Biomass Potential & Ecological Boundaries

Mazovia, Poland

SCALE UP community-driven bioeconomy development

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: Potential benefits	Use apple by-products and potential impact on environmental dimensions: Potentially detrimental
Water	Surface water bodies		• Drip irrigation, regulated deficit irrigation • Effective fertilizer management	• Overuse of chemical inputs, particulary nitrogen fertilizers
Water	Ground water bodies			
Land resources			• 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
Biodiversity	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.

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

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

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.

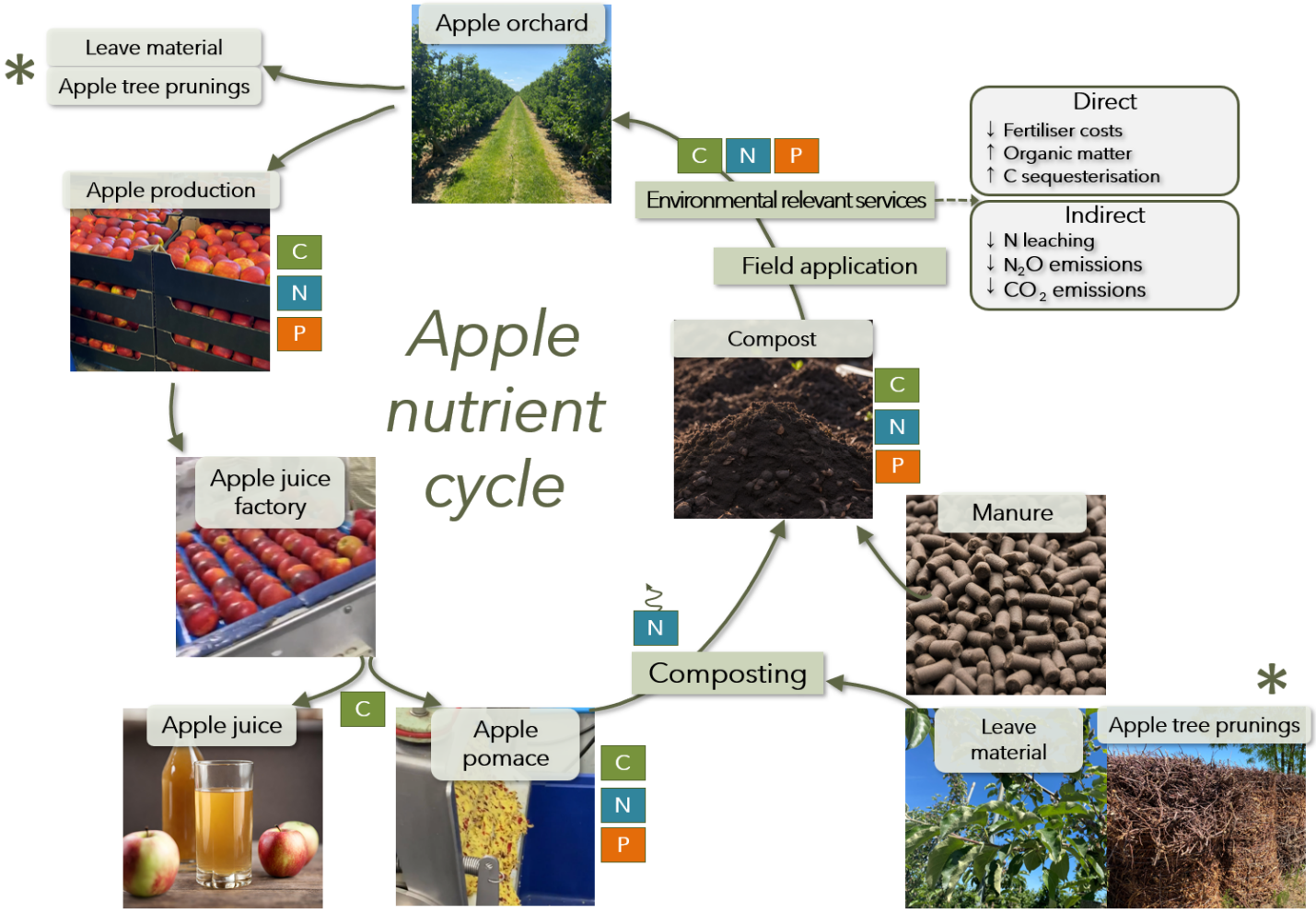
Ground water bodies: The expansion of existing, or development of new activities should be planned carefully and located smartly to avoid pressures.

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

Nutrient Recycling

Mazovia, Poland

SCALE UP
community-driven
bioeconomy development



Nutrients

For sustainable apple production, good soil and proper nutrition is essential. 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.

Nutrients can also be recycled within the apple industry. As shown in the image above, apple tree prunings and apple pomace can be composted, providing valuable nutrients and improving soil quality.

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

Recommendations

Develop and share know-how of compost from leaves and prunings and assess potential of nutrient recycling systems.

Find ways of **closing the nutrient cycle in a sustainable way**, e.g. ways to deal with pesticides in organic material for biofertilizers and soil improvers.

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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	Resources screened: Sub-Category	Rating	Olive production potential impact on environmental dimensions: Potential benefits	Olive production potential impact on environmental dimensions: 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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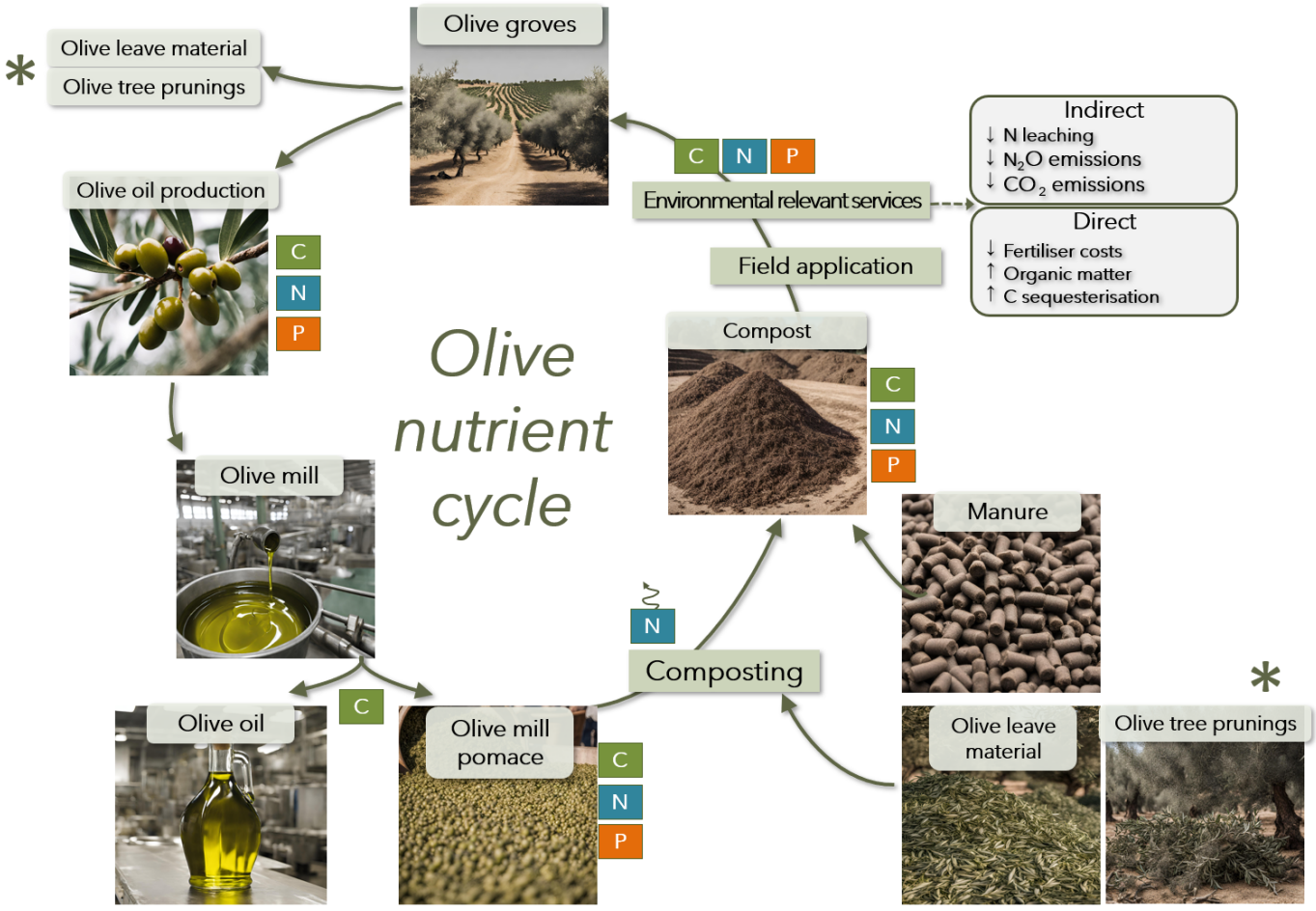

Nutrients

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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Biomass Potential & Ecological Boundaries

Upper Austria

SCALE UP 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		Rating	Use of bakery by-products and their impact on environmental dimensions	
Category	Sub-Category		Potential benefits	Potentially detrimental
Water	*Surface water bodies*		• Use of value chain for wastewater treatment • Adequate fertilizer and chemical management	• Improper waste discharge • Excessive fertilizer use
	Ground water bodies			
Land resources			• 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.	
	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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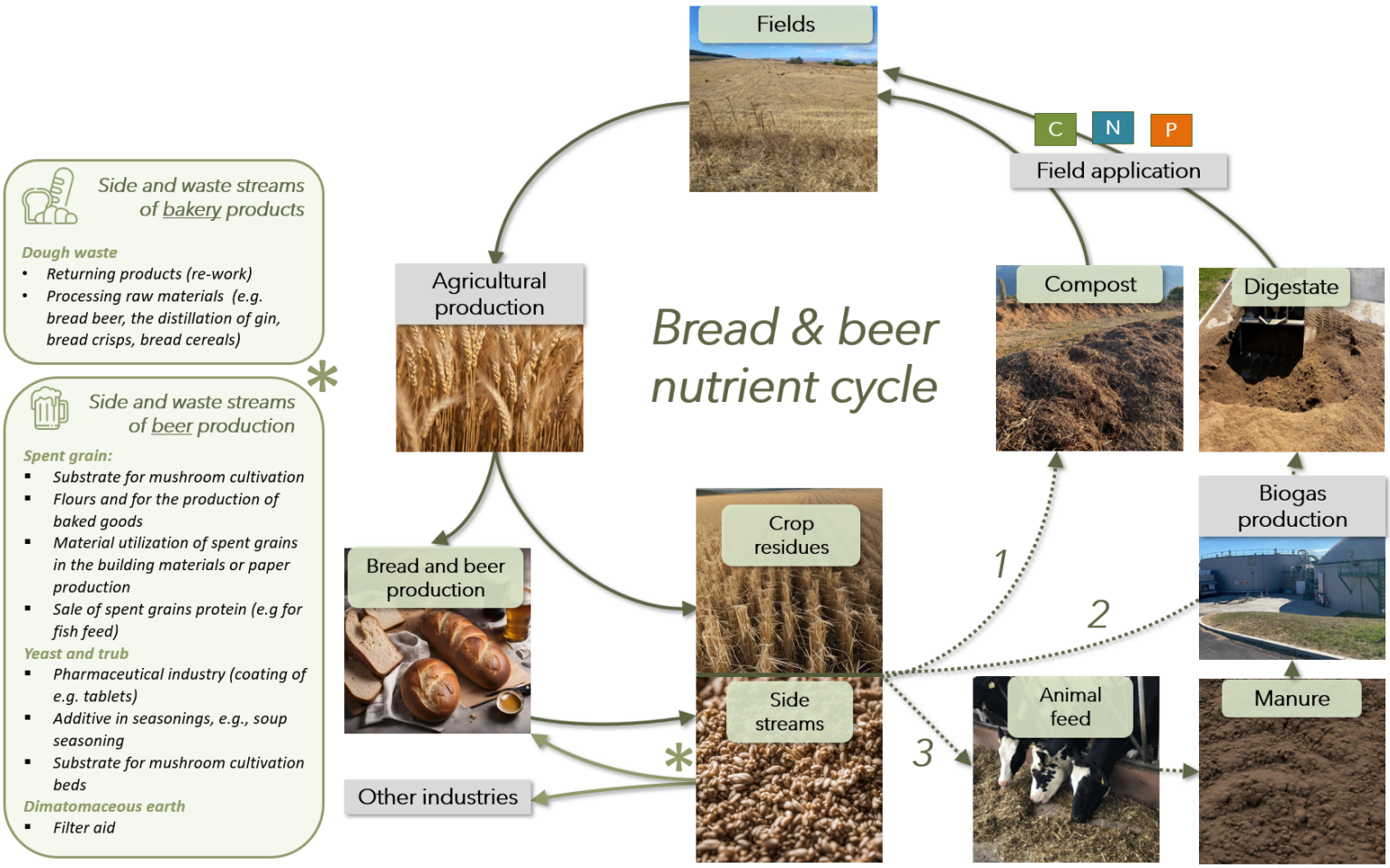
Nutrient Recycling

Upper Austria

SCALE UP
community-driven
bioeconomy development



Nutrients

The following routes exist for nutrient recycling in the bread and beer industries, and are applied depending on product quality and availability of conversion systems in the area.

1. The residues are **composted**, and nutrients are returned to the field.
2. The residues are used as **co-digestion** material producing biogas and bio-fertiliser; and the nutrients are returned to the field.
3. 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.

Alternatively, side streams from bread and beer production can also be **re-used internally** as a feedstock. For example, leftover bread can be used to produce croutons.

Recommendations

- **Improve cooperation** between research and actors in the promotion and development of nutrient recycling possibilities.
- **Research into environmental benefits and cascading principles** of the different nutrient recycling options.
- **Promote or initiate projects** to create innovative products that upcycle these by-products.

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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	Resources screened: Sub-Category	Rating	Agricultural and food production residues for compost production potential impact on environmental dimensions: Potential benefits	Potentially detrimental
Water	*Surface water bodies*		• 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			• 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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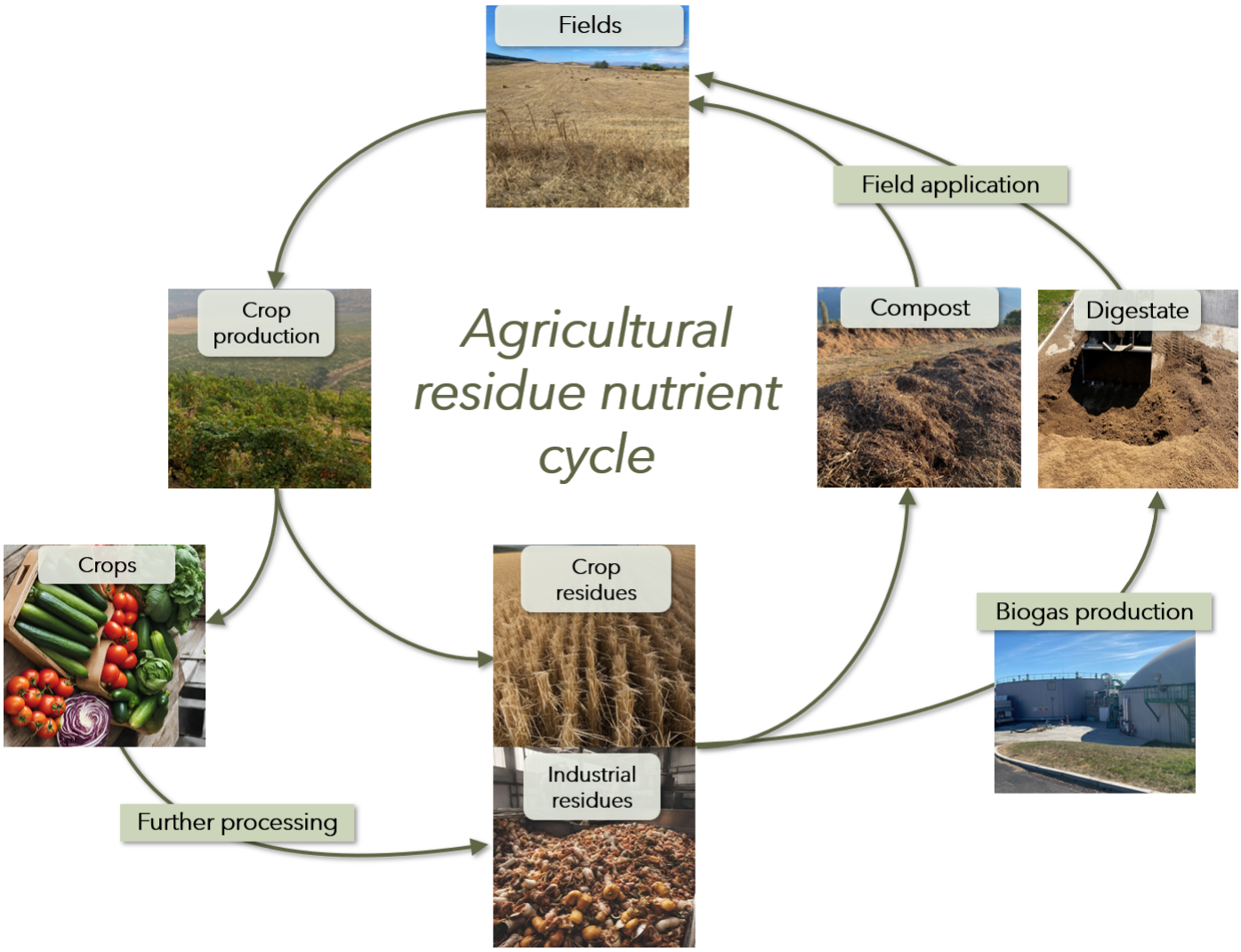
Nutrient Recycling

Strumica, North Macedonia

SCALE UP
community-driven
bioeconomy development



Nutrients

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. **Compost can be made with agricultural residues or residues from the food processing industry in the region**. The aim is to improve soil quality and provide nutrients for crops: nitrogen, phosphorus and potassium, with especially phosphorus being crucial for crop growth.

These agricultural residues could also be used in a biogas plant, resulting in digestate which can be applied in the fields.

Recommendations

Promotion of composting practices (at both the household and industrial levels) **and pilots**, in order to help farmers gain experience.

Invest in research and policies focused on nutrient recycling, e.g. composting and digestion **and promoting the use of biofertilizers** in order to reduce the use of mineral fertilizers.

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Biomass Potential & Ecological Boundaries

Atlantic Arc, France

SCALE UP community-driven bioeconomy development

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		Rating	Cultivation of flax, hemp and miscanthus and their impact on environmental dimensions	
Category	Sub-Category		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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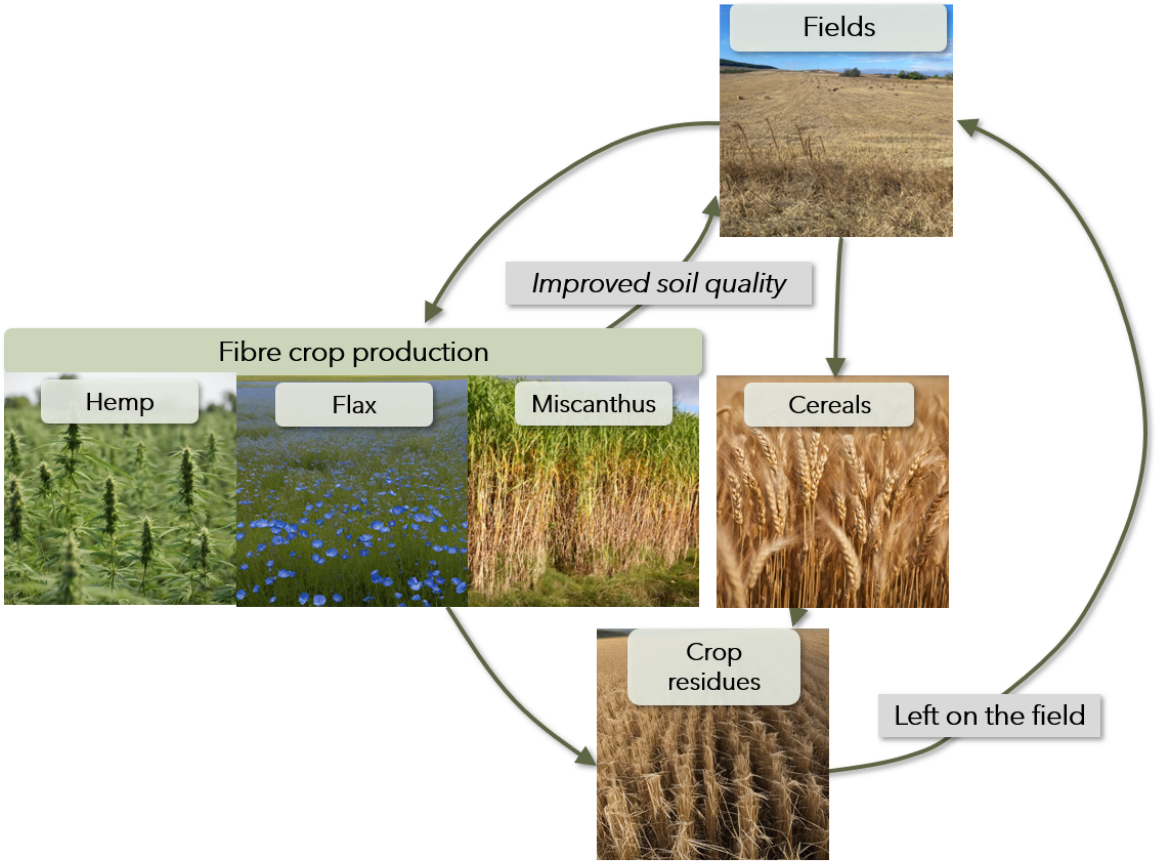
Nutrient Recycling

Atlantic Arc, France



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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Biomass Availability & Ecological Boundaries

North Sweden

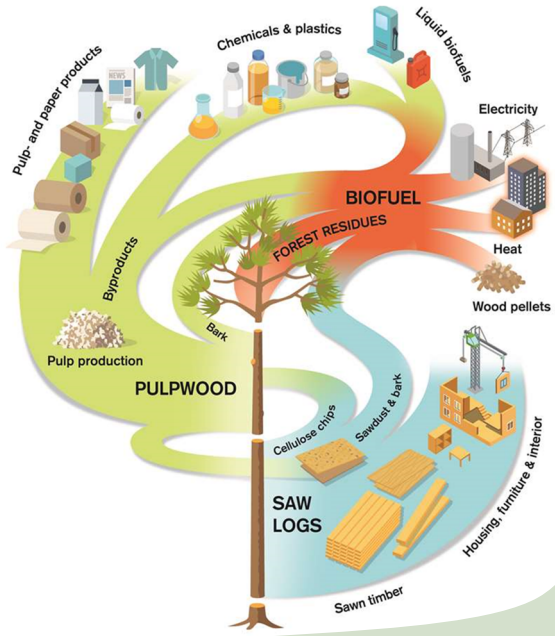
SCALE UP community-driven bioeconomy development

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	Forestry (and forest biomass extraction) management practices potential impact on environmental dimensions: Potential benefits	Potentially detrimental
Water	*Surface water bodies*		• 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			
Land resources			• 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	*Endangered 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 Endangered 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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Nutrients

Most of the nutrients in boreal forests are found in the forest soil. On poor soils, the harvesting of trees could lead to a nutrient deficiency. Forests in the northern Sweden region have mostly till soils, poor in plant-available nutrients thus the trees grow very slowly. Adding nitrogen fertilizers can increase tree growth. Forest management practices are regulated in the Swedish Forestry Act to prevent long-term impaired growth potential and nutrient leakage. The removal of logging residues on forestland comes with guidance and recommendations from the Forest Agency regarding compensation with ash. Forest owners need to report and apply to return ash to the site.

Nutrient recycling occurs through needles and twigs, and forest soils are scarified to make more nutrients available for seedlings. The removal of logging residues could have a negative impact on the soil quality and would have to be compensated, with, for example, ashes from combustion.

Recommendations

Develop pilots for the use of logging residues and **monitor the nutrient situation** of forests.

Collaboration within regional platform with forestry and environmental experts to set up nutrient monitoring system.

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