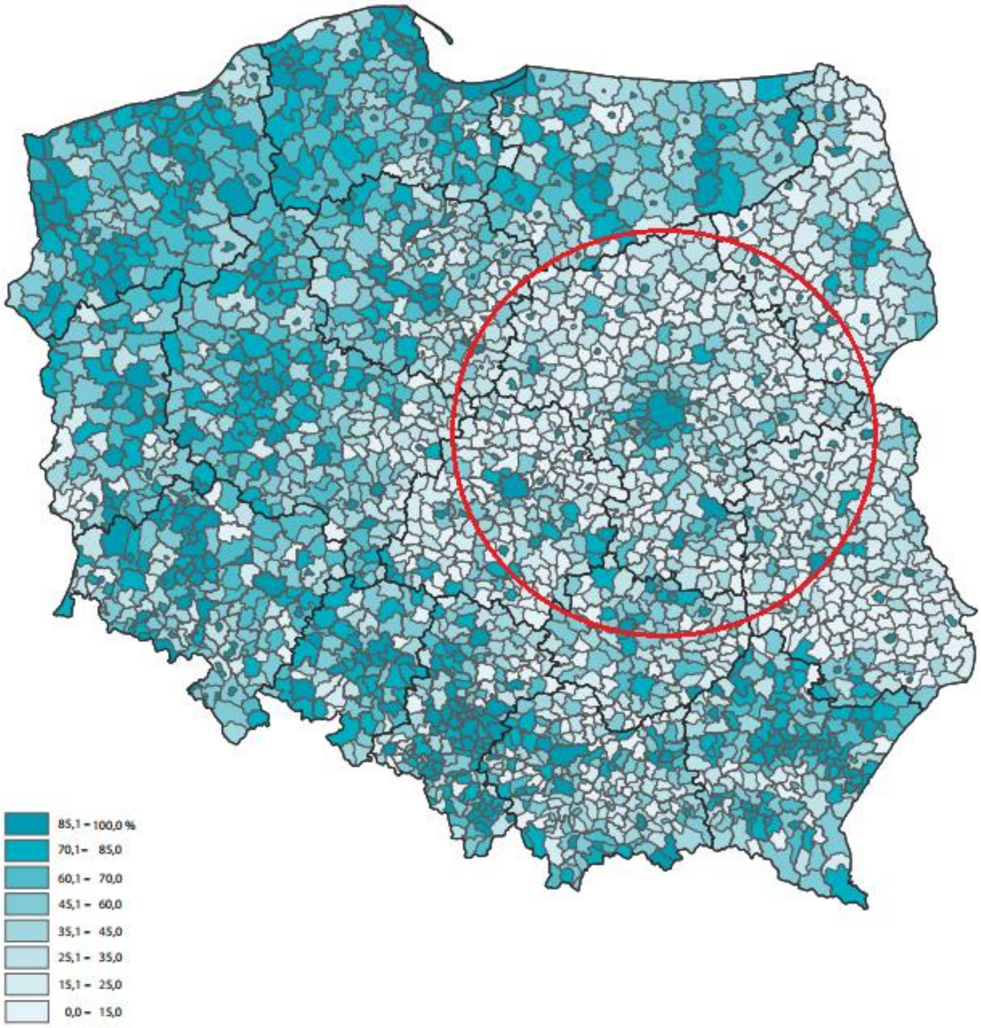

Figure 28 - Population using sewerage system in 2016. Source: Statistical Atlas of Poland, Statistics Poland, 2018.

The uncontrolled wastewater discharges from the sparsely built-up areas, from fish ponds, or due to disordered sewage management in rural areas, still cause a high level of pollution of river waters. Other wastewater discharges, even when in compliance with the permits concerning contaminant load, can significantly affect the quality of water resources. Freshwater ecosystems in areas of very high risk are estimated to have extremely poor water quality due to high levels of biochemical oxygen demand (BOD), electrical conductivity (EC) and nitrogen (Kuziemska et al., 2021).

In Mazovia ensuring that water resources meet the established quality standards can be associated with high costs, which in fact must be borne by the consumers. On the other hand, law enforcement and other measures carried out by the authorities to improve water quality are insufficient at present. The volume of untreated or insufficiently treated sewage reaching the environment remains too high. As a result, the goal of reaching the desired environmental quality standards still seems very distant.

Table 12 - Industrial and municipal wastewater discharged into waters or into the ground. Source: Statistical Office in Warszawa, 2022

SPECIFICATION	2010	2015	2020	2021	
	in hm^3				in percent
TOTAL	**2637,4**	**2613,6**	**2313,1**	**2595,5**	**100,0**
discharged directly by plants [a]	2403,3	2408,3	2084,1	2363,8	91,1
of which cooling water	2365,2	2367,3	2033,0	2312,3	89,1
discharged by sewage network	234,1	205,3	229,0	231,7	8,9
Of which wastewater requiring treatment	272,2	246,3	280,0	283,2	10,9
treated	221,4	239,4	262,7	265,9	10,2
mechanically	4,0	4,1	3,2	3,7	0,1
chemically [b]	5,5	2,8	7,5	6,9	0,3
biologically	54,6	50,7	55,4	58,1	2,2
with increased biogene removal	157,4	181,8	196,6	197,1	7,6
untreated	50,8	6,9	17,3	17,3	0,7
discharged directly by plants	0,3	4,0	7,9	7,3	0,3
discharged by sewage network	50,5	2,9	9,4	9,9	0,4

a Including cooling water and polluted water from drainage of mines and building structures as well as from contaminated precipitation water. b Data concern only industrial wastewater.

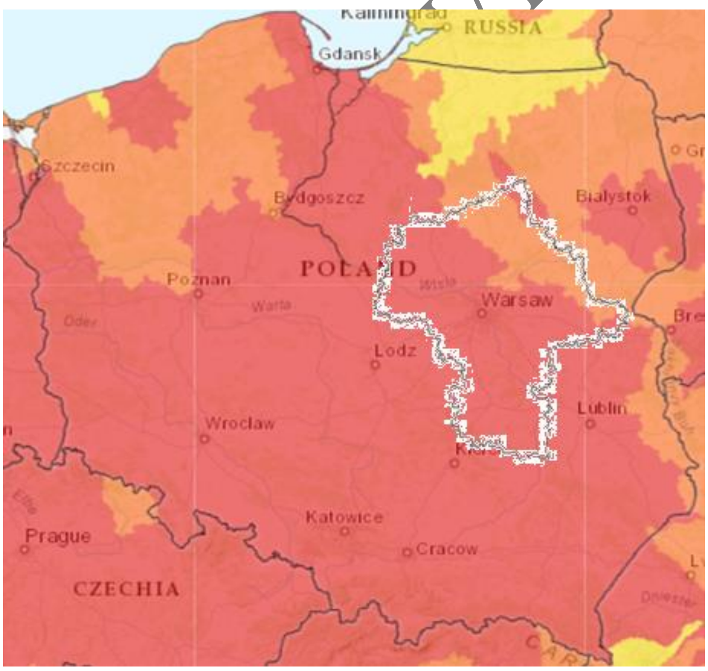

Figure 29 - Water Quality Risk in Poland and Mazovia. Source: WWF Risk Filter Suite, 2023, riskfilter.org/water/explore/map.

1.2 Land and soil resources management profile

Poland is rich in land and soil resources. Most of the soil resources in the country are moderately fertile, and approximately 40% of the country's area consists of class II and III soils. Nearly 80% of Poland's area is covered by brown soils, podzols and luvisols. They occur commonly in lowland areas and lakelands. There is less of them in the highlands and in the mountains (especially podzols). In terms of agricultural suitability, the most valuable of them are brown soils. Areas with highest quality soil in the country are scarce – chernozem occupies only about 1% of the territory (zpe.gov.pl, accessed December, 2023).

Mazovia also has diverse soil resources. Here there are mainly leached brown soils, which are very fertile and favorable for growing plants. They are well related to agriculture and constitute the basis for agricultural production in the region. Farms in north-western Mazovia have mainly coarse textured soil. Moreover, podzolic soils and alluvial soils are also found in the Mazovian voivodship.

Forests constitute approximately 30% of Poland's area and underpin ecological, economic and social functions. They also make up an important part of Mazovia's natural resources.

Table 13 – The Voivodship against the background of the country in 2021.

SPECIFICATION	Polska Poland	Województwo Voivodship	
	ogółem total		Polska=100 Poland=100
AREA – as of 31 December			
Area in km^2	312705	35559	11,4
AGRICULTURE			
Agricultural land in good agricultural condition [f] (as of June) in thousand ha	14754,9	1955,0	13,2
Sown area [f] in thousand ha	10961,8	1286,9	11,7
Production in thousand tonnes:			
cereals	34640,8	3523,9	10,2
potatoes	7081,5	821,0	11,6
ground vegetables [g]	3898,5	468,9	12,0
Yields per 1 ha in dt:			
cereals	46,5	39,1	84,1
potatoes	300	321	107,0
FORESTRY			
Forest area (as of 31 December) in thousand ha	9264,7	832,2	9,0
Forest cover in %	29,6	23,4	.

Source: Statistical Office in Warszawa, 2022.

Poland and Mazovia have diverse land and soil resources that constitute the basis for agriculture, forestry and other economic sectors. The level of land use in Poland is very high because agriculture plays an important role in the country's economy. About 60% of Poland's area is agricultural land. In Mazovia, the level of land use is also high because the region is one of the most important agricultural areas in Poland. Many farms in Mazovia specialize in growing cereals, especially wheat and corn, but also grasses and fodder plants. Other important crops include rapeseed, sugar beet, legumes and vegetables.

Table 14 - Geodetic area by land use in Mazovia as of 1 January 2022.

SPECIFICATION	2010	2015	2021	2022	
	in ha				in percent
Total area	**3555847**	**3555847**	**3555847**	**3555881**	**100,0**
of which:					
Agricultural land	2445710	2385087	2407529 [a]	2404370	67,6
Forest land as well as woodland and shrubland	839091	880976	847117	847338	23,8
Lands under surface waters	41003	42252	42641	42409	1,2
Built-up and urbanised areas	184689	201767	217338 [b]	220721	6,2
Wasteland	35721	34378	33918	33871	1,0

a Including woodland and shrubland on agricultural land, classified in the item "forest land as well as woodland and shrubland" until 2017.
b Including areas used for the construction of public roads or railways.
S o u r c e : data of the Head Office of Geodesy and Cartography, 2022.

Poland has the largest agricultural area within the Baltic Sea drainage basin and one of the regions most focused on agriculture is Mazovia. Reducing the risk of phosphorus (P) and nitrogen (N) leaching from agricultural soils to water is therefore essential. Farmers in Mazovia often use acidifying N mineral fertilizers (in the form of ammonium sulphate or urea) as a cheaper option to alternatives. Increased acidity is known to reduce soil fertility and may trigger P leaching from certain soil types. Soil P content has been documented to be positively and significantly correlated with soil pH in Polish farms, including in Mazovia. It is generally higher in pig farms in the country, where farm-gate P balance surpluses have been demonstrated. In contrast, surveying of farm-gate balances for many small mixed farms in the country have indicated deficits of P and potassium (K), and the soil can be expected to be nutrient- depleted. A coordinated approach to manure management could thus be a relevant lever to secure soil health among Polish farms. In general, more export of manure from pig farms and intensive dairy farms is needed to use the manure as a P source effectively and not build up soil the nutrient to a higher level than at present on some farms and to avoid soil depletion on other farms (Ulén et al., 2015).

Soil organic matter plays an important role in maintaining soil fertility, binding nutrients and influencing its structure. Good soil management and maintaining high organic matter content is crucial for sustainable agriculture and environmental protection. Soil management and agricultural regulations in Mazovia are controlled by various institutions, including the Ministry of Agriculture and Rural Development and the Agency for Restructuring and Modernization of Agriculture. There are also subsidy and subsidy programs for farmers that aim to encourage the use of sustainable agricultural practices and environmental protection.

1.3 Biodiversity management profile

The country profile elaborated by the Convention on Biological Diversity (CBD) states that „the total number of species in Poland is estimated to be 63,000 species, with approximately 28,000 plant species and 35,000 animal species, including 700 vertebrate species.“ According to various estimates, between 33,000 and 45,000 animal species are found in Poland. Over 90% of them are insects. Vertebrates, around 700 species (CBD, n.d.), constitute a small percentage of all fauna in the country. The most diverse group of vertebrates are birds, with around 428 known species. Despite the richness of species in Poland, declining trends of 1,318 animal- and 310 plant species reflect a need for enhanced biodiversity protection measures. Currently, 147 animal- and 133 plant species are at risk of extinction –with 89 and 74 species classified as critically endangered, respectively. Simultaneously, various ant (e.g. Formica polyctena), butterfly (e.g. Euphydryas maturna) and vertebrate (e.g. Lutra lutra) species which are classified as endangered (some critically) in Europe and beyond are faring well in Poland (CBD, n.d.).

There are few endemic species in the country. This is mainly because the living nature in Poland is relatively young, developing since the retreat of the Scandinavian ice sheet approximately 10,000 years ago (the north of the country was covered by ice, and south of it the polar desert and tundra vegetation dominated in the periglacial climate). Moreover, the area of Poland is mostly lowland (without barriers hindering the spread of plants and animals), and the main geographical areas extend into neighboring countries. Most endemics occur in the mountains - the Tatra Mountains, the Pieniny Mountains and the Sudetes (especially in the Karkonosze Mountains).

Endemic plants (mainly perennials - herbaceous perennial plants) include:

- Tatra bluegrass (Poa nobilis) from the Poaceae/grass family - found in the Tatra Mountains,
- Carpathian urdzia (Soldanella carpatica) from the primrose family - occurring abundantly in the Tatra Mountains and Babia Góra, sparsely in Pilsko, Poliska, the Gorce and Pieniny Mountains,
- the Pieniny moth (Erysimum pieninicum) from the cabbage family - occurring in 4 locations in the Polish part of the Pieniny Proper and Małe Pieniny,
- Karkonosze bluebell (Campanula bohemica) from the bellflower family - occurring (as 2 subspecies) in the Karkonosze Mountains and the Wielki Jeseník.
- or the Polish spoonbill (Cochlearia polonica) from the cabbage family - formerly found in the area of the Błędowska Desert, now in several locations in the region.

There are even fewer endemics among animals. These include, among others;

- Allogamus starmachi - an aquatic insect from the order of caddisflies, found in the Tatra Mountains (larvae live in periodically flowing Tatra streams),
- or the Tatra voles (Microtus tatricus), a rodent from the vole subfamily - a Carpathian endemic, found mainly in the Tatra Mountains.

A characteristic of Mazovia's biodiversity is un-diverse vegetation. Mazovia is marked by characteristic forests, including deciduous and coniferous forests, pine forests and riparian forests. There are also meadows and fields hosting several species of herbaceous plants. The Mazovian region is home to many animal species. In the country there are, among others: moose, deer, roe deer, martens, foxes, badgers, ferrets, hares and many species of rodents. Rivers and lakes here are common habitats of water birds such as the mute swan, cormorant, gray heron, great crested grebe and lapwing. Many species of land birds are also known, such as magpies, kings, nuthatches and woodpeckers. Mazovia also has many accessible nature areas that are particularly important for maintaining diversity. The most important of them include Puszcza Kampinoska. The biological diversity of Mazovia is threatened by pressures of urbanization, deforestation, and agriculture. It is important to take action to protect and preserve this unique diversity.

According to the research conducted by Lisek (2012) on synanthropic flora in the orchards of central Poland (near Skierniewice, Łowicz and Grójec), a total of 186 species belonging to 39 botanical families was noted and 60% of the found species occurred occasionally or rarely. The most numerous group in the examined orchards was made up of the therophytes (50%), while within the vascular flora segetal species (26%) were predominant.

Error! Reference source not found. below shows the locations of Key Biodiversity Areas (KBAs) in Poland and the Mazovian region. KBAs are defined as "*globally important sites that are large enough or sufficiently interconnected to support viable populations of the species for which they are important*" (Bibby, 1998, as cited in Eken et al., 2004).

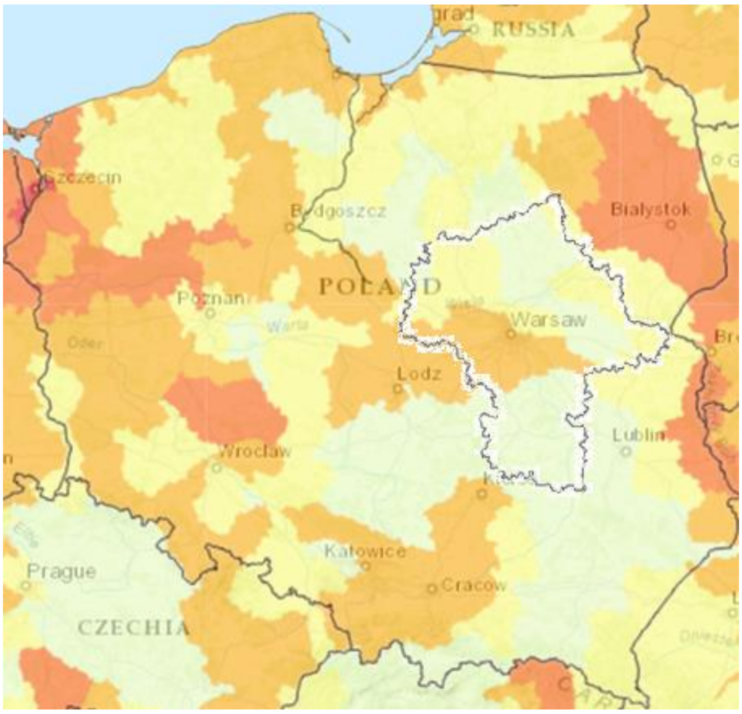

Figure 30 - Key Biodiversity Areas in Poland and Mazovia. Source: WWF Risk Filter Suite, 2023, riskfilter.org/water/explore/map

Currently, 39.6% of Poland's terrestrial territory is designated as protected areas, which is significantly above the EU value of 26.4%. The EU Biodiversity Strategy has set a target of reaching 30% protected area coverage at the EU level by 2030. With a coverage of 21.87% in its marine waters, Poland surpasses the EU value of 12.1%.[112] Poland has a total of 3,063 protected areas, comprising 2,061 sites designated under national laws and 1002 recognized as Natura 2000 sites. These Natura 2000 sites are designated under the Birds Directive, encompassing 145 Special Protection Areas, and the Habitats Directive, encompassing 867 Sites of Community Importance. Many sites are designated under both Directives.

[112] See: https://www.eea.europa.eu/en/analysis/indicators/marine-protected-areas-in-europes-seas

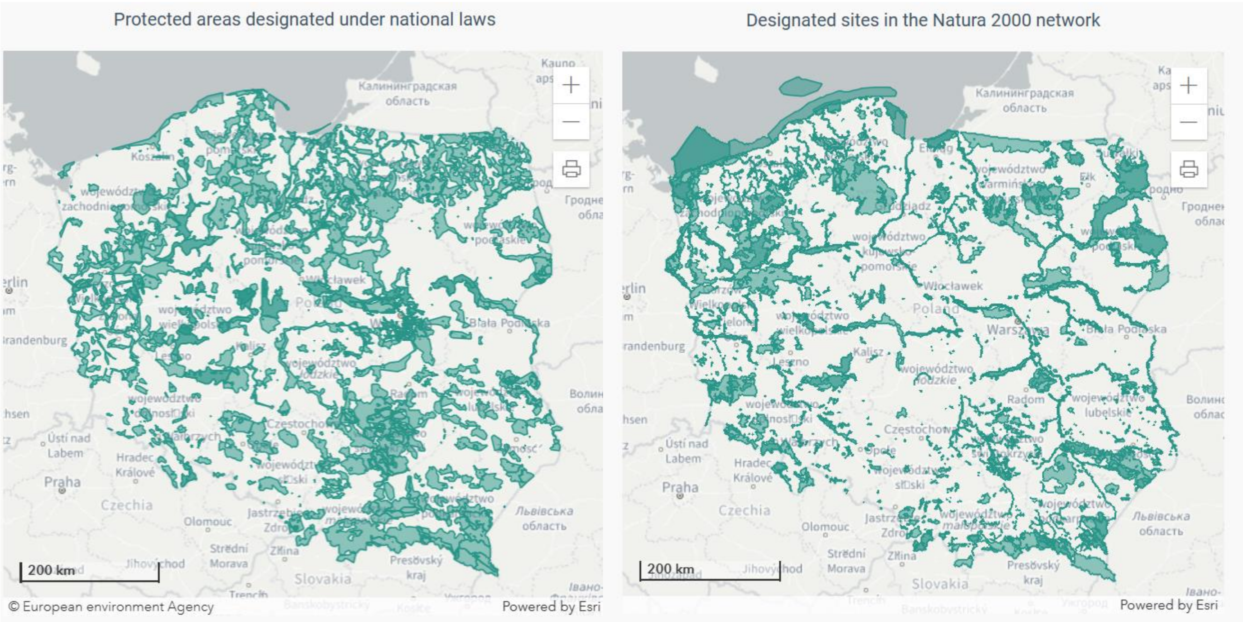

Figure 31 - Protected areas in Poland. Sites designated under national laws (left) and in the Natura 2000 network (right). Source: EEA, n.d.

Natura 2000 sites in Poland cover 270 species and 81 habitats from the nature directives. The number of species and habitats protected in each site varies depending on the location of the site, the biodiversity in the region, the designation being used, and the features the site is being created to protect.

Table 15 - Area of special nature value under legal protection in Poland[a]

SPECIFICATION	2010	2015	2020	2021		
	in ha				in % of total area of the Voivodship	per capita in m²
TOTAL	**1055243**	**1055738**	**1058139**	**1057050**	**29,7**	**1917**
National parks	38476	38476	38476	38476	1,1	70
Nature reserves	18203	18861	19539	19537	0,5	35
Landscape parks[b]	168396	168662	168674	168567	4,7	306
Protected landscape areas[b]	822506	822064	823407	822456	23,1	1492
Documentation sites	522	522	521	537	0,0	1
Landscape-nature complexes	5316	5316	5642	5591	0,2	10
Ecological areas	1824	1837	1880	1886	0,1	3

Source: Statistical Office in Warszawa, 2022

[a] Data do not include information concerning the areas of the Natura 2000 network, data include only the part located within other legally protected areas.

[b] Excluding nature reserves and other forms of nature protection located within those areas.

The Mazovian Natura 2000 network covers an area of approximately 466,497 ha, constituting approximately 13.12% of the voivodeship's territory. It consists of 16 areas of special protection for birds, 59 special areas of conservation of habitats or areas of Community importance (future special areas of conservation of habitats) and one area protected under both the Birds and Habitats Directives - Puszcza Kampinoska PLC140001.

Of the 16 areas established under the Birds Directive indicated above, the largest located entirely in the Mazovian Voivodeship is Puszcza Biała PLB140007 (83,779.74 ha), and the smallest is Bagno Pulwy PLB140015 (4,112.4 ha). The largest among those created under the Habitats Directive is Puszcza Kozienicka (28,230.37 ha), and the smallest is Aleja Pachnicowa (1.1 ha).

Legal framework for biodiversity conservation in Poland

Protection of nature and biodiversity in Poland is organized at the central and local government levels (regional, counties and communes).

At central level, Ministry of Climate and Environment (*Ministerstwo Klimantu i Środowiska*) is responsible for mainstreaming environmental issues in all legislation and for overall environmental policy. In its activities, the ministry is supported by the Chief Inspectorate f Environmental Protection (*Główny Inspektorat Ochrony Środowiska*).This Inspectorate is in charge of different tasks, including monitoring the implementation and enforcement of regulations on environmental protection and the use of natural resources, assessing the impact of the adopted environmental protection policies, plans, and programmes, as well as monitoring of the state of the environment.

Within other relevant institutions, it is possible to distinguish Instytut Ochrony Środowiska (The Institute of Environmental Protection) and Instytut Ekologii Terenów Uprzemysłowionych (The Institute for Ecology of Industrial Areas) that are responsible for performing planning, research, monitoring, educational and other functions.

At regional level, regional authorities are responsible for environmental protection and adopting regional protection plans for implementing the national guidelines. Counties (*powiaty*) are responsible for environmental protection and agriculture (including the conduct of the land merging procedures and land exchange, issuing a decision declaring the forest to be protective or depriving it of this character, issuing a decision on conversion of forest to agricultural. Local authorities at commune level (gminy) are responsible for protecting the local environment.

The monitoring of the status of species and habitat biodiversity is carried out by the State Environmental Monitoring System. Research conducted by science centres is also an important source of information about the state of biodiversity. Current research findings as well as results from monitoring are made available on the website of the Chief Inspectorate for Environmental Protection. A database on Alien Species in Poland has also been under development since 1999 at the Polish Academy of Sciences Institute for Nature Conservation.

Numerous educational programmes and campaigns are undertaken in the area of biological diversity. At the central level the Ministry of the Environment launched research on the ecological awareness and environmental behavior of Polish citizens as part of a long-term project. The Ministry of Environment has also carried out a campaign on biodiversity and ecosystem services.

For many years, the National Fund for Environmental Protection and Water Management, the Voivodship Funds for Environmental Protection and Water Management, the EcoFund Foundation and others have played and continue to play a very important role in the implementation process. Actively operating since 1992, EcoFund's income has been primarily provided by Polish debt-for-environment swaps with the United States, France, Switzerland, Italy and Norway. Moreover, significant financial opportunities are made available as result of Poland’s membership in the EU (e.g. access to a number of funds, including the European Regional Development Fund, European Social Fund, European Fisheries Fund, European Agricultural Fund for Rural Development, LIFE+ Financial Instrument for the Environment).

Significant progress has been made in enhancing the role of environmental impact assessments and limiting negative pressures on protected areas during planned economic undertakings. Recognizing the need to increase the efficiency of the EIA system, especially in regard to biological diversity protection issues, and to align EIA requirements with those of the EU, Poland adopted the Act on Sharing Information on the Environment and its Protection, Involvement of Society in Nature Conservation, and on Environmental Impact Assessment. Through this Act, a new compact system for supervising EIA procedures was created, comprised of a General Directorate for Environmental Protection and regional directorates for environmental protection, responsible for environmental impact issues and protection of the Natura 2000 network. The Act's provisions significantly strengthened the role of public consultations in EIA procedures and introduced the requirement for repeated assessments in undertakings that could considerably impact on the environment.

Supervision over implementation of the National Strategy is entrusted to the Steering Committee, consisting of the representatives of all stakeholders. Additionally, the effectiveness of the implementation of the NBSAP will be subjected to periodic assessments and cyclical meetings with the participation of stakeholders.

2 Methodology for the appraisal of available capacity of the regional ecosystem

The text in this chapter is strongly based on the description of the methodology for the BE-Rural Sustainability Screening presented in Anzaldúa et al. (2022), with only minor adaptations that resulted from the implementation of the approach in SCALE-UP. It has been included here in its full extent instead of simply referring to the cited report to allow this document to be used as a stand-alone piece.

2.1 Water data and indicators

To run the sustainability screening of surface and groundwater bodies potentially relevant to the Mazovian Region in Poland, the authors of this report have reviewed the data reported in the 2nd River Basin Management Plans (RMBPs) of the Vistula River Basin District published in 2016 (data from the 3rd reporting cycle was not yet available on the WISE Database at the time of the analysis). The benefits of tapping on this reporting process is that it includes well-defined indicators like the status of water bodies in each RBD as well as data on significant pressures and impacts on them. Further, these data are official, largely available, accessible, and updated periodically (every six years). Authorities in charge of developing a regional bioeconomy strategy would generally be expected to have good access to the entity in charge of developing the River Basin Management Plan (i.e. the River Basin Authority), and so could theoretically consult it if necessary.

2.1.1 Description of the data / definition of the indicators employed

Data reviewed for this part of the screening included the reported ecological and chemical status of rivers and lakes as well as the quantitative and chemical status of groundwater bodies in the RBD that roughly coincide territorially with the Mazovian region. These data give indications on water quality in the river basin according to the five status classes defined in the WFD. These are: high (generally understood as undisturbed), good (with slight disturbance), moderate (with moderate disturbance), poor (with major alterations), and bad (with severe alterations) (EC, 2003). Further, data on significant pressures and significant impacts on the water bodies in the river basin district are used to indicate the burden of specific pressure and impact types on water ecosystems in the regions based on the number and percentage of water bodies subject to them. Significant pressures are defined as the pressures that underpin an impact which in turn may be causing the water body to fail to reach at least the good status class (EEA, 2018).

All data described above were accessed on 20.06.2023 from the WISE WFD data viewer (Tableau dashboard) hosted on the European Environment Agency's (EEA) website[113].

Table 16 - Indicators used for the water component of the sustainability screening

Category	Indicator Family	Indicator	Spatial level	Unit of measure	Comments/Reference
Water	Water quality	Status of water bodies according to the EU Water Framework Directive	River Basin District	Number of water bodies in high, good, moderate, poor, bad or unknown status	WISE WFD Data Viewer[114] Disaggregated data for ecological and chemical status of surface water bodies; quantitative and chemical status of groundwater bodies, per River Basin District
	Burden on water bodies	Significant pressures on water bodies	River Basin District	No. and % of water bodies under significant pressures per pressure type	WISE WFD Data Viewer
	Burden on water bodies	Significant impacts on water bodies	River Basin District	No. and % of water bodies under significant impacts per impact type	WISE WFD Data Viewer

Source: Anzaldúa et al., 2022.

To determine which status class a certain water body falls into, WFD assessments evaluate the *ecological* and *chemical* status of surface waters (i.e. rivers and lakes) and the *quantitative* and *chemical* status of groundwater bodies. Ecological status refers to *"an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters".* It covers assessments of biological (e.g. presence and diversity of flora and fauna), physico-chemical (e.g. temperature and oxygen content) and hydromorphological criteria (e.g. river continuity) (EC, 2003; BMUB/UBA, 2016). The chemical status of a surface water body is determined by comparing its level of concentration of pollutants against pre-determined Environmental Quality Standards (EQS) established in the WFD (concretely in Annex IX and Article 16(7)) and in other relevant Community legislation. These standards are set for specific water pollutants and their acceptable concentration levels.

In the case of groundwater bodies, chemical status is determined on the basis of a set of conditions laid out in Annex V of the WFD which cover pollutant concentrations and saline discharges. Additionally, the water body's quantitative status is included in the WFD assessments, defined as "*an expression of the degree to which a body of groundwater is affected by direct and indirect abstractions*". This gives indication on groundwater volume, a relevant parameter to evaluate hydrological regime (BMUB/UBA, 2016).

113 https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd
114 WISE WFD Data Viewer (https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd)

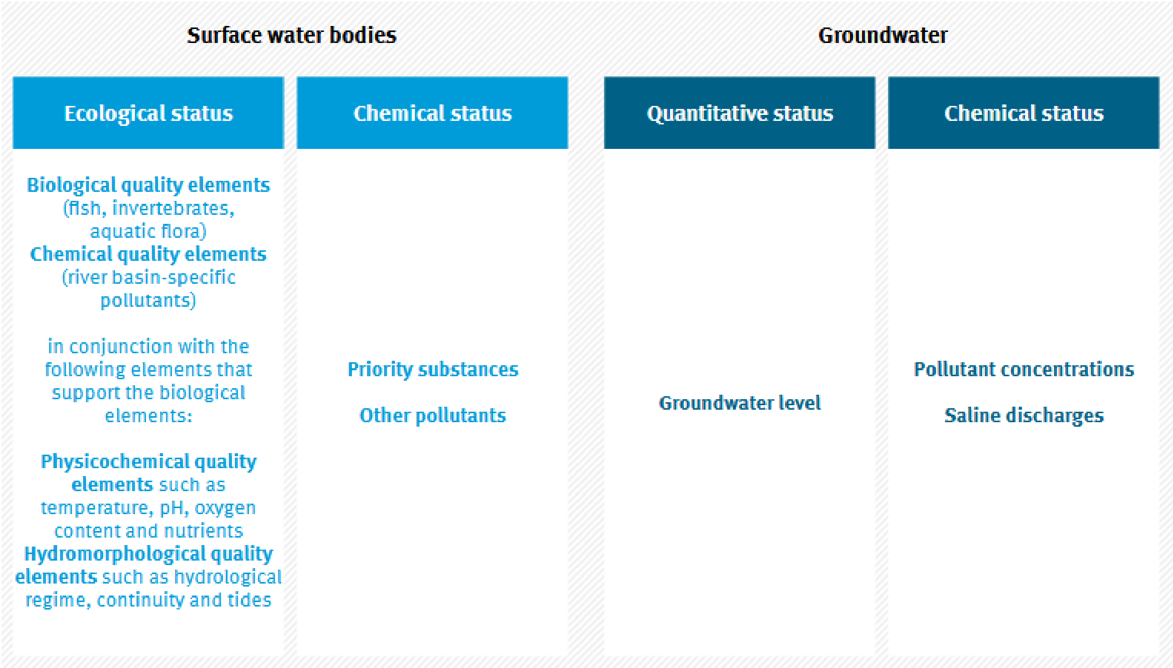

Figure 32 - Overview of surface water body and groundwater status assessment criteria, as per the Water Framework Directive. Source: BMUB/UBA, 2016.

In the case of surface water bodies, the WFD objective is not only that they reach good status, but that quality does not deteriorate in the future (EC, 2003), which is relevant in the context of the development of bioeconomy value chains.

2.1.2 Methodology applied

The authors of this report have followed the approach described in Anzaldúa et al. (2022) to valorise the data from the WFD reporting described in the previous sub-section that allows for an appraisal that is non-resource intensive (based on reliable, publicly available and accessible data) yet capable of providing a rough overview of the state of the Mazovian waters. This is in line with the rationale of this sustainability screening, which aims to enable stakeholders with limited financial resources and/or expertise in the field to consider ecological limits in a structured manner when exploring bioeconomy activities. The preferred option for this part of the assessment would have been to supplement the WFD data with a water quantity balance indicator like the Water Exploitation Index plus (WEI+) developed by the EEA and its partners. That indicator compares the total fresh water used in a country per year against the renewable freshwater resources (groundwater and surface water) it has available in the same period. This could have strengthened the water quantity element in the screening. However, the calculation of the WEI+ at regional level is currently not conducted or foreseen by its developers, and it would entail a disproportionately large effort that falls beyond the scope of this task in SCALE-UP. For these reasons, the reported data from the WFD process has been employed exclusively within the following methodology.

The overall apportionment of rivers, lakes and groundwater bodies in the Mazovian region according to their WFD status classification can be used to set the baseline for the sustainability screening. It provides initial insight on the situation in the demarcation as regards “ensuring access to good quality water in sufficient quantity”, “ensuring the good status of all water bodies”, “promoting the sustainable use of water based on the long-term protection of available water resources” and “ensuring a balance between abstraction and recharge of groundwater, with the aim of achieving good status of groundwater bodies”, all explicit aims of the WFD that are aligned with the consideration of ecological limits. Further, the data on significant impacts and pressures affecting the water bodies in the river basins are useful as they can point towards specific problems (e.g. nutrient pollution) and the types of activities that may be causing them (e.g. discharge of untreated wastewater, agriculture).

As a first step, the approach used for this element of the screening entails calculating what proportion of the total number of surface water bodies located in the RBD is reported as failing to achieve Good Ecological Status/Good Chemical Status or for which conditions are unknown. Similarly for groundwater bodies, the proportion is calculated of those who are reported as failing to achieve Good Chemical Status/Good Quantitative Status or for which conditions are unknown. The resulting ratios are then compared to the respective EU proportions, which are used as (arbitrary) thresholds. According to the latest assessment published by the EEA in 2018, "around 40% of surface waters (rivers, lakes and transitional and coastal waters) are in good ecological status or potential, and only 38% are in good chemical status" (EEA, 2018). Accordingly, "good chemical status has been achieved for 74% of the groundwater area, while 89% of the area achieved good quantitative status" (EEA, 2018). Using these markers, the following step is to rank the current conditions of the Mazovian region using an ordinal risk rating (high, moderate, low) based on the distance of the result of each indicator to the EU level results. On this basis, the thresholds and ordinal ranking convention suggested by the authors of this report are as shown in Table 10 and Table 11.

Table 17 - Proposed thresholds for the water section of the sustainability screening

Water body type	Status category	2018 EU-level assessment results (proportion of water bodies achieving good status)	Proposed thresholds for the sustainability screening		
			High concern	Moderate concern	Low concern
Surface water bodies	Ecological status	~40%	0-40%	41-89%	90-100%
	Chemical Status	38%	0-38%	39-89%	90-100%
Groundwater bodies	Chemical status	74%	0-74%	75-89%	90-100%
	Quantitative status	89%	0-89%	-	90-100%

Source: Anzaldúa et al., 2022.

Table 18 - Ordinal ranking convention for the water section of the sustainability screening

Ordinal ranking for water resources		Chemical status		
		High concern	Moderate concern	Low concern
Ecological or Quantitative status	High concern			
	Moderate concern			

	Low concern			

Source: Anzaldúa et al., 2022.

This initial appraisal based on the thresholds shown above is then supplemented with a review of the reported data on the types of significant pressures and impacts on surface and groundwater bodies. In this case percentage values are already given, and so this step in the screening simply entails the listing of the reported pressures and impacts and the identification of those which are more frequently reported. From here, the screening team can seek potential correlations between the most reported pressure types and the most reported impact types (e.g. diffuse sources causing nutrient pollution).

The final step in the approach is to draft a note describing the share of water bodies failing to reach good status and formulating preliminary statements on the types of bioeconomy activities that could be considered, those that should be considered with reserve, and those that should be avoided. These initial statements are used to frame the discussion of the group of stakeholders involved in the development of the bioeconomy value chains in focus in the SCALE-UP project.

2.1.3 Data uncertainties

The data resulting from the assessments reported in the WISE Database are subject to the limitations of the scientific and methodological approaches used by their authors. It thus must be considered that the official assessments are based on estimates, include assumptions, and will therefore carry a margin of error. Further, some of the reported data may differ from what the Central Statistical Office in Poland currently makes available (e.g. due to updates or differences in the indicators measured).

An important limitation bound to the implementation of the sustainability screening is that the WFD data used refer to the Vistula RBD, whose territorial boundaries do not coincide entirely with those of the Mazovian region (the former is much larger). A future iteration of this exercise by the local stakeholders could increase the resolution of the screening of water resources by tapping on additional information sources, like higher resolution data for the specific territorial demarcation of the Mazovian region, if they become available.

Lastly, another issue to consider is the data currently available on WISE is from 2016, while more updated assessments are already available at the time of writing of this document. These come as part of the 3rd cycle of river basin management planning (2022-2027), but are not yet reflected on the WISE Database hosted by the EEA. Here as well, such sources could be considered by the stakeholders performing the sustainability screening to avoid overlooking any relevant recent developments.

2.1.4 Methodological uncertainties

The proposed methodology for the water section used in this application of the sustainability screening is straight-forward and accessible, yet it must be used with care and, where possible, should incorporate higher resolution data evaluated by thematic experts. As previously mentioned, the thresholds set in this case have been the proportions, at EU-level, of water bodies that fail to achieve good status or for which conditions have been reported as unknown. This has been a pragmatic, yet easy to challenge way of defining a benchmark for Mazovia. Conditions and context in other European RBDs may be significantly distinct to those in Central Poland, and thus a more appropriate reference point could be defined in those cases. For this, the authors envision the contributions and guidance from the team of local and foreign experts as briefly described in Section 3.2 of Anzaldúa et al., 2022. Optimally, these thematic experts should know the regional context well and thus be in a good position to guide the setting of such thresholds. This would hopefully help address any discrepancies between assumptions and methodological arrangements made in this study and others carried out on the Mazovian context. Beyond this, the simplicity of the necessary calculations and the fact that the data on significant pressures and impacts are used without further computation and compared in relative terms within the RBD limit the possibility of additional accuracy or uncertainty issues emerging.

2.2 Soil data and indicators

2.2.1 Description of the data / definition of the indicators employed

The selected indicators for vulnerability to soil depletion are closely interrelated and refer specifically to soil erosion **by water**. These are:

- Estimated mean soil erosion rate (in $t\ ha^{-1}\ a^{-1}$)
- Share (%) of area under severe erosion (>10 $t\ ha^{-1}\ a^{-1}$)

In broad terms, soil erosion describes the process through which land surface (soil or geological material) is worn away (e.g. through physical forces like water or wind) and transported from one point of the earth surface to be deposited somewhere else (Eurostat, 2020). The above-mentioned indicators describe particularly the amount of soil (in t) per unit of land surface (in ha) that is relocated by water per year.

Variations of these indicators can be calculated by considering different combinations of land cover classification groups, such as *all land*[115] and *agricultural land*[116]. As shown in Figure 19, at EU level in 2016, about three quarters of soil loss occurred in agricultural areas and natural grasslands, while the remaining quarter occurred in forests and semi natural areas (Eurostat, 2020). Therefore, since it is the type of land cover that is most vulnerable to erosion, the present sustainability screening will consider in first line the above-mentioned indicators specifically for agricultural areas and natural grasslands. This scope of the indicators is also in line with the two sub-indicators for soil erosion considered by the Joint Research Centre European Soil Data Centre (JRC ESDAC). Moreover, both the *mean erosion rate for agricultural land* and the *share of agricultural area under severe erosion* are part of the EU Common Agriculture Policy (CAP) context indicator 42 (CCI42) for the period 2014-2020.

[115] This refers to all potentially erosive-prone land (in simplified terms), specifically to CORINE Land Cover classification groups: Agricultural areas (2), forest and semi natural areas (3) excluding beaches, dunes, sand plains (3.3.1), bare rock (3.3.2), glaciers and perpetual snow (3.3.5). These, as well as other classes, are excluded because they are not subject to soil erosion.
[116] This refers only to agricultural land (agricultural cropland as well as grassland in simplified terms), specifically to CORINE Land Cover classification groups: Agricultural Areas (2) and Natural Grasslands (321)

Figure 33 - Share of land cover and soil loss across the EU-27 in 2016.[117] Source: JRC, Eurostat

The data has been extracted from EUROSTAT, specifically the dataset "Estimated soil erosion by water, by erosion level, land cover and NUTS 3 regions (source: JRC) (aei_pr_soiler)". For determining the baseline in the sustainability screening, we have selected the latest available data, i.e. for 2016.

Mean soil erosion rate, which undergirds both selected indicators, is considered useful because it provides a solid baseline to estimate the actual erosion rate in the regions (Panagos et al., 2015). This indicator is based on the latest Revised Universal Soil Loss Equation of 2015 (RUSLE2015), specifically adapted for the European context (see Panagos et al., 2015), which is a model that takes into account various aspects, including two dynamic factors, namely the cover-management[118] and policy support practices[119] (both related to human activities) (Panagos et al., 2020).

The estimated mean soil erosion rate value obtained through the RUSLE2015 model refers to water erosion only, but it is considered to be the most relevant at least in terms of policy action at EU level, due to the relative predominance of water erosion over other types of erosion. Furthermore, it offers the important advantage of providing a viable estimation for erosion vulnerability at a relatively small geographic scale, i.e. the local or regional level. This can serve as an important tool for monitoring the effect of local and regional policy support strategies of good environmental practices (Panagos et al., 2015, 2020, and Eurostat, 2020).

2.2.2 Methodology applied

The near-universal indicators available to track soil vulnerability are related to either erosion or the decline in soil organic carbon (SOC)/soil organic matter (SOM) (Karlen & Rice, 2015). However, there are major data gaps regarding to SOC/SOM and data is currently only available at national level. According to Panagos et al. (2020), soil organic carbon does not change so quickly and therefore is not so sensitive to human influence on short term. Therefore, they recommend using just a sole indicator for monitoring impact of policies: "estimated mean soil erosion rate" (by water), which they calculate using the RUSLE2015 model. For our purposes, we have complemented the *mean soil*

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[117] Excluding not erosion-prone land (e.g. beaches, dunes, etc.). Forest and natural areas exclude also natural grasslands, which are evaluated together with agricultural areas.
[118] Known as the c-factor, it has a non-arable component, which includes changes in land cover and remote sensing data on vegetation density, as well as an arable component, which includes Eurostat data on crops, cover crops, tillage and plant residues.
[119] Known as the p-factor, it reflects the effects of supporting policies in estimating the mean erosion rate by including data reported by member states on Good Agricultural Environmental Conditions (GAEC) according to the CAP, specifically contour farming, as well data from LUCAS Earth observation on stone walls and grass margins.

erosion rate indicator, with the *share of agricultural area under severe erosion* in order to gain a comprehensive picture of soil erosion in a region.

Soil erosion is considered generally as a sort of proxy indicator of soil degradation, which in turn is the most relevant component of land degradation at EU level (EC, 2018). However, not all types of bio-based activities have a direct effect on erosion, but rather primary production of biomass. Nonetheless, as these are currently the most widespread bioeconomy activities in rural areas, we will consider their impact on soil degradation, and therefore on soil erosion, to be the most relevant one for this assessment.

The indicators for vulnerability to soil degradation were selected, on one hand, due to the limited number of soil indicators available at the required regional scale. On the other hand, the RUSLE2015 model used for this data also represents the current state-of-the-art methodology for calculating soil erosion. These aspects are crucial, since the choice of indicators needs to be: a) acceptable to experts, b) routinely and widely measured, and c) have a currency with the broader population to achieve global acceptance and impact (Stockmann et al., 2015). In order to carry out the screening of soil vulnerability, a number of datasets need to be accessed. As mentioned above, these data can be accessed via Eurostat.

In terms of processing the erosion data, it is important to consider that the overall erosion rate changes across geographic areas, meaning the vulnerability/risk is not necessarily evenly distributed. In cases where the mean soil erosion rate exceeds the 10 t ha^{-1} a^{-1}, erosion is considered severe and activities that can generate, or are associated with a high erosion impact should be strongly discouraged. Erosion rates between 5 and 10 t ha^{-1} a^{-1} are considered moderate, requiring some attention towards practices that have a high impact on erosion, but with less urgency. However, it is relevant to take a look not only at the mean erosion rate for the area itself, but also at its spatial distribution, which is roughly reflected on the indicator of share of (agricultural) area under severe erosion.

2.2.3 Data uncertainties

The data used is produced from an empirical computer model (RUSLE2015) and produces estimates. Hence, there are several uncertainties related to the figures if compared to data collected on the ground, or to those that the Central Statistical Office in Poland may generate in national level surveys. However, the purpose of the model is to generate data for a large spatial scale taken into account human intervention, which is not possible to do only through empirical measurements. That being said, like every model, assumptions have to be made and there is an intrinsic level of uncertainty. Specifically related to the RUSLE methodology, Benavidez et al. (2018) critically reviewed the RUSLE methodology, upon which RUSLE2015 is based, and identified following main limitations:

- its regional applicability to regions that have different climate regimes and land cover conditions than the ones considered (in the original RUSLE for the USA, in RUSLE 2015 for Europe)
- uncertainties associated generally with soil erosion models, such as their inability to capture the complex interactions involved in soil loss, as well as the low availability of long-term reliable data and the lack of validation through observational data of soil erosion, among others.
- issues with input data and validation of results,
- its limited scope, which considers only soil loss through sheet (overland flow) and rill erosion, thus excluding other types of erosion which may be relevant in some areas, e.g. gully erosion and channel erosion, to name a few. Moreover, it also excludes wind erosion.

A further factor of uncertainty in the data is the fact that the RUSLE model is calculated using mean precipitation data over multiple years and a large territorial scale (in this case Europe). Thus, it fails to account the changes in rainfall intensity, which are highly relevant for determining water erosion accurately. This is the case not only considering the seasonality of rainfall, but also its distribution across the continent (Panagos et al., 2020). Another important uncertainty identified by Panagos et al. (2020) is the lack of georeferenced data for annual crops and soil conservation practices in the field at a continental level, which has had to be estimated from statistical data.

Nonetheless, when considered best available estimates, the mean soil erosion values generated through the application of RUSLE2015 model offer a very suitable basis for assessing vulnerability to soil loss in general terms, even if the generated absolute values are to be taken with caution (Benavidez et al., 2018).

2.2.4 Methodological uncertainties

Among the most relevant uncertainties regarding the application of the sustainability screening in terms of soil vulnerability are the selection of the threshold against which the severity of erosion is evaluated and the selection of the land cover types that will be considered.

Regarding the threshold of 10 t ha^{-1} a^{-1} for severe erosion, it is important to mention that this was obtained directly from the dataset that was used[120]. However, it is still an arbitrary value which can be adapted. For instance, some sources like Panagos et al. (2015, 2020), who were involved in the generation of the data for the JRC ESDAC, consider severe erosion to be above 11 t ha^{-1} a^{-1}. In this regard, we have also decided to stick to the lower value described in the Eurostat dataset because it is more conservative and, as such, more suitable for an initial (and indicative) sustainability screening like the one we are proposing.

The selection of land cover types presents another area for potential uncertainty. Choosing between “all lands” and “agricultural lands” can have considerable implications for interpreting the data. For example, it is possible that the mean soil erosion rate is 5 t ha^{-1} a^{-1} (moderate erosion) in one land cover type, but lower in the other. This would have an effect on the assessment, which would present any potential concerns about erosion and steps that should be taken. As such, it is important to have solid grounding for the choice of dataset. The ultimate decision whether to consider all lands (including forests) is arbitrary and lays with the group performing the sustainability screening. Particularly when that decision is based on considerations of the economic relevance of forestry related industries in the region rather than on the actual share of the area that is covered with forest (it should be high to justify their inclusion), the values of soil erosion (for all lands) shall be taken with some reservations. This is because these values tend to be lower than the value for agricultural land and can create the impression that vulnerability to erosion is lower than it actually is. However, due to the indicative (and non-exhaustive) nature of the present sustainability screening, this uncertainty is not especially relevant for cases such as Mazovia, where both values (for all lands and agricultural land with natural grassland) are low (see section 4.1).

2.3 Biodiversity data and indicators

2.3.1 Description of the data / definition of the indicators employed

Unlike for water- and soil-related risks, there are no reliable indices or standardized metrics to operationalize and compare risks to biodiversity at the regional level and in an integrated manner. Biodiversity is intricate and multifaceted, spanning genetic, species, and ecosystem diversity across various regions. Attempting to consolidate this diversity into a singular index may oversimplify it, leading to the loss of crucial information (Ledger et.al 2023; Brown & Williams 2016). Instead, biodiversity risks in a given region could be uncovered by considering the status of all species known to inhabit the region under scrutiny on a one-by-one basis, without trying to synthesize their collective status in a single index. Accordingly, our methodology suggests screening for biodiversity risks of a region by taking stock of its species of flora, fauna and fungi present in the demarcation and considering their conservation status. The Red List of Threatened Species of *the International Union for Conservation of Nature* (IUCN) is a globally recognized system for classifying the conservation status of species[121]. It is structured along the following risk categories (IUCN 2001, 2003):

[120] See metadata of the used dataset at https://ec.europa.eu/eurostat/cache/metadata/en/aei_pr_soiler_esms.htm

[121] The International Union for Conservation of Nature (IUCN) is a global environmental organization that was founded on October 5, 1948. It is the world's oldest and largest global environmental network. The

(1) Critically Endangered (CR): This is the highest risk category assigned by the IUCN Red List for wild species. Species in this category are facing an extremely high risk of extinction in the wild.
(2) Endangered (EN): Species in this category are facing a high risk of extinction in the wild.
(3) Vulnerable (VU): Species in this category are facing risks of extinction in the wild.
(4) Near Threatened (NT): Species in this category are close to qualifying for, or are likely to qualify for, a threatened category soon.
(5) Least Concern (LC): Species in this category have been evaluated but do not qualify for any other category. They are widespread and abundant in the wild.
(6) Data Deficient (DD): A category applied to species when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution or population status.
(7) Not Evaluated (NE): A category applied to species that have not yet been evaluated against the criteria.

Data description

Data on the risk category of each species found in the SCALE-UP regions is accessed through the online database of the IUCN Red List website. The IUCN Red List serves as a comprehensive repository of information, offering insights into the present extinction risk faced by assessed animal, fungus, and plant species. In 2000, IUCN consolidated assessments from the 1996 IUCN Red List of Threatened Animals and The World List of Threatened Trees, integrating them into the IUCN Red List website with its interactive database, currently encompassing assessments for over 150.300 species. Since 2014, assessors of species have been mandated to furnish supporting details for all submitted assessments. Among the recorded details are the species' (1) IUCN Red List category, (2) distribution map, (3) habitat and ecology, (4) threats and (5) conservation actions. The assessment of these dimensions is elaborated below:

(1) The IUCN Red List category: The IUCN Red List categories (CR, EN, VU, NT, LC, DD, NE) are determined through the evaluation of taxa against five quantitative criteria (a-e), each grounded in biological indicators of population threat:
    a. Population Size Reduction: This criterion evaluates the past, present, or projected reduction in the size of a taxon's population. It considers the percentage reduction over a specific time frame, with different thresholds indicating different threat levels.
    b. Geographic Range Size and Fragmentation: This criterion assesses the size and fragmentation of a taxon's geographic range. Factors such as few locations, decline, or fluctuations in range size contribute to the evaluation.
    c. Small and Declining Population Size and Fragmentation: This criterion focuses on taxa with small and declining populations, considering factors like population size, fragmentation, fluctuations, or the presence of few subpopulations.
    d. Very Small Population or Very Restricted Distribution: This criterion addresses taxa with extremely small populations or limited distributions. It assesses whether the taxon is at risk due to its small population size or restricted geographic range.
    e. Quantitative Analysis of Extinction Risk: This criterion involves a quantitative analysis, such as Population Viability Analysis, to estimate the extinction risk of a taxon. It considers various factors influencing population dynamics and extinction risk.

IUCN works to address conservation and sustainability issues by assessing the conservation status of species, promoting sustainable development practices, and providing guidance and expertise on environmental policy and action. The IUCN also plays a crucial role in influencing international environmental policies and fostering collaboration among governments, NGOs, and the private sector to promote conservation efforts worldwide (IUCN 2018).

While listing requires meeting only one criterion, assessors are encouraged to consider multiple criteria based on available data. Quantitative thresholds of the IUCN Red List categories were developed through wide consultation and are set at levels judged to be appropriate, generating informative threat categories spanning the range of extinction probabilities. To ensure adaptability, the system permits the incorporation of inference, suspicion, and projection when confronted with limited information.

(2) The distribution map: The IUCN Red List distribution map serves as a reference for the taxon's occurrence in form of georeferenced data and geographic maps. This data is available for 82% of the assessed species (>123.600) and is based on the species' habitat, which is linked to land cover- and elevation maps. The indicated area marks the species extent of occurrence, which is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred, or projected sites of present occurrence of a species, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of species, such as large areas of obviously unsuitable habitat. For a detailed explanation of the mapping methodology, please refer to the *Mapping Standards and Data Quality for the IUCN Red List Spatial Data* (IUCN 2021).

(3) Habitat and Ecology: The IUCN classifies the specific habitats that a species depends on for its survival. These habitats are categorized into three broad systems: terrestrial, marine, and freshwater. A species may inhabit one or more of these systems, and so the possible permutations result in seven categories of natural systems. Beyond these seven system categories, the IUCN offers a more nuanced classification system for habitats, comprising 18 different classes at level 1 (e.g., forest, wetlands, grassland, etc.), and 106 more specific classes listed at level 2 (e.g., Forest – Subtropical/tropical moist lowland, Wetlands (inland) – Permanent inland deltas; Grassland - Temperate) (IUCNa n.d.). For SCALE-UP's sustainability screening, the IUCN classification of the seven systems is sufficient to refine the search while not excluding relevant habitats. The EU Habitats Directive, in contrast, distinguishes 25 habitat types that are considered threatened and require active and recurring conservation action. The Directive demands member states to take measures to maintain or restore these natural habitats and wild species. If data on these became accessible in the future, it could be used in future iterations of the sustainability screening to supplement the results that using the IUCN classification yields.

(4) Threats: The IUCN database encompasses various general threats that can negatively impact a species. Direct threats denote immediate human activities or processes impacting, currently impacting, or potentially affecting the taxon's status, such as unsustainable fishing, logging, agriculture, and housing developments. Direct threats are synonymous with sources of stress and proximate pressures. Assessors are urged to specify the threats that prompted the taxon's listing at the most granular level feasible within this hierarchical classification of drivers. These threats could be historical, ongoing, or anticipated within a timeframe of three generations or ten years. These generalized threat categories encompass residential and commercial development, agriculture and aquaculture, energy production and mining, transportation and service corridors, biological resource use, human intrusion and disturbances, natural system modifications, invasive and other problematic species, genes and diseases, pollution, geological events, and climate change and severe weather. Beneath each general threat, more specific threats are detailed.

Please refer to the IUCN Red List's website[122] for a detailed list of all threats, including explanations.

(5) Conservation Actions: The IUCN database contains conservation action needs for each species, providing detailed information on the current conservation efforts and recommended actions for protecting the taxon. It includes general conservation actions such as research & monitoring, land/water protection, management, and education. Specific conservation actions are listed under each general action, along with a description of the current conservation status and recommended actions to protect the taxon. A hierarchical structure of conservation action categories (see the IUCN Red List's website[123]) indicates the most urgent and significant actions needed for the species, along with definitions, examples, and guidance notes on using the scheme. Assessors are encouraged to be realistic and selective in choosing the most important actions that can be achieved within the next five years, informed by the conservation actions already in place.

Note: the IUCN Red List and the EU Habitats Directive

Both, the EU's Habitats Directive and the IUCN Red List aim to preserve biodiversity, but they employ distinct methods and standards for evaluating conservation status. The Habitats Directive is centered on preserving natural habitats and wild species of flora and fauna within the EU, mandating that member states establish Special Areas of Conservation for habitats and species listed in its annexes. The Directive categorizes conservation status into three groups: favorable, unfavorable-inadequate, and unfavorable-bad. This classification system of habitats and species is based on how far they are from the defined 'favorable' conservation status, not their proximity to extinction (Sundseth 2015).

Conversely, the IUCN Red List is a worldwide evaluation of the conservation status of species, categorizing them according to their extinction risk. The Red List employs a set of five rule-based criteria to assign species to a risk category (see above). However, there are inconsistencies and weak agreement between the conservation status assessments of the Habitats Directive and the IUCN Red List. These inconsistencies can be significant, and correlations can vary greatly between taxonomic groups. Specifically, the Red List assessment tends to be more pessimistic than the Directive's Annex (Moser et.al 2016). Amos (2021), on the other hand, has found strong correlations between the two classifications systems for plants, while recognizing the Red List's quicker reaction to changes in the conservation status.

In summary, while both the Habitats Directive and the IUCN Red List aim to protect and conserve biodiversity, they use different methodologies and criteria to assess conservation status, leading to discrepancies in their assessments. However, they can complement each other in providing a comprehensive view of the conservation status of species and habitats at both the European and global levels (IUCN 2010).

2.3.2 Methodology applied

The methodology aims to derive a list of species which would require special consideration (e.g. close monitoring and safeguarding) in the context of implementing bioeconomy activities. To generate this list, the search function of the interactive IUCN database is used following five steps:

(1) Scope of Assessment: Selection of Europe as the scope of assessment to evaluate the conservation status of the European population rather than the global population. This approach ensures

[122] See here: https://www.iucnredlist.org/resources/threat-classification-scheme
[123] Ibid.

that species are identified as threatened based on their status in Europe, irrespective of their global abundance.

(2) Geographical Delineation: Utilization of the interactive map of the IUCN database to draw a polygon that exceeds the region of interest. Exceeding the regions ensures that the entire region is covered, as it is not possible to draw a polygon exactly matching the boundaries of the region. Moreover, a larger polygon also respects the uncertainty of delineating a species area of extent, since the actual area of extent is possibly more fluid than its statically indicated geolocations. Consequently, the larger polygon minimizes the risk of excluding any relevant species for which geolocations are registered just minimally outside of the regions' administrative boundaries, but which could inhabit parts of the region in the future. There is no rule of thumb for a correct distance between polygon boundary and region boundary.

(3) Species Selection: Limiting of the search results to endangered and critically endangered species to focus on those facing the most severe risks.

(4) Habitat Selection: selection of all habitats to ensure the full coverage of habitat types present in the geographical delineation defined in step 2.

(5) Threat Selection: Selection of threats associated with the respective regional bioeconomy and/or value chain to refine the search results to species likely to be impacted by them.

By following these steps, a targeted list of species is derived, focusing on species facing significant risks within the context of the regional bioeconomy strategy or value chain being explored, aligning with the specific conservation and bioeconomic priorities of the region.

2.3.3 Data and methodological uncertainties

It is important to acknowledge certain limitations and uncertainties associated with the data and methodologies used:

(1) Inaccurate representation of relevant area: The IUCN database allows for the interactive drawing of a map for a regional assessment. However, this drawn map might not accurately represent the area directly relevant to the bioeconomy strategy or value chain being explored. Since the selected polygon is larger than the actual bioregion, the assessment risks to include species that are not relevant to the bioregion and the bioeconomic strategy of the region.

(2) Lack of local habitat differentiation: The spread of species is indicated as its extent of occurrence without differentiating between habitats at the local level. This means that certain species might solely inhabit very particular habitats within the indicated extent of occurrence. An endangered amphibious species, for instance, might have an area of extent covering an entire country. However, it will only be found in very rare habitats within this area of extent (e.g., pond with very specific qualities). Accordingly, a regional assessment as outlined here (e.g., at the municipal level) might list certain species that do not occur in the assessed regions due to a lack of suitable habitats on the local level.

(3) Potential oversights in conservation status: Using Europe as a scope of assessment might hide any problematic conservation status of a species at the global or at the local level.

(4) Outdated data: The IUCN aims to have the category of every species re-evaluated at least every ten years and aims to update the list every two years (IUCNb n.d.). Nevertheless, the data might be outdated, which could lead to inaccuracies in the assessment of biodiversity risks. For this screening carried out for Mazovia, 17 percent of the data were older than 5 years, with the most dated being from 2011.

(5) Incomplete data: The data might be incomplete, which could limit the comprehensiveness of the assessment.

(6) Limited species coverage: It is estimated that the world hosts about 8,7 million species (Sweetlove, 2011). As of now, more than 150.300 species (16.120 in Europe) have been assessed for the Red List, leaving large data gaps at the global level.

(7) Taxonomic standards: The taxon being assessed must follow the taxonomic standards used for the IUCN Red List. Any deviation from these standards could lead to inaccuracies in the assessment.

3 Potential ecological burden of regionally relevant bioeconomic activities

3.1 Bioeconomic activity selected for the screening

The focus in the area is on the use of waste and byproducts from apple orchards and juice production for bio-based packaging and organic fertilizers. We have therefore carried out a sustainability screening of the valorisation of this waste, to identify potential environmental impacts associated with this value stream. Given the relatively specific field, literature on the topic remains somewhat limited.

The following sections provide some working definitions and an overview of the value chain. This chapter aims to synthesize the results of a literature review on potential impacts of the use of apple pomace and orchards on water, land, and biodiversity, respectively.

3.2 Overview, management practices and potential burden on the resources examined

3.2.1 Potential burden on water resources

Orchards can have significant implications for water resources management, especially concerning nitrogen usage and irrigation practices. Efficient nitrogen management is crucial for mitigating nitrate water pollution, with carefully managed fertilizer use imperative for preserving water quality (Goossens et al., 2017). Modern irrigation methods like drip irrigation help optimize water use, particularly in arid regions where water diversion for agriculture is substantial. Techniques such as regulated deficit irrigation are also being adopted to reduce water consumption without compromising crop productivity. Additionally, the perennial nature of orchards poses challenges for pest and disease management, indirectly affecting water resources. Integrated pest management strategies are essential for minimizing water-intensive treatments and ensuring sustainable water management in orchards (Demestihas et al., 2017).

3.2.2 Potential burden on land and soil resources

While there is a possibility for soil carbon sequestration in orchards (as in all agricultural soils), the potential linked specifically to orchards is debated. Orchards may also contribute to denitrification of soils, though this can depend on irrigation practices and weather conditions. Furthermore, the frequent use of cover crops in orchards has the possibility of increasing the fungi and bacteria leading to humification of soils, while also reducing the need for herbicides and fertilizers. In general, improved soil health and biological activity will depend on management practices – not only cover crops, but also reduced tillage and drip irrigation. Overall, the impact of orchards on soil resources is multifaceted, influenced by agricultural practices that can either degrade or enhance soil health and ecosystem functioning (Demestihas et al., 2017).

A life cycle assessment carried out by Goossens et al. (2017) identified concerns related to soil acidification impacts from fertilizer use and changes of soil organic matter due to the use of diesel in machinery. The assessment also pointed to potential benefits for soil fertility and biodiversity where reduced tillage practices are applied.

A study by Dyjakon et al. (2019) explored the environmental implications associated with energy use of waste biomass from apple orchards. They note that pruning residues can provide important ecosystem services related to maintaining soil organic carbon levels or reducing soil erosion. The removal of these materials for other uses, such as energy generation, may have adverse effects on soil fertility and stability. The study outlines a number of conditions where prunings should not be removed, depending on e.g. vegetation cover between trees, soil structure, or if the topsoil is prone to water logging. The study does note that in typical apple orchards in Poland, there are other sources of nutrient and mineral supply for the soil, such as spoiled fruit, mowed grass, or leaves. As such, activities in Mazovia should be conscious of the local situation when deciding when and how to remove extra biomass from orchards.

3.2.3 Potential burden on biodiversity

Orchards exhibit a dichotomy in their impact on biodiversity, stemming from their perennial nature and diverse habitat characteristics alongside intensive agricultural practices. The presence of multi-strata habitats and plant diversity within orchards fosters high levels of biodiversity. Pesticides have historically had significant impacts on wild farmland species and crucial functions like pollination, as well as disrupting food webs and natural nutrient decomposition processes. There is, however, a growing awareness among producers to adopt methods that minimize pesticide reliance. Yet, complex landscapes with dense, interconnected perennial habitats, including orchard areas, have shown potential for enhancing natural enemy populations, aiding in pest control. However, the effectiveness of biodiversity-supported pest management in orchards remains debated, with research on the impacts of agricultural practices on biodiversity still incomplete. Orchards also benefit from management practices that introduce planned plant biodiversity, initiating ecological processes that influence pest niche and dispersal dynamics. However, pesticides and other factors like hail nets can impair bee colonies, impacting pollination and biodiversity conservation efforts. Efforts to address habitat provision for biodiversity conservation extend to landscape-scale modifications, such as planting fruit trees to enhance connectivity across various taxa, offering promising avenues for mitigating the negative impacts of orchards on biodiversity (van der Meer et al., 2020; Demestihas et al., 2017).

4 Screening results and recommendations

4.1 Summary/Overview

Resources screened		Ordinal Baseline Rating	Use of waste and byproducts from apple orchards and juice production and its potential impact on environmental dimensions	
Category	**Sub-Category**		**Potentially beneficial to the baseline status**	**Potentially detrimental to the baseline status**
Water	**Surface water bodies**		- Drip irrigation/regulated deficit irrigation - Effective fertilizer management	- Overuse of chemical inputs, particularly nitrogen fertilizers
	Groundwater bodies			
Land Resources	**-**		- Consistent use of cover crops - Creating incentives against planting crops on high slopes; - Creating incentives for erosion control practices such as contouring, - Conservation tillage or mulching - Responsible use of drip irrigation	- Overuse of fertilizers and chemical inputs - Diesel use in heavy machinery - Removal of prunings (depending on soil health)
Biodiversity	**Endangered Species**	**5**	- Planting a diversity of species - Focusing on connectivity	- Overreliance on harmful pesticides - Hail nets
	Critically Endangered Species	**1**		

4.2 Recommendations

Surface water bodies: The proportion of rivers and lakes in the river basin district that achieve Good Ecological Status is significantly below the EU average. Simultaneously, more than half of the rivers and half of the lakes in the region still fail to achieve this WFD target. Thus, the scale and placement of any economic activities that could have substantial negative impacts on river and lake ecology should be planned very carefully to ensure that progress attained so far in meeting regulatory targets is not lost and instead continues to expand. According to the reported data, just above two-thirds of surface water bodies achieve Good Chemical Status. However, the chemical status of more than three-quarters of lakes is unknown, a figure that should be verified with the respective authority responsible for reporting these data. If they are failing to achieve good status, then economic activities that keep this situation from improving, or that could further deteriorate the chemical properties of lakes, should be avoided. Bioeconomy activities and management practices that could contribute to improve the chemical status of water bodies in the river basin district should be sought and promoted. According to the reported data, just over half of the rivers in the river basin district are affected by unknown anthropogenic pressures. If possible, further information on this should be gathered from the relevant authorities to understand the source of the pressure. Diffuse sources of pollution affect more than half of lakes, and one-fifth of rivers. The causes of this pollution should be verified with authorities, and economic activities that could exacerbate such pollution should be avoided. According to the reported data, half of rivers in the river basin district are subject to unknown impacts. This figure should be verified with the responsible authority for further clarification. Over half of all lakes have significant impacts from nutrient pollution. This is consistent with the reported data on diffuse pollution as a pressure and most probably directly related. It should anyway be confirmed via consultation with the responsible authority. In any case, economic activities associated to moderate or high discharges of nutrient pollutants to the environment should be avoided."

Groundwater bodies: Nearly all groundwater bodies in the river basin district are in Good Quantitative and Chemical Status, and only 11 of them are being affected by point and diffuse sources of pollution or a combination of both. A low number of these groundwater bodies suffer significant impacts from chemical, nutrient, or microbiological pollution. Similarly, low numbers of groundwater bodies are affected by pressures from groundwater recharge or water level (7), and these also suffer impacts related to their water balance. There are other impacts related to saline intrusion or terrestrial ecosystems, for example, but they are low numbers. It is important that any expansion of existing economic activities, and/or development of new ones, is planned thoroughly and located smartly to avoid the exacerbation of existing pressures on currently affected aquifers as well as the affectation of others.

Soil: With a soil erosion rate in all lands of 0.69 T/ha per year, Radomski is not vulnerable to erosion. Erosion in arable lands is 1.2 T/ha per year, which is still well below the European threshold for low risk/vulnerability. both in all lands and arable lands. In this context, soil erosion does not pose a risk for the sustainability of the bioeconomy in the region. However, in areas where soil erosion crosses the risk threshold, or where erosion rates are increasing, some measures can be taken: creating incentives against planting crops on high slopes; creating incentives for erosion control practices such as contouring, conservation tillage or mulching. Specific alternative tillage and mulching practices will depend on the crops being planted, and can often increase yields and reduce costs, however they can lead to an increase in pesticide consumption.

Biodiversity: As with any agricultural practices, the use of pesticides can have negative impacts on biodiversity. In orchards, the impacts of pesticides are especially significant for pollinators, food webs, and nutrient decomposition processes. As such, pesticide use should be kept to a minimum whenever possible. Additionally, hail nets should also be avoided when possible, as they can also have negative impacts on pollinators and other insects. In general, cultivation practices should focus on connectivity, especially between perennial habitats and species, as this can have a natural effect of enhancing pest enemy populations, thus supporting a more natural balance of plant and insect biodiversity.

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SCALE UP
community-driven
bioeconomy development

Sustainability Screening - Strumica, MK

March 2024

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EXECUTIVE SUMMARY

The sustainability screening conducted in the Strumica region of North Macedonia systematically evaluates the ecological implications associated with various bioeconomic activities. Primarily centered around agriculture, which spans nearly 25,000 hectares, including pastures, meadows, and crops like tomatoes and peppers, the screening encompasses diverse elements contributing to the bioeconomy. Noteworthy it includes fruit production, along with forest residues, afforestation efforts, and municipal biowaste, particularly organic waste, indicating the potential for compost production.

The second chapter introduces the methodology for the SCALE-UP sustainability screening in the Strumica Region, emphasizing water resources, soil analysis, and biodiversity. It discusses the use of indicators to assess ecological and chemical status in surface and groundwater bodies, addressing potential issues like nutrient pollution. The analysis incorporates the RUSLE2015 model for soil erosion indicators and employs the IUCN Red List to evaluate the conservation status of individual species. The chapter recognizes data uncertainties, underlining the need for cautious methodology use and encourages future iterations with enhanced data for more precise assessments.

The comprehensive evaluation meticulously dissects the potential burdens imposed by these bioeconomic activities on crucial environmental facets such as water resources, soil, and biodiversity. In the context of water, the assessment scrutinizes potential risks, including eutrophication, acidification, and pollution stemming from agricultural residues and composting practices. The soil analysis delves into aspects like soil quality, erosion, and organic matter enrichment, primarily associated with the removal of agricultural residues and the composting process. The examination of biodiversity, while acknowledged as understudied in North Macedonia, draws inferences from prevalent practices like leaving residues on farmland and incorporating compost.

The screening results are carefully summarized, offering insights into the potential advantages and disadvantages concerning water bodies, soil resources, and biodiversity. Currently the water condition is considered low for the surface waters and there is no data on the situation with the groundwater bodies. On the soil screening the baseline rating is good, with low erosion on the arable land. Regarding the biodiversity, Strumica region has only 2 endangered species, and no critically endangered. Subsequently, a set of recommendations is presented to address the identified concerns and foster more sustainable practices. For water resources, the Regional Basin Management Plan unfolds as a pivotal guide, laying out regulatory actions, waste management strategies, and erosion control plans. The soil quality predicaments can be alleviated through strategic urban planning, advocating sustainable agricultural practices, afforestation initiatives, and the application of biochar. Biodiversity preservation recommendations span from comprehensive monitoring to revitalization efforts and public awareness campaigns. Crucially, feedback from regional stakeholders significantly contributes to refining the proposed recommendations. This feedback provides insights based on the experience and knowledge of four regional stakeholders actively involved in advancing and developing the Strumica region.

The sustainable agriculture recommendations advocate for a multifaceted approach. This encompasses erosion control, discouragement of burning crop residues, promotion of plowing practices, and the endorsement of crop rotation and diversification for enhanced soil health. Citizen involvement is underscored, urging them to engage in composting practices and adopt beneficial practices gleaned from both the region and European countries. Preservation of biodiversity necessitates proactive measures and initiatives. A fundamental step involves declaring the ecologically significant Monospitovo Swamp as a protected area, recognizing its crucial role in maintaining biodiversity. Similar initiatives are recommended for safeguarding Belasica, acknowledging the importance of preserving this natural habitat.

In conclusion, the sustainability screening serves as a pragmatic tool for comprehending and addressing the ecological impacts associated with bioeconomic activities in the Strumica region. The recommendations, spanning water, soil, and biodiversity aspects, reflect a commitment to fostering sustainability and resilience in the face of the evolving dynamics of the environment.

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Abbreviations

EQS	**Environmental Quality Standards**
EEA	**European Environment Agency**
EU	**European Union**
EUNIS	**European Nature Information System**
RBD	**River Basin District**
RBMP	**River Basin Management Plan**
LSGU	**Local self-government units**
SOC	**Soil Organic Carbon**
SOM	**Soil Organic Matter**
WME	**Water Management Enterprises**
WEI+	**Water Exploitation Index plus**
WFD	**Water Framework Directive**
WISE	**Water Information System for Europe**
MoEPP	**Ministry of Environment & Physical Planning of the Republic of North Macedonia**
JRC	**Joint Research Center**
LUC	**Land Use Cover**
IUCN	**International Union for Conservation of Nature**
CR	**Critically Endangered**
EN	**Endangered**

VU	**Vulnerable**
NT	**Near Threatened**
LC	**Least Concern**
DD	**Data Deficient**
NE	**Not Evaluated**
NGO	**Non-Governmental Organization**

1 Resource management profiles

1.1 Water resources management profile

The water quality in Strumica region is a critical aspect that encompasses water supply, its use for various purposes (population, industry, agriculture), and the management of waste- and stormwater. Management efforts are guided by the National Water Strategy, the Water Management Foundation, and ongoing plans for catchment area management, all governed by a comprehensive legal framework that encompasses the Law on Waters, Environmental Law, Health Care Law, Law on drinking water supply and urban wastewater disposal, and a multitude of specific regulations like the Rulebook on water safety, Water Classification Ordinance, and others. The Law on Waters which is operational since 2010, is in compliance to the EU Directives in the Water Quality Sector (Water Framework Directive (2000/60/EC) as the framework legislation; Urban Wastewater Treatment Directive (91/271/EEC), Nitrates Directive (91/676/EEC), Dangerous Substances to Water Discharges Directive (76/464/EEC) as emission control oriented legislation; water quality oriented directives; pollution prevention and control directives and monitoring and reporting directives (Hidroinzinering, 2010).

Management of water, coastal land and waterways residences is under the jurisdiction of the state administration bodies, with with the exception of those matters which, according to this law, are under the jurisdiction of the bodies of the municipalities (Munistry of environmetal and physical planning, 2015). The buildings and installations, which make up the water supply system in the territory of Strumica region, are managed by the public utility company "Komunalec"-Strumica.

The institutional arrangements for transposition and implementation of flood risk assesment are identical with the Water Framework Directive (WFD). Local self-government units (LSGU) and water management enterprises (WME) are responsible for assessment and management of flood risks at their respective areas. Areas not falling within the jurisdiction of LSGUs or WME areas are responsibility of the Ministry of Environment & Physical Planning of the Republic of Macedonia (MoEPP). MoEPP is competent authority to coordinate the activities for planning and management of floods. Flood risk assessment shall be prepared by WME for the territory they are responsible for or by municipalities for the territories that do not fall under competencies of the WME.

The Strumica region, with around 49,955 inhabitants, has nearly 99% coverage by the water supply system, serving about 8,600 households. The Turia reservoir has been the primary water source since 1978, delivering 5.5 – 6 million m^3 of raw water annually. The Turia reservoir also serves as a reserve, storing 10 million m^3 yearly. The Turia reservoir supplies 3-18 million m^3 annually for irrigation of 10.000 ha arable land, generating hydroelectric power (Municipality of Strumica, 2023). Vodocha reservoir built in 1966 on the river Vodochica is located 7 km west of Strumica. Its purpose is for water supply of Strumica city and irrigation of roughly 3,100 ha of farmland in the Strumica valley (PointPro Consulting, 2015). The Markova Reka reservoir provides water supply to around 5,000 inhabitants and irrigation for 300 ha.

Region's water demand is covered with water resources abstracted from built dams and reservoirs, drainage channels and river discharge

As part of the Water Supply Resources in Strumica region are few bigger rivers:

- **Strumica River** serves as the main recipient for the acceptance of surface waters for the Strumica field in the district of Strumica
- **Turia River** regulation involved digging a new river bed to divert it to Azmak, facilitating unloading of the Strumica River. Also serves as a recipient for HMS Turia's wastewater, covering a gross area of 11015 ha.
- **Trkajna River** serves as regulatory works from the Monospitovo channel mouth at km 0+000 to km 4+980, covering about 5.0 km, a base partition to calm torrential waters.
- **Vodocha River**

The basin of the Strumica River encompasses the southeasternmost region of Macedonia, extending in a northwest-southeast direction as shown on **Error! Reference source not found.**.

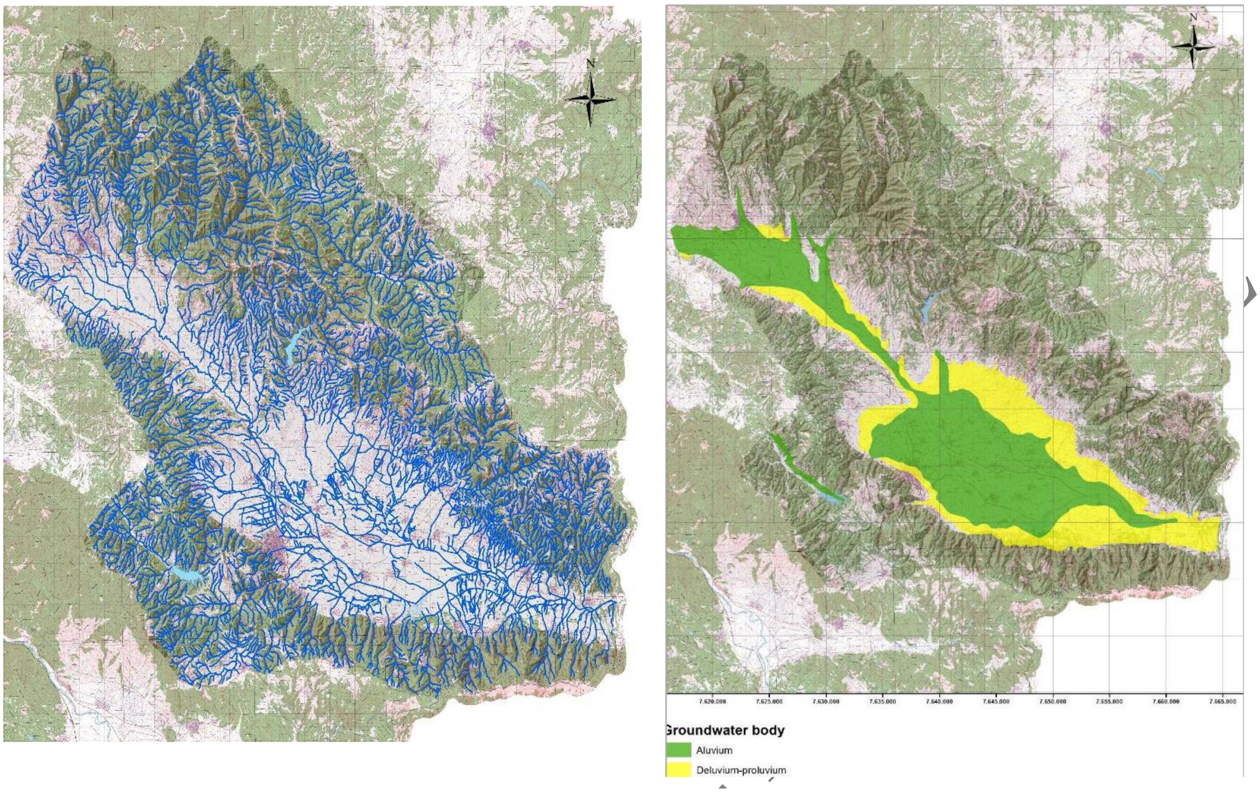

Figure 34 - Strumica River Basin Hydrography Network and Groundwater bodies. Source: PointPro Consulting, 2015

Effective drainage and regulation of riverbeds, including the Strumica River, Turia River, Trkajna River, and Vodocha River, have played a crucial role in flood prevention and overall water management. The region faces the ongoing risk of floods, attributed to factors such as heavy rainfall, snow melting, overflowing of the waters from the riverbeds, specifaily in March and April, non-absorption of stormwater in the sewage system, and potential damage to protective structures. The upper part of the watershed, lacking significant flood protection, poses challenges during intense weather conditions, leading to rapid water concentration and flood waves downstream. While protective structures exist, continuous improvement is essential to enhance the capacity of riverbeds and canal networks for effective flood prevention.

Water management practices in Strumica involve a holistic approach, incorporating a robust legal and regulatory framework, reservoirs for water supply, hydropower generation, irrigation systems, and measures for flood protection. The medium risk of flooding (yellow), as assessed by the Center for Crisis Management, underscores the importance of ongoing revitalization management measures within established legal procedures. The overall conclusion emphasizes the need for sustained efforts to manage water resources effectively, address vulnerabilities, and enhance the overall resilience of the Strumica region to potential water-related crises. As the region navigates the complexities of water management, a continued commitment to comprehensive planning and strategic interventions remains crucial for the sustainable and resilient future of Strumica's water resources.

1.2 Soil resources management profile

Among the most important laws related to agriculture and land use are Law on Agricultural Land, Law on Organic Production, Law on Agriculture and Rural Development, and others. (Ministry of

Agriculture, Forestry and Water Management, n.d.) Key documents aimed at enhancing soil quality and advancing agricultural land in the Republic of Macedonia include the "National Development Program of Agriculture and Rural Development" spanning the period 2021-2027 and the National Plan for Organic Production 2013 – 2020". The strategic documents provide several key directions for the organic agriculture sector. These include expanding areas for collecting wild plants and fruits, producing diverse organic products in ample quantities, integrating advanced technologies into production processes, enhancing market transparency, raising public awareness and visibility of Macedonian organic products, promoting eco-tourism through organic food experiences, incorporating organic agriculture into mainstream education, and initiating research to explore the potential of natural resources for organic production in the Strumica municipality. The competent authority for the implementation of these laws is the Ministry of Agriculture, Forestry, and Water Economy. In specific cases requiring control, oversight is conducted through the Agency for Financial Support in Agriculture and Rural Development.

The regulation of forests and forest land in the Strumica region is governed by the Law on Forest. The implementation of these laws is carried out by legal entities responsible for managing these forests, as well as by state institutions overseeing their enforcement. In the territory of the municipality of Strumica, forest management falls under the responsibility of legal entities such as the Public Enterprise "National Forests" - Branch Forestry Belasica, Strumica Watershed, and the City Public Utility Company "Komunalec.".

The soil in the municipality of Strumica is rich and well-suited for growing crops. The catchment area in Strumica region is relatively low, with an average altitude of 350 m and consist of the following soil types:

- Deluvial formations, made up of sand and clay particles with low porosity and an average depth of 0.5 to 2 m.
- Proluvium formations, consisting of soft particles from metamorphic and magmatic rock masses, along with gravel and clay sand, displaying relatively high porosity.
- Alluvial formations or river sediment, mainly composed of sand and gravel with some clay.
- Upper and lower river terraces, characterized by dust, clay, sand, and gravel, with medium to high density, high porosity, and depths ranging from 10 to 25 meters.
- Pliocene deposits, which go as deep as 1,200 meters and include gravel, clay, marl, and limestone particles.

The total arable land in the Strumica river catchment area is 33,430 ha. Of this, 24,332 ha (72.8%) are used for growing agricultural crops, while the remaining 9,000 ha are dedicated to perennial crops and greenhouses. A notable feature is the widespread distribution of arable lands among individual farmers.

The majority of the municipality's territory is covered with high-quality soils, primarily alluvial, alluvial-carbonate, and deluvial-carbonate soils. The productive land in the Strumica region (including several villages) totals 9,035 ha, out of which, 7,298 ha (80.7%) are used for agriculture, while 1,737 ha (19.3%) are designated as forest land.

Several issues pertaining to soil conditions in the Strumica region include soil contamination from the use of agricultural chemicals, a decrease in the extent of fertile agricultural land, insufficient urban planning leading to the occupation of land for residential and industrial zones, unauthorized constructions, the transformation of agricultural land for economic purposes, and pollution arising from inadequate collection and treatment of municipal wastewater (NIRAS, 2022).

Due to various factors such as environmental conditions, geographical position, climatic features, relief characteristics, historical development, anthropogenic influences, and others, the municipality of Strumica is distinguished by a substantial forest cover, encompassing approximately 38.8% of the municipality's territory (18,860 ha). Quality forests are prevalent at altitudes ranging from 1,000 to 1,500 meters above sea level. Areas below 500 meters primarily consist of degraded forests and thickets.

The total area of these tall forest communities is 2,320 hectares, with the following distribution: Beech: 1,373 ha; Gorun: 243 ha; Black pine: 570 ha; Conifers: 122 ha and Plantations and crops: 12 ha. The varieties and extents of low-stemmed forest communities in the Municipality with the following distribution: Flatterer - 6,491 ha; Gorun - 4,539 ha; Blagun - 2,198 ha; Leaf trees - 1,199 ha; Gaber - 1,161 ha; Shikari - 568 ha; Beech - 353 ha and Conifers - 30 ha, adding up to total of 16,539 ha.

According to the National Spatial Plan, the forests in Strumica are expected to cover an area of 50,900 hectares, with a wood mass of 112 m^3 per hectare. In *Figure 35* the Land Cover from 2022 on national scale is presented, including water areas, forest and crops, built area and rangeland.

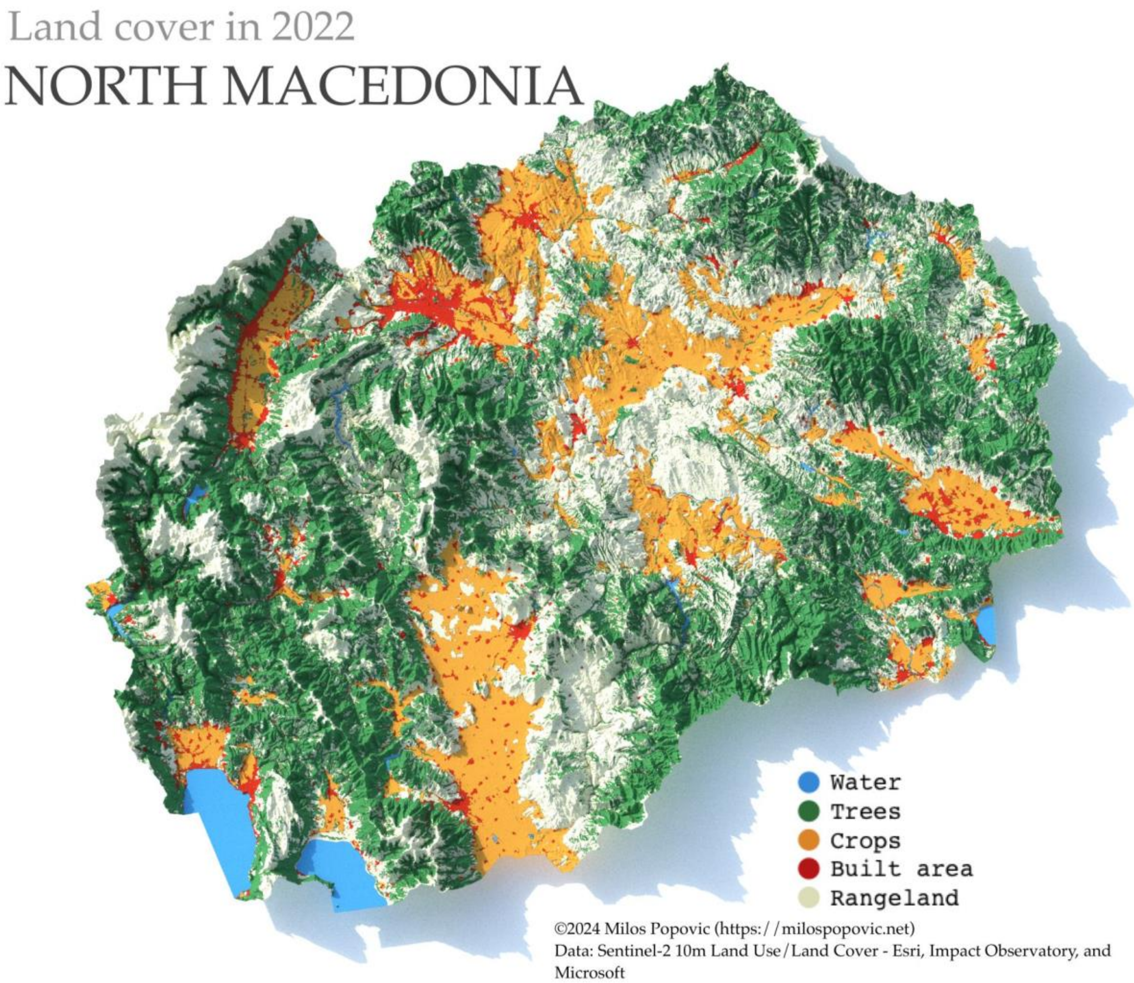

Figure 35 - Land cover of North Macedonia in 2022. Source: Milos Popovic, 2024.

1.3 Biodiversity management profile

North Macedonia is prioritizing forest use and management in line with Europe Union (EU) integration, emphasizing nature protection and biodiversity in its forestry policies. While aligning with EU directives is progress, there's a need for further measures, especially in bio-security under the Convention on Biological Diversity. The challenge lies in synergizing the National Strategy for Biological Diversity, the second national action plan for the environment, and the National Strategy for Sustainable Development. The country is aligning with EU regulations and the Pan-European strategy, having ratified the Birds and Habitats Directive, with NATURA 2000 initiation underway (GIZ and Working group for regional rural development in SEE, 2018).

In 2024, the promotion of national Habitat Map marked a significant milestone (Figure 36). This map is a crucial element in the ongoing effort to identify and assess the ecological status of various regions in the country. It serves as a valuable tool to support planning processes and enhance the environmental evaluation of potential impacts from development projects. The identification and mapping of habitats were conducted using the European Nature Information System (EUNIS) classification, identifying 126 habitats up to level 3. Covering a total area of 25,463 km², forest and scrub habitats predominate (59.61% of the mapped area), followed by grassland habitats (13.80%), water and wet habitats (3.22%), and agricultural and artificial habitats (23.35%).[124]

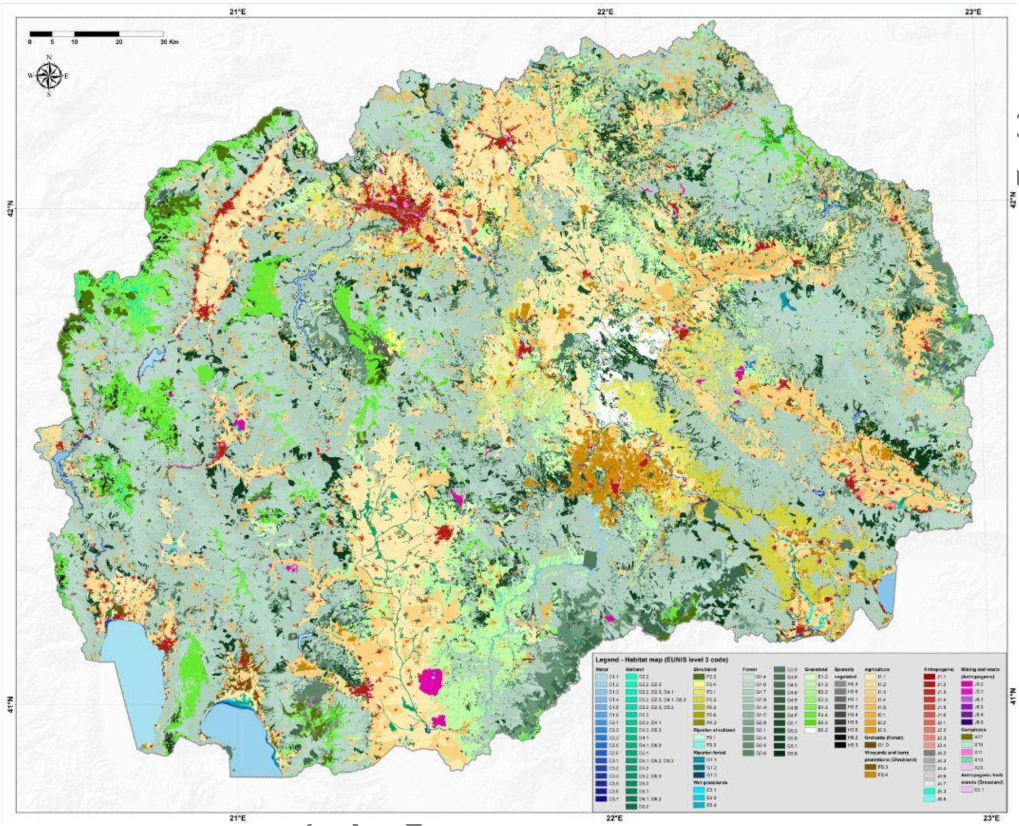

Figure 36 - Habitat map of North Macedonia. Source: MANEKO Solutions, 2024.

The Strumica region is rich with flora, fungi, and fauna, with numerous endemic species attributed to its unique geographical position and climate. The Belasica and Ograzden mountains host thriving forest ecosystems, characterized by deciduous forests dominating the landscape, while evergreen forests are scarce and mainly found in higher elevations. The region's fauna is diverse and includes indigenous and endemic species such as bears, wolves, deer, chamois, wild boars, martens, wild cats, as well as various bird species like eagles, falcons, hawks, and grouse. Additionally, the region is home to a variety of fungi, including boletus, chanterelle, and morel, as well as lizards, snakes, and many insect species.

The region's aquatic flora and fauna are equally diverse, featuring various reeds, marsh vegetation, and algae that support a diverse range of fish species. The area also attracts many migratory bird species, including herons, ducks, and swans.

124 https://www.moepp.gov.mk/en/nastani/%D0%BF%D1%80%D0%B5%D0%B7%D0%B5%D0%BD%D1%82%D0%B8%D1%80%D0%B0%D0%BD%D0%B0-%D0%BF%D1%80%D0%B2%D0%B0%D1%82%D0%B0-%D0%B2%D0%B5%D1%80%D0%B7%D0%B8%D1%98%D0%B0-%D0%BD%D0%B0-%D0%BD%D0%B0%D1%86%D0%B8%D0%BE/

However, the region faces challenges, particularly in its riverbeds, which often receive wastewater, negatively impacting the existing ecosystems and leading to a reduction in flora, fungi, and fauna populations.

The Law on Nature Protection governs the conservation of nature, including the protection of biological and regional diversity, natural heritage within and outside protected areas, and rare natural features. Conservation efforts are guided by the principle of a high level of protection, requiring all individuals and entities to prioritize the conservation of biological and regional diversity, natural heritage, and the public role of nature in their activities.

According to the sectoral "Study for the Protection of Natural Heritage" (1999) commissioned for the Spatial Plan of the Republic of North Macedonia, the following localities and species in the municipality of Strumica are either protected or proposed for protection:

1. **Monospitov swamp**

The 250-hectare swamp lies at the base of Belasica in Strumicko Pole at an altitude of 240 meters. Thsi monument of nature under III category of protection is home to Glyceria fluitans, Sparganium neglectum, Scirpus maritimus, and Typha angustifolia. Along its fluctuating waterline, forest vegetation thrives, featuring Alnus glutinosa, Periploca graeca, Acer tataricum, Osmunda regalis, Pteridium aquilinum, and Nephrodium thelipteris. This area hosts the Periploco-Alnetum glutinosae association (**Error! Reference source not found.**). It is worth mentioning that Monospitovo swamp is part of the Emerald network in Europe, which preceded the establishment of the Natura 2000 .

Figure 37 – Monospitovo swamp in Strumica region. Source: Doma, 2023.

The protection of Monospitovo swamp is a priority, mandated not only by national laws but also by international conventions and agreements ratified by the Republic of North Macedonia. Additionally, Monospitovo swamp is part of several international initiatives, such as European Green Belt, cross-border protected areas, etc.

2. **Cham Chiflik**

Cham Chiflik is a hill situated between the gorges of the Vodochnica and Trkajna rivers, above Strumica, covering an area of 428 hectares.This site is under IV category of protectio The Coccifero-Carpinetum orientalis pinetosum pallasiana association is present in this area.

The slopes are steep and covered with pine forest (Pinus nigra - Pinus pallasiana) and Scotch oak (Quercus coccifera). Moreover, other Mediterranean species like Clematis flammula, Osyris alba, Cistus villosus, and Carex dystachya are also found here.

3. River Vodenishnica

This special natue reserve reserve was surveyed in 1993 and found to hold significant value, thus being under a propoasal for protection of IV category. It is home to protected species in the country, such as yew (Taxus baccata) and wild fir (Ilex aquifolium). The reserve spans 12 hectares and is situated 4 kilometers upstream from the Bansko spa, along the Vodenishnica river.

4. Shenkoi Orei

This scientific-research nature reserve is a small stream located east of R'nedova Cheshma, covering an area of 0.3 hectares. Curretly is under proposal for IV category protection. The Platano-Castanerum sativae association is present in this area. In its lower reaches, the stream's water spills over fluvial sediments, creating a wet terrain sheltered from regional climatic influences. This unique habitat supports a diverse floral composition, including Platanus orientalis, Castanea sativa, Juglans regia, Fagus moesiaca, Osmunda regalis, Ruscus aculeatus, and Salix cinerea.

2 Methodology for appraisal of the available capacity of the regional ecosystem

*The text in this chapter is strongly based on the description of the methodology for the BE-Rural Sustainability Screening presented in Anzaldúa et al. (2022), with only minor adaptations that resulted from the implementation of the approach in SCALE-*UP.

2.1 Water data and indicators

To run the sustainability screening of surface and groundwater bodies potentially relevant to the Strumica Region in North Macedonia, the authors of this report have reviewed the data reported in the River Basin Management Plan (RBMP) for Strumica River Basin District (RBD) for the period 2016-2027. The benefits of tapping on this reporting process is that it includes well-defined indicators like the status of water bodies in each RBD as well as data on significant pressures and impacts on them. Further, these data are official, largely available, accessible, and updated periodically. On national level, there is no Bioeconomy Strategy in place, therefore having regional bioeconomy strategies is a step that is desirable in the future, yet very much needed. Currently, the RBMP is compiled by third support parties, however that does not minimize the importance of the data and information provided for Strumica RBD.

2.1.1 Description of the data / definition of the indicators employed

Data reviewed for this part of the screening included the reported ecological and chemical status of rivers and lakes as well as the quantitative and chemical status of groundwater bodies in the Strumica RBD that is slightly territorially wider than the Strumica Region. The data give indications on water quality of the river basin according to the five status classes defined in the WFD (Table 19). These are: high (generally understood as undisturbed), good (with slight disturbance), moderate (with moderate disturbance), poor (with major alterations), and bad (with severe alterations) (EC, 2003). Further, data on significant pressures and significant impacts on the water bodies in the RBD are used to indicate the burden of specific pressure and impact types on water ecosystems in the regions based on the number and percentage of water bodies subject to them. Significant pressures are defined as the pressures that underpin an impact which in turn may be causing the water body to fail to reach at least the good status class (EEA, 2018).

As non-EU country, North Macedonia is not part of the WISE WFD Data. All data described above were extracted from the River Basin Management Plan for Strumica River Basin District for the period 2016-2027 which comply with the WISE WFD categorization, except for data on significant impacts which are not being analysed in the RBMP and therefore not reported in the sustainability screening for Strumica region.

Table 19 - Indicators used for the water component of the sustainability screening

Category	Indicator Family	Indicator	Spatial level	Unit of measure	Comments/Reference
Water	Water quality	Status of water bodies according to the EU Water Framework Directive	River Basin District	Number of water bodies in high, good, moderate, poor, bad or unknown status	River Basin Management Plan for Strumica River Basin District for the period 2016-2027[125]
	Burden on water bodies	Significant pressures on water bodies	River Basin District	No. and % of water bodies under significant pressures per pressure type	
	Burden on water bodies	Significant impacts on water bodies	River Basin District	No. and % of water bodies under significant impacts per impact type	No data available

Source: Adapted from Anzaldúa et al., 2022.

To determine which status class a certain water body falls into, WFD assessments evaluate the *ecological* and *chemical* status of surface waters (i.e. rivers and lakes) and the *quantitative* and *chemical* status of groundwater bodies. Ecological status refers to *"an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters".* It covers assessments of biological (e.g. presence and diversity of flora and fauna), physico-chemical (e.g. temperature and oxygen content) and hydromorphological criteria (e.g. river continuity) (EC, 2003; BMUB/UBA, 2016). The chemical status of a surface water body is determined by comparing its level of concentration of pollutants against pre-determined Environmental Quality Standards (EQS) established in the WFD (concretely in Annex IX and Article 16(7)) and in other relevant Community legislation. These standards are set for specific water pollutants and their acceptable concentration levels.

In the case of groundwater bodies, chemical status is determined on the basis of a set of conditions laid out in Annex V of the WFD which cover pollutant concentrations and saline discharges. Additionally, the water body's quantitative status is included in the WFD assessments, defined as "*an expression of the degree to which a body of groundwater is affected by direct and indirect abstractions"*. This gives indication on groundwater volume, a relevant parameter to evaluate hydrological regime (BMUB/UBA, 2016).

In the case of surface water bodies, the WFD objective is not only that they reach good status, but that quality does not deteriorate in the future (EC, 2003), which is relevant in the context of the development of bioeconomy value chains.

[125] https://www.moepp.gov.mk/wp-content/uploads/2015/01/RBMP-Strumica-2016-2027_MK.pdf

2.1.2 Methodology applied

The authors of this report have followed the approach described in Anzaldúa et al. (2022) to valorise the data from the River Basin Management Plan For Strumica River Basin District for the period 2016-2027 which to larger extend comply with WFD reporting described in the previous sub-section that allows for an appraisal that is non-resource intensive (based on reliable, publicly available and accessible data) yet capable of providing a rough overview of the state of the waters in Strumica region. This is in line with the rationale of this sustainability screening, which aims to enable stakeholders with limited financial resources and/or expertise in the field to consider ecological limits in a structured manner when exploring bioeconomy activities. As non-EU country that has not yet adopted the WFD, the reported data from the RBMP is still following the WFD process that has been employed exclusively within the following methodology.

The overall apportionment of rivers, lakes and groundwater bodies in the Strumica Region according to their RBMP (complement to the WFD) status classification can be used to set the baseline for the sustainability screening. It provides initial insight on the situation in the demarcation as regards "ensuring access to good quality water in sufficient quantity", "ensuring the good status of all water bodies", "promoting the sustainable use of water based on the long-term protection of available water resources" and "ensuring a balance between abstraction and recharge of groundwater, with the aim of achieving good status of groundwater bodies", all explicit aims of the WFD that are aligned with the consideration of ecological limits. Further, the data on significant impacts and pressures affecting the water bodies in the river basins are useful as they can point towards specific problems (e.g. nutrient pollution) and the types of activities that may be causing them (e.g. discharge of untreated wastewater, agriculture).

As a first step, the approach used for this element of the screening entails calculating what proportion of the total number of surface water bodies located in the RBD is reported as failing to achieve Good Ecological Status/Good Chemical Status or for which conditions are unknown. Similarly for groundwater bodies, the proportion is calculated of those who are reported as failing to achieve Good Chemical Status/Good Quantitative Status or for which conditions are unknown. In the case of Strumica, groundwater monitoring in the region is performed within 23 piezometric wells established in 1953. Unfortunately, since 2000 only two of the monitoring wells are operating. In addition, organized groundwater data collection and management, as well as user register, are not in place, therefore the status on the groundwater is marked as unknown. The resulting ratios are then compared to the respective EU proportions, which are used as (arbitrary) thresholds. According to the latest assessment published by the EEA in 2018, "around 40% of surface waters (rivers, lakes and transitional and coastal waters) are in good ecological status or potential, and only 38% are in good chemical status" (EEA, 2018). Accordingly, "good chemical status has been achieved for 74% of the groundwater area, while 89% of the area achieved good quantitative status" (EEA, 2018). Using these markers, the following step is to rank the current conditions of the Strumica Region using an ordinal risk rating (high, moderate, low) based on the distance of the result of each indicator to the EU level results. On this basis, the thresholds and ordinal ranking convention suggested by the authors of this report are as shown in Table 20 and Table 21.

Table 20 - Proposed thresholds for the water section of the sustainability screening

Water body type	Status category	2018 EU-level assessment results (proportion of water bodies achieving good status)	Proposed thresholds for the sustainability screening		
			High concern	Moderate concern	Low concern
Surface water bodies	Ecological status	~40%	0-40%	41-89%	90-100%
	Chemical Status	38%	0-38%	39-89%	90-100%

Groundwater bodies	Chemical status	74%	0-74%	75-89%	90-100%
	Quantitative status	89%	0-89%	-	90-100%

Source: Anzaldúa et al., 2022.

Table 21 - Ordinal ranking convention for the water section of the sustainability screening

Ordinal ranking for water resources		Chemical status		
		High concern	Moderate concern	Low concern
Ecological or Quantitative status	High concern			
	Moderate concern			
	Low concern			

Source: Anzaldúa et al., 2022.

This initial appraisal based on the thresholds shown above is then supplemented with a review of the reported data only for the types of significant pressures, omitting the quantity impacts (due to lack of data) on surface and groundwater bodies classified as unknown. In this case percentage values are already given, and so this step in the screening simply entails the listing of the reported pressures and impacts and the identification of those which are more frequently reported. From here, the screening team can seek potential correlations between the most reported pressure types and the most reported impact types (e.g. diffuse sources causing nutrient pollution).

The final step in the approach is to draft a note describing the share of water bodies failing to reach good status and formulating preliminary statements on the types of bioeconomy activities that could be considered, those that should be considered with reserve, and those that should be avoided. These initial statements are used to frame the discussion of the group of stakeholders involved in the development of the bioeconomy value chains in focus in the SCALE-UP project.

2.1.3 Data uncertainties

The data resulting from the assessments reported in the RBMP are subject to the limitations of the scientific and methodological approaches used by their authors. It thus must be considered that the official assessments are based on estimates, include assumptions, and will therefore carry a margin of error.

An important limitation bound to the implementation of the sustainability screening is that the RBMP data used refer to the Strumica RBD of the , whose territorial boundaries do not coincide entirely with those of the Strumica Region. A future iteration of this exercise by the local stakeholders could increase the resolution of the screening of water resources by tapping on additional information sources, like significant impacts or measuring data on groundwater bodies in the Strumica region, if they become available.

Lastly, another issue to consider is the data currently available on RBMP is from 2016, however it happens that there is no updated data on this regard as the plan is spanning over the period 2016 up to 2027. In addition, when the WFD will be fully transposed in North Macedonia, the data gathering and reporting on waters will be simplified and more punctual and that is the goal that the country is aiming to.

2.1.4 Methodological uncertainties

The proposed methodology for the water section used in this application of the sustainability screening is straight-forward and accessible, yet it must be used with care and, where possible, should incorporate higher resolution data evaluated by thematic experts. As previously mentioned, the thresholds set in this case have been the proportions, at EU-level, of water bodies that fail to achieve good status or for which conditions have been reported as unknown. This has been a pragmatic, yet easy to challenge way of defining a benchmark for the Strumica Region. The conditions and context of the Strumica RBD are not necessarily comparable to those of other European regions, and thus the ordinal classification of the water resources in Strumica used for the screening could be contested. Further, the territorial outline of the Strumica RBD does not match the NUTS3 level of Strumica (it scopes a broader area). This can generate additional noise in the results. For this, the authors envision the contributions and guidance from the team of local and foreign experts as briefly described in Section 3.2 of Anzaldúa et al., 2022. Optimally, these thematic experts should know the regional context well and thus be in a good position to guide the setting of such thresholds. Beyond this, the simplicity of the necessary calculations and the fact that the data on significant pressures are used without further computation and compared in relative terms within the RBD limit the possibility of additional accuracy or uncertainty issues emerging.

2.2 Soil data and indicators

2.2.1 Description of the data / definition of the indicators employed

The selected indicators for vulnerability to soil depletion are closely interrelated and refer specifically to soil erosion **by water**. These are:

- Estimated mean soil erosion rate (in $t\ ha^{-1}\ a^{-1}$)
- Share (%) of area under severe erosion (>10 $t\ ha^{-1}\ a^{-1}$)

In broad terms, soil erosion describes the process through which land surface (soil or geological material) is worn away (e.g. through physical forces like water or wind) and transported from one point of the earth surface to be deposited somewhere else (Eurostat, 2020). The above-mentioned indicators describe particularly the amount of soil (in t) per unit of land surface (in ha) that is relocated by water per year.

Variations of these indicators can be calculated by considering different combinations of land cover classification groups, such as *all land*[126] and *agricultural land*[127]. As shown in Figure 38, at EU level in 2016, about three quarters of soil loss occurred in agricultural areas and natural grasslands, while the remaining quarter occurred in forests and semi natural areas (Eurostat, 2020). Therefore, since it is the type of land cover that is most vulnerable to erosion, the present sustainability screening will

[126] This refers to all potentially erosive-prone land (in simplified terms), specifically to CORINE Land Cover classification groups: Agricultural areas (2), forest and semi natural areas (3) excluding beaches, dunes, sand plains (3.3.1), bare rock (3.3.2), glaciers and perpetual snow (3.3.5). These, as well as other classes, are excluded because they are not subject to soil erosion.

[127] This refers only to agricultural land (agricultural cropland as well as grassland in simplified terms), specifically to CORINE Land Cover classification groups: Agricultural Areas (2) and Natural Grasslands (321)

consider in first line the above-mentioned indicators specifically for agricultural areas and natural grasslands. This scope of the indicators is also in line with the two sub-indicators for soil erosion considered by the Joint Research Centre European Soil Data Centre (JRC ESDAC). Moreover, both the *mean erosion rate for agricultural land* and the *share of agricultural area under severe erosion* are part of the EU Common Agriculture Policy (CAP) context indicator 42 (CCI42) for the period 2014-2020.

Figure 38 - Share of land cover and soil loss across the EU-27 in 2016. Source: JRC, Eurostat.[128]

Gathering data for Strumica region regarding the soil component is challenging task, mostly due to the fact that as non-EU country, the EUROSTAT and Joint Research Center (JRC) data are not applicable. In this case several sources were used to populate the data required for the baseline scenario in the SCALE-UP sustainability screening and to comply with the adopted methodology. For the data on the forest land the Local Environmental Action Plan for Municipality of Strumica in the period 2024-2029[129] was used. Additionally, some recalculations were conducted in order the data to match the Land Use Cover (LUC) class according to CORINE. Moreover, State Statistical Office (SSO) data from 2022[130] was used to depict the agricultural land status in Strumica region. The erosion indicators for arable land were integrated based on the expert's data which was extracted from a map for soil loss developed under the RUSLE method. Because this methodology is not suitable for forest land, there is no data for it. For forest land, the expert's calculations are expressed in m^3 per ha, however, they provided a mean erosion indicator on the forest land converted in tonnes per hectares.

Mean soil erosion rate, which undergirds both selected indicators, is considered useful because it provides a solid baseline to estimate the actual erosion rate in the regions (Panagos et al., 2015). This indicator is based on the latest Revised Universal Soil Loss Equation of 2015 (RUSLE2015), specifically adapted for the European context (see Panagos et al., 2015), which is a model that takes into account various aspects, including two dynamic factors, namely the cover-management[131] and policy support practices[132] (both related to human activities) (Panagos et al., 2020).

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[128] Excluding not erosion-prone land (e.g. beaches, dunes, etc.). Forest and natural areas exclude also natural grasslands, which are evaluated together with agricultural areas.
[129] https://strumica.gov.mk/leap/
[130] https://makstat.stat.gov.mk/PXWeb/pxweb/en/MakStat/MakStat__Zemjodelstvo__RastitelnoProizvodstvo/425_RastPr_Op_PovrsNtes13_ml.px/
[131] Known as the c-factor, it has a non-arable component, which includes changes in land cover and remote sensing data on vegetation density, as well as an arable component, which includes Eurostat data on crops, cover crops, tillage and plant residues.
[132] Known as the p-factor, it reflects the effects of supporting policies in estimating the mean erosion rate by including data reported by member states on Good Agricultural Environmental Conditions (GAEC)

The estimated mean soil erosion rate value obtained through the RUSLE2015 model refers to water erosion only, but it is considered to be the most relevant at least in terms of policy action at EU level, due to the relative predominance of water erosion over other types of erosion. Furthermore, it offers the important advantage of providing a viable estimation for erosion vulnerability at a relatively small geographic scale, i.e. the local or regional level. This can serve as an important tool for monitoring the effect of local and regional policy support strategies of good environmental practices (Panagos et al., 2015, 2020, and Eurostat, 2020).

2.2.2 Methodology applied

The near-universal indicators available to track soil vulnerability are related to either erosion or the decline in soil organic carbon (SOC)/soil organic matter (SOM) (Karlen & Rice, 2015). However, there are major data gaps regarding to SOC/SOM and data is currently only available at national level. According to Panagos et al. (2020), soil organic carbon does not change so quickly and therefore is not so sensitive to human influence on short term. Therefore, they recommend using just a sole indicator for monitoring impact of policies: "estimated mean soil erosion rate" (by water), which they calculate using the RUSLE2015 model. For our purposes, we have complemented the *mean soil erosion rate* indicator, with the *share of agricultural area under severe erosion* in order to gain a comprehensive picture of soil erosion in a region.

Soil erosion is considered generally as a sort of proxy indicator of soil degradation, which in turn is the most relevant component of land degradation at EU level (EC, 2018). However, not all types of bio-based activities have a direct effect on erosion, but rather primary production of biomass. Nonetheless, as these are currently the most widespread bioeconomy activities in rural areas, we will consider their impact on soil degradation, and therefore on soil erosion, to be the most relevant one for this assessment.

The indicators for vulnerability to soil degradation were selected, on one hand, due to the limited number of soil indicators available at the required regional scale. On the other hand, the RUSLE2015 model used for this data also represents the current state-of-the-art methodology for calculating soil erosion. These aspects are crucial, since the choice of indicators needs to be: a) acceptable to experts, b) routinely and widely measured, and c) have a currency with the broader population to achieve global acceptance and impact (Stockmann et al., 2015). In order to carry out the screening of soil vulnerability, a number of datasets need to be accessed. As mentioned above, these data can be accessed via Eurostat, however in this particular case of non-EU countries, other datasets or expert's judgment needs to be into consideration

In terms of processing the erosion data, it is important to consider that the overall erosion rate changes across geographic areas, meaning the vulnerability/risk is not necessarily evenly distributed. In cases where the mean soil erosion rate exceeds the 10 t ha^{-1} a^{-1}, erosion is considered severe and activities that can generate, or are associated with a high erosion impact should be strongly discouraged. Erosion rates between 5 and 10 t ha^{-1} a^{-1} are considered moderate, requiring some attention towards practices that have a high impact on erosion, but with less urgency. However, it is relevant to take a look not only at the mean erosion rate for the area itself, but also at its spatial distribution, which is roughly reflected on the indicator of share of (agricultural) area under severe erosion.

2.2.3 Data uncertainties

The data used is produced from an empirical computer model (RUSLE2015) and produces estimates. Hence, there are several uncertainties related to the figures if compared to data collected on the ground. However, the purpose of the model is to generate data for a large spatial scale taken into account human intervention, which is not possible to do only through empirical measurements. That being said, like every model, assumptions have to be made and there is an intrinsic level of uncertainty. Specifically related to the RUSLE methodology, Benavidez et al. (2018) critically

according to the CAP, specifically contour farming, as well data from LUCAS Earth observation on stone walls and grass margins.

reviewed the RUSLE methodology, upon which RUSLE2015 is based, and identified following main limitations:

- its regional applicability to regions that have different climate regimes and land cover conditions than the ones considered (in the original RUSLE for the USA, in RUSLE 2015 for Europe)
- uncertainties associated generally with soil erosion models, such as their inability to capture the complex interactions involved in soil loss, as well as the low availability of long-term reliable data and the lack of validation through observational data of soil erosion, among others.
- issues with input data and validation of results,
- its limited scope, which considers only soil loss through sheet (overland flow) and rill erosion, thus excluding other types of erosion which may be relevant in some areas, e.g. gully erosion and channel erosion, to name a few. Moreover, it also excludes wind erosion.

A further factor of uncertainty in the data is the fact that the RUSLE model is calculated using mean precipitation data over multiple years and a large territorial scale (in this case Europe). Thus, it fails to account the changes in rainfall intensity, which are highly relevant for determining water erosion accurately. This is the case not only considering the seasonality of rainfall, but also its distribution across the continent (Panagos et al., 2020). Another important uncertainty identified by Panagos et al. (2020) is the lack of georeferenced data for annual crops and soil conservation practices in the field at a continental level, which has had to be estimated from statistical data.

Nonetheless, when considered best available estimates, the mean soil erosion values generated through the application of RUSLE2015 model offer a very suitable basis for assessing vulnerability to soil loss in general terms, even if the generated absolute values are to be taken with caution (Benavidez et al., 2018).

2.2.4 Methodological uncertainties

Among the most relevant uncertainties regarding the application of the sustainability screening in terms of soil vulnerability are the selection of the threshold against which the severity of erosion is evaluated and the selection of the land cover types that will be considered.

Regarding the threshold of 10 t ha^{-1} a^{-1} for severe erosion, it is important to mention that the value from EUROSTAT database is being followed in the case of Strumica as well, as there is no other verified and official source to compare the data.[133] However, it is still an arbitrary value which can be adapted. For instance, some sources like Panagos et al. (2015, 2020), who were involved in the generation of the data for the JRC ESDAC, consider severe erosion to be above 11 t ha^{-1} a^{-1}. In this regard, it is reasonable to proceed with the lower value described in the Eurostat dataset because it is more conservative and, as such, more suitable for an initial (and indicative) sustainability screening like the one we are proposing.

The selection of land cover types presents another area for potential uncertainty. Choosing between “all lands” and “agricultural lands” can have considerable implications for interpreting the data. For example, it is possible that the mean soil erosion rate is 5 t ha^{-1} a^{-1} (moderate erosion) in one land cover type, but lower in the other. This would have an effect on the assessment, which would present any potential concerns about erosion and steps that should be taken. As such, it is important to have solid grounding for the choice of dataset. The ultimate decision whether to consider all lands (including forests) is arbitrary and lays with the group performing the sustainability screening. Particularly when that decision is based on considerations of the economic relevance of forestry related industries in the region rather than on the actual share of the area that is covered with forest (it should be high to justify their inclusion), the values of soil erosion (for all lands) shall be taken with some reservations. This is because these values tend to be lower than the value for agricultural land and can create the impression that vulnerability to erosion is lower than it actually is. However, due to the indicative (and non-exhaustive) nature of the present sustainability screening, this uncertainty is not especially relevant for cases such as the Strumica Region, where both values (for forest and agricultural land with natural grassland) are low (see section 4.1).

[133] See https://ec.europa.eu/eurostat/cache/metadata/en/aei_pr_soiler_esms.htm

2.3 Biodiversity data and indicators

2.3.1 Description of the data / definition of the indicators employed

Unlike water- and soil-related risks, there are no reliable indices or standardized metrics to operationalize and compare risks to biodiversity at the regional level and in an integrated manner. Biodiversity is intricate and multifaceted, spanning genetic, species, and ecosystem diversity across various regions. Attempting to consolidate this diversity into a singular index may oversimplify it, leading to the loss of crucial information (Ledger et.al 2023; Brown & Williams 2016). Instead, biodiversity risks in a given region could be uncovered by considering the status of all species known to inhabit the region under scrutiny on a one-by-one basis, without trying to synthesize their collective status in a single index. Accordingly, our methodology suggests screening for biodiversity risks of a region by taking stock of its species of flora, fauna and fungi present in the demarcation and considering their conservation status. The Red List of Threatened Species of *the International Union for Conservation of Nature* (IUCN) is a globally recognized system for classifying the conservation status of species[134]. It is structured along the following risk categories (IUCN 2001, 2003):

(1) Critically Endangered (CR): This is the highest risk category assigned by the IUCN Red List for wild species. Species in this category are facing an extremely high risk of extinction in the wild.

(2) Endangered (EN): Species in this category are facing a high risk of extinction in the wild.

(3) Vulnerable (VU): Species in this category are facing risks of extinction in the wild.

(4) Near Threatened (NT): Species in this category are close to qualifying for, or are likely to qualify for, a threatened category soon.

(5) Least Concern (LC): Species in this category have been evaluated but do not qualify for any other category. They are widespread and abundant in the wild.

(6) Data Deficient (DD): A category applied to species when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution or population status.

(7) Not Evaluated (NE): A category applied to species that have not yet been evaluated against the criteria.

Data description

Data on the risk category of each species found in the SCALE-UP regions is accessed through the online database of the IUCN Red List website. The IUCN Red List serves as a comprehensive repository of information, offering insights into the present extinction risk faced by assessed animal, fungus, and plant species. In 2000, IUCN consolidated assessments from the 1996 IUCN Red List of Threatened Animals and The World List of Threatened Trees, integrating them into the IUCN Red List website with its interactive database, currently encompassing assessments for over 150.300 species. Since 2014, assessors of species have been mandated to furnish supporting details for all submitted assessments. Among the recorded details are the species' (1) IUCN Red List category, (2) distribution map, (3) habitat and ecology, (4) threats and (5) conservation actions. The assessment of these dimensions is elaborated below:

(1) The IUCN Red List category: The IUCN Red List categories (CR, EN, VU, NT, LC, DD, NE) are determined through the evaluation of taxa against five quantitative criteria (a-e), each grounded in biological indicators of population threat:

[134] The International Union for Conservation of Nature (IUCN) is a global environmental organization that was founded on October 5, 1948. It is the world's oldest and largest global environmental network. The IUCN works to address conservation and sustainability issues by assessing the conservation status of species, promoting sustainable development practices, and providing guidance and expertise on environmental policy and action. The IUCN also plays a crucial role in influencing international environmental policies and fostering collaboration among governments, NGOs, and the private sector to promote conservation efforts worldwide (IUCN 2018).

a. Population Size Reduction: This criterion evaluates the past, present, or projected reduction in the size of a taxon's population. It considers the percentage reduction over a specific time frame, with different thresholds indicating different threat levels.
b. Geographic Range Size and Fragmentation: This criterion assesses the size and fragmentation of a taxon's geographic range. Factors such as few locations, decline, or fluctuations in range size contribute to the evaluation.
c. Small and Declining Population Size and Fragmentation: This criterion focuses on taxa with small and declining populations, considering factors like population size, fragmentation, fluctuations, or the presence of few subpopulations.
d. Very Small Population or Very Restricted Distribution: This criterion addresses taxa with extremely small populations or limited distributions. It assesses whether the taxon is at risk due to its small population size or restricted geographic range.
e. Quantitative Analysis of Extinction Risk: This criterion involves a quantitative analysis, such as Population Viability Analysis, to estimate the extinction risk of a taxon. It considers various factors influencing population dynamics and extinction risk.

While listing requires meeting only one criterion, assessors are encouraged to consider multiple criteria based on available data. Quantitative thresholds of the IUCN Red List categories were developed through wide consultation and are set at levels judged to be appropriate, generating informative threat categories spanning the range of extinction probabilities. To ensure adaptability, the system permits the incorporation of inference, suspicion, and projection when confronted with limited information.

(2) The distribution map: The IUCN Red List distribution map serves as a reference for the taxon's occurrence in the form of georeferenced data and geographic maps. This data is available for 82% of the assessed species (>123.600) and is based on the species' habitat, which is linked to land cover- and elevation maps. The indicated area marks the species extent of occurrence, which is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred, or projected sites of present occurrence of a species, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of species, such as large areas of obviously unsuitable habitat. For a detailed explanation of the mapping methodology, please refer to the *Mapping Standards and Data Quality for the IUCN Red List Spatial Data* (IUCN 2021).

(3) Habitat and Ecology: The IUCN classifies the specific habitats that a species depends on for its survival. These habitats are categorized into three broad systems: terrestrial, marine, and freshwater. A species may inhabit one or more of these systems, and so the possible permutations result in seven categories of natural systems. Beyond these seven system categories, the IUCN offers a more nuanced classification system for habitats, comprising 18 different classes at level 1 (e.g., forest, wetlands, grassland, etc.), and 106 more specific classes listed at level 2 (e.g., Forest – Subtropical/tropical moist lowland, Wetlands (inland) – Permanent inland deltas; Grassland - Temperate) (IUCNa n.d.). For SCALE-UP's sustainability screening, the IUCN classification of the seven systems is sufficient to refine the search while not excluding relevant habitats. The EU Habitats Directive, in contrast, distinguishes 25 habitat types that are considered threatened and require active and recurring conservation action. The Directive demands member states to take measures to maintain or restore these natural habitats and wild species. If data on these became accessible in the future, it could be used in future iterations of the sustainability screening to supplement the results that using the IUCN classification yields.

(4) Threats: The IUCN database encompasses various general threats that can negatively impact a species. Direct threats denote immediate human activities or processes impacting, currently impacting, or potentially affecting the taxon's status, such as unsustainable fishing, logging, agriculture, and housing developments. Direct threats are synonymous with sources of stress and proximate pressures. Assessors are urged to specify the threats that prompted the taxon's listing at the most granular level feasible within this hierarchical classification of drivers. These threats could be historical, ongoing, or anticipated within a timeframe of three generations or ten years. These generalized threat categories encompass residential and commercial development, agriculture and aquaculture, energy production and mining, transportation and service corridors, biological resource use, human intrusion and disturbances, natural system modifications, invasive and other problematic species, genes and diseases, pollution, geological events, and climate change and severe weather. Beneath each general threat, more specific threats are detailed. Please refer to the IUCN Red List's website[135] for a detailed list of all threats, including explanations.

(5) Conservation Actions: The IUCN database contains conservation action needs for each species, providing detailed information on the current conservation efforts and recommended actions for protecting the taxon. It includes general conservation actions such as research & monitoring, land/water protection, management, and education. Specific conservation actions are listed under each general action, along with a description of the current conservation status and recommended actions to protect the taxon. A hierarchical structure of conservation action categories (see the IUCN Red List's website[136]) indicates the most urgent and significant actions needed for the species, along with definitions, examples, and guidance notes on using the scheme. Assessors are encouraged to be realistic and selective in choosing the most important actions that can be achieved within the next five years, informed by the conservation actions already in place.

2.3.2 Methodology applied

The methodology aims to derive a list of species which would require special consideration (e.g. close monitoring and safeguarding) in the context of implementing bioeconomy activities. To generate this list, the search function of the interactive IUCN database is used following five steps:

(1) Scope of Assessment: Selection of Europe as the scope of assessment to evaluate the conservation status of the European population rather than the global population. This approach ensures that species are identified as threatened based on their status in Europe, irrespective of their global abundance.

(2) Geographical Delineation: Utilization of the interactive map of the IUCN database to draw a polygon that exceeds the region of interest. Exceeding the regions ensures that the entire region is covered, as it is not possible to draw a polygon exactly matching the boundaries of the region. Moreover, a larger polygon also respects the uncertainty of delineating a species area of extent, since the actual area of extent is possibly more fluid than its statically indicated geolocations. Consequently, the larger polygon minimizes the risk of excluding any relevant species for which geolocations are registered just minimally outside of the regions' administrative boundaries, but which could inhabit parts of the region in the future. There is no rule of thumb for a correct distance between polygon boundary and region boundary.

(3) Species Selection: Limiting the search results to endangered and critically endangered species to focus on those facing the most severe risks. Additionally in the case of Strumica re-

[135] See here: https://www.iucnredlist.org/resources/threat-classification-scheme
[136] Ibid.

gion, vulnerable criteria is also taken into consideration, as the region do not have any critically endangered species.

(4) Habitat Selection: selection of all habitats to ensure the full coverage of habitat types present in the geographical delineation defined in step 2.

(5) Threat Selection: Selection of threats associated with the respective regional bioeconomy and/or value chain to refine the search results to species likely to be impacted by them.

By following these steps, a targeted list of species is derived, focusing on species facing significant risks within the context of the regional bioeconomy strategy or value chain being explored, aligning with the specific conservation and bioeconomic priorities of the region.

2.3.3 Data uncertainties

It is important to acknowledge certain limitations and uncertainties associated with the data and methodologies used:

(1) Inaccurate representation of relevant area: The IUCN database allows for the interactive drawing of a map for a regional assessment. However, this drawn map might not accurately represent the area directly relevant to the bioeconomy strategy or value chain being explored. Since the selected polygon is larger than the actual bioregion, the assessment risks to include species that are not relevant to the bioregion and the bioeconomic strategy of the region.

(2) Lack of local habitat differentiation: The spread of species is indicated as its extent of occurrence without differentiating between habitats at the local level. This means that certain species might solely inhabit very particular habitats within the indicated extent of occurrence. An endangered amphibious species, for instance, might have an area of extent covering an entire country. However, it will only be found in very rare habitats within this area of extent (e.g., pond with very specific qualities). Accordingly, a regional assessment as outlined here (e.g., at the municipal level) might list certain species that do not occur in the assessed regions due to a lack of suitable habitats on the local level.

(3) Potential oversights in conservation status: Using Europe as a scope of assessment might hide any problematic conservation status of a species at the global or at the local level.

(4) Outdated data: The IUCN aims to have the category of every species re-evaluated at least every ten years and aims to update the list every two years (IUCNb n.d.). Nevertheless, the data might be outdated, which could lead to inaccuracies in the assessment of biodiversity risks. For the screenings carried out in SCALE-UP for the Strumica region, 32% of the data is published within the last 5 years (2019-2024), and 66% is published during the period 2010-2017.

(5) Incomplete data: The data might be incomplete, which could limit the comprehensiveness of the assessment.

(6) Limited species coverage: It is estimated that the world hosts about 8,7 million species (Sweetlove, 2011). As of now, more than 150.300 species (16.120 in Europe) have been assessed for the Red List, leaving large data gaps at the global level.

(7) Taxonomic standards: The taxon being assessed must follow the taxonomic standards used for the IUCN Red List. Any deviation from these standards could lead to inaccuracies in the assessment.

At both the national and regional levels, there exists the National Biodiversity Strategy with Action Plan covering 2018-2023[137] *and the Biodiversity Strategy and Action Plan for the Southeast Planning*

[137] https://www.moepp.gov.mk/wp-content/uploads/2018/05/STRATEGIJA%20ZA%20BIOLOSKA%20RAZNOVIDNOST%20SO%20AKCISKI%20PLAN%202018_2023.pdf

Region starting from 2020[138]*. Although these documents could potentially validate data in the IUCN database, this validation was not conducted as part of the SCALE-UP project's current task. However, it is recommended as a future initiative for regional experts and stakeholders to ensure a unified approach within the project.*

3 Potential ecological burden of regionally relevant bioeconomic activities

3.1 Bioeconomic activity selected for the screening

The agricultural land use in the Strumica region covers nearly 25,000 hectares, mainly for pastures, meadows, and garden crops like tomatoes and peppers. Garden crops contribute over 140,000 tons annually. Fruit production, particularly apples, is significant, with substantial orchard areas and high production numbers. Wine production, though not the primary focus, yields a considerable amount, emphasizing the potential use of pruning residues for composting. Forest residues, afforestation, and gross felled timber provide additional biomass resources. Municipal biowaste from households and commercial sectors, especially organic waste, is considerable, with a focus on composting. The regional municipal waste generation in 2022 was 71,724 tonnes, of which 60% is estimated to be organic waste. Industries, including vegetable and fruit processing, wood processing, and beverage production, contribute to secondary residues. As a result, the Strumica region has a potential for utilization of agricultural residues for compost production. Although it has good examples to some extent, further systematic approach is needed, thus willingness of the farmers to contribute to the enhancement of the region in a sustainable manner.

3.2 Overview, management practices and potential burden on the resources examined

3.2.1 Potential burden on water resources

Water Eutrophication and Acidification: Giuntoli et al. (2014) elaborate on general tendencies related to the impact of agricultural residue removal on water ecosystems. In particular, increased removal of agricultural residues could lead to greater soil erosion and nutrient runoff, leading to problems with sediment delivery and eutrophication in nearby water bodies.

Moreover, an analysis by Persiani et al. (2020) of several procurement systems of bulking agents and agricultural crop residues allocated to composting on-farm in Southern Italy identifies the least environmentally harmful approaches. Such include transportation of agricultural residues in pallets on a small truck as well as manual loading and uploading (ibid.). With this system, eutrophication amounts to 4.7E-04 kg PO4 – eq and acidification is 1.5E-03 kg SO_2 eq, according to the conducted LCA (ibid.).

[138] https://southeast.mk/wp-content/uploads/2021/07/%D0%A1%D1%82%D1%80%D0%B0%D1%82%D0%B5%D0%B3%D0%B8%D1%98%D0%B0-%D0%B7%D0%B0-%D0%B1%D0%B8%D0%BE%D0%BB%D0%BE%D1%88%D0%BA%D0%B0-%D1%80%D0%B0%D0%B7%D0%BD%D0%BE%D0%B2%D0%B8%D0%B4%D0%BD%D0%BE%D1%81%D1%82-%D0%B8-%D0%90%D0%BA%D1%86%D0%B8%D0%BE%D0%BD%D0%B5%D0%BD-%D0%9F%D0%BB%D0%B0%D0%BD-%D0%B7%D0%B0-%D0%88%D1%83%D0%B3%D0%BE%D0%B8%D1%81%D1%82%D0%BE%D1%87%D0%B5%D0%BD-%D0%BF%D0%BB%D0%B0%D0%BD%D1%81%D0%BA%D0%B8-%D1%80%D0%B5%D0%B3%D0%B8%D0%BE%D0%BD-%D1%84%D0%B8%D0%BD%D0%B0%D0%BB%D0%BD%D0%BE.pdf

Water Pollution and potential implications on water availability: In general, the risks of water contamination by surface runoff are found to be reduced through composting of agriculture wastes in comparison to conventional land management (stock piling manure) (Mukaetov, 2013). Specifically for Strumica, a study by Kovacevik et al. (n.d.) has shown the presence of arsenic pollution in groundwater bodies located in the central valley of the Strumica region. The presence of contaminants here has been related to natural processes, yet its potential implications (e.g. reduced overall availability of safe drinking water for human and animal use and potential toxicity threats for future agricultural production in the Strumica region) would call for careful consideration when scaling up activities that could disproportionately increase the demand for such resources in the future. This can be especially relevant for agricultural operations in Strumica, where water availability is already a limiting factor and where plant stress due to insufficient water has been documented (Mukaetov et al., 2014).

3.2.2 Potential burden on soil resources

Soil quality (incl. SOC, SOM, erosion): Long periods of drought alternating with intense rains are common in North Macedonia, which causes soil erosion and land degradation. Extreme changes in temperature and precipitation are expected to increase due to climate change, and they put large pressure on agricultural production. The southeastern region of the country, where Strumica is located, already shows sharp and progressive increases in air temperature (Mukaetov et al., 2014). Composting helps to disseminate nutrient levels across the area thereby fertilizing the soil (Persiani et al., 2020; Vlachokostas et al., 2021). Compost amended soil is also more resistant to wind and water erosion due to the improved soil structure and enhanced soil moisture-holding capacity (Mukaetov, 2013). This can be very relevant in the Strumica Region, where runoff from intense rainfall and flooding has been a challenge in the past (.e.g in the Spring of 2013) and is projected to increase due to climate change (Mukaetov et al., 2014). However, if improperly managed, composting of fresh residues is likely to release a large quantity of leachates alongside undesirable by-products (Persiani et al., 2020). Adding a bulking agent or structural material, for instance, wood chips, straw, rice husks, cotton waste, helps to eliminate these issues improving ventilation and water penetration as well as enhancing microbial growth and activity (ibid.). Also, these bulking agents may be employed to modify the availability of carbon, the C/N ratio, and the pH level throughout the composting process. These adjustments can accelerate the breakdown of materials, improve the stability of the composted organic matter, and inhibit the growth of pathogens and parasites (ibid.).

Another way to utilize agricultural residues is anaerobic digestion which allows recovering the energy content in addition to producing digestate, the final bioproduct of the procedure (Vlachokostas et al., 2021). The digestate can be used on farmland as liquid organic fertilizer soil improver or a component in growing media on account of its significant nutrient content (ibid.). Simultaneously, it should be kept in mind that removing agricultural residues from the land for different purposes, for example, to use as an energy source can adversely affect the soil. Possible effects include reduced soil carbon and nutrient levels, a decline in organic matter, decreased water retention capacity of soils, and a heightened risk of erosion (Chukaliev, 2010; Kluts et al., 2017). Keeping agricultural residues on the ground can contribute to the enrichment of the soil ecosystem with nutrients and to its enhancement with organic matter, reducing the risk of soil erosion, and helping to maintain soil moisture, thereby supporting soil health and quality (Chukaliev, 2010; Ristakjovska Shirgovska & Prentovikj, 2021).

Maintaining and increasing SOC content in soil is especially important for Southern Europe where it is found to be already low or decreasing (Giuntoli et al., 2014). Znaor et al. (2022) list several common carbon practices that can be employed in North Macedonia to increase SOC, among other things, conservation tillage is named. This practice implies that at least 30% of crop residues are left in the field which also help to reduce soil erosion (Mukaetov, 2013). Kluts et al. (2017) find that sustainable removal rates of 40% for cereal crops and 50% for maize, rice, rapeseed and sunflower are used most often. Chukaliev (2010) draws an example of straw incorporated in soil, calculating equivalences between nutrient loads of residues and those of fertilizers (per 1 t of straw: 6-7 kg N; 2-2,5 kg P_2O_5; and 14-17 kg K_2O) and evaluating which leads to more carbon sequestrated in the soil, enrichment of soil with organic matter and erosion protection. Ristakjovska Shirgovska & Prentovikj

(2021) confirm that cereal residues should be considered for the purpose of enhancing soil organic matter, due to their high carbon and nitrogen ratio and slow decomposition rates.

Lastly, it is not recommended to discharge residues if they were subject to substantial processing. For example, looking further into the value chain of wine, one of the relevant products of the Strumica Region, this could be the case for leftover distilled wine lees no longer used for alcohol production and subsequently usually treated as waste. Naziri et al. (2014) found the direct discharge of lees in the agricultural field harmful. A possible way of valorising them is as a component for plant growing media. However, the limitation of this approach is that the nutritional value of wine lees is reduced after distillation.

Soil Acidification and Pollution: The Third National Communication on Climate Change for North Macedonia indicates that between 30 and 80 thousand hectares of irrigated agricultural land in the country are susceptible to salinization and other forms of degradation (Mukaetov et al., 2014). Among other things, composting is found to help minimize soil contamination (Vlachokostas et al., 2021). As regards the management and collection of agricultural crop residues and bulking agents necessary for composting, the study by Persiani et al. (2020) cited earlier in this section also provides insights on the positive effects of employing more extensive procurement systems on soil ecotoxicity and acidification.

3.2.3 Potential burden on biodiversity

The impacts of these bioeconomy activities on biodiversity in North Macedonia remain largely understudied. Some general tendencies can be inferred from above-described practices, such as leaving part of agricultural residues on the farmland or utilizing compost which leads to increase in SOM and SOC. Znaor et al. (2022) point out that these components determine the state of biodiversity. Moreover, compost itself contains a large number of microorganisms (e.g., bacteria, fungi, algae) the diversity of which defines the compost quality (Persiani et al., 2020). Therefore, compost environment provides living space for microbial communities.

In addition, it is possible to examine specific examples and cases of biodiversity-related applications of agricultural residues. For instance, a possible solution for the utilization of distilled wine lees is as supplement in animal nutrition or for plant growing media. Here, it is still important to consider the limitations of such approach linked to the finding that nutritional value of wine lees after distillation is reduced (Naziri et al., 2014).

Giuntoli et al. (2014) describe some general trends how agricultural residue removal can affect biodiversity. For example, species reliant on farmland environments, e.g., farmland birds, may be adversely affected. A reduced addition of new organic matter to the soil may affect species that live on the soil surface and within it, potentially leading to a cascading effect on these ecosystems overall (ibid.).

Giuntoli et al. (2014) further claim that digestate enhances soil microbial biomass and dehydrogenase activity, which is recognized as a reliable biomarker for indicating shifts in microbial activity. In such a way, biological activity in soil is maintained with digestate application.

4 Screening results and recommendations

4.1 Overview - Strumica

Resources screened		Ordinal Baseline Rating	Use of agricultural and food production residues for compost production	
Category	**Sub-Category**		**Potentially beneficial to the baseline status**	**Potentially detrimental to the baseline status**
Water	**Surface water bodies**		- Shifting from stockpiling of agricultural waste (e.g. manure) in the field, to preparation of compost in securely lined spaces and its controlled application - Implementing natural water retention measures to deal with limited water resources in the region - Increasing irrigation efficiency while keeping expansion of agricultural operations in check	- Unrestrained removal of agricultural residues (e.g. driven by a created demand for byproducts) that could potentially lead to nutrient runoff and eutrophication - Continued lack of maintenance and investment on (ground)water monitoring infrastructure, prolonging the current lack of insight on the state of aquifers in the region
	Groundwater bodies	**n/d**		
Land & Soil Resources	**-**		- Conservation tillage, leaving 30% (or more, depending on the crop) of crop residues in the field, to maintain/increase Soil Organic Carbon and nutrient levels, and reduce soil erosion - Incorporating bulking- or structure-enhancing agents (e.g. wood chips, straw) to fresh residues used in the compost to avoid leachate	- Unrestrained removal of agricultural residues (e.g. driven by a created demand for byproducts) that could potentially lead to increased soil erosion - Discharge of substantially processed agricultural- or food and beverage production residues (e.g. wine lees) onto the agricultural field, resulting in soil contamination
Biodiversity	**Endangered Species**	**2**	- Carefully controlling the compost quality so that the desired microorganisms can thrive and pathogen and parasite growth is inhibited - Where applicable, considering applying digestate at proportionate levels to enhance the soil microbial biomass	- Large-scale removal of residues on which farmland birds may depend - Introduction of new crop hybrids or varieties (to maintain production levels under a changing climate) without diligent consideration of their impact on local species, water and nutrient requirements.
	Critically Endangered Species	**0**		

4.2 Recommendations

The RBMP for Strumica delineates a comprehensive Program of Measures aimed at preserving and reinstating water quality, with a focus on addressing significant challenges within the RBD. These measures encompass regulatory actions, involving the implementation of stringent regulations to ensure the protection of water quality. The plan includes initiatives to monitor and manage the discharge of urban wastewater and regulate wastewater discharge from areas lacking proper sewer systems. Agricultural pollution is tackled through strategies encompassing the management of waste and hazardous materials, soil management, erosion control, and the regulation of fertilizer and pesticide use. Furthermore, the RBMP addresses water withdrawals by regulating both municipal and irrigation water withdrawals to sustainably manage water resources. The plan also incorporates various additional measures, covering actions in protected areas, flood protection, and enhancements in solid waste management and sludge control. In essence, the RBMP for Strumica is a comprehensive strategy aimed at safeguarding and restoring the water status by implementing a diverse array of measures across regulatory, agricultural, and environmental domains.

To address soil quality and utilization concerns in the municipality of Strumica, a set of recommendations is proposed in the scope of the Local Environmental Action Plan for Strumica for the period 2024- 2029.[139] This includes completing urban and spatial planning documentation, enhancing collaboration between central and local authorities, and documenting agricultural activities in rural areas. Soil quality tests are recommended, along with the creation of a map to identify suitable areas for organic farming. The transition to micro-irrigation systems is suggested for efficient water use. Additionally, implementing reduced or protective tillage techniques and continuing farmer education on proper agronomic practices are emphasized. The installation of sewage systems in all populated areas, afforestation, and controlled forest cutting are also recommended measures to combat erosion and adapt to climate change. Biochar application on low-fertile land is a recommended mitigation measure, offering a strategy for carbon sequestration and "negative emissions." This technology involves the thermal conversion of biomass, resulting in long-term carbon sequestration with additional benefits, such as reducing nitrous oxide emissions and improving nutrient and water-use efficiencies.

In order to overcome biodiversity concerns, several recommendations are given by the experts and stakeholders responsible for conducting the Local environmental action plan for Strumica. This includes conducting comprehensive monitoring across four seasons to identify persistent biodiversity, assess habitat conditions, and propose protective measures. The revitalization of the Monospitovo Swamp is suggested, emphasizing inter-municipal collaboration in the Southeastern region. Additionally, documentation for the valorization of Mount Elenica is recommended, focusing on the protection and proper management of specific areas, habitats, or species. Revitalization efforts for degraded areas of Mount Elenica and Plavush are also recommended. Public awareness campaigns are proposed to highlight the importance of natural wealth preservation, and efforts to raise awareness about the use of agrochemicals and promote organic farming are encouraged.

Furthermore, having feedback from the regional stakeholders which are directly involved in the advancement and development of the Strumica region is significantly critical and greatly contribute to the general recommendation. The feedback is gathered during a regular platform meeting held in February 2024 and it is based on the experience and knowledge of four regional stakeholders.

In recent years, efforts have been made to improve water-related activities in Stumica river basin region. Cleaning of the Trkanja River was done last year, and plans are in place to do the same for the Vodoshnica River this year. Canals stretching 2.5 km were constructed, and new channels for stormwater were established in collaboration with the MoEPP. Recommendations for the future include improving groundwater monitoring and updating data on groundwater, building a new sewage treatment plant for smaller settlements, since the current one caters to 55,000 households, and its capacity is already fulfilled, implementing atmospheric sewage in Murtino, establishing a water

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purification station in Bansko, and efficiently utilizing thermal waters, potentially through the construction of a spa center.

To enhance sustainable agriculture, a series of measures are proposed. This includes improving practices to address erosion, advocating against burning crop residues, and encouraging plowing instead. Crop rotation and diversification are promoted for soil health, with a recommended cycle of changing crops every 1-3 years. Citizen involvement is crucial, urging them to compost and adopt good practices from the region and European countries. Instead of burning plant waste, a system of collection and compost distribution as an incentive is proposed. Planting on erosive areas is emphasized, along with the establishment of dedicated areas for separating organic production and other plant residues. Lastly, strict enforcement of regulations is advocated to prevent the construction of photovoltaic installations on specific agricultural land categories and discourage their conversion for alternative purposes.

Preserving biodiversity in the Strumica region requires proactive measures and initiatives. One crucial step is to declare the Monospitovo Swamp as a protected area, recognizing its ecological significance. Similarly, there is a need for initiatives aimed at safeguarding Belasica, acknowledging the importance of preserving this natural habitat. Additionally, attention must be directed towards the endangered status of ferns, necessitating the implementation of appropriate measures to prevent their disappearance. These initiatives collectively contribute to the conservation and sustainable management of the region's biodiversity, ensuring the long-term health and balance of the local ecosystems.

Following the recommendations mentioned above regarding the water, soil and biodiversity, could significantly enhance compost production and the management of inputs (residues) in the Strumica region. Initially, it is strongly recommended to promote successful composting practices among farmers, households, and businesses. Establishing community composting facilities or decentralized units can efficiently manage organic waste. Source segregation of organic waste at various levels is crucial for high-quality compost production. Providing training programs and capacity-building workshops for farmers and waste management personnel can improve composting techniques. Developing and implementing regulations supporting composting and organic waste management, along with public awareness campaigns, can encourage community participation. Investing in research and development, and fostering partnerships with local stakeholders, will further strengthen the composting ecosystem in the region.

In terms of sustainable agriculture, integrated composting systems offer innovative solutions that synergize with water and soil management practices. Incorporating treated wastewater into composting processes enhances nutrient content, promoting soil enrichment and water conservation. Furthermore, biochar integration, derived from agricultural residues, contributes to carbon sequestration, improved soil structure, and enhanced nutrient retention. This dual-purpose approach supports both environmental and soil health goals. To foster biodiversity, composting practices are designed to attract and sustain beneficial organisms, promoting ecological balance. Nutrient cycling takes center stage, tailoring compost mixes to meet the specific needs of local soils and crops, ensuring a holistic approach to soil enrichment. Nonetheless, precision agriculture techniques, including soil mapping and monitoring, optimize compost application, maximizing its efficacy. Encouraging cover cropping and green manure practices alongside composting enhances organic matter content, soil structure, and pest management. Finally, establishing monitoring and evaluation systems ensures continuous refinement of composting practices for optimal results.

In conclusion, the integration of recommendations, including improved composting practices, sustainable agriculture, and proactive biodiversity preservation, collectively forms a holistic strategy to enhance the ecological well-being and long-term sustainability of the Strumica region.

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Sustainability Screening – Upper Austria, AT

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EXECUTIVE SUMMARY

This report is a product of the SCALE-UP project, which receives funding from the Horizon Europe research and innovation programme. The project's objective is to facilitate the development and support of small-scale bioeconomy solutions in rural areas throughout varying European regions. This regional sustainability screening encompasses the study of different ecological parameters in the Upper Austrian region. The constraints focused on are water, soil, and biodiversity, which hold high significance for the bioeconomy. The bioeconomy, which relies on renewable biological resources, is intricately linked to the health and resilience of regional ecosystems. Water availability and quality directly impact the growth and vitality of bio-based crops and processes, making it imperative to assess and manage water resources sustainably. Similarly, soil health is a fundamental determinant for successful bioeconomic activities, influencing plant productivity, nutrient cycling, and carbon sequestration. Biodiversity, the intricate web of life, plays a pivotal role in maintaining ecosystem stability and resilience, thereby safeguarding the foundation of the bioeconomy. Regional sustainability screening ensures that bioeconomic initiatives not only thrive but also contribute positively to environmental and social well-being, fostering a balanced and resilient bio-based economy for the future.

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Abbreviations

BFW	Bundesforschungszentrum für Wald
BMK	Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie
BMLRT	Bundesministerium für Landwirtschaft, Regionen und Tourismum
BMUB/UBA	Umweltbundesamt
BORIS	Bodeninformationssystem

CAP	Common Agriculture Policy
CCI42	Context indicator 42
CORINE	Coordination of Information on the Environment
CR	Critically endangered
DD	Data Deficient
DORIS	Digitales oberösterreichisches Raum-Informations-System
DRBD	Danube River Basin District
EC	European Commission
EEA	European Economic Area
EEC	European Economic Community
EN	Endangered
EU	European Union
EUSO	EU Soil Observatory
FAO	Food and Agriculture Organisation
GAEC	Good Agricultural Environmental Conditions
ha	hectares
HQ100	100-year flood events
ICPDR	International Commission for the Protection of the Danube River
IUCN	International Union for Conservation of Nature
JRC ESDAC	Joint Research Centre European Soil Data Centre
LC	Least Concern
LUCAS	Land Use and Coverage Area frame Survey
MBT	Mechanical Biological Treatment
MFC	Microbial Fuel Cells
NE	Not Evaluated
NGO	Non-governmental Organisation
NGP	Nationaler Gewässerbewirtschaftungsplan
NT	Near Threatened
NUTS	Nomenclature des Unités territoriales statistiques
NWMP	National Water Management Plan
OÖ	Oberösterreich (Upper Austria)
RBD	River Basin District
RBMP	River Basin Management Plan
RMP2021	flood risk management plan 2021
RUSLE2015	Revised Universal Soil Loss Equation
SOC	Soil Organic Carbon
SOM	Soil Organic Matter

USA	United States of America
VU	Vulnerable
WEI+	Water Exploitation Index Plus
WFD	European Water Framework Directive
WISE	Water Information System for Europe
WWF	World Wide Fund for Nature

1 Resource management profiles

1.1 Water resources management profile

Water management in Austria

The European Water Framework Directive (WFD), implemented in 2000, takes a holistic approach to water bodies in Austria, viewing them as habitats (river basin districts). The directive establishes a standardized legal framework for the European Union's water policy, with the overarching goal of promoting sustainable and environmentally compatible water utilization (Federal Ministry of Agriculture, Forestry, Regions and Water Management, n.d.a). The aim of the directive is to gradually improve the status of aquatic ecosystems and to prevent further deterioration. Sustainable water use based on the long-term protection of existing resources is promoted. The directive was transposed into national law with the 2003 amendment to the Water Rights Act 1959, the national Austrian water law (Water Rights Act, 1959).

For the management of water resources in frame of the WFD, Upper Austria is part of the Danube River Basin District (DRBD), which is managed on national level through the Federal Ministry for Agriculture, Forestry, Regions, and Water Management. At regional level, the directory State of Upper Austria manages Upper Austrian water resources and bodies and directly reports to the Federal Ministry. In order to achieve the objectives and principles of the Water Framework Directive, the Austrian federal ministry draws up a National Water Management Plan (NWMP) every six years in cooperation with the water management planning departments of the federal states. The water agencies and the responsible departments of the federal states are responsible for implementing the objectives of the NWMP). The current water management planning period (2022-2027) feeds into the 3rd National Water Management plan (Nationaler Gewässerbewirtschaftungsplan, NGP 2021) and includes the planned measures for water management. It defines the guidelines for the balanced and sustainable management of water resources; sets the quality and quantity objectives to be achieved for each water bodies in the basin (rivers, water bodies, groundwater, estuaries), and determines the developments and provisions needed to prevent deterioration and ensure the protection and improvement of the status of water and aquatic environments, to achieve these objectives. Further, it includes the impact of climate change on water economics and the resulting water shortages. Lastly, the main findings for flood control management within the flood risk management plan (RMP2021) are focused on (Federal Ministry of Agriculture, Forestry, Regions and Water Management, 2021). For facilitated implementation of the federal water management actions, and for the management of drinking water supply, wastewater disposal, melioration (drainage) and irrigation, water cooperatives act under the public law and are a main contact for residents and the federal state representatives (Land Oberösterreich, n.d.a). Finally, the management of urban water services (drinking water and sanitation), the management of aquatic environments and flood protection are the responsibility of the municipalities or their groupings. Each municipality has to pay a fee for the connection to the water supply and in each municipality, households directly pay a water usage fee in periodic intervals for the use of the water supply (drinking water and sanitation) (Land Oberösterreich, n.d.b).

Water resources and use

In this report, we look at the main river basin in Austria, and Upper Austria respectively, which is the Danube River basin district. A small percentage of water bodies in Northern Upper Austria drain into Elbe River basin at the border of the Czech Republic, but the data has not been regarded for this report, since the scale of the area and the impact on the overall study is respectively low. The administrative region, which implements and manages the water sources is the Federal State of Upper Austria and their respective Sectors for Water Management. (Fig. 1)

Figure 39: River Basin Districts (Danube, Elbe, Rhine) in Austria and Upper Austria (Federal Ministry of Agriculture, Forestry, Regions and Water Management, 2021)

In general, the Danube River Basin District covers around 817,000 km^2 catchment area and stretches over 19 countries in Europe, which is the most international river basin in the world. The Danube River springs in the Black Forest in Germany and flows into the Black Sea in Romania. The basin area is home to more than 80 million people and with a total length of 2,800 km the Danube River is the second longest river in Europe. In Austria, just over 96% of the territory (80,565 of 83,851 km^2 total area) drains to the Danube and contributes around 25% of the Danube inflow into the Black Sea.

Table 22: Key figures for the Danube River basin in Austria (Federal Ministry of Agriculture, Forestry, Regions and Water Management, 2021)

Key figures for the Danube River basin in Austria (Federal Ministry of Agriculture, Forestry, Regions and Water Management, 2021)	
Surface area	80,565 km^2
River	30,751 km
Water bodies	7,769

The average annual precipitation in Upper Austria is around 1150 Liters per m^2, although the distribution of rain fall is greatly uneven across the federal state. In the western part of Upper Austria, the accumulation of precipitation is higher, due to the geographical conditions as the Alp line progresses (Land Oberösterreich, n.d.c).

The overall annual water demand in Austria is approx. 3,14 km^3, which corresponds to an approximate of 3% of available volume annually. Around 60% of the annual water demand is covered by surface water bodies and the remaining 40% are from groundwater bodies. The average consumption in households (not including trade, industry or large-scale users) amounts to about 126 litres per day and capita. This results in an average consumption of drinking water per 4-person household of about 184 m^3 per year. Around 70% of the annual water demand is used by industry and commerce, whereas 24% to water supply and 4% to agriculture. The rest is used by selected services, such as water for snowmaking in winter (Federal Ministry of Agriculture, Forestry, Regions and Water Management & University of Natural Resources and Life Sciences, 2021). Despite a high availability of water resources, studies show that the average amount for water supply needed will increase around 11-15% until 2050 due to the effects of climate change and intensive drought periods in Austria. Especially the groundwater resources available could decrease by up to 23% from the current status. At the moment, the amount of water needed for agriculture in comparison to other sections is comparably low, the study shows assumptions that the water resources needed for irrigation will double in the next 25 years. The sector with the highest demand of water in Upper Austria is industry and commerce, which mostly use surface water (around 84%) as a cooling water source and partly well waters. It is assumed that the water supply needed in this sector will remain at a similar level in the future, yet effective water management actions need to be further implemented to maintain the sustainability of the water ecosystem (ibid.). The satisfaction of all uses and the development of all activities with a potential impact on water resources therefore requires sustainable management in consultation with the various stakeholders.

Ecological status of surface water bodies in Upper Austria

The assessment of the ecological status of surface water bodies is based on the framework of the WFD and is a five-level assessment system to show the quality of structure and functionality in the water ecosystem of. The assessment takes place on the basis of specific data from the fields of biology, hydro-morphology and chemistry, in which a “high” or “good” status water section must not be deteriorated and mainly uninfluenced in comparison for the typical status of the respective type of water body. Water bodies or sections which are in a status that is worse than “good” must be brought into the “good status” until 2027 (Federal Ministry of Agriculture, Forestry, Regions and Water Management, n.d.a).

Data from the last reporting period shows, that more than half of rivers and lakes in the Upper Austrian region fail to achieve Good Ecological Status, which is only slightly above the EU-average. Economic activities and management practices that could have substantial negative impacts on river and lake ecology should thus be avoided, and those that could improve the ecological conditions of these water bodies should be explored and favoured.

According to the data from the second reporting cycle of the WFD (EEA, 2018a), no surface water body in Upper Austria achieve Good Chemical Status. The reasons for this are not clear, although it is assumed, that atmospheric deposition as a diffuse source of pollution affects the status tremendously. Around 1/5 of the surface waters show increased nutrient levels – mainly Nitrogen (Land Oberösterreich, n.d.d). Economic activities that could exacerbate pollution through atmospheric deposition should be avoided in the region. Further, the survey of water pollution in the course of the current status survey has shown that Upper Austria's watercourses are significantly affected by hydromorphological interventions, for example structural changes. Economic activities that associate or contribute to the restoration of these water bodies could have a positive influence. Within the new reporting actions from 2021-2027, renaturation measures are planned (depending on the financial feasibility), in which around 770 km of watercourses and around 300 restoration sites in Upper Austria are to be established in order to achieve ecological continuity (Land Oberösterreich, n.d.e).

Ecological status of groundwater bodies in Upper Austria

The groundwater landscape in Upper Austria is divided into 19 near-surface groundwater bodies and groups of groundwater bodies, two deep groundwater bodies and one thermal groundwater body in accordance with the requirements of the Water Framework Directive (WFD).

To assess the chemical status, a monitoring network was set up in accordance with the Water Cycle Survey Ordinance with a total of 290 monitoring sites. The quantitative assessment is based on the Hydrographic Service's monitoring network on the one hand and on a balance of groundwater and usage conditions on the other. Upper Austria's groundwater bodies are in good chemical and good quantitative condition according to the criteria of the Water Act (Land Oberösterreich, n.d.f). All of the groundwater bodies in Upper Austria are in Good Quantitative Status and the majority (97%) are in Good Chemical Status as well. 126 groundwater bodies are in good chemical condition, whereas 4 of them have poor chemical status as a result of diffuse pollution from agriculture. The NGP foresees precautionary actions to maintain this status.

Water Risk Filter and Floodings in Upper Austria

The WWF Water Risk Filter (WWF, n.d.a) gives an assessment of the water risks of water basins in a specific region/area, using a scoring system from 1-5, in which 1 represents low risks and 5 indicates a high risk score. The definition of the physical risk according to the data base is as follows:

"The Water Risk Filter physical risk layer represents both natural and human-induced conditions of river basins. It comprises four risk categories covering different aspects of physical risks: water scarcity, flooding, water quality, and ecosystem services status. Therefore, physical risks account for if water is too little, too much, unfit for use, and/or the surrounding ecosystems are degraded, and in turn, negatively impacting water ecosystem services." (WWF, n.d.b)

According to the Basin Physical Risk Assessment for the Danube River Basin District and the national data, Austria shows an average physical risk of water sources of 2.68, which indicates medium risk in total. There is a very low risk of water scarcity in Austria. The factor with the highest physical risk is within the water quality (4.26), which is in accordance with the evaluations from the last WFD reporting period, which shows very high chemical pollution in the surface water bodies. Figure 2 shows the Basin Risk Map for Water quality, in which can be seen that the whole federal state of Upper Austria is affected by medium water quality. Furthermore, it shows, that the high risk areas are mainly in central Upper Austria and centred geographically around the main cities Linz, Wels and Steyr. This could indicate a high influence of industrial water circles as well as urbanisation as potential pollution source.

Figure 40: Water Risk Filter Map for the Danube River Basin District in Upper Austria (Federal Ministry of Agriculture, Forestry, Regions and Water Management, n.d.b)

With a risk score of 3.07 there is a medium risk of flooding in Austria in general. The WFD as well as the national water management plan foresee actions in regards to flood control and measures to counter flooding, also to reduce soil erosion in high risk areas. The basin water risk map of Upper Austria (Figure 3) shows that in the north-eastern parts of Upper Austria, the flooding risk increases to a high-very high risk. This might be caused due to several hydroelectric plants and dams, that are stationed at the border to the eastern state Lower Austria.

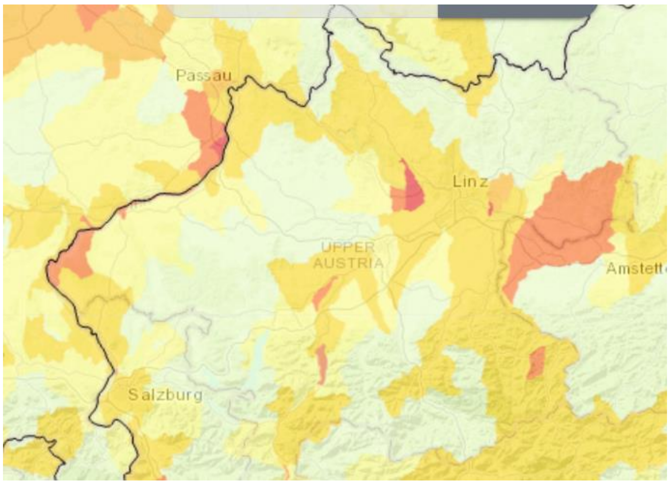


Figure 41: Flood Risk Map for the Danube River Basin District in Upper Austria (Federal Ministry of Agriculture, Forestry, Regions and Water Management, n.d.b)

For settlements and important economic and transport facilities a protection against 100-year flood events (HQ100) should be achieved. Particularly high living, cultural, and economic values, as well as areas with a high damage and hazard potential can also be protected against less frequent flood events. The construction of flood control facilities is only part of the responsibilities of the Austrian flood control sector. In addition, preventive and passive flood control, i.e. avoiding all activities that add to the flood discharge, are of great importance (Federal Ministry of Agriculture, Forestry, Regions and Water Management, n.d.b).

1.2 Soil resources management profile

Soil is integral to biodiversity in regional areas due to its role as a diverse habitat supporting a wide array of organisms, from microorganisms to insects and small animals. It plays a crucial part in nutrient cycling, offering essential elements for plant growth and influencing plant diversity. The physical structure of soil provides a foundation for plant establishment, contributing to the varied vegetation that, in turn, sustains a rich web of interconnected species. Microbial diversity within the soil enhances nutrient cycling, disease suppression, and decomposition, while certain soils emerge as biodiversity hotspots, fostering unique and endemic species. Additionally, soil regulates water flow, mitigates erosion, and serves as a reservoir for water resources, influencing the availability of vital hydration for diverse organisms in regional ecosystems.

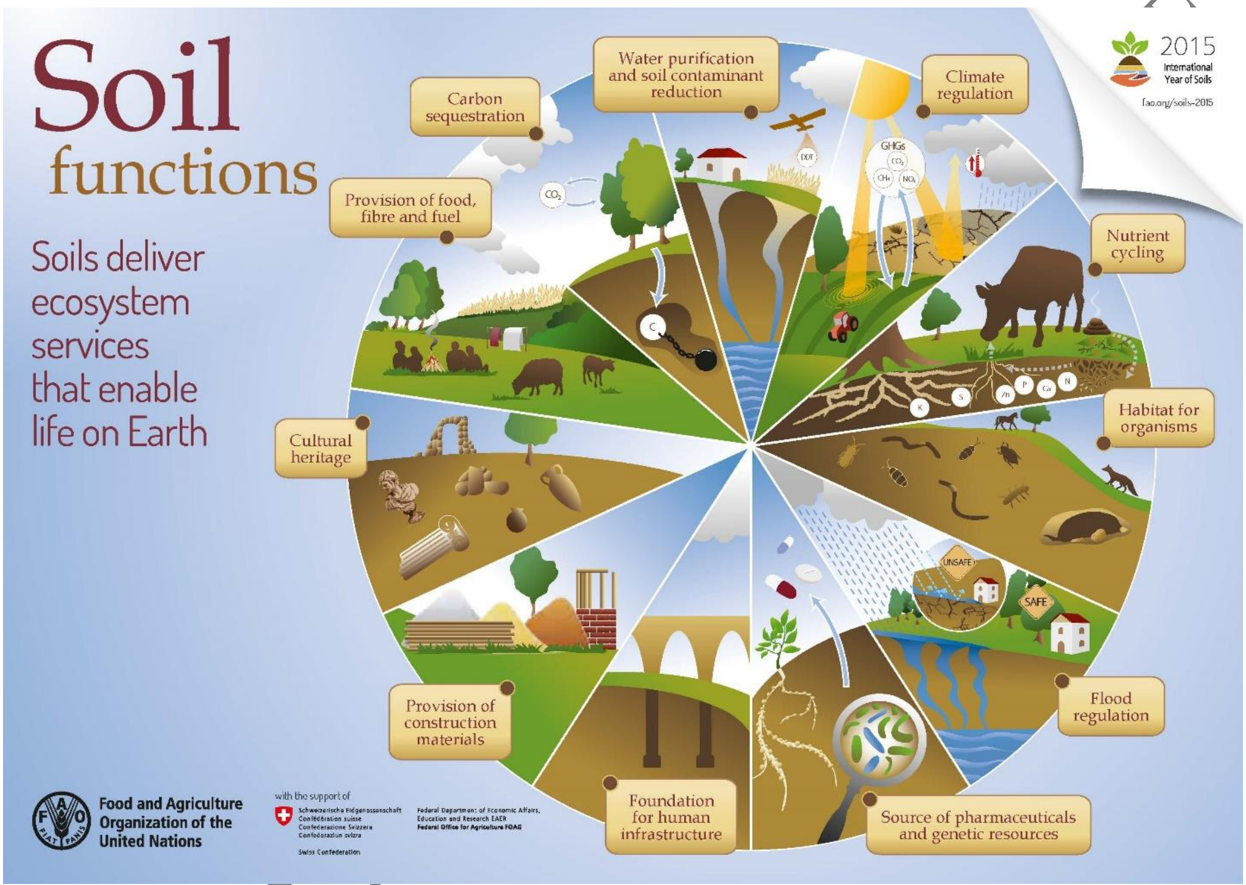


Figure 42: Functions of soil (FAO, 2015)

Land use in (Upper) Austria

The legal basis for soil protection and soil management is the Upper Austrian Soil Protection Act 1991. According to § 32, the Upper Austrian provincial government is obliged to prepare a soil information report every 5 years. The contents of the soil information report are information on measures and surveys in accordance with the Upper Austrian Soil Protection Act 1991, as well as soil analysis results and the soil balance pursuant to § 31 of the Upper Austrian Soil Protection Act. At the same time as the soil information report, the Upper Austrian provincial government must submit the soil development programme to the state parliament. This programme measures and objectives to be pursued regarding the conservation and protection of the soil and to improve soil health (Amt der Oö. Landesregierung, 2020).

The province of Upper Austria covers an area totalling around 1.2 million hectares (ha). The total area is divided into agricultural land (46 %), forest (40 %), settlement-related land (9 %), water areas (2 %) and other land areas (3 %). (Figure 5)

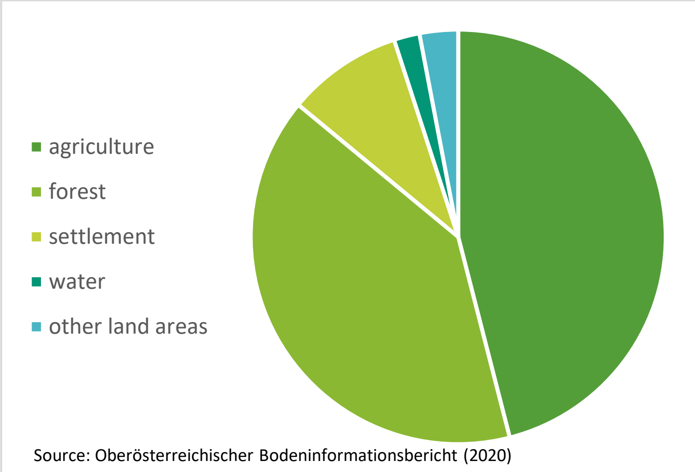


Figure 43: Overview of land use in Upper Austria according to sectors (BFW, n.d.)

A comparison with the 2015 land balance shows: The annual growth in settlement and transport areas (2020: +796 ha, 2015: +766 ha) continues to increase. Around 2.2 ha are consumed per day. The proportion of garden areas in the settlement area remains at around 55 %. At 35,995 ha, transport areas account for around 35 % of settlement-related usable land and continues to increase (2016-2020: +371 ha). Around 42 % of the settlement and transport areas used are sealed.

In 2019, the following crops were predominantly primarily represented on arable land in Upper Austria: Grain/silo maize (82,500 ha), winter wheat (48,000 ha), winter barley (40,000 ha), soya (15,500 ha), rapeseed (8,000 ha), and sugar beet (5,300 ha).

The forest area in Upper Austria currently amounts to approx. 508,000 ha12. This corresponds to an increase in forest area of 10,000 ha in the period from 2008-2017 or an average annual average annual increase of around 1,000 ha.

The Upper Austrian Soil Protection Act 1991 provides that in Upper Austria, in order to create the basis for soil health (in particular for determining the nutrient supply of soils, the contamination with pollutants and the impairment of soils through erosion and compaction) soil condition analyses are to be carried out regularly. These results are then summarised in an Upper Austrian soil register. In Upper Austria, the dominant soil type is brown earth. Other soil types are gley, pseudogley, aubic soils, podsole, rendzina and bog soil.[20]

There are several official online sources, geoinformation systems and online tools for the indication of soil quality and type:

- DORIS interMAP - Startseite (ooe.gv.at)
- eBOD2 (bodenkarte.at)
- BORIS Datenzugang (umweltbundesamt.at)

The BORIS-Tool (Bodeninformationssystem– Digital Soil Information System) is also used for monitoring the soil quality and updated with the latest data from the annual reporting periods.

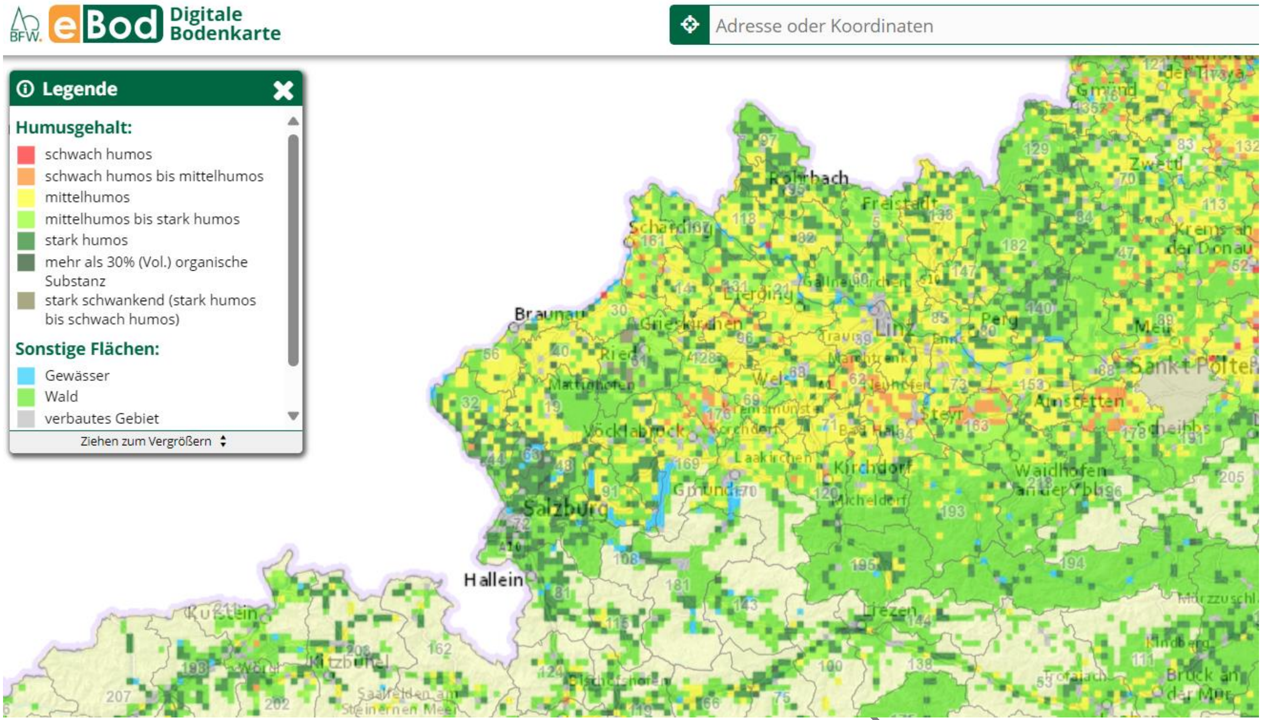


Figure 44: Digital soil map of Upper Austria (BFW, n.d.)

Approximately 35,000 soil samples were taken in recent years by Upper Austrian farmers over the past few years. The results of the pH value show that arable land at 6.43 and grassland at 5.69 are on average in an optimal range. The phosphorus content on arable land is in a low range. Around 44 % of the sampled areas are in content classes A and B; a further 38 % are in C1. From this content level upwards, the areas are sufficiently with plant-available phosphorus. On grassland the low phosphorus supply is more evident. 75 % of the areas are in a very low (content class (content class A) and low (content class B). Both the sampled arable land and the grassland areas are for the most part sufficiently supplied with potassium. A similar picture emerges for the humus. About 86 % of the arable land and over 70 % of the grassland areas are in content class C. The nitrogen replenishment potential is in the medium range with around 65 % of the arable range (Oö. Bodenschutzgesetz, 1991).

Governance and soil regulation

Soil protection is a cross-sectoral issue in Austria and is anchored in a multitude of legal provisions on federal and provincial level, often with references to the relevant hazard sources. Relevant provisions are for example contained in the Law on the Remediation of Contaminated Sites ("Altlastensanierungsgesetz"), the Smog Alarm and Ozone Act ("Smogalarm- und Ozongesetz"), the Fertilisers Act ("Düngemittelgesetz"), the Forestry Act ("Forstgesetz"), the Water Rights Act ("Wasserrechtsgesetz"), the Waste Management Act ("Abfallwirtschaftsgesetz"), the Chemicals Act ("Chemikaliengesetz"), the Austrian Trade Act ("Gewerbeordnung") and, in particular, the Soil Protection Acts of the Federal Provinces (Federal Ministry of Agriculture, Forestry, Regions and Water Management, n.d.c).

The protection of soil is based within two main regulations in Upper Austria, which are listed in Table 2. There are several sub-regulations and the protection and improvement on federal level is embedded in different strategies within the framework of the EU-sustainability goals.

Table 23: Main soil protection policies in Upper Austria

Main soil protection policies in Upper Austria	
Upper Austrian Soil Protection Act 1991	*The objectives of the Upper Austrian Soil Protection Act are the conservation of soil, the protection of soil health from harmful influences and the improvement and restoration of soil health (Oö. Bodenschutzgesetz, 1991).*
Upper Austrian Soil Values Values Regulation 2006	*Regulates the agricultural inputs that are permissible for application to soils within the framework of proper agricultural soil management defined in the Upper Austrian Soil Protection Act 1991 (Oö. Bodengrenzwerte-Verordnung, 2006)*

Summary of soil conditions in Upper Austria

In general, Upper Austria is not vulnerable to erosion. Erosion in arable lands is 5,65 T/ha per year, which is considered a moderate level according to European risk/vulnerability thresholds. Nonetheless, the share of agricultural land under severe soil erosion is about 9%, which is not negligible. In areas where soil erosion crosses this threshold, or where erosion rates are increasing, some measures can be taken: creating incentives against planting crops on high slopes; creating incentives for erosion control practices such as contouring, conservation tillage or mulching. Specific alternative tillage and mulching practices will depend on the crops being planted, and can often increase yields and reduce costs, however they can lead to an increase in pesticide consumption.

1.3 Biodiversity management profile

Biodiversity in Upper Austria

With the present biodiversity strategy 2020 Austria fulfils the pro-visions of Article 6 of the Convention on Biological Diversity (Federal Law Gazette No 213/1995). According to this Article, each Contracting Party shall for one develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programmes and additionally integrate the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies.

The Biodiversity Strategy Austria 2020+ defines five fields of action and twelve targets, in which it describes the priorities, which are in future to serve as an orientation for stakeholders of the Federal Government, Federal Provinces and municipalities, NGOs and all the other relevant stakeholders, in order to conserve and promote biodiversity and its ecosystem services over the long term. To conserve biodiversity we urgently need to scale up joint efforts. The implementation of the Biodiversity Strategy is a shared responsibility. In legal and administrative terms, the Biodiversity Strategy Austria 2020+ is implemented by the territorial authorities competent to do so according to the Federal Constitution as well as by the other actors and stakeholders involved in the field of biological diversity and indicated in the Strategy. The implementation is to be financed from a broad mix of public and private funds as well as through the EU co-financing system. For the federal level, financing of the implementation must be covered by the funds provided for in the relevant framework financial legislation (Federal Ministry of Agriculture, Forestry, Regions and Water Management, 2014).

The National Biodiversity Commission, which is composed of representatives from all groups in society, will assist and review the implementation of the strategy and the achievement of its objectives. The members of the Commission present an annual report on the measures taken in their scope of responsibility to implement the strategy and reach the objectives. In 2017, these annual reports will be summarised and presented to the Commission. In 2020, in a comprehensive evaluation report, the changes are to be presented compared to 2010 – unless the reporting obligations require that other reference years are used. Any adjustments and further strategic planning will be developed from 2020 onward (The Biodiversity Information System Europe, n.d.)

The biodiversity strategy Austria 2020+ is embedded in a variety of legal and political framework conditions. The most essential legal foundations at an international and EU level are formed by the Convention on Biological Diversity, the Habitats Directive and the Birds Directive, the Water Framework Directive and the new regulation on Invasive Alien Species. At a national level, the nature conservation laws adopted by the Federal Provinces are significant, which are complemented by further legal standards of the Federal Provinces, such as regulations on species protection and protected areas. Of relevance for biological diversity is also the National Parks Strategy. Moreover, legal 6 Non-governmental organisation regulations such as the Austrian Forest Act and regulations relating to other sectors that have a significant impact on land use, such as spatial planning, traffic planning, water management, hunting and fishing, are of further significance. Also, the relevant protocols of the Alpine Convention, the Berne, Bonn and the Ramsar Convention, as well as environment-related criminal law and the Aarhus Convention constitute further important framework conditions. The EU Biodiversity Strategy 2020, the strategies of the Federal Government and the Federal Provinces on various topics define fundamental political objectives and intentions. Also relevant to biological diversity are the strategies and planning concepts of other sectors, for example Austria's Energy Strategy, the National Action Plan on Plant Production Products (= pesticides), the Austrian Tourism Strategy, the Austrian Spatial Development Concept, the Austrian Traffic Master Plan or plans at a regional level, such as regional development programmes or zoning plans. We can conclude by pointing out that almost everything people do and, consequently, practically all legal rules and regulations may have an impact on the conservation and development of biological diversity. The protection of biological diversity helps to secure the business location Austria and should continue to do so in the future. In many areas, it is therefore crucial to develop holistic solution strategies by involving all societal stakeholders (The Biodiversity Information System Europe, n.d.).

Protecting biodiversity in Upper Austria

The Environmental Liability Directive 2004/35/EC creates a Europe-wide regulatory framework for the prevention and remediation of environmental damage. It is implemented in Austria by the Federal Environmental Liability Act, Federal Law Gazette No. 55/2009 (in relation to damage to water and soil) and in Upper Austria by the Upper Austrian Environmental Liability Act, Federal Law Gazette No. 95/2009 (in relation to damage to protected animal and plant species and natural habitats and damage to soil caused by the performance of certain professional activities) (BMK, n.d.a).

The basic principle is that an operator who causes environmental damage or the imminent threat of such damage through his or her professional activity and thus damages certain protected environmental assets should bear the costs of the necessary preventive and remedial measures. (polluter pays principle) This is intended to encourage operators to take measures and develop practices to minimize the risk of environmental damage in order to reduce the risk of financial liability (Federal Ministry of Agriculture, Forestry, Regions and Water Management, 2014).

Table 24: Main policies for protecting biodiversity in Upper Austria

Main policies for protecting biodiversity in Upper Austria	
Upper Austrian Nature and Landscape Conservation Act 1995	*The aim of the legislation is the preservation of the diversity, uniqueness and beauty of nature and landscape, the preservation of the efficiency of the natural balance as well as the preservation of biodiversity in terms of animal and plant species in Upper Austria*
Natura 2000	*European ecological network of natural sites designated under the "Habitats" and "Birds" Directives, with the aim of conserving habitats and species of Community interest (BMK, n.d.c.).*
Directive No 2009/147/EC	*The Directive aims at protecting all wild birds naturally occurring on the territory of the European Community. This goal is achieved by means of establishing bird protection areas as well as by specific provisions concerning the utilisation of species. Protected areas according to the Birds Directive are part of the Natura 2000 network (BMK, n.d.b).*
Council Directive No 92/43/EEC of 21 May 1992	*The aim of this Directive shall be to contribute towards ensuring the protection, conservation, and restoration of a sufficient and representative sample of an area of a sufficient and representative size of natural habitats in Europe. The directive is part of the Natura 2000 network (BMK, n.d.c.).*

In terms of biodiversity reporting, there are several institutions that are members of the IUCN, including the Austrian nature conservation association, the ministry for Climate Protection, Energy, Mobility, Innovation and Technology (BMK) which is also responsible for reporting, the World Wide Fund for Nature (WWF) and several associations and institutions centered around wild life protection and conservation (BMK, n.d.c).

Based on the national Red List of Threatened Species, the authors of this report have looked into the list of "endangered" and "critically endangered" species (flora and fauna) that are likely to be impacted by the development of bioeconomy activities in Upper Austria. In general, 1,274 ferns and flowering plants are on Austria's "Red List". 66 species are extinct or lost throughout Austria, 235 species are threatened with extinction and a further 973 species are endangered to a lesser or, in rare cases, unknown extent. Further, more than half of all amphibians and reptiles are critically endangered, as are almost half of all fish and a third of all birds and mammals (Umweltbundesamt, n.d.).

2 Methodology of appraisal of available capacity of the regional ecosystem

Using existing indicators and expert opinion from within and beyond the screening team, this part of the screening will yield a qualitative (ordinal) categorization of the capacity of the ecological systems in the region to underpin bioeconomy activities. Thus, the key output to be presented here is the baseline setting from which a regional bioeconomy strategy/roadmap could be updated or developed. The text in this chapter is strongly based on the description of the methodology for the BE-Rural Sustainability Screening presented in Anzaldúa et al. (2022), with only minor adaptations that resulted from the implementation of the approach in SCALE-UP.

2.1 Water data and indicators

To run the sustainability screening of surface and groundwater bodies potentially relevant to the Upper Austrian region, the authors of this report have reviewed the data reported in the 2nd River Basin Management Plans (RBMPs) of the Danube River Basin District published in 2016 (data from the 3rd reporting cycle was not yet available on the WISE Database at the time of the analysis). The benefits of tapping on this reporting process is that it includes well-defined indicators like the status of water bodies in each RBD as well as data on significant pressures and impacts on them. Further, these data are official, largely available, accessible, and updated periodically (every six years). Authorities in charge of developing a regional bioeconomy strategy would generally be expected to have good access to the entity in charge of developing the River Basin Management Plan (i.e. the River Basin Authority), and so could theoretically consult it if necessary.

2.1.1 Description of the data / definition of the indicators employed

Data reviewed for this part of the screening included the reported ecological and chemical status of rivers and lakes as well as the quantitative and chemical status of groundwater bodies in the Danube river basin district in Upper Austria. These data give indications on water quality in the river basin according to the five status classes defined in the WFD. These are: high (generally understood as undisturbed), good (with slight disturbance), moderate (with moderate disturbance), poor (with major alterations), and bad (with severe alterations) (EC, 2003). Further, data on significant pressures and significant impacts on the water bodies in the river basin districts are used to indicate the burden of specific pressure and impact types on water ecosystems in the regions based on the number and percentage of water bodies subject to them. Significant pressures are defined as the pressures that underpin an impact which in turn may be causing the water body to fail to reach at least the good status class (EEA, 2018b).

All data described above were accessed on 11.10.2023 from the WISE WFD data viewer (Tableau dashboard) hosted on the European Environment Agency's website (EEA, 2018a).

Table 25: Indicators used for the water component of the sustainability screening

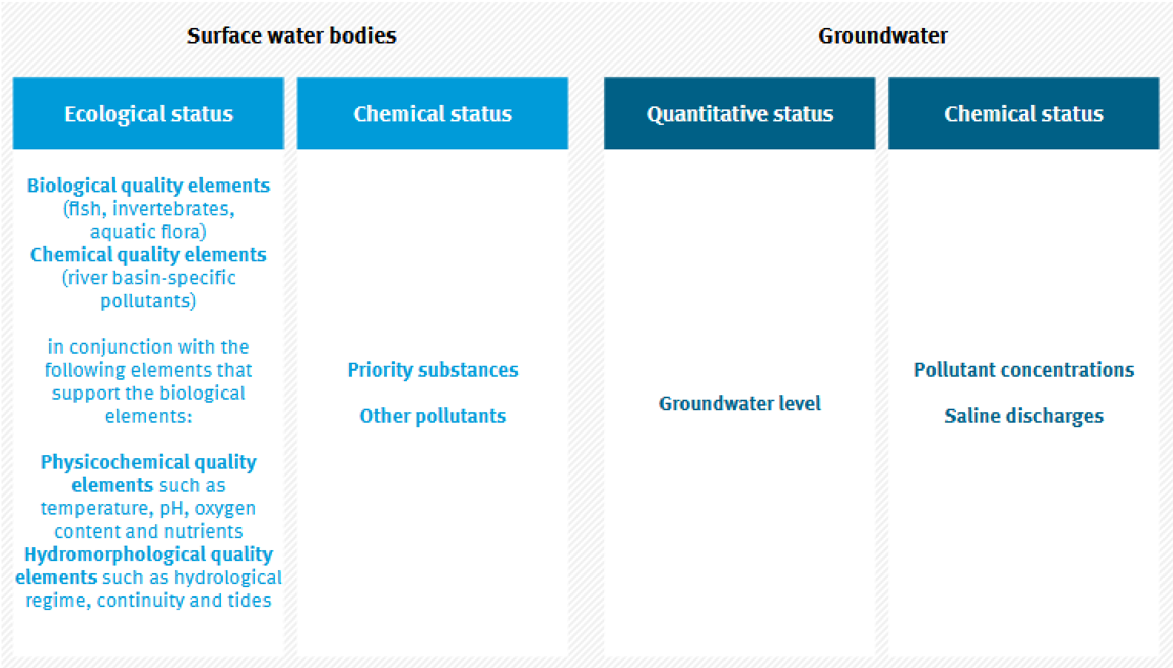
Category	Indicator Family	Indicator	Spatial level	Unit of measure	Comments/Reference
Water	Water quality	Status of water bodies according to the EU Water Framework Directive	River Basin District	Number of water bodies in high, good, moderate, poor, bad or unknown status	WISE WFD Data Viewer (EEA, 2018a) Disaggregated data for ecological and chemical status of surface water bodies; quantitative and chemical status of groundwater bodies, per River Basin District
	Burden on water bodies	Significant pressures on water bodies	River Basin District	No. and % of water bodies under significant pressures per pressure type	WISE WFD Data Viewer
	Burden on water bodies	Significant impacts on water bodies	River Basin District	No. and % of water bodies under significant impacts per impact type	WISE WFD Data Viewer

Source: Anzaldúa et al., 2022.

To determine which status class a certain water body falls into, WFD assessments evaluate the *ecological* and *chemical* status of surface waters (i.e. rivers and lakes) and the *quantitative* and *chemical* status of groundwater bodies. Ecological status refers to *“an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters”*. It covers assessments of biological (e.g. presence and diversity of flora and fauna), physico-chemical (e.g. temperature and oxygen content) and hydro-morphological criteria (e.g. river continuity) (EC, 2003; BMUB/UBA, 2016). The chemical status of a surface water body is determined by comparing its level of concentration of pollutants against pre-determined environmental quality standards established in the WFD (concretely in Annex IX and Article 16(7)) and in other relevant Community legislation. These standards are set for specific water pollutants and their acceptable concentration levels.

In the case of groundwater bodies, chemical status is determined on the basis of a set of conditions laid out in Annex V of the WFD which cover pollutant concentrations and saline discharges. Additionally, the water body’s quantitative status is included in the WFD assessments, defined as “an expression of the degree to which a body of groundwater is affected by direct and indirect abstractions”. This gives indication on groundwater volume, a relevant parameter to evaluate hydrological regime (BMUB/UBA, 2016).

Figure 45 Overview of surface water body and groundwater status assessment criteria, as per the Water Framework Directive.



Source: BMUB/UBA, 2016.

In the case of surface water bodies, the WFD objective is not only that they reach good status, but that quality does not deteriorate in the future (EC, 2003), which is relevant in the context of the development of bioeconomy value chains.

2.1.2 Methodology applied

The authors of this report have devised an approach to valorise the data from the WFD reporting described in the previous sub-section that allows for an appraisal that is non-resource intensive (based on reliable, publicly available, and accessible data) yet capable of providing a rough overview of the state of the Upper Austrian Waters. This is in line with the rationale of this sustainability screening, which aims to enable stakeholders with limited financial resources and/or expertise in the field to consider ecological limits in a structured manner when developing bioeconomy activities. The preferred option for this part of the assessment would have been to supplement the WFD data with a water quantity balance indicator like the Water Exploitation Index plus (WEI+) developed by the EEA and its partners. That indicator compares the total fresh water used in a country per year against the renewable freshwater resources (groundwater and surface water) it has available in the same period. This could have strengthened the water quantity element in the screening. However, the calculation of the WEI+ at regional level is currently not conducted or foreseen by its developers, and it would entail a disproportionately large effort that falls beyond the scope of this task in SCALE-UP. For these reasons, the reported data from the WFD process has been employed exclusively within the following methodology.

The overall apportionment of rivers, lakes and groundwater bodies in Upper Austria according to their WFD status classification can be used to set the baseline for the sustainability screening. It provides initial insight on the situation in the demarcation as regards “ensuring access to good quality water in sufficient quantity”, “ensuring the good status of all water bodies”, “promoting the sustainable use of water based on the long-term protection of available water resources” and “ensuring a balance between abstraction and recharge of groundwater, with the aim of achieving good status of groundwater bodies”, all explicit aims of the WFD that are aligned with the consideration of ecological limits. Further, the data on significant impacts and pressures affecting the water bodies in the river basins are useful as they can point towards specific problems (e.g. chemical pollution) and the types of activities that may be causing them (e.g. discharge of untreated wastewater, agriculture).

As a first step, the approach used for this element of the screening entails calculating what proportion of the total number of surface water bodies located in the RBD is reported as failing to achieve Good Ecological Status/Good Chemical Status or for which conditions are unknown. Similarly for groundwater bodies, the proportion is calculated of those who are reported as failing to achieve Good Chemical Status/Good Quantitative Status or for which conditions are unknown. The resulting ratios are then compared to the respective EU proportions, which are used as (arbitrary) thresholds. According to the latest assessment published by the EEA in 2018, "around 40% of surface waters (rivers, lakes and transitional and coastal waters) are in good ecological status or potential, and only 38% are in good chemical status" (EEA, 2018b). Accordingly, "good chemical status has been achieved for 74% of the groundwater area, while 89% of the area achieved good quantitative status" (EEA, 2018b). Using these markers, the following step is to rank the current conditions of the Upper Austrian region using an ordinal risk rating (high, moderate, low) based on the distance of the result of each indicator to the EU level results. On this basis, the thresholds and ordinal ranking convention suggested by the authors of this report are as shown in Table 5 and Table 6.

Table 26: Proposed thresholds for the water section of the sustainability screening

Water body type	Status category	2018 EU-level assessment results (proportion of water bodies achieving good status)	Proposed thresholds for the sustainability screening		
			High concern	Moderate concern	Low concern
Surface water bodies	Ecological status	~40%	0-40%	41-89%	90-100%
	Chemical Status	38%	0-38%	39-89%	90-100%
Groundwater bodies	Chemical status	74%	0-74%	75-89%	90-100%
	Quantitative status	89%	0-89%	-	90-100%

Source: Anzaldúa et al., 2022.

Table 27: Ordinal ranking convention for the water section of the sustainability screening

Ordinal ranking for water resources		Chemical status		
		High concern	Moderate concern	Low concern
Ecological or Quantitative status	High concern			
	Moderate concern			

	Low concern			

Source: Anzaldúa et al., 2022.

This initial appraisal based on the thresholds shown above is then supplemented with a review of the reported data on the types of significant pressures and impacts on surface and groundwater bodies. In this case percentage values are already given, and so this step in the screening simply entails the listing of the reported pressures and impacts and the identification of those which are more frequently reported. From here, the screening team can seek potential correlations between the most reported pressure types and the most reported impact types (e.g. diffuse sources causing nutrient pollution).

The final step in the approach is to draft a note describing the share of water bodies failing to reach good status and formulating preliminary statements on the types of bioeconomy activities that could be considered, those that should be considered with reserve, and those that should be avoided. These initial statements are intended to frame the discussion of the group of stakeholders involved in the development of the bioeconomy value chains in focus in the SCALE-UP project (BMLRT, 2021).

2.1.3 Data uncertainties

Water management in Upper Austria relies heavily on accurate and reliable data to make informed decisions regarding resource allocation, environmental protection, and disaster prevention. However, the nature of water systems and the dynamic environment introduces various uncertainties in the data collected and analysed. This chapter explores the key sources of data uncertainties in water management and the challenges they pose in the regional context.

Monitoring water quality is critical for assessing the health of water bodies and ensuring compliance with environmental standards. However, the spatial and temporal variability of pollutants, as well as the limited number of monitoring stations, contribute to uncertainties in water quality data. Additionally, the detection limits of analytical methods and the presence of emerging contaminants further complicate the assessment of water quality.

The data resulting from the assessments reported in the Upper Austrian region and subsequently in WISE are subject to the limitations of the scientific and methodological approaches used by their authors. For instance, the summary of the 2016-2021 RBMP for the Danube River Basin District (DRBD) makes references to actions undertaken to improve the accuracy and reliability of the assessment of the conditions of water bodies in the RBD relative to the first cycle reporting. Further, the implementation of the WFD within the DRBD is substance to individual implementation measures on national level, which creates uncertainties in the interpretation of data for the nations included in the DRBD. Additionally, in Austria, each of the federal states, including Upper Austria, is responsible for implementing the national management plan individually, which results in further uncertainties in measuring and reporting the respective data. Lastly, the national water management plans are open for the public to discuss and comment, which could potentially carry a margin of error.[140]

Lastly, another issue to consider is the data currently available on WISE is from 2016, while more updated (interim) assessments are already available at the time of writing of this document. These come as part of the 3rd cycle of river basin management planning (2022-2027) but are not yet publicly available. The data used from the literature review is mainly based on state of water quality in the water districts in 2020, based on data from 2016-2017.

[140] National Management Plan Updates 2021 | ICPDR - International Commission for the Protection of the Danube River

2.1.4 Methodological uncertainties

In the EU, the Water Framework Directive requires that the costs of water services provided to households are sufficiently recovered through water tariffs. Notably though, both water tariffs and their contribution to financial cost recovery are subject to a combination of intrinsic factors that often vary across, or even within, countries. Among others, such factors may range from disparities in the quality of the service itself to conceptual inconsistencies in the calculation of cost recovery levels, and from differences among management models and institutional frameworks to varying levels of dependency on public and EU funding. Thus, direct comparisons between countries are deemed unfeasible, and comparisons between national subdivisions (e.g. municipalities, RBDs) should carefully account for intrinsic differences (e.g. what services and other items, like asset depreciation, are included in the price and considered in the cost recovery calculations). Further, it should be noted that a higher rate of recovery of financial costs does not necessarily hold correlation with a higher average price for the water service. This responds to the fact that the weight of water tariffs in the mix of the service providers' total revenue, and/or in the calculation of financial cost recovery levels, varies. For instance, reported average prices between 0.58 and 4.18 Euros per cubic meter all result in more than 100% recovery of financial cost in different RBDs.

The proposed methodology for the water section used in this application of the sustainability screening is straight-forward and accessible, yet it must be used with care and, where possible, should incorporate higher resolution data evaluated by thematic experts. As previously mentioned, the thresholds set in this case have been the proportions, at EU-level, of water bodies that fail to achieve good status or for which conditions have been reported as unknown. Optimally, these thematic experts should know the regional context well and thus be in a good position to guide the setting of such thresholds. Beyond this, the simplicity of the necessary calculations and the fact that the data on significant pressures and impacts are used without further computation and compared in relative terms within the RBD limit the possibility of additional accuracy or uncertainty issues emerging.

In case of the Upper Austrian sustainability screening, the data for the ecological status of water bodies, especially regarding the failure of all surface water bodies in terms of "chemical status", was evaluated with the responsible representative at the section for water management and reporting at the federal office of the state Upper Austria. It was reported that there are still no clear indications to why all of the surface water bodies fail in regard to chemical pollution. It was discussed that uncertainties in the measurements, the influence of industrial sites – especially around the state's capital Linz which has a large-scale industrial area located along the Danube – and their wastewaters could be main impact factors to the results of the water reporting.

According to the water management plan 2021, following reasons were stated as main causes for the failure of the chemical assessment:

"…due to the contamination with ubiquitous EU pollutants (primarily mercury, brominated diphenylethers), 100% of water bodies are at risk of failing to meet the target. If only the other EU and national pollutants (here mainly fluoranthene and individual metals), 11.7% of water bodies show a risk of failing to meet the target. The reason for this is predominantly diffuse inputs. Discharges from point sources are only responsible for a very small contributors to a very small extent. Chemical pollution from industry (paper, metal, chemicals, etc.) and untreated wastewater, chemicals, etc.) and untreated municipal wastewater, which characterized the pollution pattern of Austrian waters in the 1970s and 80s have now been reduced, mainly thanks to thanks to technical wastewater treatment measures and operational prevention, retention, and purification measures" (Federal Ministry of Agriculture, Forestry, Regions and Water Management, 2021).

Further uncertainties could be derived from deviation in the interpretation of satellite imagery, scalability of the data and the scale at which the data is collected, deviations from predictions made from outdated data sources or uncertainties from variations in sampling techniques.

2.2 Soil data and indicators

2.2.1 Description of the data / definition of the indicators employed

The selected indicators for vulnerability to soil depletion are closely interrelated and refer specifically to soil erosion **by water**. These are:

- Estimated mean soil erosion rate (in $t\ ha^{-1}\ a^{-1}$)
- Share (%) of area under severe erosion (>10 $t\ ha^{-1}\ a^{-1}$)

In broad terms, soil erosion describes the process through which land surface (soil or geological material) is worn away (e.g. through physical forces like water or wind) and transported from one point of the earth surface to be deposited somewhere else (Eurostat, 2020). The above-mentioned indicators describe particularly the amount of soil (in t) per unit of land surface (in ha) that is relocated by water per year.

Variations of these indicators can be calculated by considering different combinations of land cover classification groups, such as *all land*[141] and *agricultural land*[142]. As shown in 14, at EU level in 2016, about three quarters of soil loss occurred in agricultural areas and natural grasslands, while the remaining quarter occurred in forests and semi natural areas (Eurostat, 2020). Therefore, since it is the type of land cover that is most vulnerable to erosion, the present sustainability screening will consider in first line the above-mentioned indicators specifically for agricultural areas and natural grasslands. This scope of the indicators is also in line with the two sub-indicators for soil erosion considered by the Joint Research Centre European Soil Data Centre (JRC ESDAC). Moreover, both the *mean erosion rate for agricultural land* and the *share of agricultural area under severe erosion* are part of the EU Common Agriculture Policy (CAP) context indicator 42 (CCI42) for the period 2014-2020.

Figure 46: Share of land cover and soil loss across the EU-27 in 2016

Source: JRC, Eurostat

The data has been extracted from EUROSTAT, specifically the dataset "Estimated soil erosion by water, by erosion level, land cover and NUTS 3 regions (source: JRC) (aei_pr_soiler)". For determining the baseline in the sustainability screening, we have selected the latest available data, i.e. for 2016.

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[141] This refers to all potentially erosive-prone land (in simplified terms), specifically to CORINE Land Cover classification groups: Agricultural areas (2), forest and semi natural areas (3) excluding beaches, dunes, sand plains (3.3.1), bare rock (3.3.2), glaciers and perpetual snow (3.3.5). These, as well as other classes, are excluded because they are not subject to soil erosion.

[142] This refers only to agricultural land (agricultural cropland as well as grassland in simplified terms), specifically to CORINE Land Cover classification groups: Agricultural Areas (2) and Natural Grasslands (321).

Mean soil erosion rate, which undergirds both selected indicators, is considered useful because it provides a solid baseline to estimate the actual erosion rate in the regions (Panagos et al., 2015). This indicator is based on the latest Revised Universal Soil Loss Equation of 2015 (RUSLE2015), specifically adapted for the European context (see Panagos et al., 2015), which is a model that takes into account various aspects, including two dynamic factors, namely the cover-management[143] and policy support practices[144] (both related to human activities) (Panagos et al., 2020).

The estimated mean soil erosion rate value obtained through the RUSLE2015 model refers to water erosion only, but it is considered to be the most relevant at least in terms of policy action at EU level, due to the relative predominance of water erosion over other types of erosion. Furthermore, it offers the important advantage of providing a viable estimation for erosion vulnerability at a relatively small geographic scale, i.e. the local or regional level. This can serve as an important tool for monitoring the effect of local and regional policy support strategies of good environmental practices (Panagos et al., 2015, 2020 and Eurostat, 2020).

2.2.2 Methodology applied

The data sources used were those published in the JOINT RESEARCH CENTRE (JRC). Within this database, the EUROPEAN SOIL DATA CENTRE (ESDAC) has been consulted. ESDAC is the thematic centre for soil-related data in Europe and within it is the EU Soil Observatory (EUSO). The EU Soil Observatory (EUSO) aims to become the main provider of reference data and knowledge at EU level for all soil-related issues.

The near-universal indicators available to track soil vulnerability are related to either erosion or the decline in soil organic carbon (SOC)/soil organic matter (SOM) (Karlen & Rice, 2015). However, there are major data gaps regarding to SOC/SOM and data is currently only available at national level. According to Panagos et al. (2020), soil organic carbon does not change so quickly and therefore is not so sensitive to human influence on short term. Therefore, they recommend using just a sole indicator for monitoring impact of policies: “estimated mean soil erosion rate” (by water), which they calculate using the RUSLE2015 model. For our purposes, we have complemented the *mean soil erosion rate* indicator, with the *share of agricultural area under severe erosion* in order to gain a comprehensive picture of soil erosion in a region.

Soil erosion is considered generally as a sort of proxy indicator of soil degradation, which in turn is the most relevant component of land degradation at EU level (EC, 2018b). However, not all types of bio-based activities have a direct effect on erosion, but rather primary production of biomass. Nonetheless, as these are currently the most widespread bioeconomy activities in rural areas, we will consider their impact on soil degradation, and therefore on soil erosion, to be the most relevant one for this assessment.

The indicators for vulnerability to soil degradation were selected, on one hand, due to the limited number of soil indicators available at the required regional scale. On the other hand, the RUSLE2015 model used for this data also represents the current state-of-the-art methodology for calculating soil erosion. These aspects are crucial, since the choice of indicators needs to be: a) acceptable to experts, b) routinely and widely measured, and c) have a currency with the broader population to achieve global acceptance and impact (Stockmann et al., 2015). In order to carry out the screening of soil vulnerability, a number of datasets need to be accessed. As mentioned above, this data can be accessed via Eurostat.

[143] Known as the c-factor, it has a non-arable component, which includes changes in land cover and remote sensing data on vegetation density, as well as an arable component, which includes Eurostat data on crops, cover crops, tillage and plant residues.
[144] Known as the p-factor, it reflects the effects of supporting policies in estimating the mean erosion rate by including data reported by member states on Good Agricultural Environmental Conditions (GAEC) according to the CAP, specifically contour farming, as well data from LUCAS Earth observation on stone walls and grass margins.

In terms of processing the erosion data, it is important to consider that the overall erosion rate changes across geographic areas, meaning the vulnerability/risk is not necessarily evenly distributed. In cases where the mean soil erosion rate exceeds the 10 t ha^{-1} a^{-1}, erosion is considered severe and activities that can generate, or are associated with a high erosion impact should be strongly discouraged. Erosion rates between 5 and 10 t ha^{-1} a^{-1} are considered moderate, requiring some attention towards practices that have a high impact on erosion, but with less urgency. However, it is relevant to take a look not only at the mean erosion rate for the area itself, but also at its spatial distribution, which is roughly reflected on the indicator of share of (agricultural) area under severe erosion.

2.2.3 Data uncertainties

The data used is produced from an empirical computer model (RUSLE2015) and produces estimates. Hence, there are several uncertainties related to the figures if compared to data collected on the ground. However, the purpose of the model is to generate data for a large spatial scale taken into account human intervention, which is not possible to do only through empirical measurements. That being said, like every model, assumptions have to be made and there is an intrinsic level of uncertainty. Specifically related to the RUSLE methodology, Benavidez et al. (2018) critically reviewed the RUSLE methodology, upon which RUSLE2015 is based, and identified following main limitations:

- its regional applicability to regions that have different climate regimes and land cover conditions than the ones considered (in the original RUSLE for the USA, in RUSLE 2015 for Europe)
- uncertainties associated generally with soil erosion models, such as their inability to capture the complex interactions involved in soil loss, as well as the low availability of long-term reliable data and the lack of validation through observational data of soil erosion, among others.
- issues with input data and validation of results,
- its limited scope, which considers only soil loss through sheet (overland flow) and rill erosion, thus excluding other types of erosion which may be relevant in some areas, e.g. gully erosion and channel erosion, to name a few. Moreover, it also excludes wind erosion.

A further factor of uncertainty in the data is the fact that the RUSLE model is calculated using mean precipitation data over multiple years and a large territorial scale (in this case Europe). Thus, it fails to account the changes in rainfall intensity, which are highly relevant for determining water erosion accurately. This is the case not only considering the seasonality of rainfall, but also its distribution across the continent (Panagos et al., 2020). Another important uncertainty identified by Panagos et al. (2020) is the lack of georeferenced data for annual crops and soil conservation practices in the field at a continental level, which has had to be estimated from statistical data.

Nonetheless, when considered best available estimates, the mean soil erosion values generated through the application of RUSLE2015 model offer a very suitable basis for assessing vulnerability to soil loss in general terms, even if the generated absolute values are to be taken with caution (Benavidez et al., 2018).

2.2.4 Methodological uncertainties

Among the most relevant uncertainties regarding the application of the sustainability screening in terms of soil vulnerability are the selection of the threshold against which the severity of erosion is evaluated and the selection of the land cover types that will be considered.

Regarding the threshold of 10 t ha^{-1} a^{-1} for severe erosion, it is important to mention that this was obtained directly from the dataset that was used (Eurostat, 2019). However, it is still an arbitrary value which can be adapted. For instance, some sources like Panagos et al. (2015, 2020), who were involved in the generation of the data for the JRC ESDAC, consider severe erosion to be above 11 t ha^{-1} a^{-1}. In this regard, we have also decided to stick to the lower value described in the Eurostat dataset because it is more conservative and, as such, more suitable for an initial (and indicative) sustainability screening like the one we are proposing.

The selection of land cover types presents another area for potential uncertainty. Choosing between “all lands” and “agricultural lands” can have considerable implications for interpreting the data. For example, it is possible that the mean soil erosion rate is 5 t ha^{-1} a^{-1} (moderate erosion) in one land cover type, but lower in the other. This would influence the assessment, which would present any potential concerns about erosion and steps that should be taken. As such, it is important to have solid grounding for the choice of dataset. The ultimate decision whether to consider all lands (including forests) is arbitrary and lays with the group performing the sustainability screening. Particularly when that decision is based on considerations of the economic relevance of forestry related industries in the region rather than on the actual share of the area that is covered with forest (it should be high to justify their inclusion), the values of soil erosion (for all lands) shall be taken with some reservations. This is because these values tend to be lower than the value for agricultural land and can create the impression that vulnerability to erosion is lower than it actually is. However, due to the indicative (and non-exhaustive) nature of the present sustainability screening, this uncertainty is not especially relevant for cases such as Upper Austria, which has a high proportion of forest land and where both values (for all lands and agricultural land with natural grassland) are low.

2.3 Biodiversity data and indicators

2.3.1 Description of the data / definition of the indicators employed

Unlike for water- and soil-related risks, there are no reliable indices or standardized metrics to operationalize and compare risks to biodiversity at the regional level and in an integrated manner. Biodiversity is intricate and multifaceted, spanning genetic, species, and ecosystem diversity across various regions. Attempting to consolidate this diversity into a singular index may oversimplify it, leading to the loss of crucial information (Ledger et.al 2023; Brown & Williams 2016). Instead, biodiversity risks in a given region could be uncovered by considering the status of all species known to inhabit the region under scrutiny on a one-by-one basis, without trying to synthesize their collective status in a single index. Accordingly, our methodology suggests screening for biodiversity risks of a region by taking stock of its species of flora, fauna and fungi present in the demarcation and considering their conservation status. The Red List of Threatened Species of *the International Union for Conservation of Nature* (IUCN) is a globally recognized system for classifying the conservation status of species[145]. It is structured along the following risk categories (IUCN, 2001; IUCN, 2003):

(1) Critically Endangered (CR): This is the highest risk category assigned by the IUCN Red List for wild species. Species in this category are facing an extremely high risk of extinction in the wild.

(2) Endangered (EN): Species in this category are facing a high risk of extinction in the wild.

(3) Vulnerable (VU): Species in this category are facing risks of extinction in the wild.

(4) Near Threatened (NT): Species in this category are close to qualifying for, or are likely to qualify for, a threatened category soon.

(5) Least Concern (LC): Species in this category have been evaluated but do not qualify for any other category. They are widespread and abundant in the wild.

[145] The International Union for Conservation of Nature (IUCN) is a global environmental organization that was founded on October 5, 1948. It is the world's oldest and largest global environmental network. The IUCN works to address conservation and sustainability issues by assessing the conservation status of species, promoting sustainable development practices, and providing guidance and expertise on environmental policy and action. The IUCN also plays a crucial role in influencing international environmental policies and fostering collaboration among governments, NGOs, and the private sector to promote conservation efforts worldwide (IUCN, 2018).

(6) Data Deficient (DD): A category applied to species when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution or population status.

(7) Not Evaluated (NE): A category applied to species that have not yet been evaluated against the criteria (IUCN, 2001; IUCN, 2003).

Data on the risk category of each species found in the SCALE-UP regions is accessed through the online database of the IUCN Red List website. The IUCN Red List serves as a comprehensive repository of information, offering insights into the present extinction risk faced by assessed animal, fungus, and plant species. In 2000, IUCN consolidated assessments from the 1996 IUCN Red List of Threatened Animals and The World List of Threatened Trees, integrating them into the IUCN Red List website with its interactive database, currently encompassing assessments for over 150.300 species. Since 2014, assessors of species have been mandated to furnish supporting details for all submitted assessments. Among the recorded details are the species' (1) IUCN Red List category, (2) distribution map, (3) habitat and ecology, (4) threats and (5) conservation actions. The assessment of these dimensions is elaborated below:

(1) The IUCN Red List category: The IUCN Red List categories (CR, EN, VU, NT, LC, DD, NE) are determined through the evaluation of taxa against five quantitative criteria (a-e), each grounded in biological indicators of population threat:

   a. Population Size Reduction: This criterion evaluates the past, present, or projected reduction in the size of a taxon's population. It considers the percentage reduction over a specific time frame, with different thresholds indicating different threat levels.
   b. Geographic Range Size and Fragmentation: This criterion assesses the size and fragmentation of a taxon's geographic range. Factors such as few locations, decline, or fluctuations in range size contribute to the evaluation.
   c. Small and Declining Population Size and Fragmentation: This criterion focuses on taxa with small and declining populations, considering factors like population size, fragmentation, fluctuations, or the presence of few subpopulations.
   d. Very Small Population or Very Restricted Distribution: This criterion addresses taxa with extremely small populations or limited distributions. It assesses whether the taxon is at risk due to its small population size or restricted geographic range.
   e. Quantitative Analysis of Extinction Risk: This criterion involves a quantitative analysis, such as Population Viability Analysis, to estimate the extinction risk of a taxon. It considers various factors influencing population dynamics and extinction risk.

While listing requires meeting only one criterion, assessors are encouraged to consider multiple criteria based on available data. Quantitative thresholds of the IUCN Red List categories were developed through wide consultation and are set at levels judged to be appropriate, generating informative threat categories spanning the range of extinction probabilities. To ensure adaptability, the system permits the incorporation of inference, suspicion, and projection when confronted with limited information.

(2) The distribution map: The IUCN Red List distribution map serves as a reference for the taxon's occurrence in form of georeferenced data and geographic maps. This data is available for 82% of the assessed species (>123.600) and is based on the species' habitat, which is linked to land cover- and elevation maps. The indicated area marks the species extent of occurrence, which is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred, or projected sites of present occurrence of a species, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of species, such as large areas of obviously unsuitable habitat. For

a detailed explanation of the mapping methodology, please refer to the *Mapping Standards and Data Quality for the IUCN Red List Spatial Data* (IUCN 2021).

(3) Habitat and Ecology: The IUCN classifies the specific habitats that a species depends on for its survival. These habitats are categorized into three broad systems: terrestrial, marine, and freshwater. A species may inhabit one or more of these systems, and so the possible permutations result in seven categories of natural systems.

(4) Beyond these seven system categories, the IUCN offers a more nuanced classification system for habitats, comprising 18 different classes at level 1 (e.g., forest, wetlands, Grassland, etc.), and 106 more specific classes listed at level 2 (e.g., Forest – Subtropical/tropical moist lowland, Wetlands (inland) – Permanent inland deltas; Grassland - Temperate) (IUCN, n.d.a). For SCALE-UP's sustainability screening, the IUCN classification of the seven systems is sufficient to refine the search while not excluding relevant habitats. The EU Habitats Directive, in contrast, distinguishes 25 habitat types that are considered threatened and require active and recurring conservation action. The directive demands member states to take measures to maintain or restore these natural habitats and wild species.

(5) Threats: The IUCN database encompasses various general threats that can negatively impact a species. Direct threats denote immediate human activities or processes impacting, currently impacting, or potentially affecting the taxon's status, such as unsustainable fishing, logging, agriculture, and housing developments. Direct threats are synonymous with sources of stress and proximate pressures. Assessors are urged to specify the threats that prompted the taxon's listing at the most granular level feasible within this hierarchical classification of drivers. These threats could be historical, ongoing, or anticipated within a timeframe of three generations or ten years. These generalized threat categories encompass residential and commercial development, agriculture and aquaculture, energy production and mining, transportation and service corridors, biological resource use, human intrusion and disturbances, natural system modifications, invasive and other problematic species, genes and diseases, pollution, geological events, and climate change and severe weather. Beneath each general threat, more specific threats are detailed. Please refer to the appendix for a detailed list of all threats including explanations.

(6) Conservation Actions: The IUCN database contains conservation action needs for each species, providing detailed information on the current conservation efforts and recommended actions for protecting the taxon. It includes general conservation actions such as research & monitoring, land/water protection, management, and education. Specific conservation actions are listed under each general action, along with a description of the current conservation status and recommended actions to protect the taxon. A hierarchical structure of conservation action categories (see appendix) indicates the most urgent and significant actions needed for the species, along with definitions, examples, and guidance notes on using the scheme. Assessors are encouraged to be realistic and selective in choosing the most important actions that can be achieved within the next five years, informed by the conservation actions already in place.

IUCN Red List and Habitat Directive
Both the EU's Habitats Directive and the IUCN Red List aim to preserve biodiversity, but they employ distinct methods and standards for evaluating conservation status. The Habitats Directive is centered on preserving natural habitats and wild species of flora and fauna within the European Union, mandating that member states establish Special Areas of Conservation

for habitats and species listed in its annexes. The Directive categorizes conservation status into three groups: favorable, unfavorable-inadequate, and unfavorable-bad. This classification system of habitats and species is based on how far they are from the defined ‘favorable’ conservation status, not their proximity to extinction (Sundseth, 2015).

Conversely, the IUCN Red List is a worldwide evaluation of the conservation status of species, categorizing them according to their extinction risk. The Red List employs a set of five rule-based criteria to assign species to a risk category (see above).

However, there are inconsistencies and weak agreement between the conservation status assessments of the Habitats Directive and the IUCN Red List. These inconsistencies can be significant, and correlations can vary greatly between taxonomic groups. Specifically, the Red List assessment tends to be more pessimistic than the Directive’s Annex (Moser et.al, 2016). Amos (2021), on the other hand, has found strong correlations between the two classifications systems for plants, while recognizing the Red List’s quicker reaction to changes in the conservation status.

In summary, while both the Habitats Directive and the IUCN Red List aim to protect and conserve biodiversity, they use different methodologies and criteria to assess conservation status, leading to discrepancies in their assessments. However, they can complement each other in providing a comprehensive view of the conservation status of species and habitats at both the European and global levels (IUCN 2010).

2.3.2 Methodology applied

The methodology aims to derive a list of species which would require special consideration (e.g. close monitoring and safeguarding) in the context of implementing a bioeconomy strategy or rolling out bioeconomy activities. To generate this list, the search function of the interactive IUCN database is used following five steps:

(1) Scope of Assessment: Selection of Europe as the scope of assessment to evaluate the conservation status of the European population rather than the global population. This approach ensures that species are identified as threatened based on their status in Europe, irrespective of their global abundance.
(2) Geographical Delineation: Utilization of the interactive map of the IUCN database to draw a polygon that exceeds the region of interest. Exceeding the region ensures that the entire region is covered, as it is not possible to draw a polygon exactly matching the boundaries of the region. Moreover, a larger polygon also respects the uncertainty of delineating a species area of extent, since the actual area of extent is possibly more fluid than its statically indicated geolocations Consequently, the larger polygon minimizes the risk of excluding any relevant species for which geolocations are registered just minimally outside of the region’s administrative boundaries, but which could inhabit parts of the region in future. There is no rule of thumb for a correct distance between polygon boundary and region boundary, but it would be advisable to keep this distance below 100 km.
(3) Species Selection: Limiting of the search results to endangered and critically endangered species to focus on those facing the most severe risks.
(4) Habitat Selection: selection of all habitats to ensure the full coverage of habitat types present in the geographical delineation defined in step 2.
(5) Threat Selection: Selection of threats associated with the respective regional bioeconomy and/or value chain to refine the search results to species likely to be impacted by them.

By following these steps, a targeted list of species is derived, focusing on species facing significant risks within the context of the regional bioeconomy strategy or value chain being explored, aligning with the specific conservation and bioeconomic priorities of the region.

2.3.3 Data and methodological uncertainties

It is important to acknowledge certain limitations and uncertainties associated with the data and methodologies used:

(1) Inaccurate representation of relevant area: The IUCN database allows for the interactive drawing of a map for a regional assessment. However, this drawn map might not accurately represent the area directly relevant to the bioeconomy strategy or value chain being explored. Since the selected polygon is larger than the actual bioregion, the assessment risks to include species that are not relevant to the bioregion and the bioeconomic strategy of the region.

(2) Lack of local habitat differentiation: The spread of species is indicated as its extent of occurrence without differentiating between habitats at the local level. This means that certain species might solely inhabit very particular habitats within the indicated extent of occurrence. An endangered amphibious species, for instance, might have an area of extent covering an entire country. However, it will only be found in very rare habitats within this area of extent (e.g., pond with very specific qualities). Accordingly, a regional assessment as outlined here (e.g., at the municipal level) might list certain species that do not occur in the assessed region due to a lack of suitable habitats on the local level.

(3) Potential oversights in conservation status: Using Europe as a scope of assessment might hide any problematic conservation status of a species at the global or at the local level.

(4) Outdated data: The IUCN aims to have the category of every species re-evaluated at least every ten years and aims to update the list every two years (IUCN, n.d.b). Nevertheless, the data might be outdated, which could lead to inaccuracies in the assessment of biodiversity risks. For this screening carried out for Upper Austria, 71 percent of the data was older than 5 years, the most dated being from 2010.

(5) Incomplete data: The data might be incomplete, which could limit the comprehensiveness of the assessment.

(6) Limited species coverage: It is estimated that the world hosts about 8,7 million species (Sweetlove, 2011). As of now, more than 150.300 species (16.120 in Europe) have been assessed for the Red List, leaving large data gaps at the global level.

(7) Taxonomic standards: The taxon being assessed must follow the taxonomic standards used for the IUCN Red List. Any deviation from these standards could lead to inaccuracies in the assessment.

3 Potential ecological burden of regionally relevant bioeconomic activities

3.1 Bioeconomic activity selected for the screening

The regional strategy formulated for Upper Austria explores the use of side products and waste from the food industry, specifically bakeries, for use in bio-based packaging, cosmetics, and fertiliser production; production of novel fibres; production of nutraceuticals and dietary supplements. We have therefore carried out a sustainability screening of the valorisation of bakery waste, to identify potential environmental impacts associated with this value stream. Given the relatively specific field, literature on the topic remains somewhat limited.

The following sections provide some working definitions and an overview of the value chain. The rest of this chapter aims to synthesise the results of a literature review on potential impacts of the use of bakery waste on water, land, and biodiversity, respectively.

3.2 Overview of bakery waste and side-products and their potential burden on the resources examined

3.2.1 Definitions

Cereals are grains that usually come from cultivated grasses, such as wheat, rye, spelt, oats or millet (BZfE, n.d.).

Summer cereals are sown in spring and need only a couple of months before they are ready to harvest. On account of climate change and the tendency of summers to be hot and dry, summer cereal crops in Austria are declining (Federal Ministry of Agriculture, Forestry, Regions and Water Management, n.d.d).

Winter cereals are planted in autumn (as of September) and, depending on crop growth and weather conditions, harvested as of mid-June in the following year. Due to the longer period of growth and thanks to winter humidity, winter cereals bring in higher yields than summer cereals. Unlike summer cereals, winter cereals need exposure to cold as a stimulus to induce the flowering process and seed production (vernalisation) (Federal Ministry of Agriculture, Forestry, Regions and Water Management, n.d.d).

Common wheat is the main crop grown in Austria with an annual average production of 1.6 million tonnes. Wheat is ranked into 9 quality categories, category 1 representing the lowest and category 9 the highest baking quality. It is produced as summer and winter cereal (Gartner, 2018).

Bakery Products/Baked Goods is the generic term for foods with cereals or cereal products as the main ingredient that are baked and is one of the main staple foods in Austria and Europe.

3.2.2 Overview of grain cultivation practices and side-products and waste from bakeries

Commonly used grains used for the production of flour and milling products for the production of baked goods are for instance wheat, rye, spelt, oats, maize or others. Depending on the grain type, there are different cultivation and crop management practices that are commonly used in Upper Austria. Table 7 shows an overview of the main crop types used for the production of baked goods and their cultivation practices.

Table 28: Grain cultivation practices for the production of baked goods

Grain cultivation practices for the production of baked goods	
Wheat	• **Cultivation**: planting either in fall (winter cereal) or spring (summer cereal); prefers well-drained loamy soils; soil fertility is crucial (adding of organic matter and nutrients); fertilization with nitrogen, phosphorus and potassium; harvesting time during summer months • **Management practices**: crop rotation with soy and corn and avoidance of continuous singular-field wheat cultivation for managing soil quality
Rye	• **Cultivation**: planted in fall (winter cereal) and harvested in late spring; adaptable to various soil types but thrives in well-drained, fertile soils; • **Management practices**: incorporating organic matters (e.g. deep-root crop) to enhance soil structure; utilization of rye as cover/top crop to prevent erosion and enhance soil health; crop rotation with legumes or brassicas advisable
Spelt	• **Cultivation**: plant in fall (winter cereal) or spring (spring cereal); Spelt prefers well-drained loamy soils with good fertility • **Management practices**: 5-year crop rotation with clover grass, broad bean and

	protective cereal (e.g. rye)
Oat	• **Cultivation**: planted in spring (spring cereal) as fast growing crop (spring-sown crop); adaptable to a variety of soils but thrive in well-drained loamy soils; needs adequate soil fertility with • **Management practices**: crop rotation with canola, peas, lentils, soybeans or other legumes to increase soil quality and reduce weed risk

Moving along the bakery value chain, the crops are harvested, dried and milled. Depending on the regions, bakeries and used crop, there is a large variety of bakery products produced in Upper Austria by micro-, small-, and large-scale companies.

In the bakery sector, 90% of the market is shared by commercial bakers and 10% by industrial companies. It also includes the flour milling, baking agent and pasta industries (Baier et al., 2016).

- By-products from the manufacturing process:
    - Mainly dough types from bakeries, pastries and pasta production
    - losses generated by the cutting processes (biscuits, pasta,...)
- Finished baked goods
    - Free returns from supermarkets (going back to bakeries)
    - Bread, pastries, et. left in supermarkets

A distinction must be made here between by-products that are generated in the manufacturing process during production and finished bakery products that are left over in sales as scrap goods. By-products of production are mainly dough types (Hietler et al., 2021).

Free returns from supermarkets: bread and pastries that the bakeries first deliver to the supermarket in the form of chilled dough pieces and then receive back as baked goods that could not be sold. The bakeries credit the supermarkets for the quantity returned, so the supermarkets do not suffer any financial losses, disposal problems or risks (Hietler et al., 2017).

There are common recycling routes for used bakery products (Table 8), which could potentially influence the ecological burden in different aspects. One ecological burden of the wasted bakery products are the greenhouse gas emissions that are emitted along the whole value chain.

Table 29: Recycling routes for used bakery products from 44 Austrian bakeries

Recycling route	Shares in %
Feeding	86,6
Internal utilization (e.g. breadcrumbs)	3,3
Social Institutions	3,3
Biogas Production	4,8
Composting	1,8
Residual Waste (waste incineration plant or MBT)	0,01
Other Utilization (e.g. alcohol production)	0,03

3.2.3 Potential burden on water resources

Hassan et al. (2021) note the strong environmental impact of cereal industrial waste due to its high organic load, solid waste, and nutrient levels. As mentioned above, algal growth on water can pollute the water resource and have harmful effects on freshwater ecosystems. This is partially attributed to the pesticide residues and nutrients present in the runoff, leading to hypertrophication and groundwater pollution.

Looking at the use of food waste in general for biogas production, Chew et al. (2021) note that the anaerobic digestion step can cause eutrophication, acidification, and create photochemical oxidants. In a study on the use of bakery waste for microbial fuel cells (MFC), Hussain et al. (2022) point to their potential as an ecologically friendly and cost-effective approach to wastewater treatment. Using food waste as a substrate, these MFCs are good at removing pollutants and reducing the concentration of metal ions in water.

3.2.4 Potential burden on land resources

Looking at the use of food wastes in general for feed and compost production, Vandermeersch et al. (2014) note that while these uses lead to lower global warming potential and higher resource recovery than landfill disposal, they can also cause negative impacts for soil resources including acidification.

In their assessment of the use of agro-industrial residues for biorefineries, Tonini et al. (2015) warn that such a valorization, where residues may otherwise be used for animal feed, presents the risk of expanded crop production and intensification and indirect land-use change with potential negative environmental impacts, including to soil.

Govindaraju et al. (2021) studied the implications of using bakery waste in the production of compost, and conclude that use of the waste, even of creamy bakery products, can indeed lead to an effective compost, complying with standard chemical values for composts and thus having helpful effects for soil health.

Looking at the waste materials from cereals processing, Hassan et al. (2021) note that cereal and corn waste can cause soil pollution, enhancing acidification in areas with caustic soils. Thus, it is safe to assume that the use and valorization of these waste streams could lead to beneficial effects for soils where they may otherwise be released.

3.2.5 Potential burden on biodiversity

In a study different uses of bakery waste, Ungureanu-Comanita et al. (2021) note that during the process of anaerobic digestion, about 100% of nutrients from the organic matter is recovered if the fermented material is incorporated immediately after spreading on arable land. This can lead to an effective fertilizer which does not spread plant or animal diseases.

There are concerns surrounding improper treatment and discharge of cereal industrial waste on ecosystems. Notably, it can lead to a high level of algae on water surfaces, which can prevent the growth of marine animals (Hassan et al., 2021).

4 Screening results and recommendations

4.1 Overview

Resources screened		Ordinal Baseline Rating	Use of side products and waste from the baking industry, and their potential impact on environmental dimensions	
Category	**Sub-Category**		**Potentially beneficial to the baseline status**	**Potentially detrimental to the baseline status**
Water	**Surface water bodies**		**Use of value chain for wastewater treatment**, which can be effective at removing pollutants and reducing metal ions in water **Adequate fertilizer and chemical management**	**Improper waste discharge**, which has high organic load, solid waste, and nutrient levels. **Excessive fertilizer use,** especially ortho-phosphate fertilizers.
	Groundwater bodies			
Land Resources	**-**		- Creating incentives against planting crops on high slopes; in order to reduce crops contributing to erosion risks - Creating incentives for erosion control practices such as contouring, - Conservation tillage or mulching leaving 30% (or more, depending on the crop) of crop residues in the field, as a means to maintain/increase Soil Organic Carbon and nutrient levels, and reduce soil erosion	**Poor fertilizer management** **Expanded production and intensification**, leading in land use change with potentially harmful effects on soil.
Biodiversity	**Endangered Species**	**40**	Concrete statements or generalised evidence from scientific literature on the impact of the considered bioeconomic activities on biodiversity have not been found (or were insufficient) in the studies reviewed.	
	Critically Endangered Species	**11**		

4.2 Recommendations

Surface water bodies: the screening of reported data has shown that the majority of rivers and lakes in Upper Austria fail to achieve the objectives of the EU WFD. The chemical status of surface water bodies is especially concerning, with every river and lake failing to achieve good status. This raises concern for new or increased pressures that could arise from the development of new economic activities in the region or the expansion of existing operations. The literature indicates that cereal industrial waste can have negative impacts on water resources as a result of its nutrient levels and organic load. As such, care should be taken that no waste materials or side-products are improperly discharged. At the same time, these byproducts can be effectively used for wastewater treatment, which could be a potential valuable use case for the region. Similarly, fertilizers and chemical inputs should be kept only to the absolutely necessary levels and reduced as much as possible, especially orthophosphate fertilizers. Adequate fertilizer management will be imperative to ensure that the chemical status of surface water bodies is not further impacted by the valorisation of the value chain.

Groundwater bodies: The quantitative and chemical status of groundwater bodies remains of low concern in the area. However, given the impacts of climate change of water availability, care should be taken with regards to water use in the value chain. Water use must be carefully managed, especially in summer months and periods where water shortages may be a concern. Although the chemical status of groundwater is reported as being in good status, potential surface-ground water interactions could cause risks where waste products are improperly discharged and so care must be taken in this regard. Similarly, fertilizer and chemical management must be handled very carefully to ensure that there is no excessive runoff or leaching into groundwater bodies.

Soil: Soil resources in the region must be treated cautiously. Average erosion in arable lands is considered moderate, according to European thresholds, with 9% of arable lands facing “severe” erosion. Special care should be taken in areas where soil erosion crosses this threshold, or where erosion rates are increasing. Within the wheat and cereal growing domain, a number of measures can be taken to reduce the risks of erosion: creating incentives against planting crops on high slopes; creating incentives for erosion control practices such as contouring, conservation tillage or mulching. Activities and practices that restore and preserve soils should be promoted. For example, conservation tillage and mulching not only has benefits with regards to erosion but can also maintain or even increase soil organic carbon and nutrient levels, leading to overall beneficial impacts on soil health. Care should be taken that the use of side products from the baking industry does not lead to expanded production or intensification of the associated crops, which can lead to land use change and negative impacts on soil.

Biodiversity: The production of the crops relevant for the bakery value chain in Upper Austria can have important benefits for biodiversity. Although there are no specific concerns related to biodiversity in the region, these crops are subject to high scientific research in order to ensure long-term food security and therefore well researched in terms of creating locally adapted varieties that are in line with the regional biodiversity management plans. As mentioned for the other resources, improper discharge of cereal waste materials can have harmful effects on ecosystems, and so waste management must be adequately considered. In addition to the recommendations regarding biomass, awareness raising and building measures on consumer level can initiate more open-mindedness towards more non-conventional cereals for baked goods that show higher sustainability and biodiversity characteristics, for example sorghum.

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Sustainability Screening – French Atlantic Arc, FR

March 2024

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Regional biomass availabilities, nutrient balances and ecological boundaries

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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
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EXECUTIVE SUMMARY

This report has been produced as part of the SCALE-UP project funded by the Horizon Europe research and innovation programme. The aim of this project is to support the development of small-scale bioeconomy solutions in rural areas across Europe. The aim of this study is to raise awareness of the ecological limits on the French Atlantic Arc, based on three resources: water, soil and biodiversity. The bioeconomy is by definition the economy of bioresources (from agriculture, forestry, aquaculture and biowaste), therefore of the living. It is essential to design bioeconomy sustainably, and that its development takes into account the potential impact on the environment. Furthermore, in the current context of fighting against climate change and environmental degradation, bioeconomy activities that provide environmental benefits (water quality, preservation of biodiversity, etc.) must be sought and encouraged. This report is therefore aimed at project leaders and stakeholders in the bioeconomy willing to develop an activity, to enable them to integrate these environmental considerations into the development of their strategy, product or service.

The French Atlantic Arc region for the SCALE-UP project corresponds to the four administrative regions of Brittany, Normandy, New-Aquitaine and Pays de la Loire. These regions correspond to the field of action of the Association of the Chambers of Agriculture of the Atlantic Area (AC3A), the French partner in the project. Agriculture is dominant in this large territory, with 144,000 farms (RGA 2020) covering an area of 89,656 km². This agriculture is very diverse, though dominated by livestock farming (2/3 of farms are predominantly livestock farms), and by field crops, which accounts for between 32% and 39% of the Utilised Agricultural Area (UAA). Another feature common to the four regions that make up the Atlantic Arc is the strong demographic pressure due to the region's proximity to the Atlantic seaboard and the English Channel. Finally, this large territory is fully affected by the impacts of climate change, with rising temperatures and significant pressure on water resources, soils and biodiversity. These considerations about climate change and its consequences need to be considered in the development of bioeconomy activities.

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Glossary

Agricultural land	It includes cultivated land (annual and market garden crops, permanent crops, temporary grassland, fallow land, etc.) and grassland used for livestock farming. (Source: AGRESTE)
Biodiversity	Biodiversity refers to all living organisms and the ecosystems in which they live. It also includes the interactions of species with each other and with their environment (Source: OFB).
Bioeconomy	The bioeconomy encompasses economic activities based on renewable resources: forestry, agriculture, aquaculture and biowaste. These activities are designed to provide a sustainable response to society's need for food and part of its need for materials and energy, while preserving the natural resources (agricultural, aquacultural and forestry biomass) of an area and guaranteeing the production of high-quality environmental services. (Source: French Ministry of Agriculture and Food)
Common generalist birds	Birds that tolerate a wide range of environmental conditions, can thrive in a variety of environments and make use of a wide range of resources. (Source: OFB)
Common specialist birds	Birds whose survival depends on specific environmental conditions and which can only be found in specific habitats such as farmland, built-up areas or forests (Source: OFB).
Ecological status of surface waters	The state of an aquatic ecosystem, making it possible to determine its structure and how well it functions on the basis of its fauna and flora, certain physico-chemical characteristics and its physical state (banks, dams, etc.). (Source: OFB)
Eutrophication	Excessive enrichment of watercourses and bodies of water with nutrients such as phosphorus and nitrogen, which act as fertiliser for aquatic plants. Eutrophication manifests itself through the proliferation of aquatic plants and a significant reduction in the oxygen content of the water. The consequences include reduced animal and plant diversity and disrupted uses (Source: OFB).
Good Ecological Status	The WFD default objective for all water bodies, defined as a slight variation from undisturbed conditions. The elements that make up Ecological Status include: biological elements (including fish, macro-invertebrates, macrophytes and diatoms); and supporting elements (made up of hydromorphology, ammonia, pH, phosphates, dissolved oxygen and 18 pollutants including some heavy metals and pesticides). Each of these elements contributes to the overall ecological status. A lowest common denominator rule is applied to the elements, so the lowest scoring element denotes the overall status of the water body. For example, if a biological quality element was at moderate and other quality elements were at good, it would be assumed that the water body as a whole is at moderate status. (Source: ECRR).
Invasive alien species	Species introduced into an area distinct from its area of origin by human beings, deliberately or accidentally, proliferating in its area of establishment

	and disrupting the functioning of ecosystems or harming native species through competition, predation or transmission of disease. (Source: OFB)
IUCN Red List	IUCN Red List A regularly revised list of species classified according to the degree of threat to which they are exposed, based on a methodology defined by the IUCN. (Source: OFB)
Macropollutant	A combination of suspended solids, organic matter and nutrients such as nitrogen and phosphorus. Macropollutants may occur naturally in water, but human activities increase their concentrations (industrial or domestic wastewater discharges, or agricultural practices). (Source: OFB)
Micropollutant	A group of mineral or organic substances which, even at very low concentrations of the order of µg/l or ng/l, can be toxic to humans and/or ecosystems. They are generally classified into families: metalloids, hydrocarbons, PAHs, PCBs, polybrominated diphenyl ethers (PBDEs), volatile organic compounds (VOCs), volatile organohalogen compounds (VOCs), phenolic compounds, dioxins and furans, phthalates, etc. (Source: OFB)
Natural soils	They include woodland, moorland and fallow land, bare soil (coastal dunes, sandy or pebble beaches, etc.) and wetlands (Source: AGRESTE).
Quantitative status of groundwater	Assessment of a body of water, taking into account the level of volumes of water withdrawn in relation to the resource's capacity to renew itself and its capacity to maintain the supply of surface ecosystems (Source: OFB).
Red List Index	Index measuring the risk of extinction of species by noting more or less rapid declines in numbers. It is constructed using the number of species in each IUCN threat category and the number of species that have changed category. (Source: OFB)
River basin	Area delimited by watersheds in which run-off water converges through a network of rivers, streams and possibly lakes towards the sea (Source: OFB).
Soil sealing	Transformation of agricultural, natural or forest land by development actions, which may result in it being totally or partially sealed. (Source: INSEE)
Sealed soil	They include built-up land (dwellings, factories, etc.), paved land (roads, squares, etc.), stabilised land (railways, quarries, building sites, etc.) and other artificial land (gardens, parks and green spaces, etc.). (Source: AGRESTE)
Water body	According to the Water Framework Directive, a body of surface water is a distinct and significant part of surface water (lake, reservoir, river or canal, part of a river or canal, transitional water or part of coastal waters). For watercourses, the delimitation of water bodies is based mainly on the size of the watercourse and the notion of hydro-ecoregion. A groundwater body is a distinct volume of groundwater within one or more aquifers. (Source: OFB)

Abbreviations

AC3A	Association of the Chambers of Agriculture of the Atlantic Area
AEE	European Environment Agency
AESN	Seine-Normandy Water Agency
CE	European Commission
CLE	Local Water Commission

CNRS	National Centre for Scientific Research
DCE	Water Framework Directive
DREAL	Direction régionale de l'environnement, de l'aménagement et du logement (Regional directorate for the environment, planning and housing)
FAO	Food and Agriculture Organization of the United Nations
FREC	Circular economy roadmap
IPCC	Intergovernmental Panel on Climate Change
HCBC	Brittany High Council for Climate
INRAE	French National Research Institute for Agriculture, Food and the Environment
INSEE	French National Institute for Statistics and Economic Studies
GHG	Greenhouse gases
MNHN	National Museum of Natural History
OFB	French Biodiversity Office
ONB	National Biodiversity Observatory
SAGE	Water development and management plan
SAU	Useful Agricultural Area
SDAGE	Master plan for water development and management
SDES	Statistical Data and Studies Department
SNBC	National low-carbon strategy
IUCN	International Union for Conservation of Nature

1 Resource management profiles

1.1 Water resources management profile

Water management in France

In France, the law 2004-338[146] transposed the 2000 EU Water Framework Directive (WFD) into national law, introducing management by major river basins (six in metropolitan France) and setting targets for achieving good water status. Water governance is complex and relies on numerous consultation bodies and technical organisations. Basin committees (one for each river basin) play a central role in drawing up water development and management master plans (SDAGE). These committees bring together representatives of the State, local authorities, and users (industry, farmers, associations, etc.) to decide on the strategy for protecting water and aquatic environments. The SDAGE is drawn up for six years (the current period is 2022-2027), in line with European and national water policies. It defines the guidelines for the balanced and sustainable management of water resources; sets the quality and quantity objectives to be achieved for each water bodies in the basin (rivers, water bodies, groundwater, estuaries, coastal waters), and determines the developments and provisions needed to prevent deterioration and ensure the protection and improvement of the status of water and aquatic environments, to achieve these objectives[147]. The Water Agencies, public bodies, are responsible for implementing this strategy in collaboration with government departments and regional and county councils. These agencies play a central role in water management: they collect fees from users (consumers, economic activities), which they redistribute in the form of loans and subsidies to local authorities and economic and agricultural actors to implement actions: production of high-quality drinking water, water purification, maintenance, and restoration of aquatic environments. Another key mission of the water agencies is to collect, share and disseminate data on the quality of water. Each river basin is divided into sub-basins, where a Local Water Commission (CLE), set up by the Prefect and made up of water managers, farmers, consumer, and industry representatives, is responsible for drawing up, revising, and monitoring the application of the Water Development and Management Scheme (SAGE). Finally, the management of urban water services (drinking water and sanitation), the management of aquatic environments and flood protection are the responsibility of the municipalities or their groupings[148].

Water resources and use

On a national level, the average consumption per person is 146 litres of drinking water a day, representing an average annual cost per household of 500 €. Annual rainfall in France amounts to 500 billion m^3, 60% of which returns to the atmosphere, with the remainder flowing into rivers, lakes, and groundwater. 37 billion m^3 of water (excluding hydroelectricity) is withdrawn for various uses: 51% is used to cool power stations, 18% to produce drinking water, 14% to supply navigation channels, 10% for irrigation, 6% for industry and 1% for other uses (source: OFB[149] 2023). Groundwater is the source of two-thirds of the water distributed to the domestic users.

In the Atlantic Arc, this situation differs at the level of each river basin but will also vary if we consider each administrative region, which may be integrated by several basins, as is the case with New-

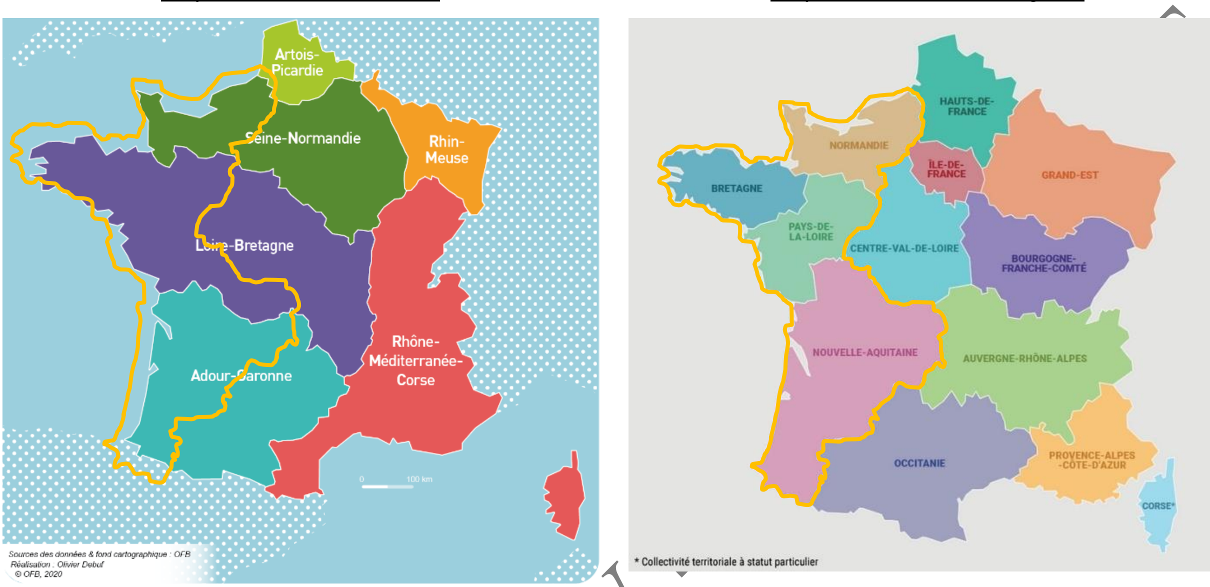
[146] Law no. 2004-338 of 21 April 2004 transposing Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.
[147] Ministère de la Transition écologique et de la Cohésion des territoires, Ministère de la Transition énergétique, *Gestion de l'eau en France*, Juin 2023. https://www.ecologie.gouv.fr/gestion-leau-en-france
[148] INRAE, Dossier de presse – *Gestion de la ressource en eau*, Juin 2023. https://www.inrae.fr/dossiers/gestion-ressource-eau/gouvernance-leau-previsions
[149] Office français de la biodiversité (OFB), *Prélèvements en eau en France, un suivi nécessaire*, Décembre 2023. https://www.eaufrance.fr/publications/prelevements-en-eau-en-france-un-suivi-necessaire

Aquitaine. The three river basin districts that we look at in this report are Adour-Garonne, Loire-Brittany, and Seine-Normandy. The scale of the basin is preferred to that of the administrative region because the data used in this report is the official data reported by the water agencies.

Figure 47 Overlay of the boundaries of the four administrative regions in the French Atlantic Arc against the River Basin Districts they lie in

Map of river basin districts

Map of administrative regions



© OFB[150], 2020

© Ministère de l'Intérieur et des Outre-Mer[151], 2016

French Atlantic Arc

[150] Source: https://www.eaufrance.fr/media/les-bassins-hydrologiques-metropolitains

[151] Source: https://mobile.interieur.gouv.fr/Archives/Archives-des-actualites/2016-Actualites/Les-noms-des-nouvelles-regions-sont-actes

Adour-Garonne river basin district

The Adour-Garonne river basin district is made up of several sub-basins (Adour, Charente, Dordogne, Garonne, Lot, Tarn-Aveyron), the coastline and coastal areas, and groundwater.

Figure 48 The Adour-Garonne River Basin District

© Agence de l'eau Adour-Garonne[152]

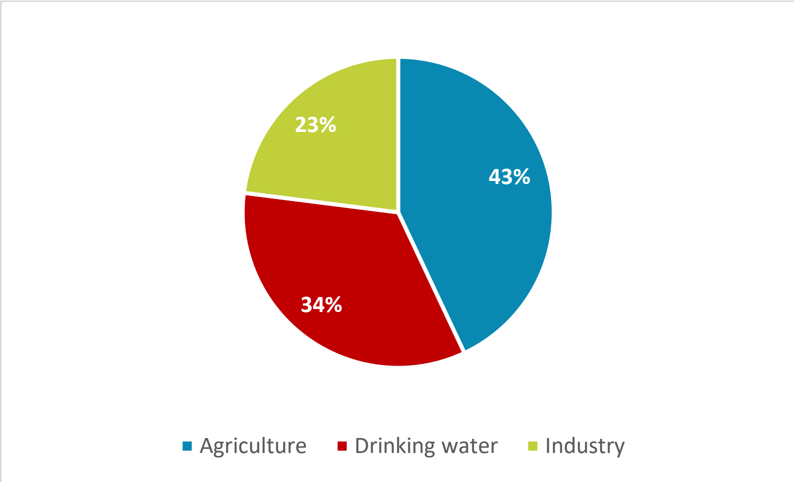
Table 30 Key figures for the Adour-Garonne basin	
Surface area	117,650 km²
River	116,817 km
Coast	630 km
Water bodies	2,952

Source : Water Agency of Adour-Garonne (Agence de l'eau Adour-Garonne)[153].

[152] Source: https://sigesaqi.brgm.fr/-dans-le-bassin-Adour-Garonne-.html
[153] Source: https://eau-grandsudouest.fr/agence-eau/bassins-territoires/bassin-adour-garonne

The Adour-Garonne basin is home to more than 8 million inhabitants and is expected to have 1.5 million more inhabitants by 2050, with consequences for drinking water demand and consumption. Largely rural (50% of the basin's surface area is farmland), agriculture is a major and diversified economic activity (cereal crops, market gardening, mixed farming, livestock farming, wine growing, etc.). This river basin alone accounts for 1/3 of the total number of French farms. Hydroelectricity production amounts to 15,000 GWh (20% of national production), with 1,100 hydroelectric installations and a storage capacity of 2.5 billion m³ of water in large dams[154].

Figure 49 Breakdown of water withdrawal in Adour-Garonne (2 billion m3/year)



Source: Agence de l'eau Adour-Garonne, Septembre 2021[155].

Despite a high average annual rainfall (600 mm in the middle part of the Garonne valley to 2000 mm on the higher ground), water resources are subject to significant seasonal fluctuations and the basin regularly experiences severe low-water periods, resulting from an imbalance between abstractions and available resources[156]. The low flows of the rivers are then compensated for by large artificial reserves: more than 640 million m^3. Large hydroelectricity reserves store 2.5 billion m^3, of which more than 160 million can be mobilised in the summer to support river flows. Projections of the impact of climate change on water resources are particularly alarming: natural low-water flows would be halved by 2050 in a scenario where the average air temperature will have risen by 2°C compared with today. The satisfaction of all uses and the development of all activities with a potential impact on water resources therefore requires sustainable management in consultation with the various stakeholders.

Key figures and recommendations regarding surface water bodies

More than half of rivers and lakes in the Adour-Garonne river basin district fail to achieve Good Ecological Status. Economic activities and management practices that could have substantial negative impacts on river and lake ecology should thus be avoided, and those that could improve the ecological conditions of these water bodies should be explored and favoured.

154 Agence de l'eau Adour-Garonne, *Eau et changements climatiques dans le grand Sud-Ouest*, Septembre 2021. https://www.calameo.com/agence-de-leau-adour-garonne/read/000222592d3688961fd70?page=1
155 *Ibid.*
156 Agence de l'eau Adour-Garonne, *L'état des ressources, gestion quantitative*, 2020. https://eau-grandsudouest.fr/usages-enjeux-eau/eau-grand-sud-ouest/etat-ressources-gestion-quantitative

According to the data from the second reporting cycle of the WFD[157], about two-thirds of surface water bodies achieve Good Chemical Status, though this figure remains below the EU average. Nitrogen and phytosanitary pressures are significant for more than 35% of surface water bodies, mainly in areas where field crops are concentrated[158]. A significant number of rivers are reported as having an unknown chemical status. Economic activities that keep this situation from improving, or that could further deteriorate the chemical properties of water resources, should be avoided. Bioeconomy activities and management practices that could contribute to improve the chemical status of water bodies in the river basin district should be sought and promoted.

According to the reported data, half of the rivers and one-third of lakes in the river basin district are affected by atmospheric deposition as a diffuse source of pollution. This shows that economic activities that could exacerbate pollution through atmospheric deposition should be avoided in the region.

About half of the rivers in the region are affected by some form of chemical, nutrient, or organic pollution. Activities resulting in discharges of these substances should thus be avoided.

Habitat alterations resulting from changes in morphology are a significantly recurrent impact on lakes and rivers in the region: 38% of water bodies in rivers and lakes suffer from a high degree of morphological alteration[159], particularly in relation to hydroelectric dams and river weirs. Economic activities and management practices that facilitate or promote the restoration of these lakes should be favoured.

Key figures and recommendations regarding groundwater bodies

A significant portion of groundwater bodies in the river basin district are in Good Quantitative Status and a large proportion (two-thirds) are in Good Chemical Status as well. The 28 groundwater bodies are in good chemical condition, but 6 of them are in poor quantitative condition due to the pressure of water withdrawals: the Adour-Garonne basin withdraws 293 million of m^3 of groundwater annually[160], 70% of which for drinking water. These pressures on groundwater resources are likely to increase with the impact of climate change: as it is forecasted that there will be a shortfall of 1.2 billion m^3 between needs and surface water resources[161].

There are around 4,800 water catchments in the Adour-Garonne basin, 80% of which have been protected to prevent occasional or accidental pollution. Of these, 95 water catchments have been identified as priorities for restoring quality because of damage caused by diffuse pollution (nitrates and/or pesticides)[162]. Groundwater bodies in poor chemical conditions are being affected by diffuse sources of pollution and, to a lesser extent, abstraction. Economic activities that could exacerbate these pressures should be avoided. Chemical pollution is the most recurrent impact on groundwater bodies in the river basin district. Economic activities associated to moderate or high discharges of chemicals to the environment should be avoided.

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[157] WISE WFD Data Viewer (https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd). Data from the 3rd WFD reporting cycle was not yet available on the WISE Database at the time of the analysis.
[158] Agence de l'eau Adour-Garonne, *SDAGE 2022-2027*, Mars 2022. https://eau-grandsudouest.fr/sites/default/files/2022-04/SDAGE%202022-2027%20ADOUR%20GARONNE.pdf
[159] *Ibid.*
[160] Agence de l'eau Adour-Garonne, SDAGE 2022-2027 – Commission territoriale nappes profondes, *Synthèse de l'état des lieux*, Mai 2020. https://www.calameo.com/agence-de-leau-adour-garonne/read/0002225928abd87967b70
[161] Agence de l'eau Adour-Garonne, *Le changement climatique sur le bassin*, 2020. https://eau-grandsudouest.fr/usages-enjeux-eau/changement-climatique/changement-climatique-bassin
[162] Agence de l'eau Adour-Garonne, *La qualité des eaux*, 2020. https://eau-grandsudouest.fr/usages-enjeux-eau/eau-grand-sud-ouest/qualite-eaux

Loire-Brittany river basin district

The Loire-Bretagne basin is made up of the Loire (France's longest river at over 1,000 km) and its tributaries, the coastal basins of Brittany and Vendée, and the Marais Poitevin. The region is characterised by its extensive coastline, large but heavily used groundwater resources and numerous wetlands.

Figure 50 The Loire-Brittany River Basin District

© Agence de l'eau Loire-Bretagne[163]

Table 31 Key figures for the Loire-Bretagne basin	
Surface area	156,000 km²
River	135,000 km
Coast	2,600 km
Water bodies	2,210

Source : Water Agency of Loire-Brittany (Agence de l'eau Loire-Bretagne)[164].

[163] Map date: 13 octobre 2017 – Period of the data: October 2017 - © Agence de l'eau Loire-Bretagne. https://agence.eau-loire-bretagne.fr/home/bassin-loire-bretagne/le-territoire-naturel-de-loire-bretagne.html

The Loire-Brittany basin has significant renewable water resources: annual rainfall ranges from 500 mm to 1,700 mm but is unequally distributed across the region. Drinking water supply comes largely from reservoirs that are filled by winter rainfall, and when winter and spring are very dry, there is considerable pressure on the resource. For example, the summer of 2022 was marked by drought, caused by a severe water deficit during the previous winter (rainfall of between 2 and 25% of normal monthly levels in some counties). Many counties in Brittany and Pays de la Loire were placed on drought alert, with restrictions applied to the use of drinking water.

In similarity to the Adour-Garonne basin, climate forecasts predict a significant drop in river flows between now and 2050 (-40%) and in groundwater recharge (-10 to -30%)[165]. These changes will have an impact on water quality (increased risks of pollution), saline intrusions (associated to reduced water volumes in the aquifers compounded with sea level rise), and an increase in the surface area of mud deposits in estuaries. Drier soils will reduce the capacity to recharge groundwater and increase run-off: the Loire basin will experience more sudden, intense, and widespread flooding, which will also have an impact on the quality of water in rivers.

Key figures and recommendations regarding surface water bodies

Three-quarters of rivers and lakes in the river basin district fail to achieve Good Ecological Status, with regional variations: in the Pays de la Loire region, 86% of surface waters could fail to achieve good ecological status by 2027[166].

This is due to the numerous pressures affecting hydrology (withdrawals), morphology (obstacles to water flow) and pollution (diffuse pollution by transfers of nitrates and pesticides into watercourses, occasional pollution caused by macro-pollutants). As a result, 79% of watercourses (1,492 of the 1,887 existing water bodies) are at risk of failing to meet their environmental objectives by 2027[167].

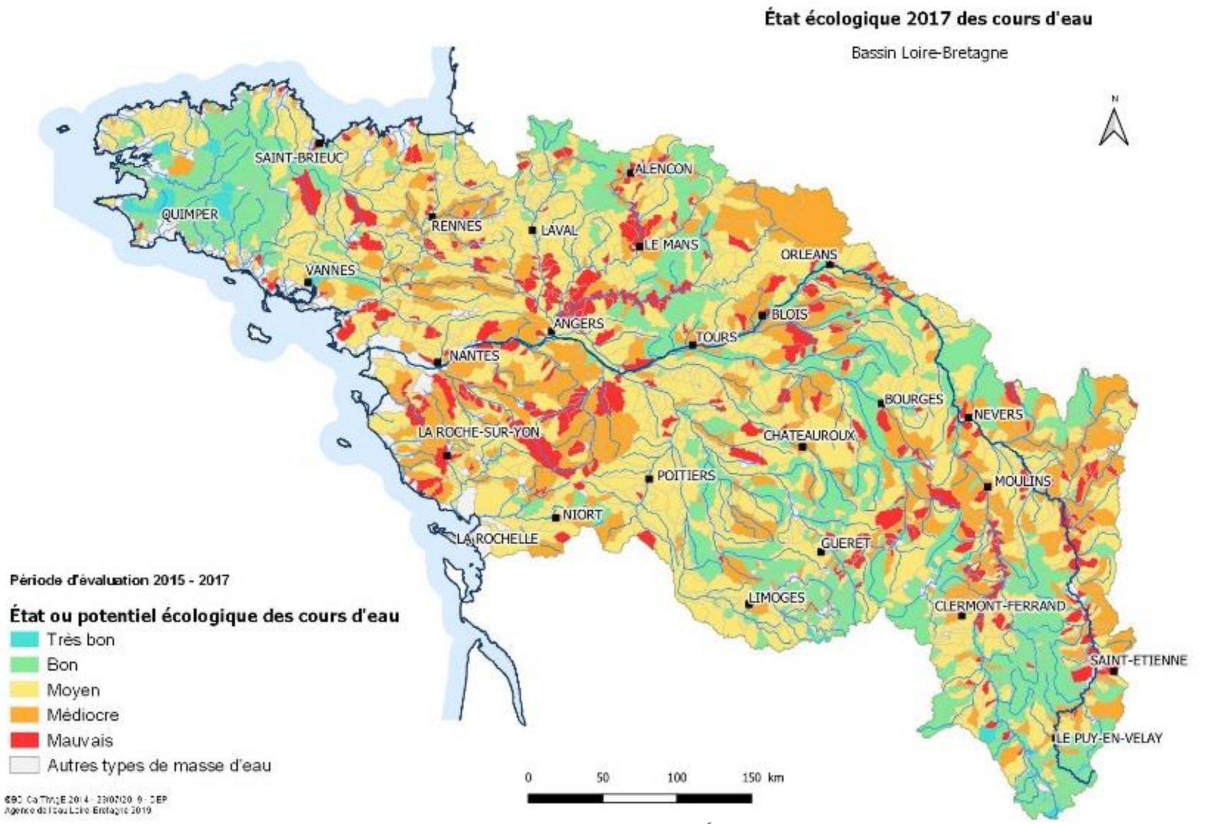
[164] Agence de l'eau Loire-Bretagne, *SDAGE 2022-2027 - Etat des lieux du bassin Loire-Bretagne*, Décembre 2019. https://sdage-sage.eau-loire-bretagne.fr/files/live/mounts/midas/Donnees-et-documents/EDL2019-Erratum.pdf

[165] Agence de l'eau Loire-Bretagne, *Prospective territoriale 2050 à l'échelle du bassin Loire-Bretagne*, Septembre 2023. https://sdage-sage.eau-loire-bretagne.fr/files/live/mounts/midas/Sdage-et-Sage/Prospective_territoriale

[166] GIEC des Pays de la Loire / Comité 21, 1er rapport, Juin 2022. https://www.calameo.com/read/002150178c7aa01db4831?page=1

[167] Agence de l'eau Loire-Bretagne, *SDAGE 2022-2027 - Etat des lieux du bassin Loire-Bretagne*, Décembre 2019. https://sdage-sage.eau-loire-bretagne.fr/files/live/mounts/midas/Donnees-et-documents/EDL2019-Erratum.pdf

Figure 51 Ecological status of rivers in the Loire-Brittany basin in 2017 (Green = Very good ; Red = Bad)



© *Agence de l'eau Loire-Bretagne*[168]

The map above shows that these pressures apply differently in different locations, depending on land use and territorial practices. Three main factors are involved: soil sealing (the quality of the water around major urban areas such as Nantes, Angers and Le Mans has deteriorated significantly due to the increased runoff among other factors), the adjustment of watercourses and farming practices (abstraction for irrigation, drainage, fertiliser, and plant protection product inputs). For example, in the Pays-de-la-Loire region, withdrawals for drinking water and irrigation increased by 16% between 2012 and 2019[169].

Therefore, economic activities and management practices that could have substantial negative impacts on river and lake ecology should be avoided, and those that could improve the ecological conditions of these water bodies should be explored and favoured.

About one-third of surface water bodies achieve Good Chemical Status, while more than half are reported as unknown. Economic activities that keep this situation from improving, or that could further deteriorate the chemical properties of water resources, should be avoided. Bioeconomy activities and management practices that could contribute to improve the chemical status of water bodies in the river basin district should be sought and promoted.

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[168] Agence de l'eau Loire-Bretagne, *Zoom sur la qualité des eaux en Loire-Bretagne*, Juillet 2019. https://agence.eau-loire-bretagne.fr/home/bassin-loire-bretagne/zoom-sur-la-qualite-des-eaux-en-loire-bretagne-2020.html?dossierCurrentElemente45c63ca-4536-4b29-97c5-1cc2713d5974=f3610971-6ff0-4ee5-9cec-2b4e42dcc203

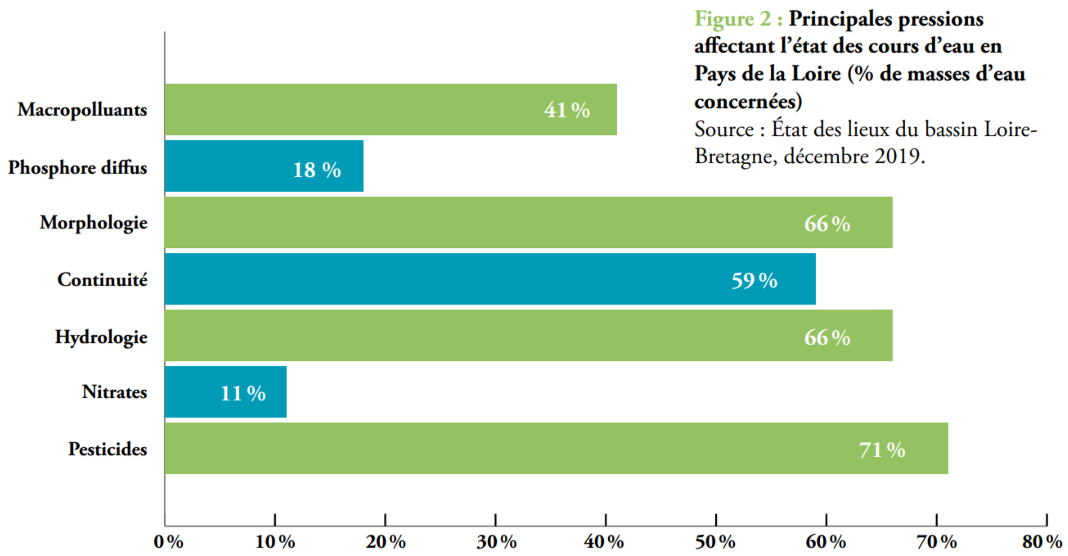
[169] Source des données : Agence de l'eau Loire-Bretagne, *SDAGE 2022-2027 - Etat des lieux du bassin Loire-Bretagne*, Décembre 2019. https://sdage-sage.eau-loire-bretagne.fr/files/live/mounts/midas/Donnees-et-documents/EDL2019-Erratum.pdf

More than half of the rivers in the region face hydromorphological pressures, leading to altered habitats. Economic activities and management practices that facilitate or promote the restoration of these rivers should be favoured.

Pollution (both point source and diffuse) is also an important pressure on about one-third of rivers, which face chemical, nutrient, and organic pollution. Activities that could exacerbate pollution through atmospheric deposition as well as chemical and organic discharges should be avoided in the region.

Furthermore, half of the lakes in the region are affected by atmospheric deposition as a diffuse source of pollution. Again, economic activities that could contribute to atmospheric pollution should be avoided.

Figure 52 Main pressures affecting the status of rivers in Pays de la Loire[170]



Key figures and recommendations regarding groundwater bodies

A significant portion (87%[171]) of groundwater bodies in the river basin district are in Good Quantitative Status and a large proportion (two-thirds) are in Good Chemical Status as well.

Groundwater bodies in poor chemical conditions are being affected by diffuse sources of pollution, mainly from agricultural origin: 42% of water bodies, corresponding to 61 water bodies, are at risk in terms of quality, 23 because of nitrates alone, 12 because of a combination of nitrates and pesticides, and 11 because of pesticides alone[172]. Therefore, economic activities that could exacerbate these pressures should be avoided.

Nutrient pollution is the most recurrent impact on groundwater bodies in the river basin district. Economic activities associated to moderate or high discharges of nutrients to the environment should be avoided.

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[170] Région Pays de la Loire, Agence de l'eau Loire-Bretagne, *Plan Etat-Région pour la reconquête de la ressource en eau en Pays de la Loire*, Décembre 2019.
https://www.paysdelaloire.fr/sites/default/files/2020-12/plan-etat-region-pour-la-reconquete-ressource-eau.pdf

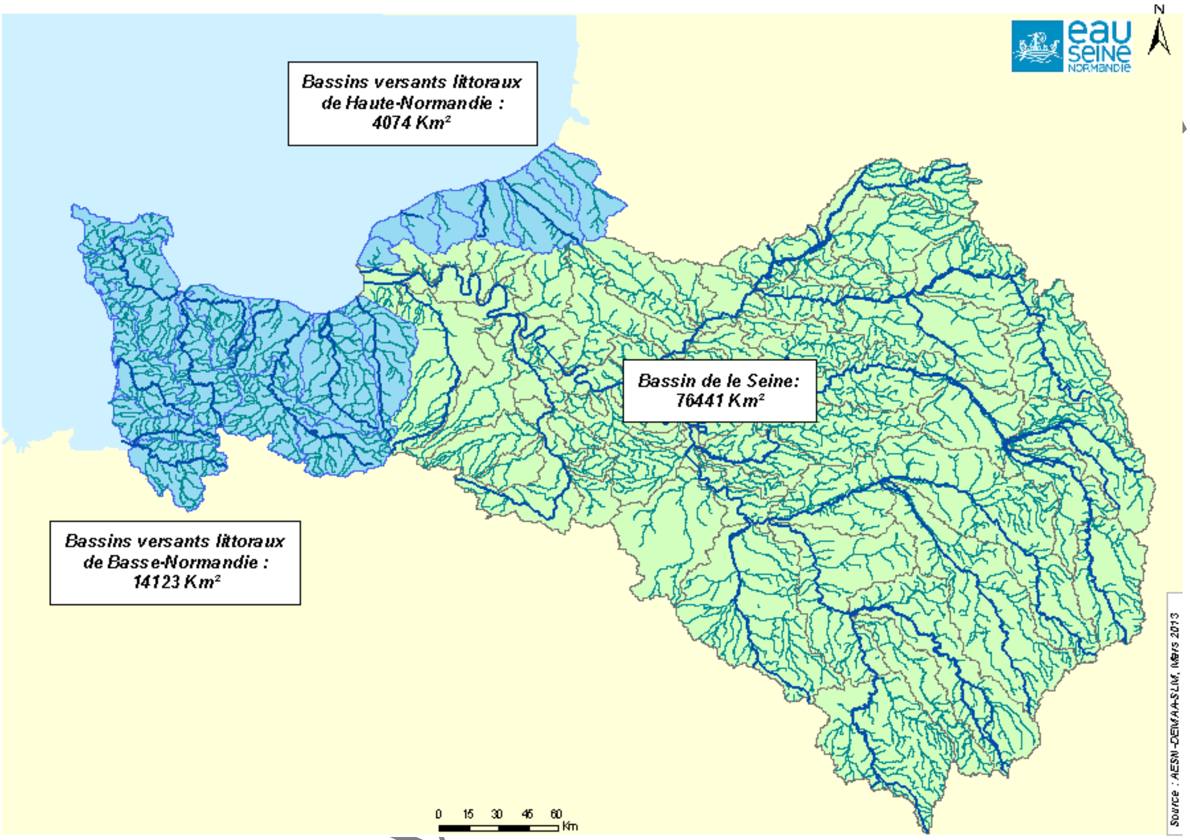
[171] Agence de l'eau Loire-Bretagne, *Zoom sur la qualité des eaux en Loire-Bretagne*, Juillet 2019.
https://agence.eau-loire-bretagne.fr/home/bassin-loire-bretagne/zoom-sur-la-qualite-des-eaux-en-loire-bretagne-2020.html?dossierCurrentElemente45c63ca-4536-4b29-97c5-1cc2713d5974=f3610971-6ff0-4ee5-9cec-2b4e42dcc203

[172] Source des données : Agence de l'eau Loire-Bretagne, *SDAGE 2022-2027 - Etat des lieux du bassin Loire-Bretagne*, Décembre 2019.
https://sdage-sage.eau-loire-bretagne.fr/files/live/mounts/midas/Donnees-et-documents/EDL2019-Erratum.pdf

Seine-Normandy river basin district

The Seine-Normandy basin is made up of tributaries and sub-tributaries of the Seine, groundwater and the coastal waters of Normandy. Most of the basin is formed by sedimentary soils, and the underground is rich in groundwater, from which half of the drinking water supply is drawn.

Figure 53 The Seine-Normandy River Basin District



© AESN, 2013

Table 32 Key figures for the Seine-Normandy basin	
Surface area	94,500 km²
River	1,651
Coast	650 km
Water bodies	1,782

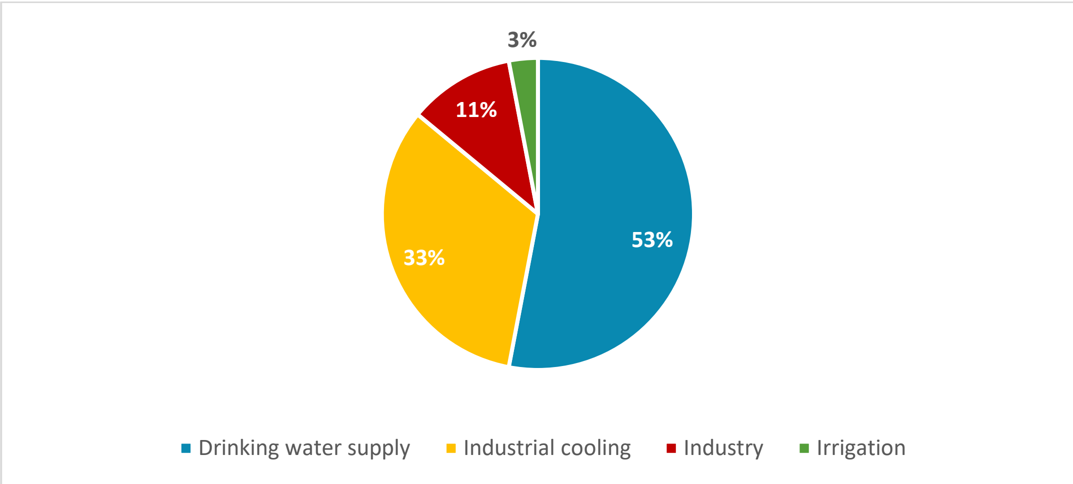
Source : Water Agency of Seine-Normandy (Agence de l'eau Seine-Normandie - AESN)[173].

The basin's extensive water resources are heavily exploited and subject to multiple pressures. Indeed, the basin is characterised by a high level of human activity: it is home to 30% of the national

[173] Data source: Agence de l'eau Seine-Normandie. https://www.eau-seine-normandie.fr/agence-de-leau/le-bassin-de-la-seine#:~:text=La%20fa%C3%A7ade%20littorale%20du%20bassin,154%20plages%20et%2019%20ports

population, 40% of industry (petrochemicals, specialised chemicals, car manufacturing, aeronautics, mechanical engineering, etc.) and 25% of agriculture (cereals, sugar beet, cattle, etc.), on 18% of the national surface area. Water abstraction (3 billion m^3 per year) puts pressure on groundwater levels and river flows and can affect the functioning of aquatic life and wetlands. In addition, the low relief of the basin makes it highly affected by river modifications, and the main estuaries are the site of large-scale port facilities. Run-off is very slow and subject to very high levels of evaporation: of the 820 mm of average annual rainfall, only 30% is run-off[174].

Figure 54 Distribution of water withdrawals in the Seine-Normandy basin



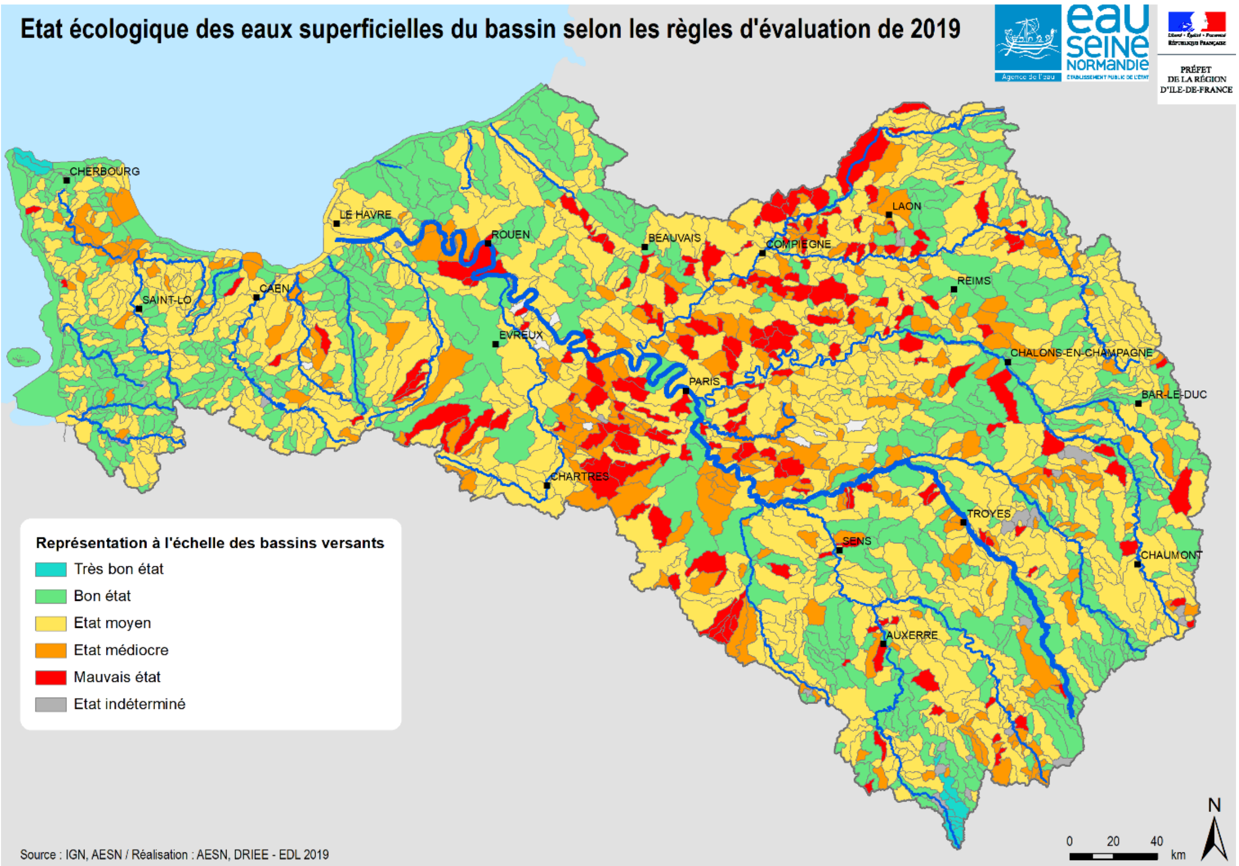
Source : AESN, SDAGE Seine-Normandie, 2019[175]

Key figures and recommendations regarding surface water bodies

More than half the region's rivers and most of the lakes are not achieving Good Ecological Status. Out of 47 lakes, only 4 achieve Good Ecological Status[176]. Thus, the scale and placement of any economic activities that could have substantial negative impacts on river and lake ecology should be planned very carefully to ensure that progress attained so far in meeting regulatory targets is not lost and instead continues to expand.

[174] Data source: Agence de l'eau Seine-Normandie, *Etat des lieux 2019 du bassin de la Seine et des cours d'eaux côtiers normands*, Janvier 2020. https://www.eau-seine-normandie.fr/sites/public_file/inline-files/AESN_Classeur.pdf
[175] Agence de l'eau Seine-Normandie, *Etat des lieux 2019*, Janvier 2020. https://www.eau-seine-normandie.fr/sites/public_file/inline-files/AESN_etat_lieux_janvier20.pdf
[176] *Ibid.*

Figure 55 Ecological status of rivers in the Seine-Normandy basin according to 2019 assessment rules (Green = Very good; Red = Bad)[177]



© AESN, 2019[178]

Two-thirds of surface water bodies fail to achieve Good Chemical Status. Economic activities that keep this situation from improving, or that could further deteriorate the chemical properties of water resources, should be avoided. Bioeconomy activities and management practices that could contribute to improve the chemical status of water bodies in the river basin district should be sought and promoted.

Almost half of the rivers in the river basin district are affected by either point source or diffuse pollution, most frequently chemical, but also nutrient and organic pollution (in particular nitrogen, phosphorus and organic matter pollution from wastewater treatment plants): the nitrogen flows reaching the Baie de Seine cause disturbances that have a serious impact on algal stranding and episodic developments of toxic microalgae, impacts that are likely to be intensified in the future by climate change[179]. Economic activities associated to moderate or high discharges of chemical pollutants as well as nutrients to the environment should be avoided.

About three-quarters of lakes in the region are affected by nutrient pollution. Economic activities that could exacerbate this should be avoided in favour of those that ameliorate the situation.

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[177] In 2019, new rules for assessing the ecological status of water have been introduced, taking into account scientific progress.

[178] Agence de l'eau Seine-Normandie, *La qualité des rivières du bassin de la Seine et des cours d'eau côtiers normands*, 2020. https://www.calameo.com/agence-de-l-eau-seine-normandie/read/004001913075e8c4b728e

[179] Agence de l'eau Seine-Normandie, *Etat des lieux 2019 du bassin de la Seine et des cours d'eaux côtiers normands*, 2019. https://www.eau-seine-normandie.fr/sites/public_file/inline-files/AESN_Classeur.pdf

Hydromorphology is the most recurrent pressure on rivers in the region: it affects 61% of watercourses. The Seine basin is very much affected by the physical modifications to its rivers and estuaries (dams, port facilities, artificial riverbanks, etc.), with major impacts on wildlife (loss of nursery and breeding areas for aquatic species, obstacles for migratory species, etc.), and on the accumulation of sediments, leading to greater risks of flooding[180]. Economic activities that could associate or contribute to the restoration of these water bodies should be explored and favoured, while those that would entail alterations of the hydromorphology of yet unaffected water bodies should be avoided.

Key figures and recommendations regarding groundwater bodies

There are 57 groundwater bodies in the district, most of them being in Good Quantitative Status (4 are in Poor Quantitative Status: linked to withdrawals for drinking water, for which groundwater supplies 48% of the volume, and the low recharge capacity of the 4 water bodies considered). However, only 30% of these are in Good Chemical Status. Almost all groundwater bodies are affected by diffuse pollution, both chemical and nutrient pollution (leading to eutrophication). Pesticides degrade 61% of groundwater, and diffuse sources of pollution are ubiquitous (linked to the soil sealing and the direct discharge of rainwater, which carries many substances, into watercourses)[181]. Since 2000, 468 drinking water catchments have been closed because of agricultural pollution (nitrates and/or pesticides). It is important that any expansion of existing economic activities, and/or development of new ones, is planned thoroughly and located smartly to avoid the exacerbation of these pressures on currently affected aquifers as well as the affectation of others.

The projections of the basin's Water Agency (AESN) of the pressure factors affecting the river basin warn of an increase in these pressures by 2027, and the risk that the status of aquatic environments and groundwater will deteriorate in the absence of further action to restore and maintain water quality. The AESN estimates that only 18% of watercourses will achieve Good Ecological Status in 2027, compared with the 32% it had forecasted in 2019[182].

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[180] Agence de l'eau Seine-Normandie, *Etat des lieux 2019 du bassin de la Seine et des cours d'eaux côtiers normands*, 2019. https://www.eau-seine-normandie.fr/sites/public_file/inline-files/AESN_Classeur.pdf.

[181] *Ibid.*

[182] *Ibid.*

Conclusions on water resources in the French Atlantic Arc regarding the development of bioeconomy activities

One of the major impacts of climate change will be on the availability (and quality) of water resources. In France, temperatures have already risen and there have been droughts for several years: in 2019, 90 counties saw their rivers dry up. That same year, two-thirds of the country was affected by water restriction measures (source: SDES[183] 2020). The issue of water will therefore have a major impact on the long-term viability of any economic activity and must be considered in the choice of bioeconomy value chains to be developed in the coming years.

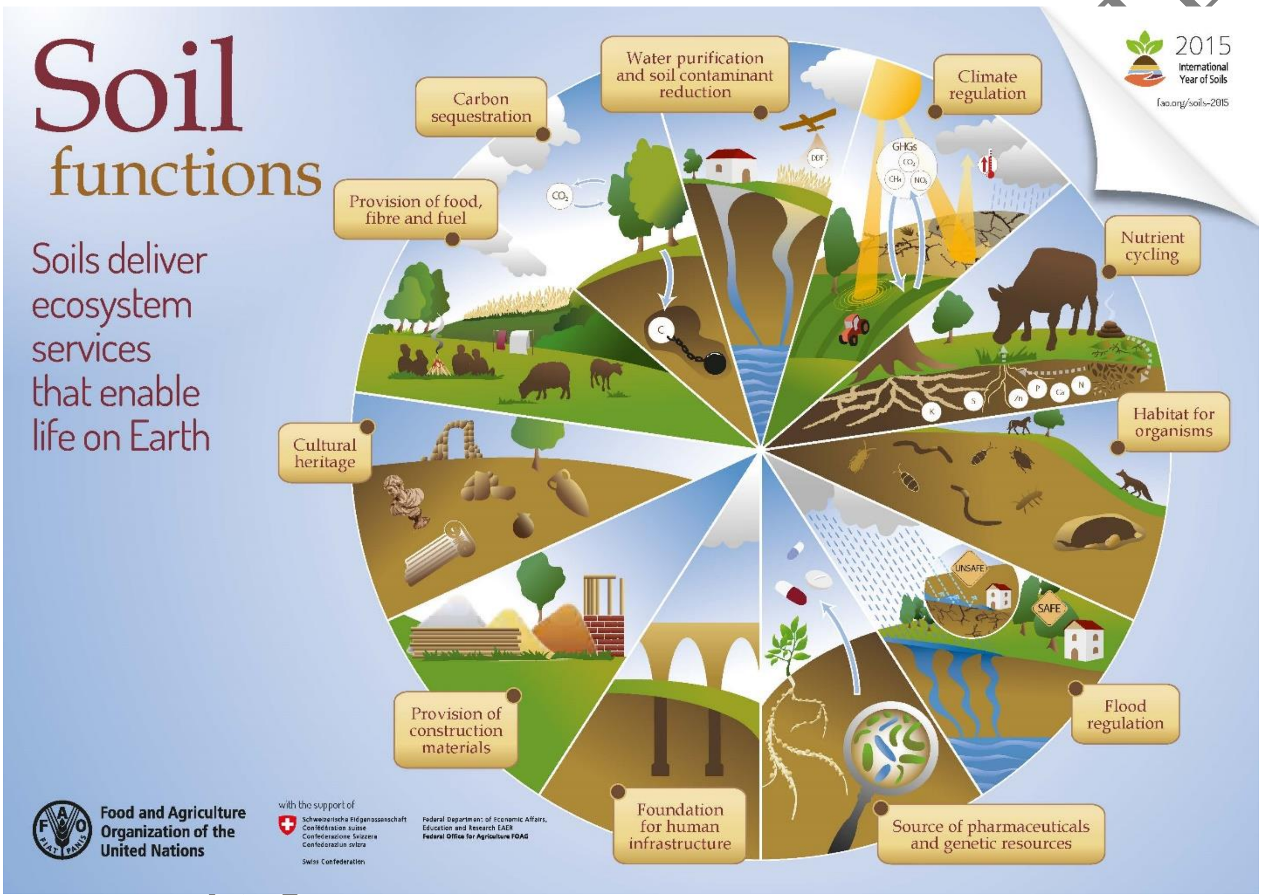
As part of the SCALE-UP project, AC3A and the Chambers of Agriculture of the Atlantic Area are working on the development of fibre crops, particularly for use in biobased building. Some of these crops, notably hemp and miscanthus, are of great interest in restoring and preserving water and soil quality, thanks to the ecosystem services they provide. These ecological benefits are detailed in the deliverable "*T2.3 Regional Biomass and Nutrient Availabilities - Study on the availability of biomass for biobased building in the French Atlantic Arc*", which completes this report.

[183] Service des données et études statistiques (SDES) en partenariat avec l'Office français de la biodiversité (OFB), *Eau et milieux aquatiques – Les chiffres clés*, 2020. https://www.statistiques.developpement-durable.gouv.fr/sites/default/files/2021-02/datalab_80_chiffres_cles_eau_edition_2020_decembre2020v2.pdf

1.2 Soil resources management profile

As with water resources, soils are essential to the proper balance of ecosystems and provide numerous services to human activity: agriculture, extraction of raw materials (sand and gravel, slate, sandstone, granite, etc.), housing and infrastructure, etc. As a result, soils are subject to numerous pressures, and their degradation has consequences such as the removal of carbon from the soil and its release into the atmosphere, the degradation of water quality and the disruption of the water cycle, and the loss of biodiversity.... Restoring and preserving them is therefore a key concern today.

Figure 56 Soil functions and ecosystem services



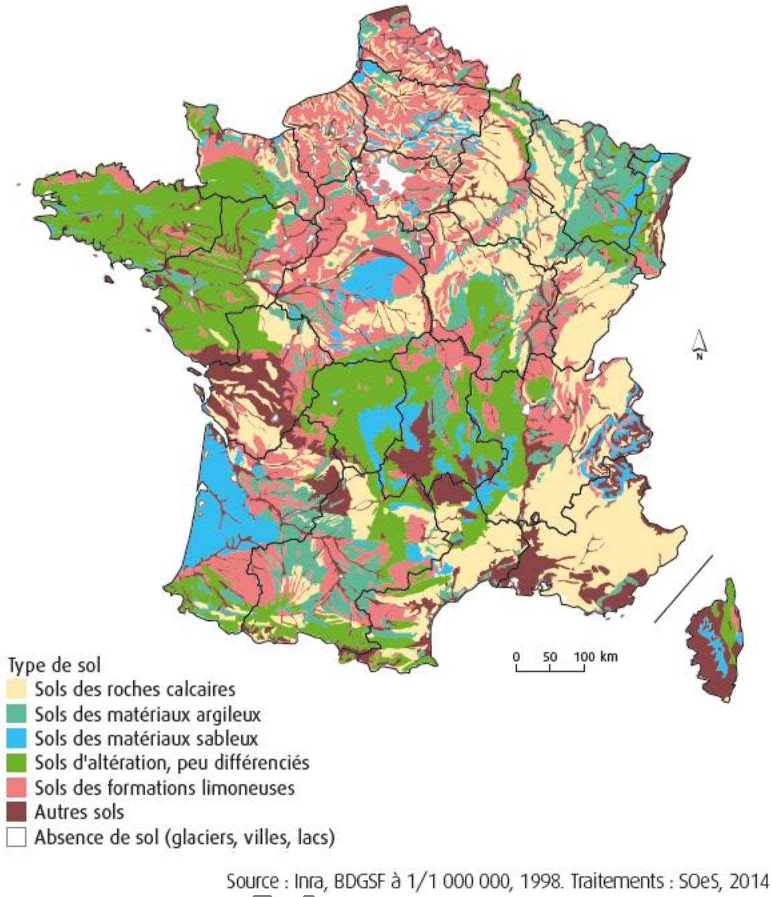
© FAO[184]

Land use in France and its challenges

France has a wide variety of soil types. The map below shows the dominant soils: the Atlantic coast has mainly weathering soils (green), sandy (blue) and calcareous (yellow) materials, as well as silty soils (pink). These different soil qualities will influence their properties and the ecosystem services they provide (for agriculture, carbon sequestration, etc.), as well as their sensitivity to the pressures they face. For example, the sandy soils of the Nouvelle-Aquitaine region are highly permeable, so they are poor at sequestering pollutants and protecting water resources. The silty soils of Normandy are more vulnerable to erosion.

[184] Source: https://www.fao.org/3/ax374e/ax374e.pdf

Figure 57 Breakdown of major soil types in mainland France[185]



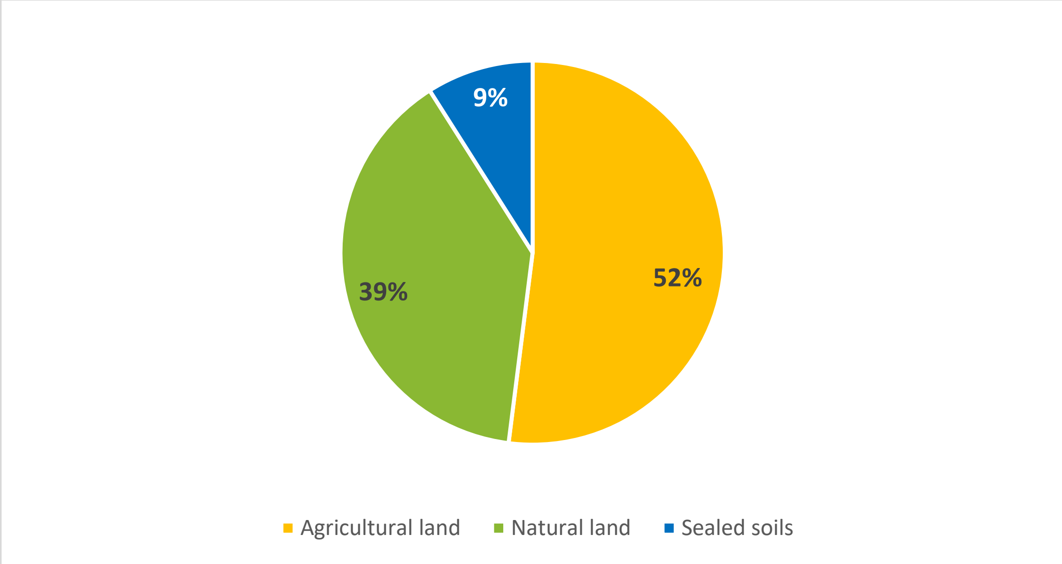
© INRAE[186]

There are three main types of land use: natural land (forests, beaches, wetlands, etc.), agricultural land (cultivated land, meadows used for livestock farming) and sealed soils (facilities, housing…).

185 Ministère de l'écologie, du développement durable et de l'énergie, *Sols et environnement, Chiffres clefs*, 2015. https://www.statistiques.developpement-durable.gouv.fr/sites/default/files/2019-01/reperes-chiffres-cles-sols-et-environnement-edition-2015-novembre2016.pdf

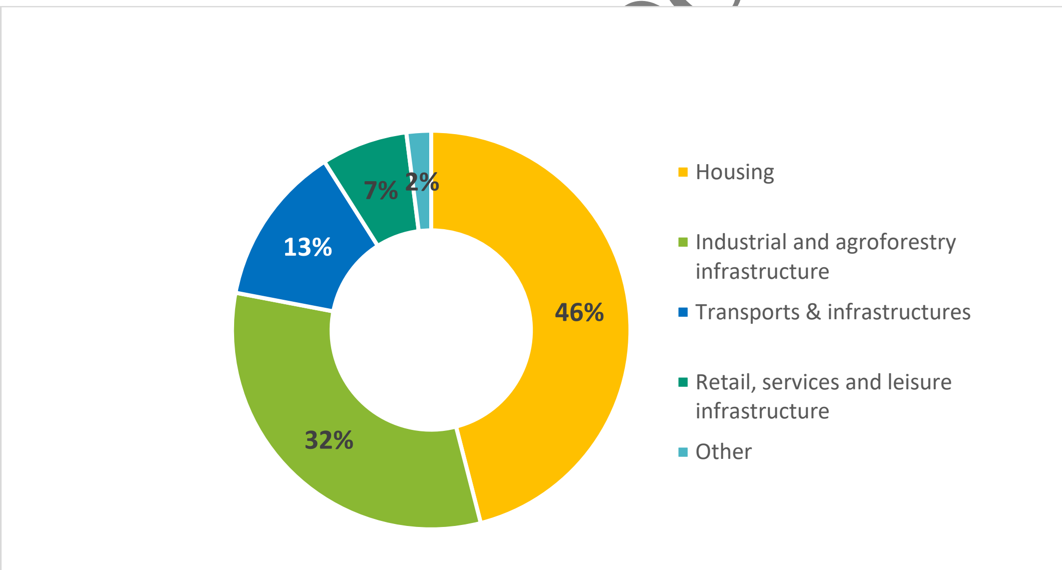
186 Source : https://www.gissol.fr/donnees/cartes/les-sols-dominants-de-france-metropolitaine-1491

Figure 58 Distribution of physical land cover in mainland France (average 2018-2019-2020) Source: Agreste, 2022



It is estimated that 9% of land is sealed, and this figure is rising steadily. Nearly 45% of sealed soils are impermeable.

Figure 59 Breakdown of sealed land by use (Source: Agreste, 2022)



Nearly irreversible, this sealing amplifies water run-off to the detriment of infiltration, thus increasing the transfer of contaminant-loaded sediments from the soil to watercourses. Sealing soils contributes to soil erosion, increases the risk of flooding, and affects biodiversity by fragmenting natural habitats and irreparably transforming ecosystems and landscapes[187].

Another major factor in soil loss is erosion, which occurs when the upper layers of a soil are carried away. The main processes involved are physical erosion, responsible for the detachment, transport and sedimentation of soil particles under the action of water (hydric erosion), tillage (arterial erosion) and wind (wind erosion)[188]. This natural and in most cases permanent phenomenon can be caused or amplified by human activity and land use, mainly agriculture and forestry: poor management of agricultural and forestry plots can lead to run-off and significant erosion. Erosion processes affect the

[187] INSEE, 2021. https://www.insee.fr/fr/metadonnees/definition/c2190
[188] Ministère de l'Agriculture et de l'Alimentation, *L'érosion des sols et ses impacts*, Décembre 2021. https://agriculture.gouv.fr/prevenir-lerosion-des-sols-pour-proteger-leurs-ressources-et-leur-biodiversite

soil's ability to perform its functions, and in particular its biomass production and carbon sequestration functions: the chemical fertility of the soil is essentially linked to the properties of the first few centimetres of soil, where the quantity of roots, organisms, living matter and dead organic matter is greatest[189]. The erosion of 15 cm of surface soil affects its fertility in the very long term, even irreversibly. Soil erosion also leads to a reduction in water resources, caused by reduced infiltration and water retention capacity of the soil, as well as a deterioration of water quality (eroded materials carrying pollutants from human activities). Erosion is particularly harmful because it attacks the most fertile soil layers, and as the formation of the soil (pedogenesis) is very slow, it is therefore a real threat to the sustainability of food production worldwide. An FAO[190] report indicates that without action to limit erosion, crop yield projections to 2050 would result in the loss of 1.5 million km² of cultivated land, the equivalent of about all of India's arable land. At national level, agricultural biomass is the second largest material extracted from the soil in terms of volume (232 million tonnes in 2019[191]), and it is estimated that soil losses due to water erosion average 1.5 t/ha/year. **Soil loss of more than 1 t/ha/year can be considered irreversible over a period of 50 to 100 years.**

Coastal erosion, corresponding to the retreat of the coastline and the lowering of beaches, is also a major issue for the regions along the Atlantic Arc, and will be accentuated by climate change, particularly the rise of sea levels.

Lastly, soil salinisation, which corresponds to an increased mineral content in the soils (sodium, potassium, magnesium, calcium, chlorine, sulphate and bicarbonate), is often caused in an agricultural context by the inappropriate irrigation of crops, and also due to massive fertiliser applications (i.e. greenhouse soils). This salinisation adversely affects certain soil organisms, as well as plant growth, making it difficult for plants to extract water. It can make soils unproductive and contaminate water, as it increases toxicity and contributes to the deterioration of soil structure. In France, it is mainly coastal areas that are at risk and could be even more so as sea levels rise, but climate change could also cause soil salinisation to increase across the country as temperatures rise.

Agroecology is one of the solutions studied today to combat soil erosion in agricultural land. Agroecology offers solutions for reducing the use of inputs and tillage while ensuring agricultural production. These solutions include biocontrol (pest control using natural predators), crop diversification, hedgerow management and winter cover.

Governance and soil conservation in France

A new European directive is in progress which results from the EU's Soil Strategy adopted in 2021, in the framework of the European Green Deal. It will step up efforts to enhance soil management, protect soil fertility, reduce erosion and sealing, increase organic matter, increase soil carbon in agricultural land and restore degraded soils, so that by 2050 all soil ecosystems are healthy.

In France, there is no policy dedicated to soil and the issue of soil is therefore addressed in several policies, but in a fragmented way. Soil is governed by the Rural Code, the Environment Code and the Town Planning Code, making public action highly complex. This situation is largely explained by the fact that land is subject to ownership, which makes it more difficult to implement protection measures, and raises problems of acceptability and conflicts of use when introducing new regulations[192]. The main policies relating to soil protection are listed in the table below:

189 *Ibid.*
190 FAO, *Sol erosion, the greatest challenge for sustainable soil management*, 2019. https://www.fao.org/3/ca4395en/ca4395en.pdf
191 Ministère de la transition écologique et de la cohésion des territoires, *Les sols en France – Synthèse des connaissances en 2021*, Mars 2022. https://www.statistiques.developpement-durable.gouv.fr/les-sols-en-france-synthese-des-connaissances-en-2021#:~:text=%C3%80%20l%27%C3%A9chelle%20mondiale%2C%20le,30%20premiers%20centim%C3%A8tres%20du%20sol
192 INRAE, *Les sols, un objet politique complexe*, Juin 2023. https://www.inrae.fr/dossiers/peut-encore-sauver-sols/sols-objet-politique-complexe

Table 33 Main soil protection policies in France

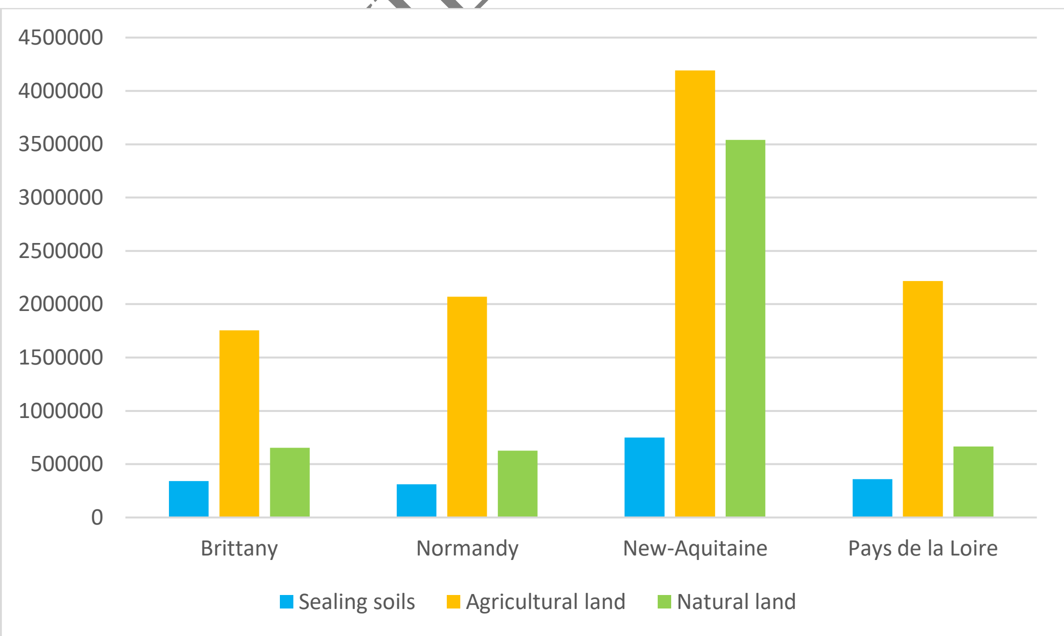
National low-carbon strategy – SNBC (2015)	As a roadmap for combating climate change, the SNBC promotes increasing natural carbon sinks to absorb greenhouse gas (GHG) emissions, through the development of agro-ecology, agro-forestry and changes in practices favourable to soil protection (in particular permanent grasslands).
Biodiversity plan (2018)	Introduces the objective of "*Zéro artificialisation nette - ZAN*" (zero land take) by 2050 by limiting the consumption of new areas and recreating natural areas. The Biodiversity Plan was followed by the "National Biodiversity Strategy 2030" adopted in 2023, which sets out 40 measures to reduce the pressures on biodiversity. Measure 26 concerns soil protection and restoration, by improving knowledge and data on soil health and developing funding for soil restoration.
National circular economy roadmap (2018)	The agricultural section of the National circular economy roadmap includes measures to improve soil quality and reduce dependence on fertilisers derived from non-renewable resources.
Sustainable bioeconomy strategy	Adopted by the ADEME (national agency for ecological transition), it is structured around three areas: sustainable management of soil, farming and forestry systems, the development of sustainable food systems, and support for sustainable bio-based industries.

In 2001, France also set up a soil scientific interest group (GIS Sol) to monitor soil quality.

Summary of soil conditions by region in the Atlantic Arc

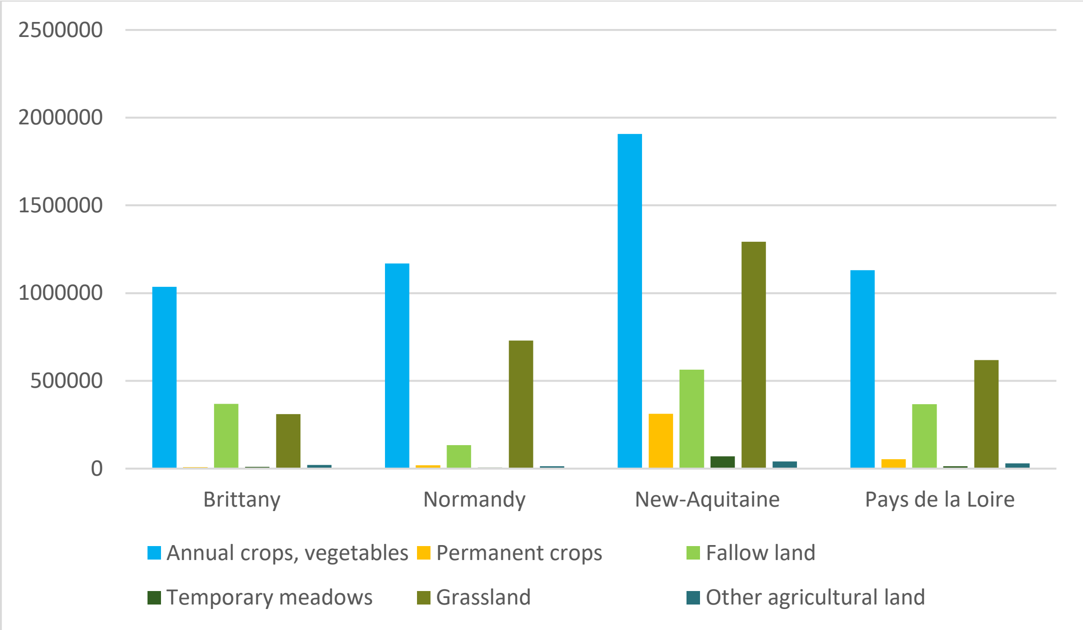
The Atlantic Arc region is exposed to the risk of erosion: coastal erosion, linked to its extensive seafront, but also arable erosion linked to the dominant agricultural use of the land and the intensive practices associated with arable and livestock farming.

Figure 60 Distribution of physical land use in the French Atlantic Arc (in hectares)[193]



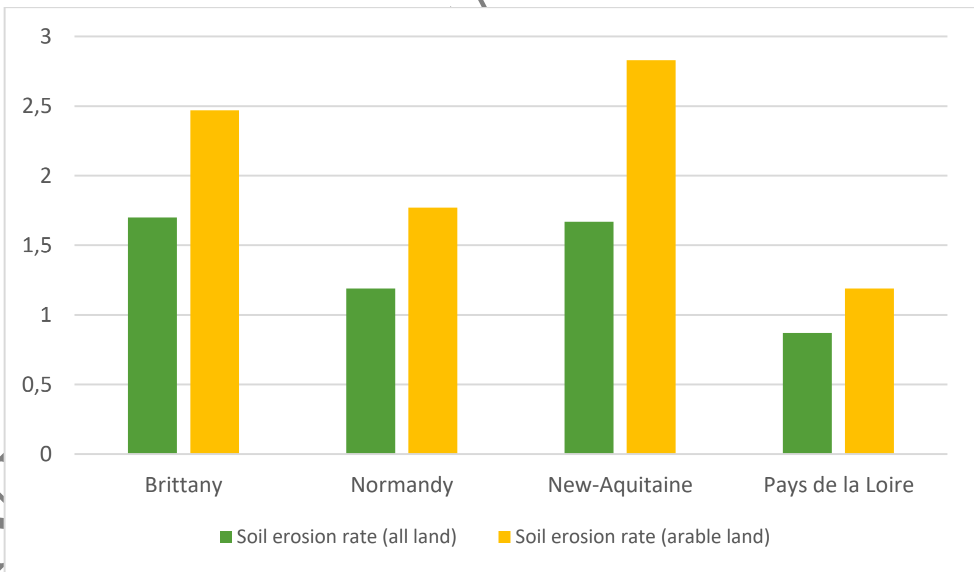
[193] Agreste, *L'utilisation du territoire en 2019 – Enquêtes Teruti 2018-2019-2020*, 2022. https://agreste.agriculture.gouv.fr/agreste-web/download/publication/publie/Chd2212/cd2022-12_teruti_2019.pdf

Figure 61 Distribution of agricultural land in the French Atlantic Arc (in hectares)[194]



The graph below shows a greater erosion of arable land, bearing in mind that the agricultural area for each region represents the largest share of land use (see previous graphs).

Figure 62 Soil erosion rate in the Atlantic Arc regions



Source: RUSLE dataset, 2015[195]

The soil erosion rates for each region remain below the European thresholds for vulnerability to erosion (severe erosion corresponding to a loss of 11 tonnes/hectare/year), but the situation varies at local level and according to the pressures affecting the soil. Therefore, in areas where soil erosion crosses this threshold, or where erosion rates are increasing, some measures can be taken: creating

194 *Ibid.*

195 https://esdac.jrc.ec.europa.eu/content/soil-erosion-water-rusle2015

incentives against planting crops on high slopes; creating incentives for erosion control practices such as contouring, conservation tillage or mulching. Specific alternative tillage and mulching practices will depend on the crops being planted, and can often increase yields and reduce costs, however they can lead to an increase in pesticide consumption.

Given the ecosystem services provided by soils (for water quality, biodiversity, etc.), any economic activity that promotes soil restoration and preservation should be encouraged. Ecosystem services are defined as the socio-economic benefits derived by humans from the sustainable use of the ecological functions of ecosystems. When applied to soils, the concept of ecosystem services highlights their capacity to provide, within ecosystems, a wide range of ecological functions that are essential for both humans and the environment.

1.3 Biodiversity management profile

Rich but threatened biodiversity in mainland France

"Biodiversity is the wealth of species and ecosystems, their genetic diversity and their interactions. Beyond their intrinsic value, these species and ecosystems provide an immeasurable number of services to our societies. For example, insects pollinate our fields, wetlands provide us with drinking water and limit the damage caused by flooding, trees protect us from the heat of the city and from erosion in the mountains, the oceans regulate the global climate, and mangroves and dunes protect us from storms. They are the fruit of 4.7 billion years of innovation"[196].

In the era of the Anthropocene, biodiversity is being eroded to such an extent that scientists are talking about a sixth mass extinction of species. At the current rate of deforestation, tropical forests could disappear within 50 to 70 years. Mainland France is not spared by this phenomenon, and the Red List Index of the International Union for Conservation of Nature (IUCN, the international body responsible for monitoring biodiversity worldwide) reports "worrying developments"[197]: 17% of flora and fauna species are now threatened or extinct in France, and their risk of extinction has increased by almost 14% in less than ten years[198]. The French Office for Biodiversity (OFB), a public body dedicated to protecting and restoring biodiversity, estimates that 14% of mammals, 24% of reptiles, 23% of amphibians and 32% of breeding birds are threatened with extinction in mainland France.

There are currently five main categories of pressure on biodiversity[199]:

1) **The destruction of natural habitats and soil sealing**. In France, this mainly takes the form of the consumption of natural areas for land development or the intensive use of certain agricultural and forestry areas. The simplification of landscapes and the reduction in the area of grassland also explain the loss of biodiversity in agricultural areas.

2) **Over-exploitation of natural resources and illegal trafficking**. This is the excessive removal of resources from the natural environment (overfishing, deforestation, etc.).

3) **Global climate change**. Rising temperatures (an increase of 1°C in France corresponds to a shift in climatic zones of around 200 km to the north) are leading to changes in the way species live and/or their ranges. It is also leading to an intensification of extreme weather phenomena, particularly droughts, with an impact on flora and fauna.

4) **Pollution of the oceans, freshwater, soil and air**. Dangerous substances, macro-waste, micro-plastics, noise and light pollution... these pollutants are numerous and omnipresent. In France, sales of plant protection products for agricultural use rose by 14% between 2009-2011 and 2018-2020[200]. At the same time, populations of birds specialising in agricultural environments have collapsed by 36% between 1989 and 2021. Generally speaking, the decline in specialist, common

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[196] Ministère de la transition écologique et solidaire, *Plan biodiversité*, Juillet 2018. https://www.ecologie.gouv.fr/sites/default/files/18xxx_Plan-biodiversite-04072018_28pages_FromPdf_date_web_PaP.pdf

[197] Ministère de la transition écologique et solidaire, *L'environnement en France – Rapport de synthèse*, 2019. https://www.notre-environnement.gouv.fr/IMG/pdf/9782111570573_lenvironnementenfrance_edition2019_rapportdesynthese_v24_web_light.pdf

[198] Office Français de la Biodiversité, *La biodiversité française en déclin, 10 ans de chiffres-clés par l'Observatoire national de la biodiversité*, 2023. https://www.calameo.com/ofbiodiversite/read/0035029487d2ed5b45958

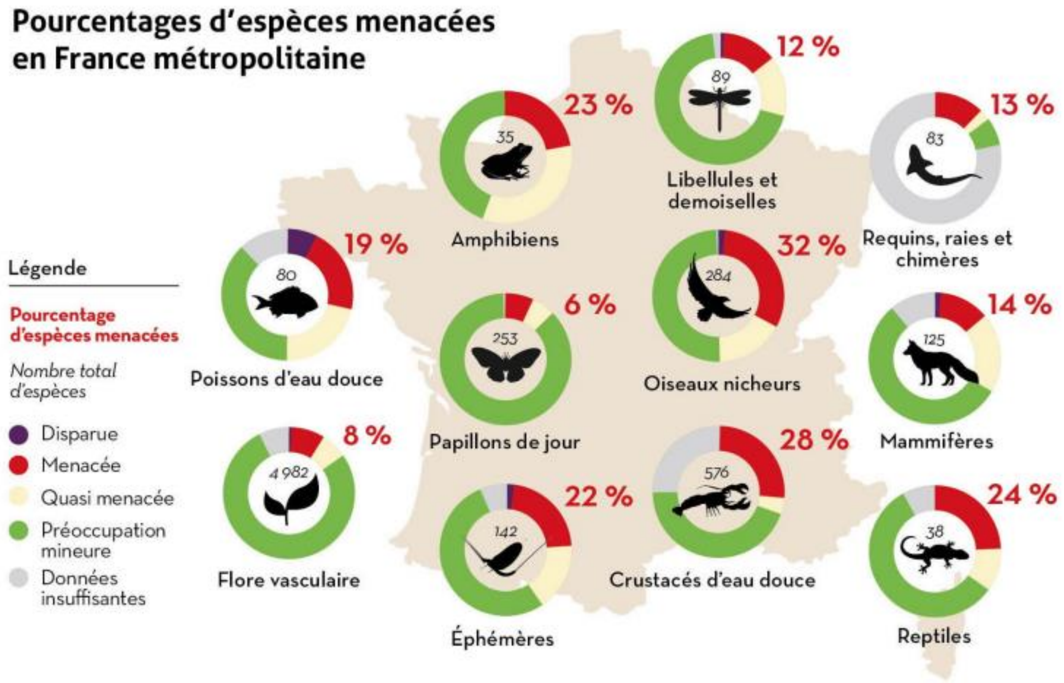
[199] Ministère de la transition écologique et solidaire, *Les 5 pressions responsables de l'effondrement de la biodiversité*, 2022. https://biodiversite.gouv.fr/les-5-pressions-responsables-de-leffondrement-de-la-biodiversite

[200] Office Français de la Biodiversité, *La biodiversité française en déclin, 10 ans de chiffres-clés par l'Observatoire national de la biodiversité*, 2023. https://www.calameo.com/ofbiodiversite/read/0035029487d2ed5b45958

or rare species (both fauna and flora) is leading to a homogenisation of biodiversity, which is one of the forms of biodiversity decline.

5) **The introduction of invasive exotic species**. Some of the most common in mainland France are the coypu, the Asian hornet, primrose, etc. These species, introduced deliberately or accidentally, disrupt ecosystems and compete with endemic species. In mainland France, there are 84 invasive alien species, with an average of six new species arriving in each county every ten years since 1979[201].

Figure 63 Percentage of threatened species in mainland France (purple = disappeared ; red = endangered ; yellow = almost endangered ; green = low concern ; grey = missing data)



IUCN, 2020[202]

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[201] Commissariat général au Développement durable, *La biodiversité sous pression*, Janvier 2020. https://www.vie-publique.fr/parole-dexpert/272596-quel-est-letat-de-la-biodiversite-en-france-les-principales-menaces#:~:text=En%20France%20m%C3%A9tropolitaine%2C%20sur%20un,vivent%20de%20nombreuses%20esp%C3%A8ces%20end%C3%A9miques.

[202] UICN, *La Liste rouge des espèces menacées en France, 13 ans de résultats*, 2020. https://uicn.fr/wp-content/uploads/2021/03/bilan-13-ans-liste-rouge-nationale.pdf

Figure 64 The Red List of threatened species in France

UICN Comité Français — MUSÉUM NATIONAL D'HISTOIRE NATURELLE

La Liste rouge des espèces menacées en France

La Liste rouge des espèces menacées en France
Nombre d'espèces évaluées par catégorie

France métropolitaine

Groupe taxonomique		EX	EW	RE	CR	EN	VU	NT	LC	DD	Nb total d'espèces évaluées	Nb total d'espèces menacées	Proportion d'espèces menacées*	Date de publication des résultats	Partenaires
MAMMIFERES	Toutes espèces	0	0	2	3	4	10	24	68	14	125	17	14%	Nov 2017	SFEPM & ONCFS
	Terrestres	*0*	*0*	*0*	*3*	*4*	*9*	*18*	*63*	*6*	*103*	*16*	*16%*		
	Marins	*0*	*0*	*2*	*0*	*0*	*1*	*6*	*5*	*8*	*22*	*1*	*5%*		
OISEAUX	Nicheurs	0	0	5	16	30	46	43	142	2	284	92	32%	Sept 2016	LPO, SEOF & ONCFS
	Hivernants	*0*	*0*	*0*	*0*	*2*	*6*	*5*	*39*	*8*	*60*	*8*	-	Mai 2011	
	De passage	*0*	*0*	*0*	*0*	*1*	*6*	*5*	*15*	*25*	*52*	*7*	-	Mai 2011	
REPTILES	Toutes espèces	0	0	0	0	3	6	4	21	4	38	9	24%	Sept 2015	SHF
	Terrestres	*0*	*0*	*0*	*0*	*3*	*6*	*4*	*21*	*1*	*35*	*9*	*26%*		
	Marins	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3*	*3*	*0*	-		
AMPHIBIENS		0	0	0	0	3	5	12	15	0	35	8	23%	Sept 2015	SHF
POISSONS D'EAU DOUCE		3	0	3	4	6	5	16	31	12	80	15	19%	Juil 2019	SFI & AFB
REQUINS, RAIES ET CHIMERES		0	0	0	3	5	3	3	6	63	83	11	13%	Dec 2013	
CRUSTACES D'EAU DOUCE		0	0	0	10	6	145	22	244	149	576	161	28%	Juin 2012	
PAPILLONS DE JOUR		0	0	1	2	3	11	18	215	3	253	16	6%	Mars 2012	OPIE & SEF
LIBELLULES		0	0	2	1	3	7	13	62	1	89	11	12%	Mars 2016	OPIE & SFO
EPHEMERES		0	0	2	5	10	16	23	77	9	142	31	22%	Juil 2018	OPIE
MOLLUSQUES TER. & EAU DOUCE		0	0	2	12	25	42	32	293	285	691	79	11%	Juil 2021	
FLORE VASCULAIRE		2	0	22	51	132	238	321	3843	373	4982	421	8%	Dec 2018	FCBN & AFB
TOTAL **		5	0	39	107	230	534	531	5017	915	7378	871			

** Proportion d'espèces menacées calculée pour les groupes d'espèces évalués en totalité et comportant au moins 10 espèces.*
*** Hors oiseaux hivernants et de passage.*

Les catégories de l'UICN pour la Liste rouge

Espèces disparues :
EX : Eteinte au niveau mondial
EW : Eteinte à l'état sauvage
RE : Disparue au niveau régional

Espèces menacées de disparition :
CR En danger critique
EN En danger
VU Vulnérable

Autres catégories :
NT : Quasi menacée (espèce proche du seuil des espèces menacées ou qui pourrait être menacée si des mesures de conservation spécifiques n'étaient pas prises)
LC : Préoccupation mineure (espèce pour laquelle le risque de disparition est faible)
DD : Données insuffisantes (espèce pour laquelle l'évaluation n'a pas pu être réalisée faute de données suffisantes)

Source : UICN Comité français & MNHN (2022). La Liste rouge des espèces menacées en France. Paris, France.

IUCN, 2022[203]

Protecting biodiversity in France

The erosion of biodiversity is recognised as a major risk factor for the functioning of our human societies and for the stability of the economic system: a report by the French Ministry of Ecology estimates that at least 80% of employment depends on biodiversity, either directly or indirectly[204]. As a result, a number of policies have been put in place to encourage the monitoring, protection and restoration of biodiversity:

Table 34 Main policies for protecting biodiversity in France

Grenelle Environment Forum	A process initiated in 2008 to encourage and accelerate the consideration of environmental challenges in all sectors (energy and construction, transport, biodiversity and natural environments, governance, environmental and health risks).
Habitat, Fauna and	European directive of 21 May 1992 for the protection of "remarkable"

[203] UICN, *La Liste rouge des espèces menacées en France*, 2022. https://uicn.fr/wp-content/uploads/2022/12/resultats-synthetiques-liste-rouge-france.pdf
[204] Emmanuel Delannoy, *La biodiversité, une opportunité pour le développement économique et la création d'emploi*, 2016. https://www.ecologie.gouv.fr/sites/default/files/DELANNOY_BIODIV_Rapport_Final_20161117.pdf

Flora Directive	environments and species, serving as the legal basis for the Natura 2000 network by providing for the designation of Special Areas of Conservation (SAC) and the protection of species throughout mainland France.
Birds Directive	European directive of 2 April 1979 on the protection of wild birds, which serves as the legal basis for the Natura 2000 network, notably by providing for the designation of Special Protection Areas (SPAs) throughout mainland France.
Objectives document	Framework document validated by the Prefect, defining, for each Natura 2000 site, an inventory of the site, the management objectives and the procedures for implementing them.
Natura 2000	European ecological network of natural sites designated under the "Habitats" and "Birds" Directives, with the aim of conserving habitats and species of Community interest.

Source: OFB

In terms of biodiversity monitoring, production of the national Red List is coordinated by the UMS PatriNat (OFB-CNRS-MNHN) and the French IUCN committee. The role of the National Biodiversity Observatory (ONB) is to make available and disseminate reliable and regularly updated information on the state of biodiversity in France.

The Red List of threatened species in the Atlantic Arc

Based on the national Red List of Threatened Species, the authors of this report have drawn up a list of 19 "endangered" and "critically endangered" species (flora and fauna) that are likely to be impacted by the development of bioeconomy activities in the Atlantic Arc in connection with the value chain of the SCALE-UP project (fibre plants for use in bio-based construction). Many are located in the Pyrenean mountains and depend on a fragile natural environment.

Table 35 Red list of species likely to be impacted by the development of the bioeconomy as part of SCALE-UP in the Atlantic Arc

Name	Status	Description
Mercuria vindilica	Endangered	A species of the mollusc family, endemic to Belle-Île-en-Mer and living in freshwater. Threatened by water degradation and urbanisation.
Belgrandia conoidea	Endangered	Small freshwater snail, only known from two freshwater sites near Montauban. Threatened by water degradation and urbanisation.
Aster pyrenaeus	Endangered	A flowering plant found only in the Pyrenees, threatened by habitat fragmentation, abandonment of traditional land management, overgrazing and recreational activities.
Cobitis calderoni	Endangered	River fish, victim of habitat degradation (gravel extraction, water catchments) and the presence of invasive exotic species.
Halictus carinthiacus	Endangered	An insect whose range is fragmented and whose decline is linked to habitat degradation, climate change, changes in land use and urbanisation.

Metrioptera buyssoni	Endangered	A grasshopper endemic to the Pyrenees, whose population is highly fragmented. The causes of its decline are poorly identified, but can be attributed to climate change (droughts) and overgrazing.
Isoetes boryana	Endangered	An aquatic plant with a very limited range that is heavily impacted by eutrophication and water management.
Cryptazeca monodonta	Endangered	A small terrestrial snail endemic to the western Pyrenees that lives in damp habitats. Its habitat is very restricted and fragmented, and it is vulnerable to increasing drought.
Oxychilus basajauna	Endangered	Land snail native to Spain, threatened by urbanisation and changes to river margins.
Rana pyrenaica	Endangered	The Pyrenean frog population is in decline due to the degradation of its natural habitat.
Isoetes tenuissima	Endangered	Aquatic species threatened by the degradation of its habitat, present in protected areas.
Sphegina limbipennis	Endangered	A flying insect found in the Pyrenees and the Armorican Basin, threatened by intensive farming practices, climate change and habitat degradation.
Chrysogaster rondanii	Endangered	A flying insect whose decline is linked to forest management, groundwater abstraction, nitrogen and pesticide deposits, and climate change.
Microdon major	Endangered	A flying insect with a restricted and fragmented range, threatened by habitat degradation.
Sphegina atrolutea	Endangered	A flying insect found in the Pyrenees, in forested areas with watercourses. Its habitat is threatened by agricultural and recreational practices, as well as by forestry operations.
Sphegina varifacies	Endangered	A flying insect whose distribution is severely fragmented, threatened by the intensification of forestry and water management.
Pseudunio auricularius	Critically endangered	The population of this river mussel has been reduced by 90% in 30 years due to river development and water abstraction, causing fragmentation and degradation of its habitat.
Corticeus bicoloroides	Endangered	A beetle found in the Pyrenees that thrives in dead wood. It is threatened by intensive forestry and farming practices.
Galemys pyrenaicus	Endangered	The Pyrenean Desman is a small mammal whose population is thought to have fallen by 50% over the last 10 years. The reasons for this decline are not well known, but are probably linked to human activities and the proliferation of invasive exotic species in its habitat.

Given the current pressures on biodiversity, any bioeconomy activity must take account of its potential impact and limit it. Activities that protect and restore biodiversity should be encouraged.

2 Methodology for the appraisal of available capacity of the regional ecosystem

This section describes the methodology that has been applied by the authors of this report to assess the water, soil and biodiversity resources in the French Atlantic Arc, and the conclusions regarding ecological boundaries in this area.

2.1 Water data and indicators

To run the sustainability screening of surface and groundwater bodies potentially relevant to the macro-region of the French Atlantic Arc, the authors of this report have reviewed the data reported in the 2nd River Basin Management Plan of the Adour-Garonne, Loire-Brittany, and Seine-Normandy River Basin Districts published in 2016 (data from the 3rd reporting cycle was not yet available on the WISE Data-base at the time of the analysis). The benefits of tapping on this reporting process is that it includes well-defined indicators like the status of water bodies in each river basin district as well as data on significant pressures and impacts on them. Further, these data are official, largely available, accessible, and updated periodically (every six years).

2.1.1 Description of the data / definition of the indicators employed

Data reviewed for this part of the screening included the reported ecological and chemical status of rivers and lakes as well as the quantitative and chemical status of groundwater bodies in the river basin districts in the Atlantic Area. These data give indications on water quality in the river basins according to the five status classes defined in the WFD. These are: high (generally understood as undisturbed), good (with slight disturbance), moderate (with moderate disturbance), poor (with major alterations), and bad (with severe alterations) (EC, 2003). Further, data on significant pressures and significant impacts on the water bodies in the river basin districts are used to indicate the burden of specific pressure and impact types on water ecosystems in the regions based on the number and percentage of water bodies subject to them. Significant pressures are defined as the pressures that underpin an impact which in turn may be causing the water body to fail to reach at least the good status class (EEA, 2018).

All data described above were accessed on 11.10.2023 from the WISE WFD data viewer (Tableau dashboard) hosted on the European Environment Agency's website[205].

Table 36 Indicators used for the water component of the sustainability screening

Category	Indicator Family	Indicator	Spatial level	Unit of measure	Comments/Reference
Water	Water quality	Status of water bodies according to the EU Water Framework Directive	River Basin District	Number of water bodies in high, good, moderate, poor, bad or unknown status	WISE WFD Data Viewer[206] Disaggregated data for ecological and chemical status of surface water bodies; quantitative and chemical status of groundwater bodies, per River Basin District

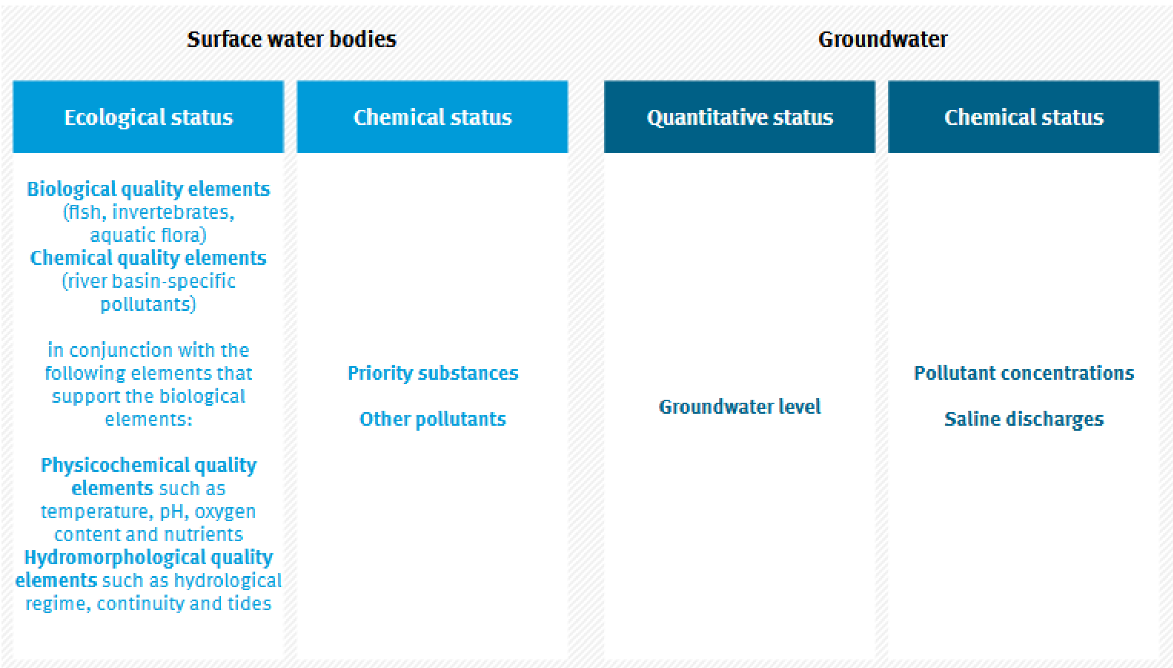
[205] https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd
[206] WISE WFD Data Viewer (https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd)

	Burden on water bodies	Significant pressures on water bodies	River Basin District	No. and % of water bodies under significant pressures per pressure type	WISE WFD Data Viewer
	Burden on water bodies	Significant impacts on water bodies	River Basin District	No. and % of water bodies under significant impacts per impact type	WISE WFD Data Viewer

Source: Anzaldúa et al., 2022.

To determine which status class a certain water body falls into, WFD assessments evaluate the *ecological* and *chemical* status of surface waters (i.e. rivers and lakes) and the *quantitative* and *chemical* status of groundwater bodies. Ecological status refers to *“an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters”.* It covers assessments of biological (e.g. presence and diversity of flora and fauna), physico-chemical (e.g. temperature and oxygen content) and hydromorphological criteria (e.g. river continuity) (EC, 2003; BMUB/UBA, 2016). The chemical status of a surface water body is determined by comparing its level of concentration of pollutants against pre-determined environmental quality standards established in the WFD (concretely in Annex IX and Article 16(7)) and in other relevant Community legislation. These standards are set for specific water pollutants and their acceptable concentration levels.
In the case of groundwater bodies, chemical status is determined on the basis of a set of conditions laid out in Annex V of the WFD which cover pollutant concentrations and saline discharges. Additionally, the water body’s quantitative status is included in the WFD assessments, defined as “*an expression of the degree to which a body of groundwater is affected by direct and indirect abstractions”*. This gives indication on groundwater volume, a relevant parameter to evaluate hydrological regime (BMUB/UBA, 2016).

Figure 65 Overview of surface water body and groundwater status assessment criteria, as per the Water Framework Directive.



Source: BMUB/UBA, 2016.

In the case of surface water bodies, the WFD objective is not only that they reach good status, but that quality does not deteriorate in the future (EC, 2003), which is relevant in the context of the development of bioeconomy value chains.

2.1.2 Methodology applied

The authors of this report have devised an approach to valorise the data from the WFD reporting described in the previous sub-section that allows for an appraisal that is non-resource intensive (based on reliable, publicly available and accessible data) yet capable of providing a rough overview of the state of the Atlantic Arc's waters. This is in line with the rationale of this sustainability screening, which aims to enable stakeholders with limited financial resources and/or expertise in the field to consider ecological limits in a structured manner when developing bioeconomy activities. The preferred option for this part of the assessment would have been to supplement the WFD data with a water quantity balance indicator like the Water Exploitation Index plus (WEI+) developed by the EEA and its partners. That indicator compares the total fresh water used in a country per year against the renewable freshwater resources (groundwater and surface water) it has available in the same period. This could have strengthened the water quantity element in the screening. However, the calculation of the WEI+ at regional level is currently not conducted or foreseen by its developers, and it would entail a disproportionately large effort that falls beyond the scope of this task in SCALE-UP. For these reasons, the reported data from the WFD process has been employed exclusively within the following methodology.

The overall apportionment of rivers, lakes and groundwater bodies in the Atlantic Arc according to their WFD status classification can be used to set the baseline for the sustainability screening. It provides initial insight on the situation in the demarcation as regards "ensuring access to good quality water in sufficient quantity", "ensuring the good status of all water bodies", "promoting the sustainable use of water based on the long-term protection of available water resources" and "ensuring a balance between abstraction and recharge of groundwater, with the aim of achieving good status of groundwater bodies", all explicit aims of the WFD that are aligned with the consideration of ecological limits. Further, the data on significant impacts and pressures affecting the water bodies in the river basins are useful as they can point towards specific problems (e.g. nutrient pollution) and the types of activities that may be causing them (e.g. discharge of untreated wastewater, agriculture).

As a first step, the approach used for this element of the screening entails calculating what proportion of the total number of surface water bodies located in the RBD is reported as failing to achieve Good Ecological Status/Good Chemical Status or for which conditions are unknown. Similarly for groundwater bodies, the proportion is calculated of those who are reported as failing to achieve Good Chemical Status/Good Quantitative Status or for which conditions are unknown. The resulting ratios are then compared to the respective EU proportions, which are used as (arbitrary) thresholds. According to the latest assessment published by the EEA in 2018, "around 40% of surface waters (rivers, lakes and transitional and coastal waters) are in good ecological status or potential, and only 38% are in good chemical status" (EEA, 2018). Accordingly, "good chemical status has been achieved for 74% of the groundwater area, while 89% of the area achieved good quantitative status" (EEA, 2018). Using these markers, the following step is to rank the current conditions of the French Atlantic Arc using an ordinal risk rating (high, moderate, low) based on the distance of the result of each indicator to the EU level results. On this basis, the thresholds and ordinal ranking convention suggested by the authors of this report are as shown in Table 8 and Table 9.

Table 37 Proposed thresholds for the water section of the sustainability screening

Water body type	Status category	2018 EU-level assessment results (proportion of water bodies achieving good status)	Proposed thresholds for the sustainability screening		
			High concern	Moderate concern	Low concern
Surface water bodies	Ecological status	~40%	0-40%	41-89%	90-100%
	Chemical Status	38%	0-38%	39-89%	90-100%
Groundwater bodies	Chemical status	74%	0-74%	75-89%	90-100%
	Quantitative status	89%	0-89%	-	90-100%

Source: Anzaldúa et al., 2022.

Table 38 Ordinal ranking convention for the water section of the sustainability screening

Ordinal ranking for water resources		Chemical status		
		High concern	Moderate concern	Low concern
Ecological or Quantitative status	High concern			
	Moderate concern			
	Low concern			

Source: Anzaldúa et al., 2022.

This initial appraisal based on the thresholds shown above is then supplemented with a review of the reported data on the types of significant pressures and impacts on surface and groundwater bodies. In this case percentage values are already given, and so this step in the screening simply entails the listing of the reported pressures and impacts and the identification of those which are more frequently reported. From here, the screening team can seek potential correlations between the most reported pressure types and the most reported impact types (e.g. diffuse sources causing nutrient pollution).

The final step in the approach is to draft a note describing the share of water bodies failing to reach good status and formulating preliminary statements on the types of bioeconomy activities that could be considered, those that should be considered with reserve, and those that should be avoided. These initial statements are intended to frame the discussion of the group of stakeholders involved in the development of the bioeconomy value chains in focus in the SCALE-UP project.

2.1.3 Data uncertainties

The data resulting from the assessments reported in the French Atlantic Arc and subsequently in WISE are subject to the limitations of the scientific and methodological approaches used by their authors. It thus must be considered that the official assessments are based on estimates, include assumptions, and will therefore carry a margin of error.

An important limitation bound to the implementation of the sustainability screening is that the WFD data used cover a larger area than that of the French Atlantic Arc region (see maps on page 11 "*Overlay of the boundaries of the four administrative regions in the French Atlantic Arc against the River Basin Districts they lie in"*). Therefore, the data used on the qualitative and quantitative status of water in the three river basins covers other neighbouring regions. Consequently, where possible, these data have been supplemented by data and contextual elements from the literature review (see references at the end of the document), based on official sources (Water Agencies of the basin districts, French Biodiversity Agency, groups of experts mandated by the regional councils such as the IPCC in Pays de la Loire and AcclimaTerra in New-Aquitaine).

Lastly, another issue to consider is the data currently available on WISE is from 2016, while more updated (interim) assessments are already available at the time of writing of this document. These come as part of the 3rd cycle of river basin management planning (2022-2027) but not already publicly available. The data used from the literature review is mainly based on state of water quality in the water districts in 2020, based on data from 2016-2017.

2.1.4 Methodological uncertainties

The proposed methodology for the water section used in this application of the sustainability screening is straight-forward and accessible, yet it must be used with care and, where possible, should incorporate higher resolution data evaluated by thematic experts. As previously mentioned, the thresholds set in this case have been the proportions, at EU-level, of water bodies that fail to achieve good status or for which conditions have been reported as unknown.

2.2 Soil data and indicators

2.2.1 Description of the data / definition of the indicators employed

The selected indicators for vulnerability to soil depletion are closely interrelated and refer specifically to soil erosion **by water**. These are:

- Estimated mean soil erosion rate (in $t\ ha^{-1}\ a^{-1}$)
- Share (%) of area under severe erosion (>10 $t\ ha^{-1}\ a^{-1}$)

In broad terms, soil erosion describes the process through which land surface (soil or geological material) is worn away (e.g. through physical forces like water or wind) and transported from one point of the earth surface to be deposited somewhere else (Eurostat, 2020). The above-mentioned indicators describe particularly the amount of soil (in t) per unit of land surface (in ha) that is relocated by water per year.

Variations of these indicators can be calculated by considering different combinations of land cover classification groups, such as *all land*[207] and *agricultural land*[208]. As shown in 14, at EU level in 2016, about three quarters of soil loss occurred in agricultural areas and natural grasslands, while the remaining quarter occurred in forests and semi natural areas (Eurostat, 2020). Therefore, since it is the type of land cover that is most vulnerable to erosion, the present sustainability screening will consider in first line the above-mentioned indicators specifically for agricultural areas and natural grasslands. This scope of the indicators is also in line with the two sub-indicators for soil erosion considered by the Joint Research Centre European Soil Data Centre (JRC ESDAC). Moreover, both the *mean erosion rate for agricultural land* and the *share of agricultural area under severe erosion* are part of the EU Common Agriculture Policy (CAP) context indicator 42 (CCI42) for the period 2014-2020.

Figure 66 Share of land cover and soil loss across the EU-27 in 2016[209]

Source: JRC, Eurostat

The data has been extracted from EUROSTAT, specifically the dataset “Estimated soil erosion by water, by erosion level, land cover and NUTS 3 regions (source: JRC) (aei_pr_soiler)”. For determining the baseline in the sustainability screening, we have selected the latest available data, i.e. for 2016.

Mean soil erosion rate, which undergirds both selected indicators, is considered useful because it provides a solid baseline to estimate the actual erosion rate in the regions (Panagos et al., 2015). This indicator is based on the latest Revised Universal Soil Loss Equation of 2015 (RUSLE2015), specifically adapted for the European context (see Panagos et al., 2015), which is a model that takes into account various aspects, including two dynamic factors, namely the cover-management[210] and policy support practices[211] (both related to human activities) (Panagos et al., 2020).

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[207] This refers to all potentially erosive-prone land (in simplified terms), specifically to CORINE Land Cover classification groups: Agricultural areas (2), forest and semi natural areas (3) excluding beaches, dunes, sand plains (3.3.1), bare rock (3.3.2), glaciers and perpetual snow (3.3.5). These, as well as other classes, are excluded because they are not subject to soil erosion.

[208] This refers only to agricultural land (agricultural cropland as well as grassland in simplified terms), specifically to CORINE Land Cover classification groups: Agricultural Areas (2) and Natural Grasslands (321)

[209] Excluding not erosion-prone land (e.g. beaches, dunes, etc.). Forest and natural areas exclude also natural grasslands, which are evaluated together with agricultural areas.

[210] Known as the c-factor, it has a non-arable component, which includes changes in land cover and remote sensing data on vegetation density, as well as an arable component, which includes Eurostat data on crops, cover crops, tillage and plant residues

[211] Known as the p-factor, it reflects the effects of supporting policies in estimating the mean erosion rate by including data reported by member states on Good Agricultural Environmental Conditions (GAEC) according to the CAP, specifically contour farming, as well data from LUCAS Earth observation on stone walls and grass margins

The estimated mean soil erosion rate value obtained through the RUSLE2015 model refers to water erosion only, but it is considered to be the most relevant at least in terms of policy action at EU level, due to the relative predominance of water erosion over other types of erosion. Furthermore, it offers the important advantage of providing a viable estimation for erosion vulnerability at a relatively small geographic scale, i.e. the local or regional level. This can serve as an important tool for monitoring the effect of local and regional policy support strategies of good environmental practices (Panagos et al., 2015, 2020 and Eurostat, 2020).

2.2.2 Methodology applied

The near-universal indicators available to track soil vulnerability are related to either erosion or the decline in soil organic carbon (SOC)/soil organic matter (SOM) (Karlen & Rice, 2015). However, there are major data gaps regarding to SOC/SOM and data is currently only available at national level. According to Panagos et al. (2020), soil organic carbon does not change so quickly and therefore is not so sensitive to human influence on short term. Therefore, they recommend using just a sole indicator for monitoring impact of policies: "estimated mean soil erosion rate" (by water), which they calculate using the RUSLE2015 model. For our purposes, we have complemented the *mean soil erosion rate* indicator, with the *share of agricultural area under severe erosion* in order to gain a comprehensive picture of soil erosion in a region.

Soil erosion is considered generally as a sort of proxy indicator of soil degradation, which in turn is the most relevant component of land degradation at EU level (EC, 2018). However, not all types of bio-based activities have a direct effect on erosion, but rather primary production of biomass. Nonetheless, as these are currently the most widespread bioeconomy activities in rural areas, we will consider their impact on soil degradation, and therefore on soil erosion, to be the most relevant one for this assessment.

The indicators for vulnerability to soil degradation were selected, on one hand, due to the limited number of soil indicators available at the required regional scale. On the other hand, the RUSLE2015 model used for this data also represents the current state-of-the-art methodology for calculating soil erosion. These aspects are crucial, since the choice of indicators needs to be: a) acceptable to experts, b) routinely and widely measured, and c) have a currency with the broader population to achieve global acceptance and impact (Stockmann et al., 2015). In order to carry out the screening of soil vulnerability, a number of datasets need to be accessed. As mentioned above, this data can be accessed via Eurostat.

In terms of processing the erosion data, it is important to consider that the overall erosion rate changes across geographic areas, meaning the vulnerability/risk is not necessarily evenly distributed. In cases where the mean soil erosion rate exceeds the 10 t ha^{-1} a^{-1}, erosion is considered severe and activities that can generate, or are associated with a high erosion impact should be strongly discouraged. Erosion rates between 5 and 10 t ha^{-1} a^{-1} are considered moderate, requiring some attention towards practices that have a high impact on erosion, but with less urgency. However, it is relevant to take a look not only at the mean erosion rate for the area itself, but also at its spatial distribution, which is roughly reflected on the indicator of share of (agricultural) area under severe erosion.

2.2.3 Data uncertainties

The data used is produced from an empirical computer model (RUSLE2015) and produces estimates. Hence, there are several uncertainties related to the figures if compared to data collected on the ground. However, the purpose of the model is to generate data for a large spatial scale taken into account human intervention, which is not possible to do only through empirical measurements. That being said, like every model, assumptions have to be made and there is an intrinsic level of uncertainty. Specifically related to the RUSLE methodology, Benavidez et al. (2018) critically reviewed the RUSLE methodology, upon which RUSLE2015 is based, and identified following main limitations:

- its regional applicability to regions that have different climate regimes and land cover conditions than the ones considered (in the original RUSLE for the USA, in RUSLE 2015 for Europe)

- uncertainties associated generally with soil erosion models, such as their inability to capture the complex interactions involved in soil loss, as well as the low availability of long-term reliable data and the lack of validation through observational data of soil erosion, among others.
- issues with input data and validation of results,
- its limited scope, which considers only soil loss through sheet (overland flow) and rill erosion, thus excluding other types of erosion which may be relevant in some areas, e.g. gully erosion and channel erosion, to name a few. Moreover, it also excludes wind erosion.

A further factor of uncertainty in the data is the fact that the RUSLE model is calculated using mean precipitation data over multiple years and a large territorial scale (in this case Europe). Thus, it fails to account the changes in rainfall intensity, which are highly relevant for determining water erosion accurately. This is the case not only considering the seasonality of rainfall, but also its distribution across the continent (Panagos et al., 2020). Another important uncertainty identified by Panagos et al. (2020) is the lack of georeferenced data for annual crops and soil conservation practices in the field at a continental level, which has had to be estimated from statistical data.

Nonetheless, when considered best available estimates, the mean soil erosion values generated through the application of RUSLE2015 model offer a very suitable basis for assessing vulnerability to soil loss in general terms, even if the generated absolute values are to be taken with caution (Benavidez et al., 2018).

2.2.4 Methodological uncertainties

Among the most relevant uncertainties regarding the application of the sustainability screening in terms of soil vulnerability are the selection of the threshold against which the severity of erosion is evaluated and the selection of the land cover types that will be considered.

Regarding the threshold of 10 t ha^{-1} a^{-1} for severe erosion, it is important to mention that this was obtained directly from the dataset that was used[212]. However, it is still an arbitrary value which can be adapted. For instance, some sources like Panagos et al. (2015, 2020), who were involved in the generation of the data for the JRC ESDAC, consider severe erosion to be above 11 t ha^{-1} a^{-1}. In this regard, we have also decided to stick to the lower value described in the Eurostat dataset because it is more conservative and, as such, more suitable for an initial (and indicative) sustainability screening like the one we are proposing.

The selection of land cover types presents another area for potential uncertainty. Choosing between “all lands” and “agricultural lands” can have considerable implications for interpreting the data. For example, it is possible that the mean soil erosion rate is 5 t ha^{-1} a^{-1} (moderate erosion) in one land cover type, but lower in the other. This would have an effect on the assessment, which would present any potential concerns about erosion and steps that should be taken. As such, it is important to have solid grounding for the choice of dataset. The ultimate decision whether to consider all lands (including forests) is arbitrary and lays with the group performing the sustainability screening. Particularly when that decision is based on considerations of the economic relevance of forestry related industries in the region rather than on the actual share of the area that is covered with forest (it should be high to justify their inclusion), the values of soil erosion (for all lands) shall be taken with some reservations. This is because these values tend to be lower than the value for agricultural land and can create the impression that vulnerability to erosion is lower than it actually is. However, due to the indicative (and non-exhaustive) nature of the present sustainability screening, this uncertainty is not especially relevant for cases such as the French Atlantic Arc, where both values (for all lands and agricultural land with natural grassland) are low with regard to the methodology used.

However, it is important to mention that the experts consulted on the subject (Seine-Normandie Water Agency, Pays de la Loire Regional Council) take the issue of soil very seriously and consider the problems of soil quality and of soil erosion to be very real issues in the Atlantic Arc regions, on which action needs to be taken.

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[212] See metadata of the used dataset at https://ec.europa.eu/eurostat/cache/metadata/en/aei_pr_soiler_esms.htm

2.3 Biodiversity data and indicators

2.3.1 Description of the data / definition of the indicators employed

Unlike for water- and soil-related risks, there are no reliable indices or standardized metrics to operationalize and compare risks to biodiversity at the regional level and in an integrated manner. Biodiversity is intricate and multifaceted, spanning genetic, species, and ecosystem diversity across various regions. Attempting to consolidate this diversity into a singular index may oversimplify it, leading to the loss of crucial information (Ledger et.al 2023; Brown & Williams 2016). Instead, biodiversity risks in a given region could be uncovered by considering the status of all species known to inhabit the region under scrutiny on a one-by-one basis, without trying to synthesize their collective status in a single index. Accordingly, our methodology suggests screening for biodiversity risks of a region by taking stock of its species of flora, fauna and fungi present in the demarcation and considering their conservation status. The Red List of Threatened Species of *the International Union for Conservation of Nature* (IUCN) is a globally recognized system for classifying the conservation status of species[213]. It is structured along the following risk categories (IUCN 2001, 2003):

(1) Critically Endangered (CR): This is the highest risk category assigned by the IUCN Red List for wild species. Species in this category are facing an extremely high risk of extinction in the wild.
(2) Endangered (EN): Species in this category are facing a high risk of extinction in the wild.
(3) Vulnerable (VU): Species in this category are facing risks of extinction in the wild.
(4) Near Threatened (NT): Species in this category are close to qualifying for, or are likely to qualify for, a threatened category soon.
(5) Least Concern (LC): Species in this category have been evaluated but do not qualify for any other category. They are widespread and abundant in the wild.
(6) Data Deficient (DD): A category applied to species when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution or population status.
(7) Not Evaluated (NE): A category applied to species that have not yet been evaluated against the criteria (IUCN 2001, 2003)

Data description

Data on the risk category of each species found in the SCALE-UP regions is accessed through the online database of the IUCN Red List website. The IUCN Red List serves as a comprehensive repository of information, offering insights into the present extinction risk faced by assessed animal, fungus, and plant species. In 2000, IUCN consolidated assessments from the 1996 IUCN Red List of Threatened Animals and The World List of Threatened Trees, integrating them into the IUCN Red List website with its interactive database, currently encompassing assessments for over 150.300 species. Since 2014, assessors of species have been mandated to furnish supporting details for all submitted assessments. Among the recorded details are the species' (1) IUCN Red List category, (2) distribution map, (3) habitat and ecology, (4) threats and (5) conservation actions. The assessment of these dimensions is elaborated below:

[213] The International Union for Conservation of Nature (IUCN) is a global environmental organization that was founded on October 5, 1948. It is the world's oldest and largest global environmental network. The IUCN works to address conservation and sustainability issues by assessing the conservation status of species, promoting sustainable development practices, and providing guidance and expertise on environmental policy and action. The IUCN also plays a crucial role in influencing international environmental policies and fostering collaboration among governments, NGOs, and the private sector to promote conservation efforts worldwide (IUCN 2018).

(1) The IUCN Red List category: The IUCN Red List categories (CR, EN, VU, NT, LC, DD, NE) are determined through the evaluation of taxa against five quantitative criteria (a-e), each grounded in biological indicators of population threat:
   a. Population Size Reduction: This criterion evaluates the past, present, or projected reduction in the size of a taxon's population. It considers the percentage reduction over a specific time frame, with different thresholds indicating different threat levels.
   b. Geographic Range Size and Fragmentation: This criterion assesses the size and fragmentation of a taxon's geographic range. Factors such as few locations, decline, or fluctuations in range size contribute to the evaluation.
   c. Small and Declining Population Size and Fragmentation: This criterion focuses on taxa with small and declining populations, considering factors like population size, fragmentation, fluctuations, or the presence of few subpopulations.
   d. Very Small Population or Very Restricted Distribution: This criterion addresses taxa with extremely small populations or limited distributions. It assesses whether the taxon is at risk due to its small population size or restricted geographic range.
   e. Quantitative Analysis of Extinction Risk: This criterion involves a quantitative analysis, such as Population Viability Analysis, to estimate the extinction risk of a taxon. It considers various factors influencing population dynamics and extinction risk.

   While listing requires meeting only one criterion, assessors are encouraged to consider multiple criteria based on available data. Quantitative thresholds of the IUCN Red List categories were developed through wide consultation and are set at levels judged to be appropriate, generating informative threat categories spanning the range of extinction probabilities. To ensure adaptability, the system permits the incorporation of inference, suspicion, and projection when confronted with limited information.

(2) The distribution map: The IUCN Red List distribution map serves as a reference for the taxon's occurrence in form of georeferenced data and geographic maps. This data is available for 82% of the assessed species (>123.600) and is based on the species' habitat, which is linked to land cover- and elevation maps. The indicated area marks the species extent of occurrence, which is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred, or projected sites of present occurrence of a species, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of species, such as large areas of obviously unsuitable habitat. For a detailed explanation of the mapping methodology, please refer to the *Mapping Standards and Data Quality for the IUCN Red List Spatial Data* (IUCN 2021).

(3) Habitat and Ecology: The IUCN classifies the specific habitats that a species depends on for its survival. These habitats are categorized into three broad systems: terrestrial, marine, and freshwater. A species may inhabit one or more of these systems, and so the possible permutations result in seven categories of natural systems. Beyond these seven system categories, the IUCN offers a more nuanced classification system for habitats, comprising 18 different classes at level 1 (e.g., forest, wetlands, Grassland, etc.), and 106 more specific classes listed at level 2 (e.g., Forest – Subtropical/tropical moist lowland, Wetlands (inland) – Permanent inland deltas; Grassland - Temperate) (IUCNa n.d.). For SCALE-UP's sustainability screening, the IUCN classification of the seven systems is sufficient to refine the search while not excluding relevant habitats. The EU Habitats Directive, in contrast, distinguishes 25 habitat types that are considered threatened and require active and recurring conservation action. The directive demands member states to take measures to maintain or restore these natural habitats and wild species.

(4) Threats: The IUCN database encompasses various general threats that can negatively impact a species. Direct threats denote immediate human activities or processes impacting, currently impacting, or potentially affecting the taxon's status, such as unsustainable fishing, logging, agriculture, and housing developments. Direct threats are synonymous with sources of stress and proximate pressures. Assessors are urged to specify the threats that prompted the taxon's listing at the most granular level feasible within this hierarchical classification of drivers. These threats could be historical, ongoing, or anticipated within a timeframe of three generations or ten years. These generalized threat categories encompass residential and commercial development, agriculture and aquaculture, energy production and mining, transportation and service corridors, biological resource use, human intrusion and disturbances, natural system modifications, invasive and other problematic species, genes and diseases, pollution, geological events, and climate change and severe weather. Beneath each general threat, more specific threats are detailed. Please refer to the hyperlink in footnote[214] for a detailed list of all threats including explanations.

(5) Conservation Actions: The IUCN database contains conservation action needs for each species, providing detailed information on the current conservation efforts and recommended actions for protecting the taxon. It includes general conservation actions such as research & monitoring, land/water protection, management, and education. Specific conservation actions are listed under each general action, along with a description of the current conservation status and recommended actions to protect the taxon. A hierarchical structure of conservation action categories (see footnote[215]) indicates the most urgent and significant actions needed for the species, along with definitions, examples, and guidance notes on using the scheme. Assessors are encouraged to be realistic and selective in choosing the most important actions that can be achieved within the next five years, informed by the conservation actions already in place.

IUCN Red List and Habitat Directive

Both, the EU's Habitats Directive and the IUCN Red List aim to preserve biodiversity, but they employ distinct methods and standards for evaluating conservation status. The Habitats Directive is centered on preserving natural habitats and wild species of flora and fauna within the European Union, mandating that member states establish Special Areas of Conservation for habitats and species listed in its annexes. The Directive categorizes conservation status into three groups: favorable, unfavorable-inadequate, and unfavorable-bad. This classification system of habitats and species is based on how far they are from the defined 'favorable' conservation status, not their proximity to extinction (Sundseth 2015).

Conversely, the IUCN Red List is a worldwide evaluation of the conservation status of species, categorizing them according to their extinction risk. The Red List employs a set of five rule-based criteria to assign species to a risk category (see above). However, there are inconsistencies and weak agreement between the conservation status assessments of the Habitats Directive and the IUCN Red List. These inconsistencies can be significant, and correlations can vary greatly between taxonomic groups. Specifically, the Red List assessment tends to be more pessimistic than the Directive's Annex (Moser et.al 2016). Amos (2021), on the other hand, has found strong correlations between the two classifications systems for plants, while recognizing the Red List's quicker reaction to changes in the conservation status.

In summary, while both the Habitats Directive and the IUCN Red List aim to protect and

[214] https://www.iucnredlist.org/resources/threat-classification-scheme
[215] https://www.iucnredlist.org/resources/conservation-actions-classification-scheme

conserve biodiversity, they use different methodologies and criteria to assess conservation status, leading to discrepancies in their assessments. However, they can complement each other in providing a comprehensive view of the conservation status of species and habitats at both the European and global levels (IUCN 2010).

2.3.2 Methodology applied

The methodology aims to derive a list of species which would require special consideration (e.g. close monitoring and safeguarding) in the context of implementing bioeconomy activities. To generate this list, the search function of the interactive IUCN database is used following five steps:

(1) Scope of Assessment: Selection of Europe as the scope of assessment to evaluate the conservation status of the European population rather than the global population. This approach ensures that species are identified as threatened based on their status in Europe, irrespective of their global abundance.

(2) Geographical Delineation: Utilization of the interactive map of the IUCN database to draw a polygon that exceeds the region of interest. Exceeding the regions ensures that the entire region is covered, as it is not possible to draw a polygon exactly matching the boundaries of the region. Moreover, a larger polygon also respects the uncertainty of delineating a species area of extent, since the actual area of extent is possibly more fluid than its statically indicated geolocations Consequently, the larger polygon minimizes the risk of excluding any relevant species for which geolocations are registered just minimally outside of the regions' administrative boundaries, but which could inhabit parts of the region in future. There is no rule of thumb for a correct distance between polygon boundary and region boundary, but it would be advisable to keep this distance below 100 km.

(3) Species Selection: Limiting of the search results to endangered and critically endangered species to focus on those facing the most severe risks.

(4) Habitat Selection: selection of all habitats to ensure the full coverage of habitat types present in the geographical delineation defined in step 2.

(5) Threat Selection: Selection of threats associated with the respective regional bioeconomy and/or value chain to refine the search results to species likely to be impacted by them.

By following these steps, a targeted list of species is derived, focusing on species facing significant risks within the context of the regional bioeconomy strategy or value chain being explored, aligning with the specific conservation and bioeconomic priorities of the region.

2.3.3 Data and methodological uncertainties

It is important to acknowledge certain limitations and uncertainties associated with the data and methodologies used:

(1) Inaccurate representation of relevant area: The IUCN database allows for the interactive drawing of a map for a regional assessment. However, this drawn map might not accurately represent the area directly relevant to the bioeconomy strategy or value chain being explored. Since the selected polygon is larger than the actual bioregion, the assessment risks to include species that are not relevant to the bioregion and the bioeconomic strategy of the region.

(2) Lack of local habitat differentiation: The spread of species is indicated as its extent of occurrence without differentiating between habitats at the local level. This means that certain species might solely inhabit very particular habitats within the indicated extent of occurrence. An endangered amphibious species, for instance, might have an area of extent covering an entire country. However, it will only be found in very rare habitats within this area of extent (e.g., pond with very specific qualities). Accordingly, a regional assessment as outlined here (e.g., at the municipal level) might list certain species that do not occur in the assessed regions due to a lack of suitable habitats on the local level.
(3) Potential oversights in conservation status: Using Europe as a scope of assessment might hide any problematic conservation status of a species at the global or at the local level.
(4) Outdated data: The IUCN aims to have the category of every species re-evaluated at least every ten years and aims to update the list every two years (IUCNb n.d.). Nevertheless, the data might be outdated, which could lead to inaccuracies in the assessment of biodiversity risks. For the screenings carried out in SCALE-UP, X% of the data was older than 5 years.
(5) Incomplete data: The data might be incomplete, which could limit the comprehensiveness of the assessment.
(6) Limited species coverage: It is estimated that the world hosts about 8,7 million species (Sweetlove 2011). As of now, more than 150.300 species (16.120 in Europe) have been assessed for the Red List, leaving large data gaps at the global level.
(7) Taxonomic standards: The taxon being assessed must follow the taxonomic standards used for the IUCN Red List. Any deviation from these standards could lead to inaccuracies in the assessment.

3 Potential ecological burden of regionally relevant bioeconomic activities

3.1 Bioeconomic activity selected for the screening

The project strategy formulated for the French Atlantic Arc explores the use of fibrous plants (straw, hemp, miscanthus, flax) for sustainable use in bio-based materials for the building industry. We have therefore carried out a sustainability screening of the cultivation and use of these crops, to identify potential environmental impacts associated with this value stream. Given the relatively specific field, literature on the topic remains somewhat limited, and is focused moreso on the cultivation of these crops, rather than their uses in bio-based products.

The following sections provide some working definitions and an overview of cultivation practices (more detailed information is available in the SCALE-UP report of the "Task 2.3 Regional Biomass and Nutrient Availabilities - Study on the availability of biomass for the bio-based building value chain in the French Atlantic Arc"). The rest of this chapter aims to synthesise the results of a literature review on potential impacts of cultivation of hemp, miscanthus and flax on water, land, and biodiversity, respectively.

3.2 Overview of straw/hemp/miscanthus/flax cultivation and their potential burden on the resources examined

3.2.1 Definitions

Straw: residue from the harvesting of cereal crops, when the grain is separated from the stalk.

Hemp: annual plant in the *Cannabinaceae* family. The only subspecies of hemp grown is the *cannabis sativa*, containing a low THC content (< 0.2%), as hemp is subject to strict regulations and only certified seed is authorised.

Miscanthus: perennial rhizomatous grass of the C4 type[216], originating from Central Asia.

Flax: annual herbaceous plant with blue flowers and oleaginous seeds.

Fibrous plant: plants cultivated for their fibres, traditionally used to make paper, fabric or rope, but nowadays their uses are diversifying to include applications in biobased materials for a variety of applications (bioplastics, insulation, etc.).

Bio-based materials: derived from renewable organic matter (biomass) of plant or animal origin, bio-based materials can have a wide range of applications in the bioeconomy. In the French Atlantic Arc for the SCALE-UP project, we specifically look into the bio-based materials from fibre plant, for the building industry market, mainly for insulation.

3.2.2 Overview of straw, hemp, miscanthus and flax cultivation and common management practices

Table 39 Fibrous plant common management practices

Straw	• Cultivation: between October and August for winter wheat (wheat straw is the only one to have professional rules for applications in biobased construction, which is why we are only dealing with this one). • Management practices: straw is a co-product of cereal production (for human

[216] It has a C4-type photosynthetic metabolism. C4 plants use the C4 carbon fixation pathway to increase their photosynthetic efficiency by reducing or eliminating photorespiration.

	and animal consumption), so converting it into a biobased material does not increase the use of fertilisers for these crops, nor the use of plant protection products.
Hemp	• Cultivation: fast-growing crop (≈100-120 days). Planted in May, harvested in August for the flowers and textile fibre, or September for the seed and technical fibre. • Management practices: included in a rotational system between two crops (5 years between two hemp cultivations on a field). There is no need to apply fertiliser or plant protection products, and growing hemp improves yields for the following crop, thanks in particular to its deep root system, which improves soil structure.
Miscanthus	• Cultivation: Miscanthus is a perennial crop (20 years), harvested annually from the second year after planting. • Management practices: a small amount of herbicide is sometimes needed at the start of the crop for the time it takes to emerge, and from the second year onwards miscanthus no longer requires any inputs.
Flax	• Cultivation: fast-growing crop (≈100 days). Planted between March and April, harvested in July. • Management practices: included in a rotational system between two crops (4 years between two flaw cultivations on a field). This crop needs very little fertiliser and does not require the use of plant protection products.

3.2.3 Potential burden on water resources

The production of hemp, flax, and miscanthus has a number of implications related to water resources, often positive ones. These effects are related either to water efficiency or the use of fertilizers.

Hemp cultivation demonstrates greater water efficiency compared to cotton, requiring less irrigated water and having a lower water footprint per unit yield output (Wise et al., 2023; Kaur & Kander, 2023). The water needs of hemp and other crops vary based on factors like climate, soil properties, and species. While hemp is generally considered to require less water compared to cotton, the water needs of fibre flax can be relatively high, although studies have a range of outcomes in this regard. Some studies suggest that flax can exhibit improved drought tolerance (Stavropoulos et al., 2023). Similarly, the water use efficiency of miscanthus is considered to be high, and the crop demonstrates strong tolerance to drought and other stresses like heat, cold, pests, and diseases (Wang et al., 2021).

Although in general hemp is considered to require little to no chemical input during cultivation, especially as regards pesticides and herbicides (Wise et al., 2023), the use of fertilizers can lead to negative environmental impacts, such as eutrophication (Kaur & Kander, 2023; Schulte et al., 2021). Fertilizers, particularly phosphate fertilizers like Triple superphosphate, contribute significantly to eutrophication indicators by releasing phosphate ions into water bodies. Optimizing fertilizer usage while maintaining yields is crucial for reducing environmental impacts (Kaur & Kander, 2023).

3.2.4 Potential burden on land resources

In general, the cultivation of hemp, flax, and miscanthus has positive effects on soil, improving soil quality and reducing the need for fertilizers and other chemical inputs.

Both hemp and miscanthus contribute to soil stability and quality. Hemp has been utilized for bioremediation purposes, removing heavy metals from soil, and increasing soil oxygenation (Kaur & Kander 2023). Miscanthus promotes carbon deposition, improves soil physicochemical properties, and prevents soil erosion. However, they may still have some ecological impacts, such as surface soil acidification in the case of miscanthus (Wang et al., 2021).

Hemp cultivation serves as a beneficial component in crop rotation systems, suppressing the growth of harmful organisms like certain fungi and nematodes, as well as weeds. It can be grown in monoculture for several years without significant yield decrease, making it a valuable predecessor for other key crops. However, care should be taken as over-reliance on hemp in monoculture may lead to a decrease in soil fertility (Pylypchenko et al., 2023).

Hemp cultivation typically requires minimal use of plant protection products and herbicides due to its efficient weed suppression capabilities. Additionally, hemp demonstrates low fertilizer requirements, particularly in regions where it shows little response to nitrogen fertilization (Ingrao et al., 2015; Kaur & Kander, 2023). The environmental performance of feedstock cultivation for crops like miscanthus heavily depends on fertilizer management practices. Opting for high-yielding genotypes with low nitrogen fertilizer requirements can improve environmental performance, and attention to conversion processes during cultivation is also crucial (Lask et al., 2018).

Flax cultivation requires an improved approach to fertilizer, herbicide, and pesticide management to improve its impact on soil (Le Duigou et al., 2011). Organic fertilizers offer a viable alternative, and research by Stravropoulos et al. (2023) suggests that a combination of both organic and inorganic methods may present a promising solution for maintaining soil fertility and improving overall efficiency.

3.2.5 Potential burden on biodiversity

Hemp is noted to have important benefits for biodiversity, especially compared to most other monocrops (Kaur & Kander, 2023). It is especially valuable crop for bee populations because it begins flowering when other crops have completed blooming, thus making it an excellent pollen resource (O’Brien & Arathi, 2019).

4 Screening results and recommendations

4.1 Overview – French Atlantic Arc

Resources screened		Ordinal Baseline Rating	Cultivation Management Practices	
Category	**Sub-Category**		**Potentially beneficial to the baseline status**	**Potentially detrimental to the baseline status**
Water	**Surface water bodies**		**- Carefully managed irrigation** **- Adequate fertilizer and chemical management.** **- Adequate management practices for hemp, miscanthus and flax cultivation can improve the status of water resources**	**- Excessive fertilizer use** (cereal straw)**,** especially phosphate fertilizers.
	Groundwater bodies			
Land Resources	**-**		- Conservation tillage and mulching (with care taken to not increase pesticide use). - Contouring - Avoiding planting crops on high slopes **- Adequate management practices for hemp, miscanthus and flax cultivation can improve the status of soil resources**	**- Excessive fertilizer use** (cereal straw)**,** especially phosphate fertilizers.
Biodiversity	**Endangered Species**	**18**	**- Hemp, flax and miscanthus plants, because of their height, density, low input requirements and harvesting outside bird nesting periods, are refuges for biodiversity**	**- Excessive water abstraction** can be damaging for habitats of certain threatened populations. **- Poor fertilizer management** can also damage aquatic and terrestrial habitats.
	Critically Endangered Species	**1**		

4.2 Recommendations

Surface water bodies: the screening of reported data has shown that the majority of rivers and lakes in the French Atlantic Arc (encompassing 3 RBDs) fail to achieve the objectives of the EU WFD. This raises concern for new or increased pressures that could arise from the development of new economic activities in the region or the expansion of existing operations. The ecological status of rivers and lakes in the three RBDs are of high concern, and the chemical status of moderate concern, with significant chemical and nutrient pollution across the region. Care must be taken to minimize the use of chemical inputs in the production of crops for the bioeconomy, and activities should aim to restore aquatic habitats where possible.

Groundwater bodies: The quantitative status of groundwater bodies remains of low concern in the area. However, given the impacts of climate change of water availability, care should be taken with regards to irrigation and water use. Fortunately, the crops discussed in this assessment are recognized for the high water efficiency. The chemical status of groundwater in the region is however of high concern, and as mentioned above, care should be taken to avoid discharge of chemical inputs including fertilizers, herbicides, and pesticides.

Soil: In general, soil resources in the region are in a good state. However, there is nonetheless exposure to erosion, both in coastal areas and arable areas, due to intensive farming practices. Although the general picture remains positive, there are variations at the local level, where erosion may be of high concern. In these areas, certain measures can be taken to reduce the risk of erosion including conservation tillage and mulching, contouring, and avoiding planting crops on high slopes. Any activities and practices that restore and preserve soils should be promoted.

Biodiversity: The production of the crops relevant in the French Atlantic Arc can have important benefits for biodiversity. Although there are no specific concerns related to biodiversity in the region, these crops act as a valuable resource for certain habitats and for bee populations.

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Sustainability Screening - Andalusia, ES

March 2024

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EXECUTIVE SUMMARY

This report has been produced as part of the SCALE-UP project funded by the Horizon Europe research and innovation programme. The aim of this project is to support the development of small-scale bioeconomy solutions in rural areas across Europe. The aim of this study is to raise awareness of the ecological limits on Andalusia (southern Spain), based on three resources: water, soil and biodiversity. The bioeconomy is by definition the economy of bioresources (from agriculture, forestry, aquaculture and biowaste), therefore of the living. It is essential to ensure the sustainability of the bioeconomy and that its development takes into account the potential impact on the environment. Furthermore, in the current context of fighting against climate change and environmental degradation, bioeconomy activities that provide environmental benefits (water quality, preservation of biodiversity, etc.) must be sought and encouraged. This report is therefore aimed at project leaders and stakeholders in the bioeconomy willing to develop an activity, to enable them to integrate these environmental considerations into the development of their product or service.

The region of Andalusia is located in the Southwest of Europe with an area of more than 87,000 km² (ca. 9Mha) and approximately 940 kilometers of coastline. The agricultural area represents about 4.4 Mha and the forestry area is about 4.6 Mha. This makes it the fourth-largest region in the European Union in terms of surface area and the most populated region in Spain, with some 8,400,000 inhabitants. Spanish agriculture is very diverse, however, it is notable that the surface area of olive groves in Spain is 2.75 million hectares, with 2.55 million hectares dedicated to olive mills (93% of the total olive grove). This crop is present in 15 of the 17 autonomous communities, with Andalusia producing the most with 1.67 million hectares (The olive tree: Spain's treasure, 2022). The sector is not only of undeniable economic importance, but also has important social, environmental, and territorial implications. Finally, this large territory is fully affected by the impacts of climate change, with rising temperatures and significant pressure on water resources, soils and biodiversity. These considerations about climate change and its consequences need to be considered in the development of bioeconomy activities.

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Abbreviations

ESDAC	European Soil Data Centre
EU	European Union
EUSO	EU Soil Observatory
JRC	Joint Research Centre
RBD	River Basin District
RBMP	River Basin Management Plan
REDIAM	Red de Información Ambiental de Andalucía (Andalusian Environmental Information Network)
RENPA	Network of Protected Natural Spaces of Andalusia
SAC	Special Areas of Conservation
SAIH	Sistema Automático de Información Hidrológica (Automatic Hydrological Information System)
SCI	Sites of Community Interest
SIA	Sistema Integrado de Información del Agua (Integrated Water Information System)
SIOSE	Spanish Land Use Information System
SIRSEIH	Sistema de Información de Redes de seguimiento del estado e información hidrológica (Information System of Hydrological Status and Information Monitoring Networks)
SNCZI	Sistema Nacional de Cartografía de Zonas Inundables (National Flood Zones Cartography System (Inventory of Dams and Reservoirs))
SPA	Special Protection Areas
TRLA	Recast Text of the Water Act (Royal Legislative Decree 1/2001, of 20 July)
WFD	Water Framework Directive

1 Resource management profiles

1.1 Water resources management profile

Water management in Spain

The management of water resources in Spain is based on the European Water Framework Directive (WFD), which came into force on 22 December 2000 (Directive 2000/60/EC). The transposition of this Directive was carried out through Law 62/2003, of 30 December, on fiscal, administrative, and social measures (Demográfico, s.f.).

National water legislation is very extensive and complex. Table 40 shows Spanish water legislation in three areas: Basic, Public Water Domain, and Planning:

Table 40 - Water legislation in Spain.

BASIC LEGISLATION	Water Law, approved by Legislative Royal Decree 1/2001 of 20 July 2001. Amended by Law 53/2002 of 30 December 2002 on fiscal, administrative, and social measures. Amended by Article 129 of Law 62/2003 on fiscal, administrative, and social measures. Law 11/2005 of 22 June 2005 amending Law 10/2001 of 5 July 2001 on the National Hydrological Plan. Royal Decree-Law 4/2007, of 13 April, amending the revised text of the Water Law. Royal Decree 2090/2008, of 22 December, approving the Regulations for the partial development of Law 26/2007, of 23 October, on Environmental Responsibility.
PUBLIC WATER DOMAIN	Regulation of the Public Hydraulic Domain (RDPH), approved by Royal Decree 849/86, of 11 April 1986, which implements the Preliminary Titles, I, IV, V, VI, and VIII of the Water Law. Modified by RD 995/2000, of 2 June, which establishes quality objectives for certain pollutants. Modified by RD 606/2003, of 23 May, which modifies RD 849/1986, of 11 April, which approves the Regulations of the Public Hydraulic Domain, which develops the Preliminary, I, IV, V, VI, and VIII Titles of Law 29/1985, of 2 August, on Water. RD 9/2008, of 11 January, amending the Regulations on the Public Hydraulic Domain, approved by Royal Decree 849/86, of 11 April. Order ARM/1312/2009, of 20 May, which regulates the systems for the effective control of the volumes of water used by the water exploitations of the public hydraulic domain, of the returns to the public hydraulic domain, and of the discharges to the same.
PLANNING	Law 10/2001 of 5 July 2001 on the National Hydrological Plan. Law 11/2005 of 22 June 2005 amending Law 10/2001 of 5 June on the National Hydrological Plan Royal Decree-Law 2/2004 of 18 June 2004 amending Law 10/2001 of 5 July 2001 on the National Hydrological Plan Regulation of the Public Administration of Water and Hydrological Planning, approved by Royal Decree 927/88, of 29 July, implementing Titles II and III of the

	Water Law. RD 907/2007, of 6 July, approving the Hydrological Planning Regulations. RD 125/2007, of 2 February, establishing the territorial scope of the hydrographic demarcations. RD 126/2007, of 2 February, regulating the composition, operation, and powers of the committees of competent authorities of the river basin districts with inter-community basins.

Source: Demográfico, s.f.

In addition to these three areas, there is extensive legislation on water quality objectives (drinking water production, bathing water, and protection of fish biodiversity), discharges, nitrates from agriculture, hazardous substances, and damage assessment.

For water management planning, Directive 2000/60/EC imposed on Member States the obligation to delimit the territorial scope of river basin districts (RBDs). In Spain, the competences to dictate legislation, and manage the planning and concession of water resources and uses correspond to the State when the river basin is intercommunity (exceeds the territory of an Autonomous Community). However, it is the responsibility of the Autonomous Communities when the waters flow only through their territories (intra-community basin).

On the other hand, the Statute of Autonomy of Andalusia itself attributes to the Autonomous Community the exclusive competence over waters that flow only through Andalusia and over hydraulic resources and exploitation, as well as over groundwater when its exploitation does not affect another territory (Andalucía, s.f.).

Decree 357/2009 of 20 October 2009 establishes the territorial scope of the River Basin District of the intra-community basins located in Andalusia. The following figure (figure 1) shows the different river basin districts of Andalusia.

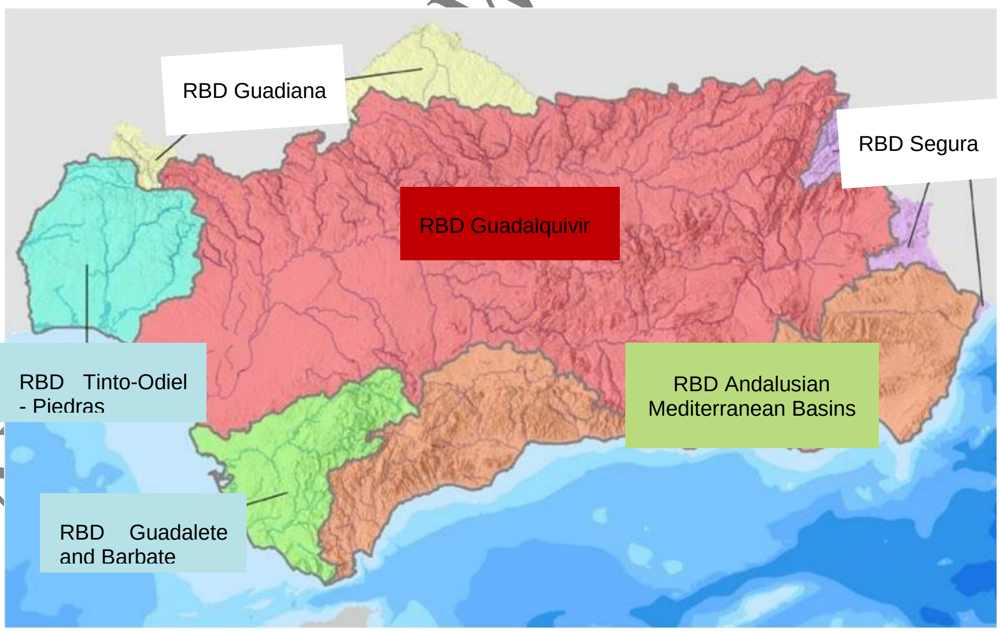

Figure 67 - River Basin Districts in Andalusia. Source: CMAOT, Junta de Andalucía (2016)

Table 2 shows the surface areas of the river basins of Andalusia in terms of: total surface area (km^2) of the basin, surface area in Andalusia (km^2), percentage of the basin represented in Andalusia and the percentage that the basin occupies of Andalusia.

Table 41 - Surface area of the hydrographic River Basin Districts in Andalusia

RIVER BASIN DISTRICTS	TOTAL SURFACE (km^2)	ANDALUSIAN SURFACE (km^2)	RBD IN ANDALUSIA (%)	RBD REPRESENTATION (%)
Guadalquivir	57,527	51,900	90.22	59.02
Andalusian Mediterranean Basins	17,944	17,944	100.00	20.40
Tinto-Odiel-Piedras	4,729	4,729	100.00	5.38
Guadalete-Barbate	5,969	5,969	100.00	6.79
Guadiana	55,528	5,618	10.12	6.39
Segura	18,870	1,780	9.43	2.02
Total	160,567	87,940	54.77	100.00

Source: IMA, 2013

In Andalusia, due to the complexity of its competences (intra-community, inter-community, and international basins), there are two management models depending on the institution responsible. The first model includes the River Basin Authorities of the Guadiana and Guadalquivir rivers, while the second model includes the smaller basins that are managed by the Regional Department of Environment and Regional Planning.

At regional level, the Andalusian Water Law 9/2010 incorporates several tools to guarantee the participation of users and society as a whole in water management. To this end, several collegiate bodies for participation, coordination, and information have been created for advisory and control purposes (Chica Ruiz, Arcila Garrido, Pérez Cayeiro, & Salle, 2017):

- The Andalusian Water Department, where all stakeholders involved in water planning and management are represented.
- The Andalusian Water Observatory, which is a collegiate body of consultative function.
- Citizen juries, a research technique used in Andalusia to know the opinion of the citizens on the management of a specific problem, in this case, water management.
- In the case of the River Basin Authorities, information on water management in each basin is structured through various computer platforms:
    - SIA: Sistema Integrado de Información del Agua (Integrated Water Information System).
    - SNCZI: Sistema Nacional de Cartografía de Zonas Inundables (National Flood Zones Cartography System (Inventory of Dams and Reservoirs)).
    - SIRSEIH: Sistema de Información de Redes de Seguimiento del Estado e Información Hidrológica (Information System of Hydrological Status and Information Monitoring Networks).
    - SAIH: Sistema Automático de Información Hidrológica (Automatic Hydrological Information System).

- In the case of Andalusia, there is a portal called HIDRA: A management tool that allows consultation of all the information associated with the river sections of the Andalusian water network.
- Part of the information is still integrated into the Andalusian Environmental Information Network (Red de Información Ambiental de Andalucía, (REDIAM)).

Due to the hydrographic extension of the Andalusian region, the present study is limited to the Guadalquivir Hydrographic Demarcation, whose information is detailed and updated in the hydrological plan for the third cycle (2022-2027).

1.2 Soil resources management profile

There are a variety of governmental initiatives focused on soil management, including the "National Action Programme against Desertification". In addition, there is the "National Inventory of Soil Erosion", which facilitates the detection, quantification, and cartographic representation of the most important erosion processes in the national territory, as well as their evolution over time. In Andalusia, the Regional Department of the Environment has statistical reports in which it is possible to estimates soil loss by province and its trend over time.

The SIOSE project (Spanish Land Use Information System), part of the Andalusian Environmental Information Network (REDIAM), has two basic levels: National and Autonomous. At the regional level, SIOSE Andalusia meets the need for a land use and occupation information system that is unique for the public administration and useful for land management. The first reference cartography corresponds to the year 2005 (Junta de Andalucía. Consejería de Sostenibilidad, s.f.) and is currently updated with data corresponding to 2020.

The Regional Department of Sustainability, Environment, and Blue Economy is in charge of carrying out the responsibilities of the Autonomous Community of Andalusia has regarding the environment and sustainable development, as well as the sustainable use, management, and conservation of marine resources. It is in charge of the natural and forestry environment, as well as the management of contaminated soils (among other activities).

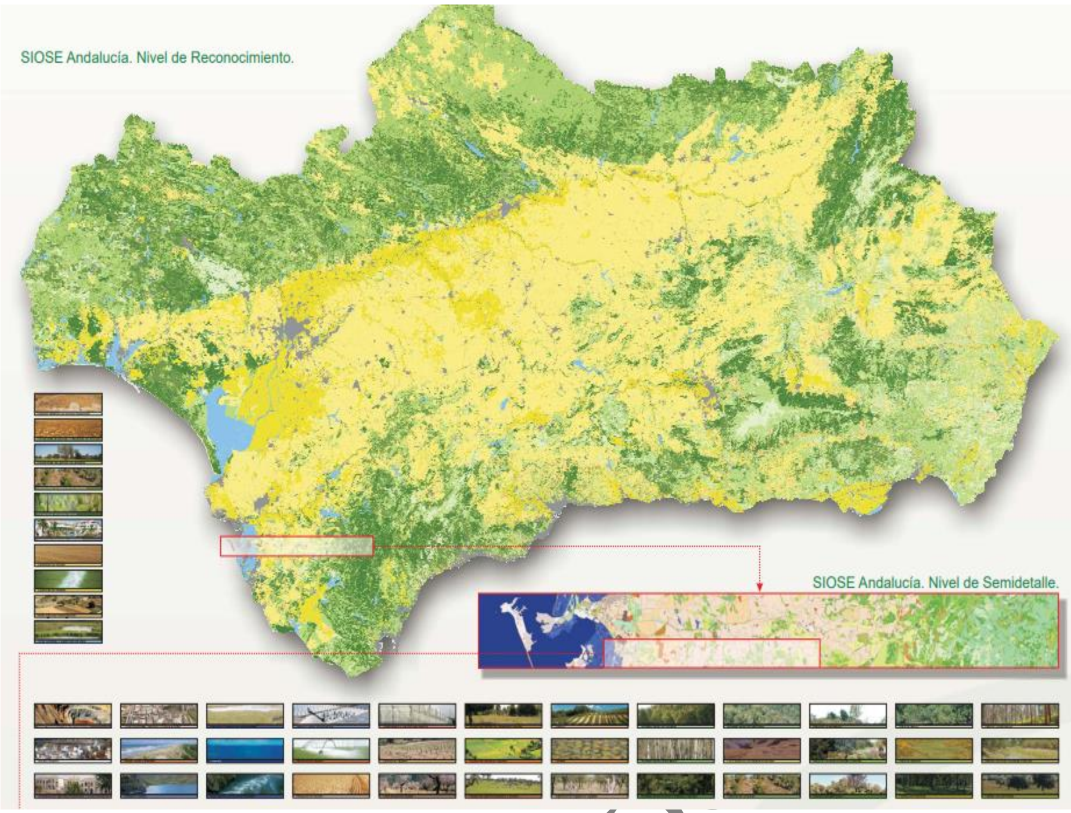

Figure 68 - SIOSE in Andalusia. Source: Romero et al. (s.f.)

1.3 Biodiversity management profile

In September 2011, the Andalusian Strategy for Integrated Biodiversity Management was approved in Andalusia by the Government Department Agreement, which was framed within the scope of the agreements approved during the 10th Conference of the Parties to the United Nations Convention on Biological Diversity, the EU Strategy on Biodiversity until 2020 and the State Strategic Plan for Natural Heritage and Biodiversity. It became a basic instrument for the correct coordination of the Administration of the Junta de Andalucía in the application of the objectives and guidelines established in the EU Birds Directive (Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds) and the EU Habitats Directive (Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora). It remained in force until 27/12/20 and now the Governing Department has approved the formulation of the Andalusian Biodiversity Strategy Horizon 2030 (EAB, 2030) with which it intends to (Andalucía, Estrategia Andaluza de Biodiversidad Horizonte 2030, 2023):

- Promote the conservation and sustainable use of biological diversity in Andalusia.
- Improving Andalusian habitats.
- Focus on the human factor, in accordance with global, European, national, and regional strategic planning.
- Update the Andalusian framework strategy to adapt it to the current context and adapt its objectives, actions, and programmes to 2030 Horizon.

The Natura 2000 Network covers 2.67 million hectares in Andalusia (under the competence of the Junta de Andalucía), of which 2.59 million are land surface and 0.07 million marine (Estrategia Energética de Andalucía 2030, 2022), and is one of the richest and most diverse networks in the EU. For its management and conservation, it is fully included in the Network of Protected Natural Spaces of Andalusia (RENPA), by Decree 95/2003, of 8 April.

The Natura 2000 Network is integrated by 197 protected areas: 63 Special Protection Areas for Birds (SPAs) and 190 Sites of Community Interest (SCI), of which 176 are declared Special Areas of Conservation (SAC) (Espacios protegidos por la Red Natura 2000, s.f.).

In the Andalusian Community, the declaration of SACs or SPAs is by decree of the Governing Department of the Andalusian Regional Government, following the process of declaration of the Natura 2000 Network of protected areas.

2 Methodology for the appraisal of available capacity of the regional ecosystem

2.1 Water data and indicators

To carry out the evaluation of the capacity of surface water and groundwater bodies potentially relevant to the region of Andalusia, the data collected in the Third River Basin Management Plan (2022-2027) of the Guadalquivir River Basin District (RBD) have been reviewed. The hydrological planning of the RBD is reviewed and updated every six years. This six-year cycle is regulated at different levels by National and Community regulations which constitute a basic and common procedure for all the Member States of the EU. The River Basin Management Plans (RBMPs) of the third cycle were approved by RD 35/2023 of 24 January, approving the revision of the RBMPs of the Western Cantabria, Guadalquivir, Ceuta, Melilla, Segura, and Jucar RBDs, and of the Spanish territory of the Eastern Cantabria, Miño-Sil, Duero, Tajo, Guadiana and Ebro RBDs.

2.1.1 Description of the data / definition of the indicators employed

The data reviewed for this section of the report include the analysis of the ecological, potential ecological, and chemical status of surface water bodies, as well as the quantitative and chemical status of groundwater bodies in the Guadalquivir River Basin District, in which Andalusia represents more than 90% of the surface area. These data give indications on water quality classifying it as "good" or "worse than good". On the other hand, data on significant pressures and significant impacts on the water bodies of the RBD are used to indicate the level of certain types of pressures and impacts on the aquatic ecosystems of the regions according to the number and percentage of water bodies subjected to them.

The acquired data line up with the Guadalquivir Hydrological Plan (Revision for the Third Cycle: 2022–2027). Access was made to the information included in the Guadalquivir Hydrographic Confederation (CHG) database of the Ministry for Ecological Transition and the Demographic Challenge.

The data are summarized in Table 42, which shows the overall status of the surface water bodies of the Guadalquivir RBD, and Table 43, which summarizes the evaluation of the status of the groundwater bodies.

Table 42 - Overall status of Surface water bodies. Guadalquivir River Basin District (Ministerio para la Transición Ecológica y Reto Demográfico, 2023).

OVERALL ASSESSMENT OF THE STATE								
STATE*		Good	%Good	no data	worse than good	% worse than good	Total body of water
Natural rivers	ES	194	67%		96	33%	290
	CS	278	96%		12	4%	290
	GLOBAL	192	66%		98	34%	290
Highly modified and artificial rivers assimilable to rivers	EP	28	52%		26	48%	54
	CS	47	87%		7	13%	54
	GLOBAL	26	48%		28	52%	54
RIVER-TYPE WATER BODIES	ES or EP	222	65%		122	35%	344
	CS	325	94%		19	6%	344
	GLOBAL	218	63%		126	37%	344
Natural lakes	ES	14	45%		17	55%	31
	CS	31	100%		0	0%	31
	GLOBAL	14	45%		17	55%	31
Heavily modified and artificial lakes	EP	1	20%	1	3	60%	5
	CS	4	80%	1	0	0%	5
	GLOBAL	1	20%	1	3	60%	5
Bodies of water highly modified or artificial by the presence of dams (reservoirs)	EP	47	80%		12	20%	59
	CS	59	100%		0%	0%	59
	GLOBAL	47	80%		12	20%	59
LAKE-TYPE WATER BODIES	ES or EP	62	65%	1	32	34%	95
	CS	94	97%	1	0	0	95
	GLOBAL	62	65%	1	32	34%	95
Natural coastal water bodies	ES	1	33%		2	67%	3
	CS	3	100%		0	0%	3
	GLOBAL	1	33%		2	67%	3
Coastal water bodies heavily modified by ports	ES	0	0%		0	0%	0
	CS	0	0%		0	0%	0
	GLOBAL	0	0%		0	0%	0
COASTAL WATER BODIES	ES or EP	1	33%		2	67%	3
	CS	3	100%		0	0%	3
	GLOBAL	1	33%		2	67%	3
TRANSITIONAL WATER BODIES	ES	1	8%		12	92%	13
	CS	12	92%		1	8%	13
	GLOBAL	1	8%		12	92%	13
State of surface water bodies.		**282**	62%	**1**	**172**	38%	455

Table 43 - Overall Status of the groundwater bodies. Guadalquivir River Basin District (Ministerio para la Transición Ecológica y Reto Demográfico, 2023).

State	Bodies in Good Condition		Bodies in Bad Condition	
	No.	%	No.	%
Quantitative State	54	63%	32	37%
Chemical state	62	72%	24	28%
Global State	**41**	**48%**	**45**	**52%**

Summary - Surface water bodies.

The total number of surface water bodies in the Guadalquivir RBD is 455. Of these, the percentage of surface water bodies that reach a good (or higher) status is 62%. The number of surface water bodies whose status is unknown is only 0.22%. Of the total number of rivers and lakes in the RBD, 65% achieve good ecological status or higher as well as 95% achieve good chemical status or higher. Both these figures are above the EU average. Combining the two results and following the thresholds proposed by Anzaldua et al. (2022), the rivers and lakes in the RBD are thus in the “Moderate Concern” category.

Determining the effects of human activity on water status through the analysis of pressures and impacts enables one to verify that the WFD is being implemented correctly. Regarding the Point Source Pressures that affect these bodies, the most recurrent ones are associated with urban wastewater, with 23%. The most widespread diffuse pressures are those related to agriculture, which affect 35.6% of the water bodies in the RBD. It should be noted that agriculture acts as a source of pressure in most of them:

- Types of pressures for water extraction and flow diversion: Agriculture (31.10%)

- Types of pressures due to physical alteration of the river channel, bank, or margins: Agriculture (16.52%)

- Types of morphological pressures by dams, weirs, and dikes: Others (37.58%)

Finally, most significant impacts on surface water bodies are those related to chemical contamination and acidification.

Summary - Groundwater bodies

The total number of groundwater bodies in the Guadalquivir RBD is 86. Of these, the percentage of groundwater bodies reaching good (or higher) status is 48%. The number of groundwater bodies whose status is unknown is 0%. Of the total number of groundwater bodies in the RBD, 63% are in good quantitative status, while 72% are in good chemical status. Both these figures fall below the EU average. Combining the two results and following the thresholds proposed by Anzaldúa et al. (2022), the groundwater bodies in the RBD are thus in the “High Concern” category.

Regarding the Point Source Pressures that affect these bodies, the most are classified under the "other" category, with 22%. The most widespread diffuse pressures are those related to agriculture, which affects 30.23% of the groundwater bodies in the RBD. Of the other pressures, agriculture acts as a source of pressure on others:

- Types of pressures for water extraction: Agriculture: 36.05%

Finally, the most significant impacts on groundwater bodies are those related to piezometric drawdown by abstraction, and nutrient pollution.

2.1.2 Methodology applied

The status of surface water bodies is determined by the worst value of its ecological status/potential or chemical status. Only when the ecological status/potential is good or very good or maximum and the chemical status is good, the overall status of the surface water bodies is assessed as "good or better". In any other case, it will be "worse than good".

Regarding groundwater bodies, the status of a groundwater body is determined by the worst value of its quantitative or chemical status. The achievement of good status in groundwater bodies requires the achievement of good quantitative status and good chemical status.

The assessment criteria are those indicated in the corresponding regulatory standards and in the Instruction of the Secretary of State for the Environment (October 14, 2020) and in the methodological guides adopted by the aforementioned instruction, where possible, "Guide for the assessment of the status of surface and groundwater" and the "Guide to the process of identification and designation of heavily modified and artificial water bodies river category." The autonomous community analyzed transitional and coastal water bodies (Ministerio para la Transición Ecológica y Reto Demográfico, 2023).

2.1.3 Data uncertainties

In order to determine the current state of surface water bodies, data from the years 2015 to 2018 have been used. According to the information in the Third Hydrological Plan of the Guadalquivir River Basin District, the quality control network has not had updated data since 2018, which raises the possibility of a deficiency in the updating of data.

To define the elements that will form part of the inventory, there is a complexity in defining general thresholds for selecting the pressures to be inventoried in order to obtain the cumulative diagnoses explaining their effects on the water bodies. For this purpose, the Water Framework Directive requires the Member States to collect and conserve information on the type and magnitude of the significant anthropogenic pressures to which the water bodies may be exposed (Ministerio para la Transición Ecológica y Reto Demográfico, 2023).

2.1.4 Methodological uncertainties

The proposed methodology for the water section in this application of sustainability screening is simple, accessible, and updated. However, it could be improved by adding higher resolution data in some areas. As previously mentioned, the established thresholds, in this case, are based on the EU-wide proportions of water bodies that do not achieve good status or whose conditions are unknown. Furthermore, the straightforward calculations and the use of data on significant pressures and impacts without additional calculations, compared in relative terms within the RBD, minimize the potential for imprecision or uncertainty.

2.2 Soil data and indicators

2.2.1 Description of the data / definition of the indicators employed

The chosen markers to assess soil depletion susceptibility are primarily linked to water-induced soil erosion. To determine the impact of rain erosion in Andalusia, the analysis considers the following factors:

1. NUTS (Nomenclature of Territorial Statistical Units).
2. Province
3. Erosion intervals (Degree of intensity of rain erosion).
4. Erosion values (Percentage (%))

The Joint Research Centre (JRC) provides updated information on the risk of secondary salinisation, mean erosion (T/ha per year), and the number of soil degradation processes.

Secondary salinization is the result of non-optimal or inappropriate irrigation, which causes an increase in soil salt concentration. This can occur due to the use of poor quality irrigation water with excessive salt content or excessive irrigation leading to a rising groundwater table. It is more prevalent in hot climates with low rainfall, where water evaporates easily, leaving salts in the soil. This layer displays the presence of irrigation in climatic areas where evaporation exceeds precipitation, in order to estimate the risk of soil salinization. Its purpose is to identify areas within the EU where secondary salinization is likely to occur. It is important to note that areas identified as being at risk of soil salinization are not necessarily affected by salinization.

On the other hand, the Junta de Andalucía promotes information through various programs, including the Thematic sub-programme of the olive grove sector. This program provides valuable information, such as the risks of soil erosion in olive groves, which is a significant and widespread environmental concern. The loss of surface horizons, which are rich in nutrients and organic matter, can negatively impact the productive capacity of soils. This can limit their ability to produce biomass, whether for productive purposes or as a support for the natural environment, which is the first link in the food chain. Finally, Soil organic matter is a crucial factor to consider for soil fertility and conservation, as stated in the Annual Report of Agriculture, Fisheries, and Food Indicators 2021 by the Ministry of Agriculture, Fisheries, and Food (Ministerio de Agricultura, 2022).

Soil organic matter is a crucial factor in maintaining soil fertility and conservation. The concentration of organic matter is highest on the surface and decreases with depth. The effects of low soil organic matter levels are:

1. Low soil fertility and decreased plant nutrient uptake.
2. Soil structure is affected, reducing water holding capacity and increasing susceptibility to compaction.
3. Increased surface water run-off can lead to erosion and reduced biodiversity. Susceptibility to acidic or alkaline conditions.

The most commonly used agri-environmental indicator to calculate the environmental pressures on agricultural systems from fertiliser nutrients is called gross nutrient balance.

2.2.2 Methodology applied

The data sources used were those published in the Joint Research Centre (JRC). Within this database, the European Soil Data Centre (ESDAC) has been consulted. ESDAC is the thematic centre for soil-related data in Europe and within it is the EU Soil Observatory (EUSO). The EUSO aims to become the main provider of reference data and knowledge at EU level for all soil-related issues. Their platform provides access to the:

- EUSO Soil Health Dashboard
- EUSO Soil Policy Dashboard (under construction).

The EUSO Soil Health Dashboard contains information such as (Commission, s.f.):

- Number of soil degradation processes
- Soil degradation indicators:
  - Soil erosion
  - Soil pollution
  - Soil nutrients
  - Loss of soil organic carbon
  - Loss of soil biodiversity
  - Soil compaction
  - Soil salinization
  - Loss of organic soils
  - Soil consumption

Additional information is provided by the Ministry of Agriculture, Fisheries and Food and the Junta de Andalusia. The following sources have mainly been consulted:

- Annual report on Agriculture, Fisheries, and Food Indicators 2021
- Thematic sub-programme of the olive grove sector (Ministerio de Agricultura, Subprograma Temático del sector del olivar 2014-2020). Provides information on Soil erosion in olive groves
- REDIAM
- Andalusian Environmental Statistics Viewer

These last two tools provide information on rainfall erosion in Andalusia, land use, vegetation, and estimation of soil losses in the Andalusian region.

REDIAM offers a geographic information viewer that allows the application of several visualization layers of different themes for the region.

2.2.3 Data uncertainties

The sources used in this section of the study are diverse, including data from the Joint Research Centre (JRC) and the RUSLE model. However, much of the data available from these sources corresponds to the years 2015-2016. To ensure the evaluation criteria are updated and to eliminate any obsolete data, regional sources such as REDIAM, regional reports, and viewers were also used. These sources provided specific data for the olive value chain.

The REDIAM environmental information catalogue is a database of Andalusian environmental information. Each topic is organized in layers produced by the Andalusian Visibility System (SVA), which can be accessed by navigating through the content structure. Metadata files (XML) are used to characterize REDIAM's environmental information. The Catalogue is regularly updated with new data source information. The Andalusia Visibility System is being enhanced by developing various parameters and algorithms that enable detailed analysis of existing and potential geometric visual relationships. The aim is to move away from the conceptual limitations that it has been facing. (Romero Romero, et al., 2016).

2.2.4 Methodological uncertainties

The indicators to measure the different parameters related to the Andalusian soil have been measured taking into consideration the entire Andalusian territory and not only limited to the Guadalquivir River Basin District. The Guadalquivir RBD covers almost 60% of the Andalusian surface area and Andalusia's share in the basin is 90% (Ministerio para la Transición Ecológica y Reto Demográfico, 2023).

2.3 Biodiversity data and indicators

2.3.1 Description of the data / definition of the indicators employed

Unlike for water- and soil-related risks, there are no reliable indices or standardized metrics to operationalize and compare risks to biodiversity at the regional level and in an integrated manner. Biodiversity is intricate and multifaceted, spanning genetic, species, and ecosystem diversity across various regions. Attempting to consolidate this diversity into a singular index may oversimplify it, leading to the loss of crucial information (Ledger et.al 2023; Brown & Williams 2016). Instead, biodiversity risks in a given region could be uncovered by considering the status of all species known to inhabit the region under scrutiny on a one-by-one basis, without trying to synthesize their collective status in a single index. Accordingly, our methodology suggests screening for biodiversity risks of a region by taking stock of its species of flora, fauna, and fungi present in the demarcation and considering their conservation status. The Red List of Threatened Species of *the International Union for Conservation of Nature* (IUCN) is a globally recognized system for classifying the conservation status of species[217]. It is structured along the following risk categories (IUCN 2001, 2003):

(8) Critically Endangered (CR): This is the highest risk category assigned by the IUCN Red List for wild species. Species in this category are facing an extremely high risk of extinction in the wild.
(9) Endangered (EN): Species in this category are facing a high risk of extinction in the wild.
(10) Vulnerable (VU): Species in this category are facing risks of extinction in the wild.
(11) Near Threatened (NT): Species in this category are close to qualifying for, or are likely to qualify for, a threatened category soon.
(12) Least Concern (LC): Species in this category have been evaluated but do not qualify for any other category. They are widespread and abundant in the wild.
(13) Data Deficient (DD): A category applied to species when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution or population status.
(14) Not Evaluated (NE): A category applied to species that have not yet been evaluated against the criteria.

Data description

Data on the risk category of each species found in the SCALE-UP regions is accessed through the online database of the IUCN Red List website. The IUCN Red List serves as a comprehensive repository of information, offering insights into the present extinction risk faced by assessed animal, fungus, and plant species. In 2000, IUCN consolidated assessments from the 1996 IUCN Red List of Threatened Animals and The World List of Threatened Trees, integrating them into the IUCN Red List website with its interactive database, currently encompassing assessments for over 150.300 species. Since 2014, assessors of species have been mandated to furnish supporting details for all submitted assessments. Among the recorded details are the species' (1) IUCN Red List category, (2)

[217] The International Union for Conservation of Nature (IUCN) is a global environmental organization that was founded on October 5, 1948. It is the world's oldest and largest global environmental network. The IUCN works to address conservation and sustainability issues by assessing the conservation status of species, promoting sustainable development practices, and providing guidance and expertise on environmental policy and action. The IUCN also plays a crucial role in influencing international environmental policies and fostering collaboration among governments, NGOs, and the private sector to promote conservation efforts worldwide (IUCN 2018).

distribution map, (3) habitat and ecology, (4) threats and (5) conservation actions. The assessment of these dimensions is elaborated below:

(6) The IUCN Red List category: The IUCN Red List categories (CR, EN, VU, NT, LC, DD, NE) are determined through the evaluation of taxa against five quantitative criteria (a-e), each grounded in biological indicators of population threat:

   a. Population Size Reduction: This criterion evaluates the past, present, or projected reduction in the size of a taxon's population. It considers the percentage reduction over a specific time frame, with different thresholds indicating different threat levels.
   b. Geographic Range Size and Fragmentation: This criterion assesses the size and fragmentation of a taxon's geographic range. Factors such as few locations, decline, or fluctuations in range size contribute to the evaluation.
   c. Small and Declining Population Size and Fragmentation: This criterion focuses on taxa with small and declining populations, considering factors like population size, fragmentation, fluctuations, or the presence of few subpopulations.
   d. Very Small Population or Very Restricted Distribution: This criterion addresses taxa with extremely small populations or limited distributions. It assesses whether the taxon is at risk due to its small population size or restricted geographic range.
   e. Quantitative Analysis of Extinction Risk: This criterion involves a quantitative analysis, such as Population Viability Analysis, to estimate the extinction risk of a taxon. It considers various factors influencing population dynamics and extinction risk.

   While listing requires meeting only one criterion, assessors are encouraged to consider multiple criteria based on available data. Quantitative thresholds of the IUCN Red List categories were developed through wide consultation and are set at levels judged to be appropriate, generating informative threat categories spanning the range of extinction probabilities. To ensure adaptability, the system permits the incorporation of inference, suspicion, and projection when confronted with limited information.

(7) The distribution map: The IUCN Red List distribution map serves as a reference for the taxon's occurrence in form of georeferenced data and geographic maps. This data is available for 82% of the assessed species (>123.600) and is based on the species' habitat, which is linked to land cover- and elevation maps. The indicated area marks the species extent of occurrence, which is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred, or projected sites of present occurrence of a species, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of species, such as large areas of obviously unsuitable habitat. For a detailed explanation of the mapping methodology, please refer to the *Mapping Standards and Data Quality for the IUCN Red List Spatial Data* (IUCN 2021).

(8) Habitat and Ecology: The IUCN classifies the specific habitats that a species depends on for its survival. These habitats are categorized into three broad systems: terrestrial, marine, and freshwater. A species may inhabit one or more of these systems, and so the possible permutations result in seven categories of natural systems. Beyond these seven system categories, the IUCN offers a more nuanced classification system for habitats, comprising 18 different classes at level 1 (e.g., forest, wetlands, grassland, etc.), and 106 more specific classes listed at level 2 (e.g., Forest – Subtropical/tropical moist lowland, Wetlands (inland) – Permanent inland deltas; Grassland - Temperate) (IUCNa n.d.). For SCALE-UP's sustainability screening, the IUCN classification of the seven systems is sufficient to refine the search while not excluding relevant habitats. The EU Habitats Directive, in contrast, distinguishes 25 habitat types that are considered threatened and re-

quire active and recurring conservation action. The Directive demands member states to take measures to maintain or restore these natural habitats and wild species. If data on these became accessible in the future, it could be used in future iterations of the sustainability screening to supplement the results that using the IUCN classification yields.

(9) Threats: The IUCN database encompasses various general threats that can negatively impact a species. Direct threats denote immediate human activities or processes impacting, currently impacting, or potentially affecting the taxon's status, such as unsustainable fishing, logging, agriculture, and housing developments. Direct threats are synonymous with sources of stress and proximate pressures. Assessors are urged to specify the threats that prompted the taxon's listing at the most granular level feasible within this hierarchical classification of drivers. These threats could be historical, ongoing, or anticipated within a timeframe of three generations or ten years. These generalized threat categories encompass residential and commercial development, agriculture and aquaculture, energy production and mining, transportation and service corridors, biological resource use, human intrusion and disturbances, natural system modifications, invasive and other problematic species, genes and diseases, pollution, geological events, and climate change and severe weather. Beneath each general threat, more specific threats are detailed. Please refer to the IUCN Red List's website[218] for a detailed list of all threats, including explanations.

(10) Conservation Actions: The IUCN database contains conservation action needs for each species, providing detailed information on the current conservation efforts and recommended actions for protecting the taxon. It includes general conservation actions such as research & monitoring, land/water protection, management, and education. Specific conservation actions are listed under each general action, along with a description of the current conservation status and recommended actions to protect the taxon. A hierarchical structure of conservation action categories (see the IUCN Red List's website[219]) indicates the most urgent and significant actions needed for the species, along with definitions, examples, and guidance notes on using the scheme. Assessors are encouraged to be realistic and selective in choosing the most important actions that can be achieved within the next five years, informed by the conservation actions already in place.

[218] See here: https://www.iucnredlist.org/resources/threat-classification-scheme
[219] Ibid.

Note: the IUCN Red List and the EU Habitats Directive
Both, the EU's Habitats Directive and the IUCN Red List aim to preserve biodiversity, but they employ distinct methods and standards for evaluating conservation status. The Habitats Directive is centered on preserving natural habitats and wild species of flora and fauna within the EU, mandating that member states establish Special Areas of Conservation for habitats and species listed in its annexes. The Directive categorizes conservation status into three groups: favorable, unfavorable-inadequate, and unfavorable-bad. This classification system of habitats and species is based on how far they are from the defined 'favorable' conservation status, not their proximity to extinction (Sundseth 2015). Conversely, the IUCN Red List is a worldwide evaluation of the conservation status of species, categorizing them according to their extinction risk. The Red List employs a set of five rule-based criteria to assign species to a risk category (see above). However, there are inconsistencies and weak agreement between the conservation status assessments of the Habitats Directive and the IUCN Red List. These inconsistencies can be significant, and correlations can vary greatly between taxonomic groups. Specifically, the Red List assessment tends to be more pessimistic than the Directive's Annex (Moser et.al 2016). Amos (2021), on the other hand, has found strong correlations between the two classifications systems for plants, while recognizing the Red List's quicker reaction to changes in the conservation status. In summary, while both the Habitats Directive and the IUCN Red List aim to protect and conserve biodiversity, they use different methodologies and criteria to assess conservation status, leading to discrepancies in their assessments. However, they can complement each other in providing a comprehensive view of the conservation status of species and habitats at both the European and global levels (IUCN 2010).

2.3.2 Methodology applied

The methodology aims to derive a list of species which would require special consideration (e.g. close monitoring and safeguarding) in the context of implementing bioeconomy activities. To generate this list, the search function of the interactive IUCN database is used following five steps:

(6) Scope of Assessment: Selection of Europe as the scope of assessment to evaluate the conservation status of the European population rather than the global population. This approach ensures that species are identified as threatened based on their status in Europe, irrespective of their global abundance.

(7) Geographical Delineation: Utilization of the interactive map of the IUCN database to draw a polygon that exceeds the region of interest. Exceeding the regions ensures that the entire region is covered, as it is not possible to draw a polygon exactly matching the boundaries of the region. Moreover, a larger polygon also respects the uncertainty of delineating a species area of extent, since the actual area of extent is possibly more fluid than its statically indicated geolocations. Consequently, the larger polygon minimizes the risk of excluding any relevant species for which geolocations are registered just minimally outside of the regions' administrative boundaries, but which could inhabit parts of the region in the future. There is no rule of thumb for a correct distance between polygon boundary and region boundary.

(8) Species Selection: Limiting of the search results to endangered and critically endangered species to focus on those facing the most severe risks.

(9) Habitat Selection: selection of all habitats to ensure the full coverage of habitat types present in the geographical delineation defined in step 2.

(10) Threat Selection: Selection of threats associated with the respective regional bioeconomy and/or value chain to refine the search results to species likely to be impacted by them.

By following these steps, a targeted list of species is derived, focusing on species facing significant risks within the context of the regional bioeconomy strategy or value chain being explored, aligning with the specific conservation and bioeconomic priorities of the region.

2.3.3 Data and methodological uncertainties

It is important to acknowledge certain limitations and uncertainties associated with the data and methodologies used:

(1) Inaccurate representation of relevant area: The IUCN database allows for the interactive drawing of a map for a regional assessment. However, this drawn map might not accurately represent the area directly relevant to the bioeconomy strategy or value chain being explored. Since the selected polygon is larger than the actual bioregion, the assessment risks to include species that are not relevant to the bioregion and the bioeconomic strategy of the region.

(2) Lack of local habitat differentiation: The spread of species is indicated as its extent of occurrence without differentiating between habitats at the local level. This means that certain species might solely inhabit very particular habitats within the indicated extent of occurrence. An endangered amphibious species, for instance, might have an area of extent covering an entire country. However, it will only be found in very rare habitats within this area of extent (e.g., pond with very specific qualities). Accordingly, a regional assessment as outlined here (e.g., at the municipal level) might list certain species that do not occur in the assessed regions due to a lack of suitable habitats on the local level.

(3) Potential oversights in conservation status: Using Europe as a scope of assessment might hide any problematic conservation status of a species at the global or at the local level.

(4) Outdated data: The IUCN aims to have the category of every species re-evaluated at least every ten years and aims to update the list every two years (IUCNb n.d.). Nevertheless, the data might be outdated, which could lead to inaccuracies in the assessment of biodiversity risks. For this screening carried out for Andalucía, 73 percent of the data were older than 5 years, the most dated being from 2006.

(5) Incomplete data: The data might be incomplete, which could limit the comprehensiveness of the assessment.

(6) Limited species coverage: It is estimated that the world hosts about 8,7 million species (Sweetlove, 2011). As of now, more than 150.300 species (16.120 in Europe) have been assessed for the Red List, leaving large data gaps at the global level.

(7) Taxonomic standards: The taxon being assessed must follow the taxonomic standards used for the IUCN Red List. Any deviation from these standards could lead to inaccuracies in the assessment.

3 Potential ecological burden of regionally relevant bioeconomic activities

Note: the sections in this chapter were produced based on a review of available and accessible scientific literature on the impacts of bioeconomy activities on water, land and soil, biodiversity, and other environmental dimensions. Quotes associating such activities (or elements thereof) with positive and negative effects on the said environmental dimensions were collected manually from the scientific studies and then fed to ChatGPT4 for structuring and synthesis into flowing text.[220] The resulting text was then thoroughly reviewed and adjusted manually to ensure fidelity with the source documents.

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[220] Quotes fed to ChatGPT were previously sorted by topic and kept in quotation marks, including their correct in-text citation. Prompts and feedback were provided to the system to synthesize the information maintaining the style, using the right scientific references, and improving by avoiding repetition, not leaving any of the provided information out, and highlighting agreements, disagreements and complementarities among quotes.

3.1 Bioeconomic activity selected for the screening

Olive cultivation, deeply rooted in regions like Andalusia, is at a crucial juncture, balancing between its rich agricultural heritage and the pressing need for sustainability. Traditionally, this practice was synonymous with biodiversity and eco-friendly farming methods, but recent trends towards intensification have led to worrying environmental consequences. Currently, traditional olive production systems are slightly more common than intensive ones in Spain (51% over 46%, respectively). Benefits like shorter investment payback periods, underpinned by lower unit production costs and increased productivity, have made intensive cultivation attractive (Pérez, 2023). While intensive cultivation can also incorporate the implementation of soil protection measures (e.g. spreading crop residues on the field), the expanding water footprint driven by the growth in irrigated olive groves, and the potential for nitrate pollution, further complicate the sustainability narrative. As the global demand for olive products rises, the challenge intensifies to adopt sustainable agricultural practices. These practices must harmonize the traditional essence of olive farming with the need to address contemporary environmental concerns, including soil conservation, water management, and biodiversity preservation.

3.2 Potential burden on water resources

The impact of olive cultivation on water resources in areas like Andalusia has become increasingly significant, primarily due to the intensification of agricultural practices.

Non-Point Source Water Pollution: The regular use of agrochemical products in olive systems, primarily herbicides and fertilizers, has deteriorated water quality, leading to increased non-point source water pollution in rivers, dams, and aquifers. This pollution has caused several health concerns, including the prohibition of drinking water from dams surrounded by olive groves, despite the removal of some harmful agrochemical products (Gomez-Limon et.al, 2010). In response, recent changes in Spanish law have incorporated stricter provisions on the types and concentration levels of agrochemical products that can be used.

Water Footprint and Consumption: Between 1997 and 2008, the total water footprint (WF) of agricultural production in the Guadalquivir basin varied significantly due to irregular rainfall patterns. Olive groves consumed the largest proportion of both green (rainfall) and blue (irrigation) water resources, with olive cultivation dominating the upper part of the basin, both under rain-fed and irrigated conditions (Dumont et.al, 2013). The expansion of olive orchards, particularly irrigated systems, has led to an upward trend in total water footprint. The average water footprints for olive oil production in Spain vary depending on the type of system (rainfed or irrigated) and the components of the water footprint (green, blue, grey) (Morgado et.al, 2022).

Overexploitation and Nitrogen Pollution: The intensification of olive cultivation has led to an overexploitation of water resources, especially in the Guadalquivir basin, where most of the water is consumed by irrigated olive farms. This intensification jeopardizes the satisfaction of water demand in the basin and increases the risk of water resource depletion (Gomez-Limon et.al, 2010). Additionally, there is a significant difference in nitrogen inputs between irrigated and rainfed olives, with irrigated olives having nearly three times higher nitrogen inputs. This increase in nitrogen use in irrigated systems could potentially contribute to nitrate pollution, although the overall impact varies across different provinces (Morgado et.al, 2022).

Land Management Practices and Environmental Impacts: The no tillage land management practice (LMP) has been shown to effectively protect olive groves from land degradation and desertification due to better soil and water conservation. This practice results in lower runoff, reduced soil sediment loss, increased water storage in the soil, and lower soil temperatures, contributing to lower costs for olive oil production and protection of sensitive areas from desertification (Kairis et.al, 2013). In a case study the area of Cordoba, olive orchards with higher water-holding capacity soils show less yield sensitivity to decreasing soil depth, underscoring the importance of soil conservation measures to limit off-site erosion damage and maintain water storage capacity for dry seasons (Gomez et.al, 2014).

Supply Chain Water Footprint: The largest portion of the water footprint for bottled olive oil lies in the olive production process itself, with other supply chain components like the bottle, cap, and label contributing less than 0.5% to the product's water footprint. This finding is consistent with previous studies, highlighting the significant environmental impact of the olive production process (Morgado et.al, 2022).

3.3 Potential burden on land resources

Olive cultivation has profound impacts on soil resources, which are crucial for sustainable agricultural practices and environmental conservation.

Soil Erosion and Land Degradation: The expansion of olive groves into areas with unfavorable conditions (e.g., steep slopes, torrential rains) has exacerbated soil erosion. The agricultural and fishery regional ministry reports significant proportions of olive farms experiencing moderate to very high soil erosion (Gomez-Limon et.al, 2010). Olive cultivation, particularly under bare soil management practices such as continuous tillage (CT) or no tillage with bare soil (NT), has been associated with unsustainable erosion rates. Studies using indicators like olive mounds or radionuclide content have confirmed these observations (Gomez et.al, 2014). However, the implementation of cover crops significantly reduces erosion rates, often to tolerable levels, typically defined as 10 to 12 t ha^{-1} $year^{-1}$ (Gomez et.al, 2014). In contrast, soil management practices at the catchment scale, especially in regions like Southern Spain, show high erosion rates, negatively impacting water quality due to offsite contamination (Gomez et.al, 2014). Additionally, model predictions in Andalusia indicate prevalent unsustainable erosion rates, highlighting the need for finely-tuned soil management and potentially the abandonment of olive cultivation in favor of natural reversion to forests in severely sloping and degraded areas (Gomez et.al, 2014).

Soil Organic Carbon and Structure: Olive orchards managed with bare soil exhibit lower phosphorus, organic matter content, and aggregate stability compared to those with cover crops. Controlled experiments reveal a direct correlation between soil management techniques and topsoil properties, with higher erosion rates and poorer soil quality indicators under bare soil management (Gomez et.al, 2014). Moreover, there has been a significant reduction in organic matter and aggregate stability in olive orchards relative to natural areas, indicating a trend towards soil degradation (Gomez et.al, 2014).

Water Storage: Different soil management practices have varying impacts on water storage. In areas like the Guadalquivir river valley, represented by the Cordoba scenario, soil depths over 60 cm appear sufficient to maintain water storage for dry seasons, supporting stable yields. However, in more mountainous areas with shallow soil profiles, like the Obejo case, a much deeper soil profile is needed for adequate water storage, as water infiltrates below the olive root zone (Gomez et.al, 2014). Hence, maintaining soil depth is crucial, particularly in areas where irrigation is not feasible, and alternative soil management strategies are needed to maintain productivity.

Impact of Different Land Management Practices: No tillage land management practices (LMPs), especially those without herbicide use, are found to be effective in protecting olive groves from land degradation and desertification. These practices lead to reduced runoff, negligible soil sediment loss, greater water storage, and lower soil temperatures, which are beneficial for organic matter preservation and plant growth (Kairis et.al, 2013). In contrast, tillage practices contribute significantly to land degradation, evidenced by greater soil displacement and sediment losses (Kairis et.al, 2013).

Overall, olive cultivation has a significant impact on soil resources, with the potential for both negative effects, such as increased erosion and land degradation, and positive outcomes, such as improved water storage and soil structure, depending on the management practices employed. Sustainable management practices, particularly the use of cover crops and no tillage techniques, are crucial for mitigating these impacts and ensuring the long-term viability of olive cultivation.

3.4 Potential burden on biodiversity

The transformation of traditional olive groves in Andalusia into more modern, intensive agricultural systems has significantly impacted biodiversity, particularly in terms of farmland bird populations.

From High Biodiversity to Diminished Ecological Richness: Traditionally, Andalusian olive groves were characterized by high biodiversity, made possible by low-intensity farming practices, including minimal use of agrochemicals, the presence of old olive trees, and semi-natural herbaceous vegetation. These groves were part of diverse land-use areas, contributing to their ecological richness (Beaufoy and Cooper, 2009). However, recent shifts towards modernization, characterized by enlargement and intensification of olive farming, have led to a significant reduction in biodiversity. The modernization process involves the establishment of large, single-crop systems, intensive use of fertilizers, pesticides, machinery, and farms with uncovered soil (Gomez-Limon et.al, 2010).

Impact on Biodiversity and Farmland Birds: The high biodiversity of traditional olive groves in the 1980s, including various insects, birds, reptiles, and mammals, has been adversely affected by the intensification of olive farming. Changes such as the disappearance of vegetable cover, water pollution, insecticide use, and soil erosion have led to a reduction in both the number and diversity of animal species in these systems (Gomez-Limon et.al, 2010). Specifically, land cover transitions to irrigated olive plantations from 1990 to 2017 had a profoundly negative impact on open farmland birds, more so than any other observed land use change in the region (Morgado et.al, 2022).

Comparative Impacts of Land Use Changes: Land use dynamics leading to the installation of irrigated olive groves scored worst in terms of impacts on open farmland birds compared to other land use transitions. This negative impact is attributed to the conversion of biodiversity-rich areas, such as rainfed cereal cultivation and smaller, multifunctional rainfed olive groves, into irrigated olive plantations. These areas were previously part of rotational systems with diverse habitats crucial for farmland bird species. The transition towards irrigated olives, often replacing these biodiversity-rich areas, has resulted in simplified bird communities dominated by generalist granivores and a significant loss in bird diversity (Morgado et.al, 2022).

Conservation Recommendations: Given these findings, the importance of maintaining and reinforcing restrictions on olive grove expansion within protected areas, particularly those designated for open farmland bird conservation, is highlighted. These areas, often part of the Natura 2000 network, are vital for the preservation of farmland bird populations (Morgado et.al, 2022).

Overall, the shift from traditional, low-intensity olive farming to modern, intensive practices in Andalusia has led to a significant decline in biodiversity, particularly affecting farmland bird populations. The replacement of diverse land-use systems with intensive, irrigated olive groves has been the primary driver of this decline, underscoring the need for conservation efforts to protect remaining biodiversity-rich landscapes.

Agriculture and olive cultivation can significantly impact species, habitats, and biodiversity. These impacts include changes in soil composition, water usage, habitat modification, chemical runoff, microclimate alterations, reduced biodiversity, disrupted pollination and seed dispersal, introduction of non-native species, and threats to specialized species. Each of these factors plays a crucial role in the survival and health of ecosystems and the species within them.

1. **Impact on Soil Composition**: Many species mentioned thrive in specific soil types, like calcareous, sandy, or dolomitic soils. Agricultural practices, including olive cultivation, can alter soil composition through erosion, compaction, and changes in pH levels. This alteration can adversely affect species that depend on particular soil types.
2. **Water Use and Quality**: The text frequently references species living in or near water bodies with specific characteristics like high dissolved oxygen, constant temperature, and low nutrient content. Agricultural practices often lead to water extraction, altering flow patterns and temperatures in nearby streams and rivers, impacting species dependent on these water bodies.

3. **Habitat Modification**: Agriculture can lead to habitat loss or fragmentation. Species mentioned are often found in grasslands, scrublands, and mountainous regions, habitats that can be encroached upon by expanding agricultural lands. This fragmentation can limit the range and movement of species, impacting their survival.
4. **Chemical Use**: Pesticides and fertilizers used in agriculture can runoff into nearby habitats, affecting non-target species. Several species in the text, like those pollinated by Lepidoptera and Hymenoptera, could be impacted by these chemicals, affecting their reproductive success.
5. **Climate and Microclimate Alterations**: Agricultural activities can modify local climates and microclimates, impacting species adapted to specific temperature and humidity ranges. This is particularly crucial for species living in mountainous regions or those with narrow ecological ranges.
6. **Biodiversity Reduction**: The preference for monoculture in agriculture, including olive cultivation, reduces biodiversity. This reduction can affect species that rely on a variety of plants for food and habitat, as well as those that are part of a complex ecosystem.
7. **Pollination and Seed Dispersal**: Many plants and insects rely on each other for pollination and seed dispersal. Changes in land use due to agriculture can disrupt these relationships, impacting the reproductive success of both plants and their insect pollinators.
8. **Introduction of Non-native Species**: Agriculture can lead to the introduction of non-native species, which can become invasive and compete with or prey upon native species. This can have a cascading effect on local ecosystems.
9. **Impact on Specialized Species**: Species with highly specialized habitats or diets, like the Iberian Lynx, are particularly vulnerable to changes brought about by agriculture. The alteration of their specific habitats or reduction in prey species due to agricultural expansion can have severe consequences.

4 Screening results and recommendations

4.1 Overview - Andalusia

Resources screened		Ordinal Baseline Rating	Olive cultivation and olive oil production Management Practices	
Category	**Sub-Category**		**Potentially beneficial to the baseline status**	**Potentially detrimental to the baseline status**
Water	**Surface water bodies**		- Extensive olive cultivation - No tillage land management practices with cover crops - Reduced use of water resources and nitrogen in irrigated systems	- Water pollution from agrochemicals (primarily herbicides and fertilizers) - Overexploitation of water resources (for irrigation) - Nitrate pollution (associated with irrigated systems)
	Groundwater bodies			
Land Resources	**-**		- Measures to increasing soil water storage capacity (e.g. maintaining or deepening the soil profile) - Natural reversion to forests in severely sloping and degraded areas	- Continuous tillage and the absence of cover crops - Expansion of olive farms into steep slopes
Biodiversity	**Endangered Species**	**45**	- Traditional, low intensity olive farming practices (with minimal use of agrochemicals, and allowing old olive trees and semi-natural herbaceous vegetation to remain)	- Transformation from diverse land-use systems to intensive olive farming and single-crop systems - Habitat encroachment (e.g. olive grove expansion into protected areas)
	Critically Endangered Species	**17**		

4.2 Recommendations

While the incorporation of high-efficiency irrigation has increased the viability of olive production at scale in water scarce regions, it can also unlock disproportionate expansion of intensive farming operations in response to market demand, if unchecked. In the face of climate change and the increased frequency and intensity of droughts that it is already causing in Spain, as well as the shifts in seasonal conditions upon which environmental management and production planning has been carried out for decades, it is important to increase our understanding of regional system dynamics to avoid –or at least minimize– the negative effects that have been associated with olive production in regions like Andalusia.

Data from the 3rd cycle of EU WFD reporting indicates that the significant pressures and impacts most recurrently observed in the Guadalquivir RBD are associated with agriculture, and more concretely here with water extraction and flow diversion, physical alteration of rivers, and diffuse pollution. To ensure that ecological boundaries within the region are not surpassed, the water demand from irrigated olive production should be carefully balanced with the requirements of other uses, including the environment. This is a longstanding challenge that will clearly continue being at the core of decision-making in Andalusia, and that perhaps will become even more elusive under climate change conditions. At the farm level, the implementation of agricultural practices and measures that allow for increased water retention and lower soil disturbance and erosion risk (like no tillage and cover cropping), and that can enhance the resilience of the system to extended drought and scarcity periods (like better management of groundwater resources), could support the region in dealing with limitations on water resource availability.

While reversion to extensive cultivation practices could potentially mitigate the current pressures on the three environmental dimensions examined in the screening, and while a return to low-density mixed vegetation could strengthen specific degraded areas and slopes at high risk of erosion and biodiversity loss, such a shift seems unrealistic under the current situation of increasing demand and prices of olive products. However, it is at these times where it is most important for policy- and decision makers to frame their current actions within a plan for the mid- and long-term, giving serious consideration to the implications that these present actions may have in the future while still being able to navigate prevailing demands from social and economic systems. An integrated, systemic perspective seems thus fundamental to come as close as possible to a thorough understanding of the multiple challenges at hand, and later on, to formulate adequate responses with the support of local and regional experts and other stakeholders. In the meantime, it will be important to reinforce the preservation of protected areas, not only from a territorial perspective (i.e. from encroachment), but also from a water management one. These changes underscore the need for sustainable water and land management practices to mitigate the adverse effects on water quality and availability, and to ensure the long-term sustainability of olive production as a fundamental pillar of the regional economy of Andalusia.

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Section 1.3

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