Deliverable 3.1 – SWOT analyses for each of the NOVAFERT Regions

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Executive Summary

The objective of this document is to identify drivers and barriers to the further implementation of alternative fertilising products using the SWOT (strengths, weaknesses, opportunities, and threats) and PEST (political, economic, social, and technological aspects) methodologies. The SWOT and PEST analyses have a regional scope and are the basis for the implementation strategies in each target region.

This document presents a regional diagnosis previous to the strategy development in order to structure the identification of key factors and lead to the further definition of objectives and priority actions of the action plans. Based on the knowledge gained in this task, a general strategy and 7 region specific action plans will be developed to overcome implementation barriers.

The initial step has been the study of the regional situation with regards to the alternative fertilising products manufacturing and use. The state-of-the-art aims to find out the regional understanding degree of alternative fertilising solutions and replicability potential. The issues analysed have varied depending on the region and the targeted secondary raw materials for each of them. This regional characterisation has been the basis to further conduct the SWOT and PEST analyses.

NOVAFERT SWOT and PEST analyses have a broad scope assessing a wide range of factors (e.g., political, technological, socio-cultural, legal, economic, etc.) that might influence regulations, markets, and the creation of new businesses.

The objective of the SWOT analysis is to identify impediments and factors of success, focusing on the economical regional aspects, on research innovation potential and on market exploitation and penetration. SWOT stands for:

- **S: Strengths**. (Internal) characteristics of the project that give it an advantage over others.
- **W: Weaknesses**. (Internal) characteristics of the project that are a disadvantage relative to others.
- **O: Opportunities**. (External) elements in the environment that the project could exploit to its advantage.
- **T: Threats**. (External) elements in the environment that could cause trouble for the project.

On the other hand, PEST is an acronym for **P: Political**, **E: Economic**, **S: Social** and **T: Technological** factors, and it is one of the most commonly used analytical tools for assessing external macro-economic factors related to a particular situation. It helps determine how these four factors will affect the performance and activities of a business in the long-term.

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SWOT and PEST analyses for alternative fertilising products' use in agriculture have been carried out for the 7 project regions (listed in alphabetical order) and their associated waste streams (following a colour code):

- Belgium – Flanders. Targeted secondary raw material: Animal manure and digestate. Regional leader: UGent.
- Croatia – Continental Croatia. Targeted secondary raw material: Bio-waste, animal manure and digestate. Regional leader: IPS.
- Finland – South-West Finland. Targeted secondary raw material: Bio-waste, digestate and animal manure. Regional leader: LUKE.
- Ireland – Wicklow / Carlow / Wexford. Targeted secondary raw material: Bio-waste and biological by-products. Regional leader: TEAGASC.
- Poland – South-East Poland. Targeted secondary raw material: Sewage sludge, animal manure and digestate. Regional leader: MEERI.
- Spain – Andalusia. Targeted secondary raw material: Wastewater and sewage sludge. Regional leader: BIOAZUL.
- Spain – Catalonia. Targeted secondary raw material: Animal manure. Regional leader: UVIC.

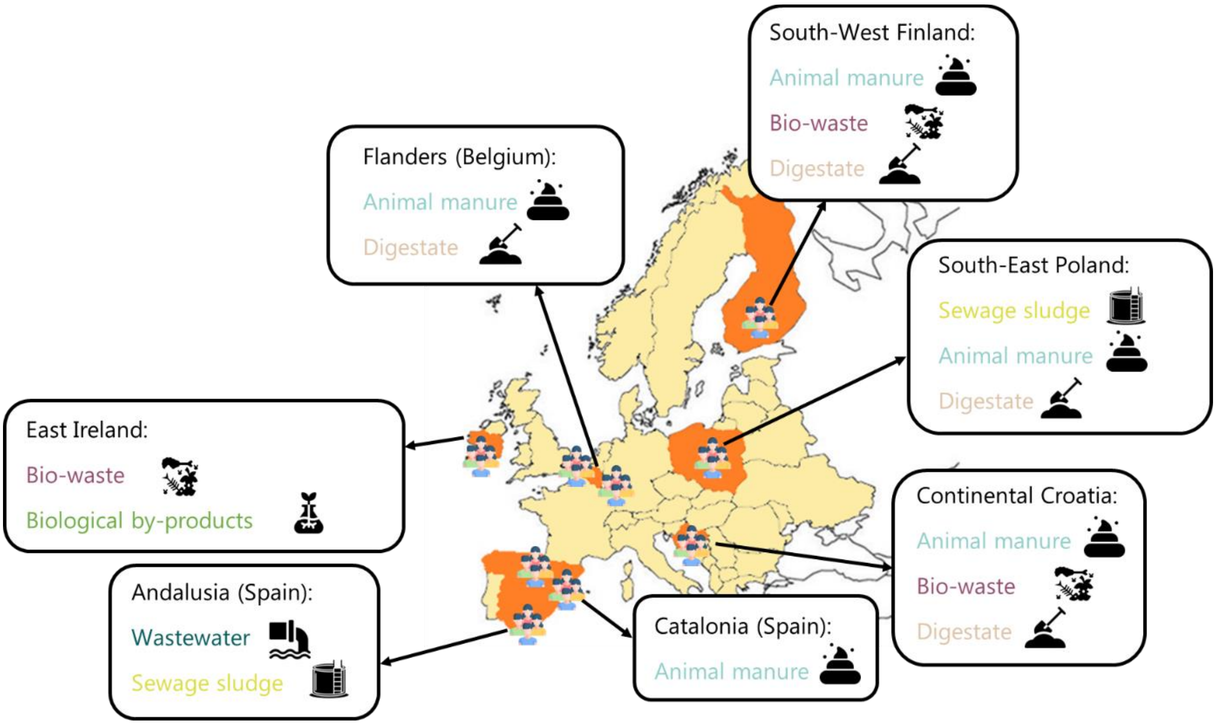

Figure 1. NOVAFERT regions and their associated waste streams

When analysing the results of the SWOT and the PEST analyses, it is found out that there are similarities, and also differences, between the regions. One of the main attributes appearing independently from the region and the waste stream analysed is the regulatory framework, both as negative and positive aspect. This is due to the fact that current legislation may be

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restrictive, but at the same time new and upcoming policies, existing recommendations and political willingness constitute an opportunity to change this fact.

Another relevant transversal issue is the lack of information for consumers and information and/or training of farmers, what constitutes an important barrier, but this is also being confronted with increasing demand or ecological products and environmental awareness.

The need of high investment and/or maintenance costs (because of energy consumption, for example) is also a transversal concern, but at the same time the decreasing availability of critical raw materials is forcing the approach to these alternatives, as well as the existence of a market gap that can be filled with secondary raw materials.

The last relevant transversal topic is the need of improving the quality of alternative fertilisers and of storing options, what is being currently confronted with research and development to improve these aspects.

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1. Introduction

One of the main objectives of NOVAFERT project is the development of a portfolio of support policies and legislative instruments suitable for local deployment in the European Union (EU) regions through 7 specific action plans and 4 policy briefs. The objective is indeed the main outcome of WP3, namely "Supporting policy formulation to overcome existing barriers and implementation at local and EU level", and will be achieved through the successful implementation of five tasks, one of which we are focusing on in this deliverable:

- Task 3.1: SWOT and PEST analyses uptake of alternative fertilising products (February 2022 – August 2023).

SWOT analysis methodology constitutes a prior step for the development of action plans. The task team has identified existing Strengths, Weaknesses, Opportunities and Threats for the implementation of alternative fertilisers in agriculture. These aspects have been identified and grouped under the four different matrices of the SWOT, divided themselves into technical and non-technical categories.

Complementarily to the SWOT analysis, the attributes of the SWOT have been studied in more detail in a PEST analysis. Thus, Political, Economic, Social, and Technological aspects have been evaluated to comprehend their influence on the implementation and potential business opportunities of alternative fertilisers in agriculture.

The analysis has been done at the regional level within the 7 target regions, and based on the waste stream(s) assigned to each of them.

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2. Methodology

2.1. Description of the SWOT analysis

The objective of the SWOT analysis is to identify impediments and factors of success, focusing on the economical regional aspects, on research innovation potential and on market exploitation and penetration.

Strengths, Weaknesses, Opportunities and Threats (SWOT) matrix is a powerful analytical tool that organisations and leaders use to guide their decision-making process.

The primary goal of SWOT analysis is to increase awareness of the factors that go into making a business decision or establishing a business strategy. To do this, SWOT analyses the internal and external environment and the factors that can impact the viability of a decision. Businesses commonly use SWOT analysis, but it is also used by non-profit organisations and, to a lesser degree, individuals for personal assessment. SWOT is also used to assess initiatives, products or projects.

SWOT analysis is often used either at the start of or as part of a strategic planning process. The framework is considered a powerful support for decision-making because it enables an organisation to uncover opportunities for success that were previously unarticulated. It also highlights threats before they become overly burdensome.

The use of conventional SWOT analysis is based on a qualitative analysis, but some methodologies attempt to include some quantitative valuation of the importance of the different attributes.

2.1.1. What does SWOT stand for?

The study takes its name from the four matrices of which the analysis is composed:

Figure 2. SWOT matrices

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- **S: Strengths**. (Internal) characteristics of the project that give it an advantage over others.
- **W: Weaknesses**. (Internal) characteristics of the project that are a disadvantage relative to others.
- **O: Opportunities**. (External) elements in the environment that the project could exploit to its advantage.
- **T: Threats**. (External) elements in the environment that could cause trouble for the project.

The items included within each of the 4 matrices are called attributes. These attributes will be afterwards scored to create the radar/spider charts.

2.1.2. Collection of information

To be able to run a SWOT analysis, a previous study of the regional situation with regards to the alternative fertilising products manufacturing and use is needed.

The state-of-the-art aims to find out the regional understanding degree of alternative fertilising solutions and replicability potential. The issues analysed have varied depending on the region and the targeted secondary raw materials for each of them. Outcomes from the previous activities of NOVAFERT WPs 1 and 2 have also contributed to feeding this regional characterisation.

This analysis has had a double purpose: on the one hand, compile information enough to define the attributes for the SWOT analysis and, on the other hand, conduct the PEST analysis. PEST stands for Political, Economic, Social, and Technological factors, as further explained. These factors determine the sections in which these regional analyses have to be divided.

The contents of each state-of-the-art vary from one region to another, as they are closely related to the waste stream(s) to be considered in each of them. However, as a general overview, the contents are related to the following topics:

Analysis of regulatory and institutional framework

Analysis of the legal framework for the application of the concerned alternative fertilising products of each region in agriculture.

The outcomes fit with the **P (Political) factor** of the PEST analysis.

Socio-economic characterisation of the region

Information about the location, climate geography, population, economic data (turnover, workforce in the agrifood sector, etc.), agricultural insight and hydrological data.

- _Characterisation of the waste stream situation and its agricultural uses once treated_: information about the waste stream, the agricultural sector and, more specifically, about the type of crops cultivated in the region, agribusiness description (exports/imports), fertilisers produced and consumed (conventional and non-conventional if data available), etc.

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- *Identification of the key actors*: this aspect runs in parallel to the creation of Regional Working Groups (RWGs, WP5) and it can be also fed with the outcomes of WP1. The key actors should represent the whole value chain, from producers to consumers.
- *Environmental aspects* related to the use of conventional fertilisers, like diffuse pollution and eutrophication events, surface and ground water quality deterioration, etc.

The outcomes fit with the **E (Economic) and S (Social) factors** of the PEST analysis.

Technological assessment

Information about technology incentives if any, innovations implemented in the region (as identified in WP1), Research and Development (R&D) activity, existing initiatives, etc.

The outcomes fit with the **T (Technical) factor** of the PEST analysis.

All this information will help to contextualise the different regions' situation and, at the same time, conduct the PEST analysis.

2.1.3. Identification, scoring and graphical representation of Strengths, Weaknesses, Opportunities and Threats

After performing the regional analysis, the task team, supported by the RWGs members, used this information as a basis and brainstormed to define the attributes of each matrix (S, W, O and T). All this information was summarised in the tool created by BIOAZUL, which consisted of an Excel file tailor-made for each region in which the attributes per matrix can be explained and scored.

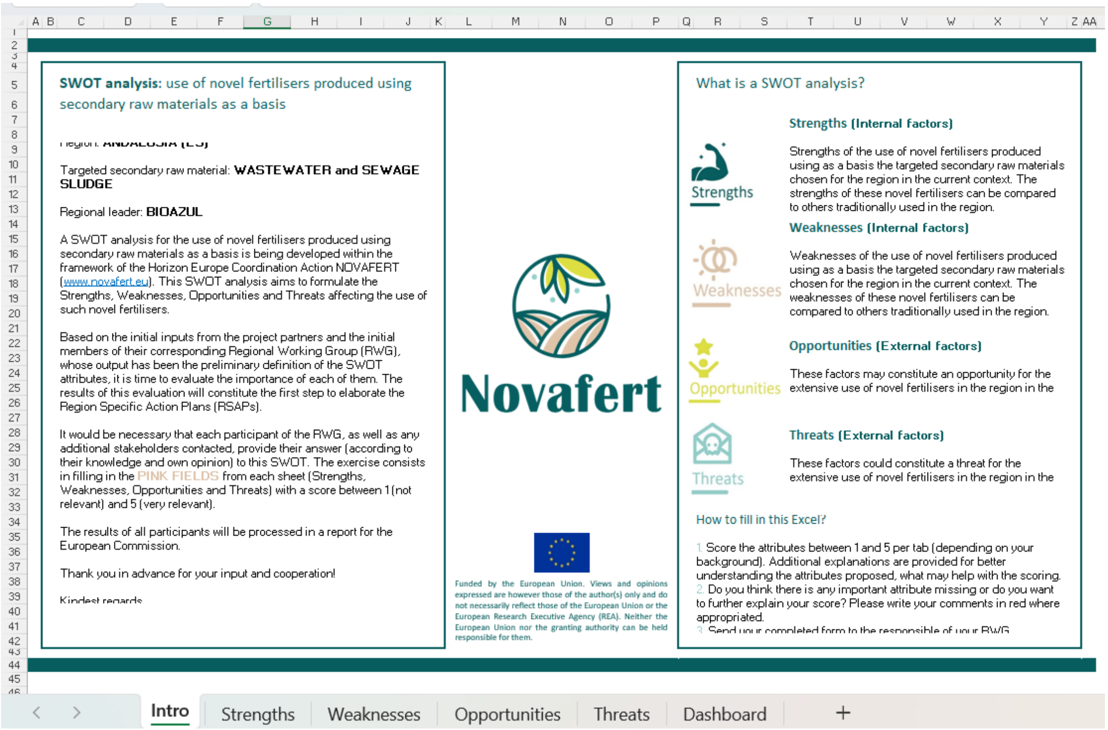

Figure 3. Introduction sheet of the NOVAFERT SWOT tool

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The initial sheet is an introduction to the SWOT analysis and provides guidance to the stakeholders who will be consulted throughout the SWOT elaboration process.

Then, there are four sheets, one per matrix (S, W, O and T), that contain a table for describing the attributes and further explain and score them according to the task team and RWG members' point of view. This scoring feeds the radar diagrams.

The blue column was completed with the definition of the attributes, the white one with a further explanation of that attribute, and the pink one with a value between 1 and 5 according to the relevance given by the RWG to each attribute.

Scoring is the way to transform the collected qualitative information into quantitative, giving a value from 1 to 5 to each of the attributes under study. Each value means:

- 1 point – Not relevant strength/weakness/opportunities/threats.
- 2 points – Weak relevance.
- 3 points – Medium.
- 4 points – Relevant.
- 5 points – Very relevant strength/weakness/opportunities/threats.

Each region had a different number of pink columns, as each one represented one of the targeted secondary raw materials (SRMs).

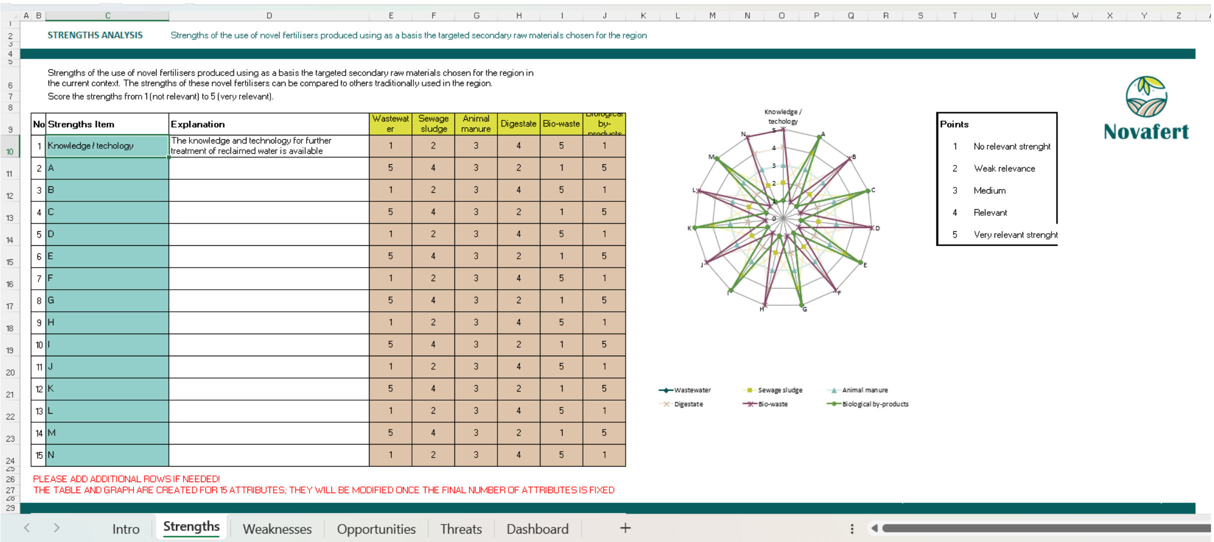

Figure 4. NOVAFERT SWOT tool matrices sheets

This information was further represented in radar charts. Radar charts (also known as spider charts) are a way to visualise multivariate data. They are used to plot one or more groups of values over multiple common variables. They do this by giving an axis for each variable, and these axes are arranged radially around a central point and spaced equally. The data from a single observation are plotted along each axis and connected to form a polygon. Multiple

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observations can be placed in a single chart by displaying multiple polygons, overlaying them and reducing the opacity of each polygon if desired.

The last sheet of the Excel file, called "dashboard", contains a compilation of all radar diagrams.

Figure 5. NOVAFERT SWOT tool dashboard sheet

2.2. Description of the PEST analysis

As already outlined in section 2.1.2, PEST is an acronym for Political, Economic, Social and Technological factors. It is one of the most commonly used analytical tools for assessing

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external macro-economic factors related to a particular situation, in this case, the implementation and business opportunities of alternative fertilisers in agriculture.

Basically, a PEST analysis helps determine how these four factors (Political, Economic, Social and Technological) will affect the performance and activities of a business in the long-term. It is often used in collaboration with other analytical business tools like the SWOT analysis to give a clear understanding of a situation and related internal and external factors.

The PEST factors refer to:

- **P: Political**. With this factor, governmental regulations and legal factors are assessed in terms of their ability to affect the business environment and trade markets. The main issues addressed in this section include political stability, tax guidelines, trade regulations, safety regulations and employment laws.
- **E: Economic**. Through this factor, businesses examine the economic issues that are bound to have an impact on the company. This would include factors like inflation, interest rates, economic growth, the unemployment rate and policies and the business cycle followed in the country.
- **S: Social**. With the social factor, a business can analyse the socio-economic environment of its market via elements like customer demographics, cultural limitations, lifestyle attitude and education. With these, a business can understand how consumer needs are shaped and what brings them to the market for a purchase.
- **T: Technological**. This factor assesses how technology can either positively or negatively impact the introduction of a product or service into a marketplace. These factors include technological advancements, lifecycle of technologies, the role of the internet and the spending on technology research by the government.

The needed information has been already described in section 2.1.2. Using this information, the task team, supported by the RWGs members, discussed, extracted and summarised the most relevant items according to each factor.

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3. Regional Executive summaries

3.1. Belgium – Flanders

3.1.1. Regional characterisation

Socio-economic characterisation of the region. Flanders is the Dutch-speaking region of northern Belgium, mostly flat with a small stretch of coastline on the North Sea. Despite accounting for just 45% of Belgium's land, it has the largest population, with 6,653,062 (or 57%) of the country's 11,431,406 residents, with Antwerp being the most populous province. Flanders accounts for 45% of the country's landmass, covering 13,522 km^2. Dutch is the primary language spoken in the area; however, most residents are also fluent in English and French.

Flanders is divided into two geographical regions: the northwestern coastal Yser basin plain, consisting mainly of sand dunes and clayey alluvial soils in the polders, and the central plain, that begins with similar soils along the lowermost Scheldt basin, a smooth, slowly rising fertile area irrigated by many waterways with an average height of about five meters above sea level. The region has wide valleys of its rivers upstream and sandy soils at around thirty meters in the Campine region to the east. Near its southern borders, close to Wallonia, there is significantly harsher ground, richer in calcium, with low hills reaching up to 150 m and small valleys, and marl caves may be found in the Meuse basin on the eastern border with the Netherlands.

The industries with the most economic growth include transportation and communications, health and social services, business services, and equipment manufacturing. The Flemish economy is heavily export-oriented. Flanders' exports account for 82.0% of Belgium's total export volume (2021). Flemish exports experienced robust growth in 2021 following a decrease in 2020 due to the Covid-19 pandemic. The region's most successful export products include chemicals and pharmaceuticals, transportation equipment and components, machinery and equipment, mineral products, and plastics. Pig farming is the most significant economic activity in Flanders' agricultural and horticultural sectors.

Agriculture. Flanders's agriculture mainly produces vegetables forage plants and cereals (Eurostat, 2019). The Agricultural areas are most prevalent in the north, where there are formerly seabeds that have fertile soils. Agriculture benefits from the mild as well. Sugar beets, grains, and potatoes are the most significant crops.

In addition to agriculture, meat and dairy products are key commodities as well. Pig alone contributes to a fourth of agricultural export value. Flanders has the most pig farms, whereas Wallonia has the largest grain output.

Fertilising products sector in relation to the waste streams studied in the region: animal manure and digestate. The nitrogen (N) ranges for cattle, pigs, and poultry are comparable. The distribution varies by province (NUTS-2). Cattle and pig nitrogen output are higher in the west, in accordance with larger animal production. In 2021 around 4,250,857 tonnes of animal manure were treated in Flanders. This tonnage equates to 39.8 million kg of

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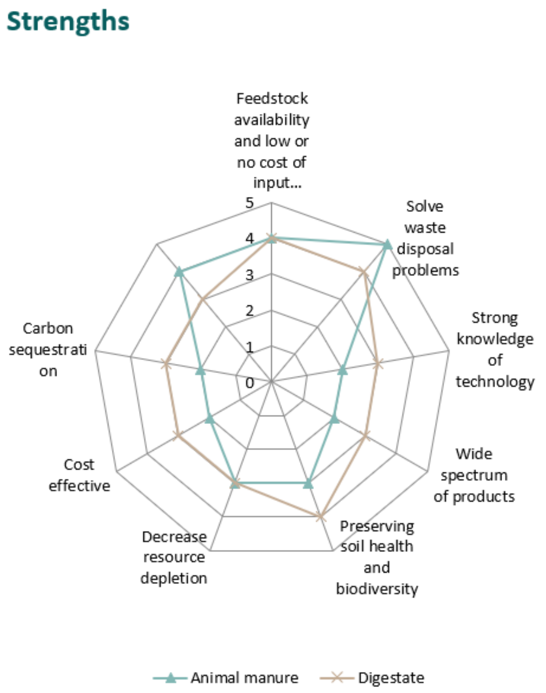
nitrogen extracted from cattle manure. In 2020, 4,632,182 tonnes (or 43,474,955 kg N) were processed. Flanders now operates 142 manure processing units. Regarding nitrogen processing, pig and poultry manure accounted for 88.9% of total manure processing, with 17.1 million kg N (43.0%) and 18.3 million kg N (45.9%), respectively. In terms of quantity, 2,812,050 tonnes of pig manure (66.2%) and 602 041 tonnes of poultry dung (14.2%) were treated.

Regulatory and institutional framework. In Flanders, manure use and management are strictly regulated by the manure decree and the manure action plans. All famers with a production of at least 300 kg P_2O_5 have to submit a manure declaration. The whole Flanders region is designated as a nitrate vulnerable zone, which means that the maximum application standard for manure is 170 kg N per ha, in line with the Nitrate Directive. The Nitrates Directive implementation via the Flemish Manure decree since 1991 is rated as having a neutral effect.

Digestate products resulting from co-fermented animal manure with plant-based input streams are considered as 'animal manure' and are therefore limited in Nitrate Vulnerable Zones (NVZ) to 170 kg N/ha/y.

3.1.2. Main SWOT findings

The main Strengths, Weaknesses, Opportunities and Threats identified for animal manure and digestate as secondary raw materials for producing alternative fertilisers in Flanders region, Belgium are summarised in the following radar diagrams, in which the different attributes are valued from very relevant (5) to not relevant (1):



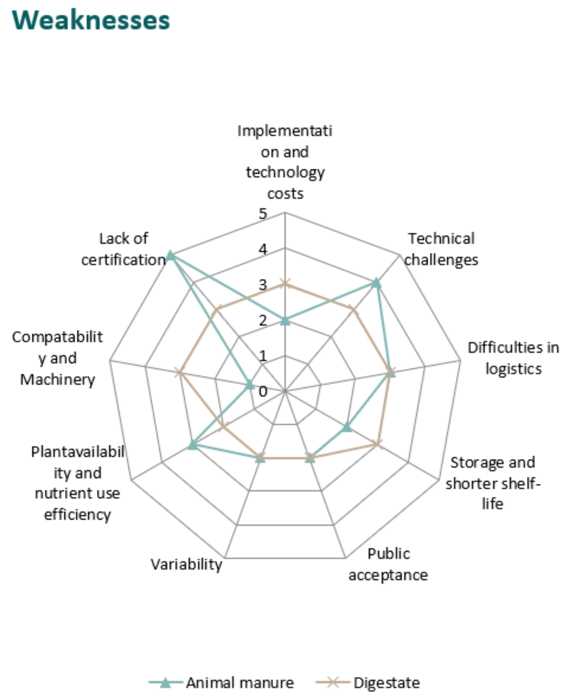


Figure 6. Strengths and weaknesses radar diagrams for Belgium - Flanders region

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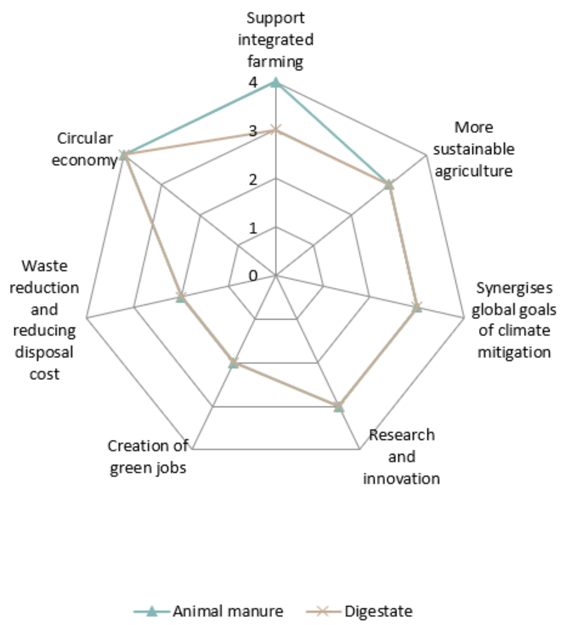
Opportunities



Threats

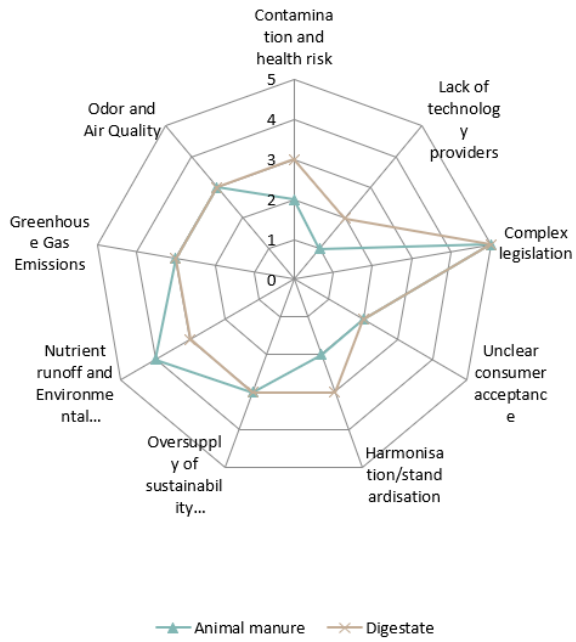


Figure 7. Opportunities and threats radar diagrams for Belgium - Flanders region

The most relevant attributes can be described as follows:

Table 1. Main findings of SWOT analysis for animal manure and digestate as secondary raw materials for producing alternative fertilisers in Flanders, Belgium

Belgium – Flanders: animal manure and digestate	
Strengths • Feedstock availability at very low or even no cost. • Great potentiality of nutrients recycling by their direct injection back to the soil. • At a lesser extent, carbon sequestration in the soil as organic compounds decompose and the variety of end and by-products according to their composition.	Weaknesses • Lack of certification, that results in lower confidence in the resulting fertilising product. • Technical challenges related to structures, equipment and labour required.
Opportunities • Contribution to integrated farming, in which animal farming, crop production and waste generation and reutilisation are complementary and feed each other. • In the same sense, contribution to circular economy practices, with which nutrients circulate through the system.	Threats • Complex legislation: EU and national legislation may be challenging and present uncertainties. • Nutrient runoff due to an excessive application of fertilisers, which can pollute the water bodies and cause eutrophication, as well as other harms to aquatic ecosystems.

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3.1.3. Main PEST findings

The main Political, Economic, Social and Technical barriers and drivers identified for **animal manure** and **digestate** as secondary raw materials for producing alternative fertilisers in Flanders region, Belgium are summarised below:

Table 2. Main findings of PEST analysis as barriers to alternative fertilisers production and usage from animal manure and digestate as secondary raw materials in Flanders, Belgium

Belgium – Flanders: animal manure and digestate	Barriers
Political • Legal restriction. • Regulatory challenges.	Economic • Environmental risk/pollution. • High installation costs.
Social • Unclear consumer acceptance. • Farmers awareness and training. • Harmonisation/standardisation (Quality control and consistency). • Effectiveness perceived by the public. • Unpleasant odour.	Technological • Oversupply of sustainability programs. • Variability. • Compatibility and machinery.

Table 3. Main findings of PEST analysis as drivers to alternative fertilisers production and usage from animal manure and digestate as secondary raw materials in Flanders, Belgium

Belgium – Flanders: animal manure and digestate	Drivers
Political • Reducing dependency on imports. • Circular Economy. • Mineral fertilisers scarcity. • Political willingness.	Economic • Creation of green jobs. • Preserving soil health and biodiversity. • New fertiliser products market. • Nutrient recycling. • Business model development. • Wide spectrum of products.
Social • Synergises global goals of climate mitigation. • Solve waste disposal problems. • Support integrated farming. • Positive public opinion.	Technological • Knowledge / technology. • Precision application technologies. • Feedstock availability and low or no cost of input streams.

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	• Research and innovation.

3.2. Croatia – Continental Croatia

3.2.1. Regional characterisation

Socio-economic characterisation of the region. Continental Croatia refers to the inland region of Croatia, located away from the country's coastline along the Adriatic Sea. It is characterised by diverse landscapes, rich cultural heritage, and historical significance. In 2021 the population of Croatia was estimated to be around 3.8 million people.

Continental Croatia is situated in the central and north-eastern parts of the country. It is primarily a lowland area, with rolling hills, fertile plains, and numerous rivers. The main soil types in Continental Croatia are Chernozem, Luvisols, Cambisols and Gleysols. Chernozem is found in the agricultural areas of Continental Croatia, especially in Slavonia and Baranja. Luvisols are prevalent in many parts of Continental Croatia. Gleysols can be found in low-lying areas and floodplains in Continental Croatia.

Continental Croatia contributes significantly to the country's economy by employing a significant portion of the region's workforce. The year 2021 was marked by the recovery of the Croatian economy and the growth of employment after the global crisis in 2020 caused by the coronavirus pandemic. In 2021, the agricultural sector achieved a production value of 20.7 billion HRK. Compared to 2020, the production value of the agricultural sector increased by 2.4 billion HRK, or 13.3%.

Agriculture. Agriculture has traditionally been an important economic activity in the region, particularly in rural areas. According to the data from the Croatian Paying Agency for Agriculture, Fisheries and Rural Development (PAAFRD) in 2021, there were 170,436 farmers registered, with the majority being family farms, representing 82.9 % of the total number of farmers. The highest number of farmers is in the Zagreb County (14,291), 8.4 % of the total number of farmers in Croatia. Croatia is self-sufficient in cereal production, and in 2020, self-sufficiency in cereal production reached 174.2 %. Croatia is also self-sufficient in oilseed production, with a self-sufficiency rate of 287.2 % in 2020. Croatia is a significant producer of soybeans within the European Union.

Fertilising products sector in relation to the waste streams studied in the region: animal manure, digestate and bio-waste. With regards to the fertilisers, Croatian fertiliser production is predicted to drop by 2 % each year, on average, from 2021 to 2026. In 2021, it was recorded at 247,820 metric tons, putting Croatia at 15th place in the world rankings. Croatia's fertiliser exports are forecasted to decrease by 2.7 % annually, from 130,020 metric tons in 2021. Croatia's fertiliser imports are estimated to rise by an average of 2.5 % each year, from 42,940 metric tons in 2021. Since 2007, the demand for fertiliser in Croatia has decreased by 4.7 %.

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According to the reported data, in 2021, a total of 1,101,925 tonnes of biodegradable municipal waste were produced, which is an increase of 3.9 % compared to 2020 when the quantity of generated biodegradable municipal waste amounted to 1,058,703 tonnes. The largest quantities of generated biodegradable municipal waste are recorded in the city of Zagreb.

Regulatory and institutional framework. According to Regulation (EU) 2019/1009, digestate can no longer be treated as organic fertiliser and soil improver, meaning it is no longer considered a fertilising product. According to the Regulation, the only place for digestate is to be used as a component in the preparation and production of specific fertilising products or as a component for creating organic soil improvers. The biggest obstacle to the use of digestate as an organic fertiliser or soil improver in Croatian legislation (Regulation on by-products and disposal of waste status) comes from meeting the legal requirements.

Regarding the animal manure, in one calendar year, the agricultural holding can fertilise agricultural areas with manure up to the limit value of nitrogen application of 170 kg/ha of N. Manure is applied in such a way as to reduce nitrogen losses to the minimum possible extent.

The management of bio-waste in Continental Croatia is governed by waste management regulations and guidelines. In the Waste Management Plan for the period from 2017 to 2022, the Republic of Croatia prescribed the dynamics of separate collection of municipal bio-waste on an annual level, according to which by 2022, 40% of the produced amount of bio-waste from municipal waste must be separately collected at the national level.

3.2.2. Main SWOT findings

The main Strengths, Weaknesses, Opportunities and Threats identified for **animal manure**, **digestate** and **bio-waste** as secondary raw materials for producing alternative fertilisers in Continental Croatia are summarised in the following radar diagrams, in which the different attributes are valued from very relevant (5) to not relevant (1):

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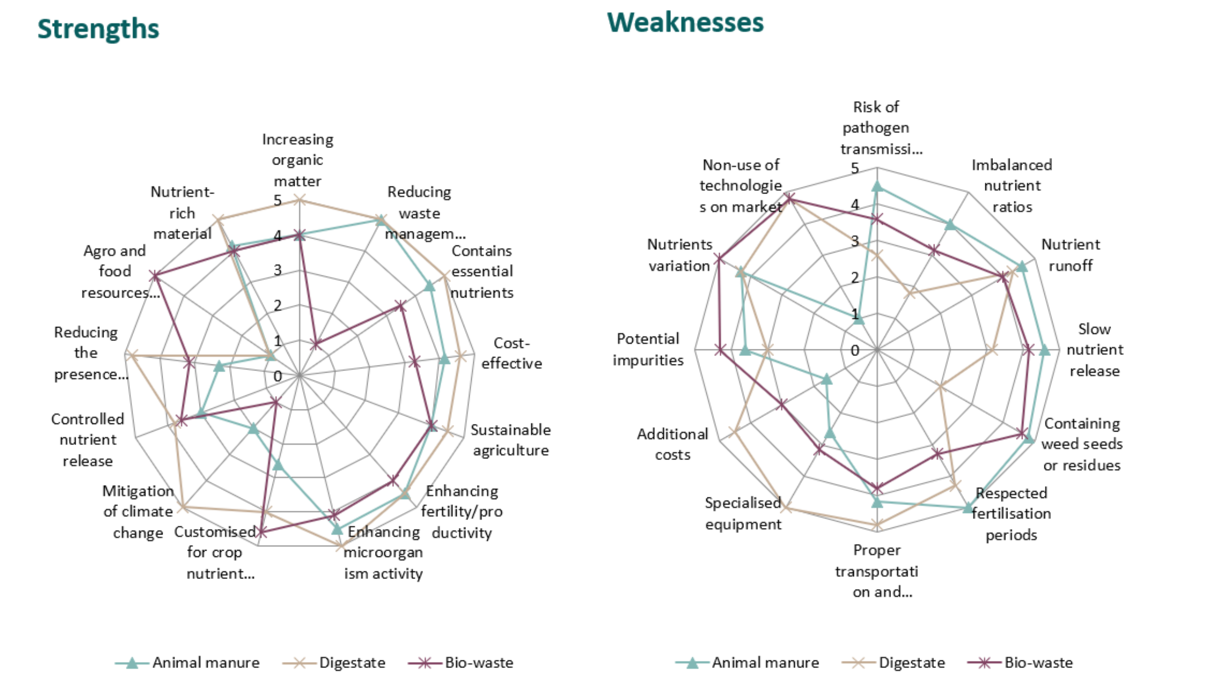

Figure 8. Strengths and weaknesses radar diagrams for Continental Croatia region

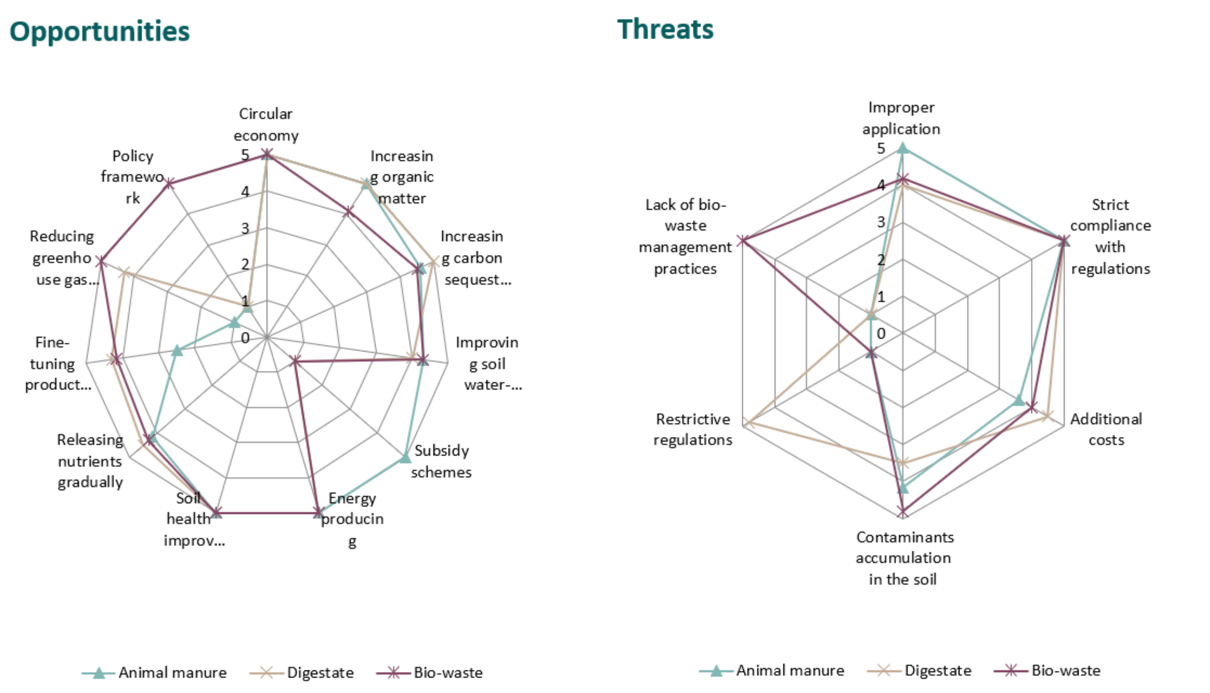

Figure 9. Opportunities and threats radar diagrams for Continental Croatia region

The most relevant attributes can be described as follows:

Table 4. Main findings of SWOT analysis for animal manure, digestate and bio-waste as secondary raw materials for producing alternative fertilisers in Continental Croatia

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Continental Croatia: animal manure, digestate and bio-waste	
• Organic matter and essential nutrients contents that alternative fertiliser products can provide to the crops, what enhances microorganisms activity, hence the soil fertility and productivity. • Possibility of adjusting the nutrient contents, what is also related to cost effectivity of these products. • Waste management needs reduction for animal manure and digestate. • Agrifood resources recovery for bio-waste	• Nutrient runoff into water bodies. • Need of transportation and storage infrastructure, what leads to a need of an additional investment. • Non-use of the technologies available in the market for digestate and bio-waste. • Content of weed seeds or residues for animal manure and bio-waste. • Need of specialised equipment for digestate.
• Contribution to circular economy practices. • Increase of carbon sequestration in agricultural soils. • Renewable energy production onsite. • Improving of soil health. • Subsidy schemes for animal manure. • Selective waste collection and appropriated treatment for bio-waste. • Reduction of greenhouse gases emissions for bio-waste and digestate.	• Strict compliance with regulations. • Improper application that leads to nutrient imbalances. • Additional costs associated with transport and application. • Possibility of nutrients accumulation in the soil. • Restrictive regulations for digestate. • Lack of management practices for bio-waste.

3.2.3. Main PEST findings

The main Political, Economic, Social and Technical barriers and drivers identified for **animal manure**, **digestate** and **bio-waste** as secondary raw materials for producing alternative fertilisers in Continental Croatia are summarised below:

Table 5. Main findings of PEST analysis as barriers to alternative fertilisers production and usage from animal manure, digestate and bio-waste as secondary raw materials in Continental Croatia

Continental Croatia: animal manure, digestate and bio-waste	
• Restrictive regulations. • Strict compliance with regulations.	• High production costs. • Lack of subsidies schemes. • Market demand.

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• Legislative obstacle. • Government support.	• Additional costs.
• Consumer preferences. • Unpleasant odour. • Lack of management practices. • Limited awareness. Social	• Unstable composition. • Strict application. • Storage and transportation difficulty. • Non-use of technologies on market. • Environmental pollution. • Specialised equipment. Technological

Table 6. Main findings of PEST analysis as drivers to alternative fertilisers production and usage from animal manure, digestate and bio-waste as secondary raw materials in Continental Croatia

Continental Croatia: animal manure, digestate and bio-waste	Drivers
• Policy framework. • Recommendations at the level of the EU. • Subsidy schemes. Political	• Cost-effective. • Resource self-sufficiency. • Circular economy. • Market demand for secondary raw materials. Economic
• Sustainable agriculture. • Change of consumer preferences. • Environmental awareness. • Agro and food resources recovery. Social	• Application technologies. • Energy production. • Technological agro-innovations. • Research and development. • Optimal application. Technological

3.3. Finland – South-West Finland

3.3.1. Regional characterisation

Socio-economic characterisation of the region. Finland lies between latitudes 60°N and 70°N, and is the sixth largest country in Europe, occupies an area of 338,312 km^2. Finland is bordered on the east and southeast by the Russian Federation, on the west by Sweden and the Gulf of Bothnia, on the north by Norway and on the south by the Gulf of Finland. Most of the country is low but not necessarily flat. Soil is very thin. Mainly moraine deposits from ice age glaciers, finer mineral soils, and organic soil types are common in Finland. One third of the fields contain clay soil types. The clay soils concentrate in Southwest Finland. The share of

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peatland in the arable land areas of Lapland, Northern Ostrobothnia and Kainuu is 20–40%. A quarter of arable land in Ostrobothnia and Southern Ostrobothnia consists of organic soil types.

Population of Finland is 5.56 million (2022). The gross domestic product (GDP) of Finland was 269 billion euros in 2022, an increase of around 18 billion euros compared with the previous year. GDP per capita amounted to 48 345 euros in 2022, which was the ninth highest in Europe. In 2022, GDP share of agriculture in Finland was 2.38%. The largest sector of the Finnish economy is services at 65 percent, followed by manufacturing and refining at 31 percent. Finland's main industrial products are paper and board, electronics and metal products. Engineering and high technology industries are the leading branches of manufacturing.

Agriculture. Finland is considered the most northerly agricultural country in the world. Finland's agriculture relies heavily on grassland and cereal varieties suited to the northern climate. The total area used for agriculture in Finland comes to about 2.3 million hectares. In recent years, cereal crops have accounted for just over 1 million hectares and grassland for some 0.7 million hectares. In 2021, approximately 14% of arable land area was used for organic production.

In 2022, there were 44,000 farms in Finland, and nearly all of them were family run (Official Statistics of Finland, 2021). Farmers and their family members perform 80% of all agricultural work in Finland. Agriculture employs 76 000 people. Crop production was the main production activity on 70% of farms and livestock production on 21% of farms. The remainder are mixed farms with no clear main production direction.

Fertilising products sector in relation to the waste streams studied in the region: animal manure, digestate and bio-waste. With regards to the fertilising products, a recent report on the need and potential for phosphorus recycling in Finland estimated the phosphorus demand for crop production on the country's 2.3 million hectares of arable land at just over 10 kg/ha (Lemola et al., 2023). Divided evenly according to need, the amount of manure phosphorus would cover 6,7 kg/ha, i.e., 65 % of the need. The need for phosphorus replenishment would be less than 4 kg/ha in the case of even distribution, but the volume of mineral fertiliser phosphorus sold in the last two decades has been around 5 kg/ha. When considering other recyclable biomasses in addition to manure, 90% of the needed phosphorus fertilisation could be covered by nutrient recycling.

In Finland, 13 million tonnes of manure are produced from livestock production. Livestock and fur animals generate over 73 million kg of nitrogen and 15 million kg of phosphorus yearly. There are large regional differences in manure production due to the high concentration of livestock production in western and southwestern Finland.

Biowaste from municipalities yields 484 000 tonnes per year containing 3 000 tonnes of nitrogen and 550 tonnes of phosphorus. Regional differences in population are reflected in the quantity of municipal biowaste.

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Novafert

Digestates are currently produced in around 130 biogas plants, including urban and industrial wastewater treatment plants, co-processing plants of various sizes and farm-scale biogas plants. The biogas production was 1 TWh in 2021.

Regulatory and institutional framework. Fertiliser use of manure and organic fertiliser products is governed via national legislation enacting the EU Nitrates Directive (91/676/EEC) and the EU Fertilising Product Regulation (EU 2019/1009). The Government Decree on Limiting Certain Emissions from Agriculture (1250/2014), known as 'Nitrates Decree', aims to reduce nitrogen emissions caused by the storage and use of manure and other organic fertiliser products and the use of inorganic fertiliser products. In the Decree, the whole of Finland is defined as a nitrate vulnerable zone and thus it controls nitrogen fertilisation in all farms across the country.

Digested biowaste and sewage sludge are also largely used as soil improvers and fertilisers in agriculture, but there are some legal restrictions. Digested sewage sludge can be used on fields where crops such as cereals, sugar beet, oilseeds or other crops are grown that are not eaten fresh, as a subsoil crop or as animal feed. Slurry can be applied to grassland by establishing the grassland with cover crops.

3.3.2. Main SWOT findings

The main Strengths, Weaknesses, Opportunities and Threats identified for **animal manure**, **digestate** and **bio-waste** as secondary raw materials for producing alternative fertilisers in South-West Finland are summarised in the following radar diagrams, in which the different attributes are valued from very relevant (5) to not relevant (1):

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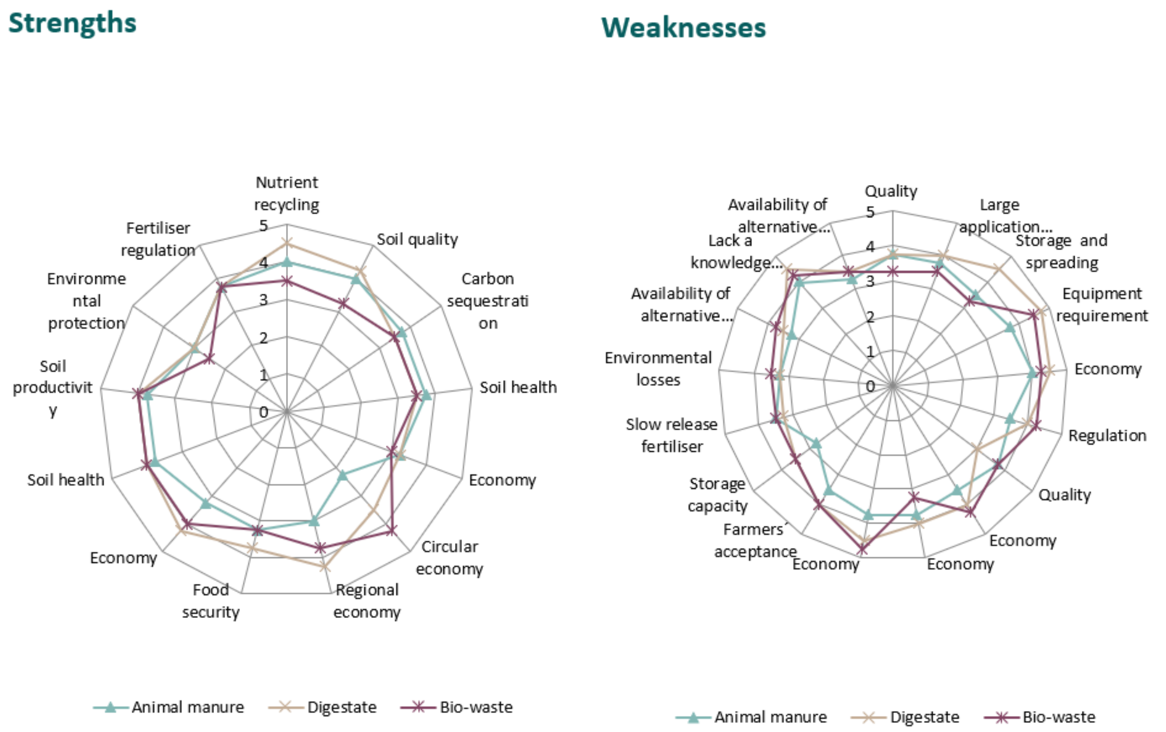

Figure 10. Strengths and weaknesses radar diagrams for Sout-West Finland region

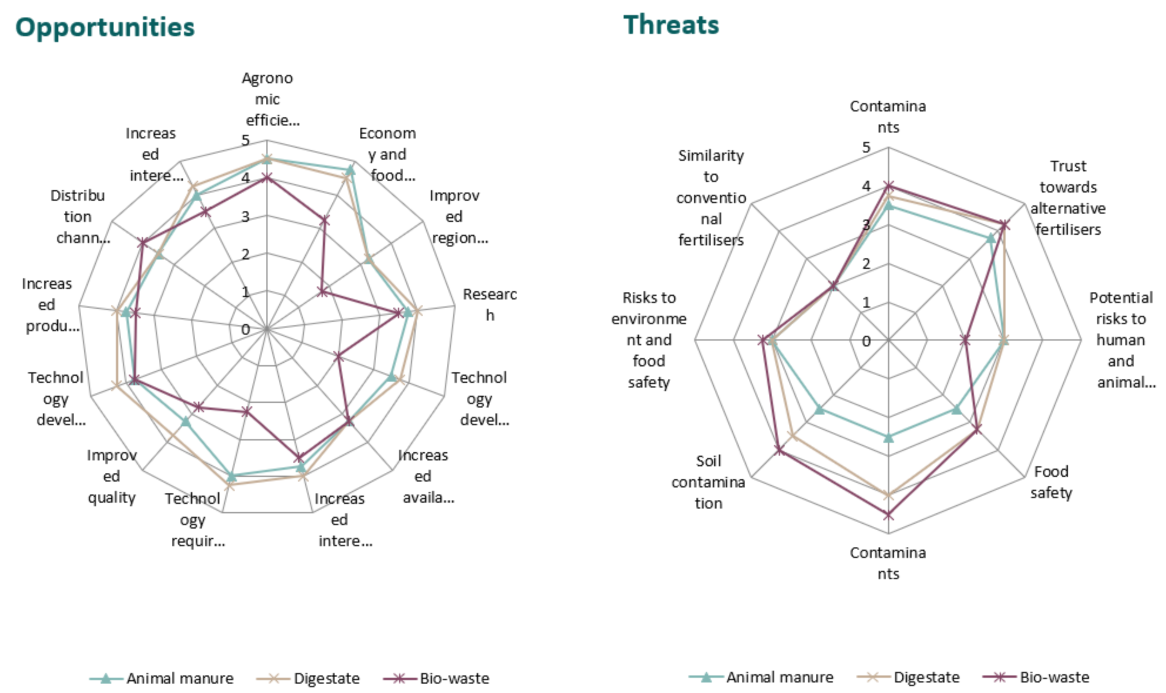

Figure 11. Opportunities and threats radar diagrams for South-West Finland region

The most relevant attributes can be described as follows:

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Table 7. Main findings of SWOT analysis for animal manure, digestate and bio-waste as secondary raw materials for producing alternative fertilisers in South-West Finland

South-West Finland: animal manure, digestate and bio-waste	
Strengths • Nutrients recycling and the consequent decrease in the use of mineral fertilisers. • Carbon sequestration in the soil. • Soil health, resilience and productivity. • Strict regulation for the use of alternative fertilisers.	Weaknesses • Equipment requirements for the production and application of alternative fertilisers. • Knowledge about the alternative fertilisers by the farmers. • Storage for animal manure.
Opportunities • Research and technological development linked to the willingness to pay for a good product. • Food security improvement for animal manure and digestate. • Technology development for animal manure and digestate	Threats • Contaminants accumulation in soils. • Lack of trust when the origin of the alternative fertiliser is not clearly stated.

3.3.3. Main PEST findings

The main Political, Economic, Social and Technical barriers and drivers identified for **animal manure**, **digestate** and **bio-waste** as secondary raw materials for producing alternative fertilisers in South-West Finland are summarised below:

Table 8. Main findings of PEST analysis as barriers to alternative fertilisers production and usage from animal manure, digestate and bio-waste as secondary raw materials in South-West Finland

South-West Finland: animal manure, digestate and bio-waste	Barriers
Political • Regulation.	Economic • Processing. • Availability.
Social • Lack of knowledge. • Trust towards alternative fertilisers. • Potential risks to human and animal health.	Technological • Quality. • Large application rates. • Equipment requirement. • Storage.

Table 9. Main findings of PEST analysis as drivers to alternative fertilisers production and usage from animal manure, digestate and bio-waste as secondary raw materials in South-West Finland

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South-West Finland: animal manure, digestate and bio-waste	Drivers
Political • Fertiliser regulation.	Economic • Nutrient recycling. • Farm economy. • Rural areas. • Soil productivity. • Quality of bio-based fertilisers (BBFs). • Organic farming. • Distribution channels. • Price development.
Social • Waste reduction. • Food security. • Environmental protection. • Research.	Technological • Soil quality. • Soil health. • Technology development.

3.4. Ireland – East Ireland

3.4.1. Regional characterisation

Socio-economic characterisation of the region. Ireland is an island situated in North-western Europe. It is surrounded by the Atlantic Ocean, with the Celtic Sea to the South, the St. George's Channel to the Southeast, and the Irish Sea to the East. Ireland has a diverse landscape that includes low-lying coastal plains, mountains, and lakes. Ireland has a temperate maritime climate, characterised by mild winters and cool summers.

The current population of Ireland is 5,097,599. Ireland has a developed and modern economy, which has undergone significant growth in recent decades. The country has a strong focus on industries such as pharmaceuticals, technology, financial services, and tourism. The agri-food sector is a hugely valuable part of the economy, and is a key contributor to economic growth. Agriculture in Ireland is responsible for 7.1% of the total workforce on the island. Ireland exports the majority of production to 180 countries around the world.

Agriculture. Irish agriculture is dominated by family-owned farms. There are 140,000 farms, with an average land holding of 32.5 hectares. The Irish climate is capable of growing grass for 9 to 10 months of the year. As a result, the dominant enterprise in Ireland is dairy and beef accounting for two-thirds of gross agricultural output. Ireland is currently one of the fastest-growing dairy producers and exporters in the world. In 2022, there was 1.7 million tonnes of dairy product shipped to 130 markets worldwide. Other than grass, crops such as wheat, barley and oats are also grown in Ireland.

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Fertilising products sector in relation to the waste streams studied in the region: bio-waste and biological by-products. Ireland is heavily dependent on importing inorganic fertiliser for food production importing over 1.8 million tonnes of fertiliser annually. Ireland imports chemical fertiliser primarily from Russia, United Kingdom, Germany, Spain and Morocco. Ireland is making efforts to reduce reliance on chemical fertilisers and explore alternative nutrient sources in agriculture. Irish stakeholders are promoting alternative farming practices which prioritises the use of biological alternative fertilisers such as compost, animal manure, crop residues, food waste, incorporating legume crops such as clover and beans to fix nitrogen. Nutrient management planning is also a key tool being used in Irish agriculture which helps optimise the use of nutrient sources and limit the loss of nutrients to the environment, which involves analysing soil nutrient levels, crop nutrient requirements and using precision application techniques such as low emission slurry spreading.

Bio-waste and agricultural by products have potential in Ireland to supply nutrients for crop production which will reduce dependence on chemical fertiliser. Therefore, feedstock availability for the use as alternative fertilisers is essential. Approximately 132 million tonnes of agricultural slurries, wastewaters, effluent, and sludge are generated in Ireland on an annual basis.There are approximately 140,686 tonnes of bio-waste processed in the republic of Ireland and 280,496 tonnes processed in Northern Ireland on annual basis. The number of licensed plants controlling bio-waste in Ireland is 8 and 5 in Northern Ireland. The total quantity of waste accepted for treatment at composting and anaerobic digestion plants in Ireland in 2020 was 601,482 tonnes and 733,881 tonnes in Northern Ireland.

Regulatory and institutional framework. Current Irish national fertiliser regulations for biological by products and bio-waste are covered under the fertilisers, feeding stuffs and mineral mixtures act 1955 and the SI No 248 of 1978 (non-EEC fertilisers) which covers mineral fertilisers, organic fertilisers, low nutrient fertilisers and ground limestone. In Ireland, there are currently no national end-of-waste criteria defined for compost and digestate derived from bio-waste and biological by product materials. There are varying quality standards being used by composting and anaerobic digestion plants.

3.4.2. Main SWOT findings

The main Strengths, Weaknesses, Opportunities and Threats identified for **bio-waste** and **biological by-products** as secondary raw materials for producing alternative fertilisers in East Ireland are summarised in the following radar diagrams, in which the different attributes are valued from very relevant (5) to not relevant (1):

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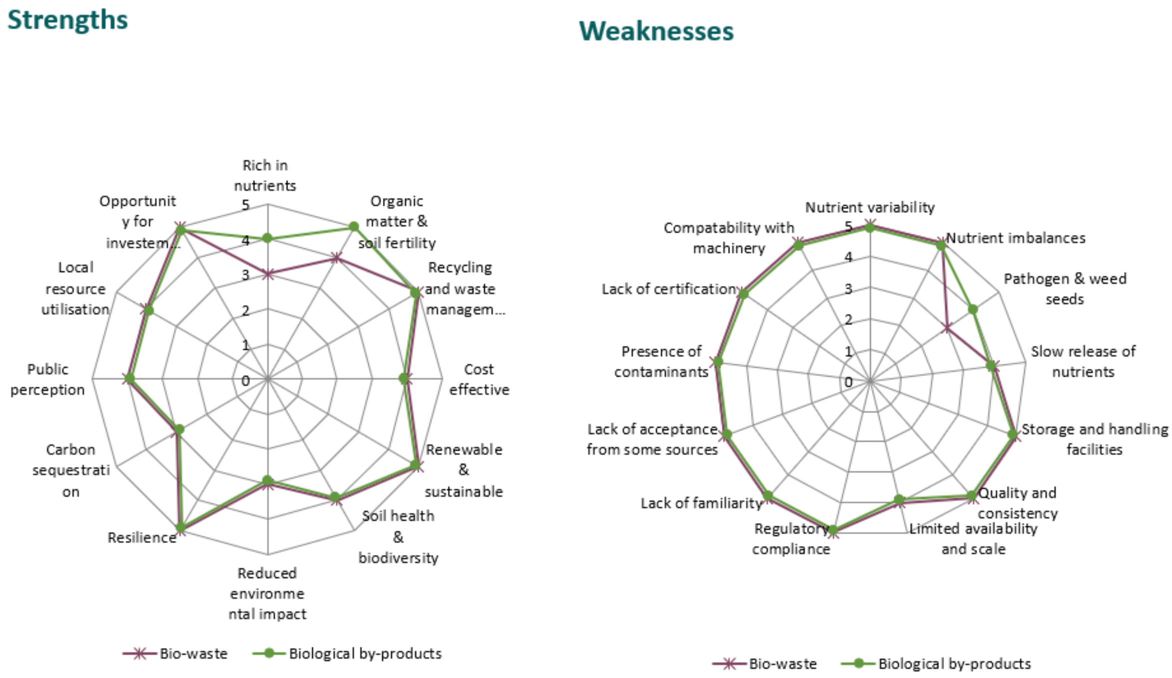

Figure 12. Strengths and weaknesses radar diagrams for Ireland – Wicklow/Carlow/Wexford region

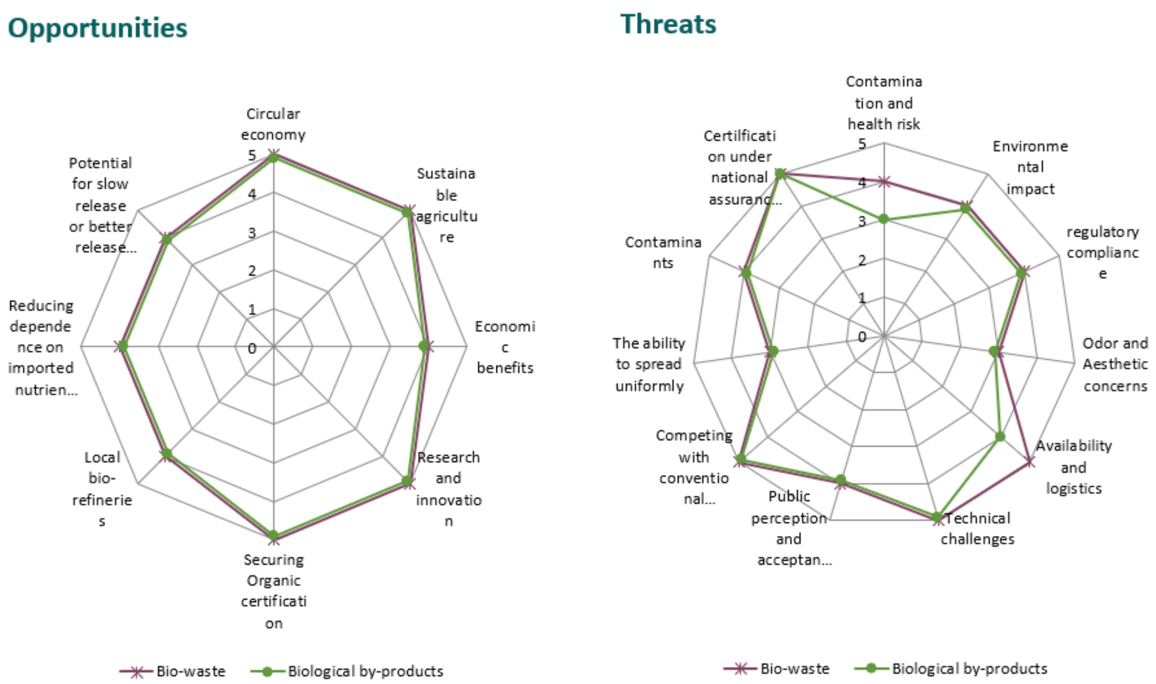

Figure 13. Opportunities and threats radar diagrams for Ireland – Wicklow/Carlow/Wexford region

The most relevant attributes can be described as follows:

Table 10. Main findings of SWOT analysis for bio-waste and biological by-products as secondary raw materials for producing alternative fertilisers in East Ireland

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East Ireland: bio-waste and biological by-products	
Strengths • Potentiality to recycle nutrients from renewable, sustainable and resilient waste streams. • Opportunity to invest on technological development in the region. • Richness in organic matter that benefits the soil and the crops for biological by-products waste stream.	Weaknesses • Quality and consistency of the bio-waste and the biological by-products, strongly related to their nutrient contents variability and the imbalance of specific nutrients. • Storage and handling, strongly related also with the compatibility of these new fertilisers with their machinery. • Lack of familiarity and, consequently, acceptance from farmers to the new fertilising products, also related to the possibility of containing contaminants. • Regulatory compliance, that could impose additional burdens and costs to the farmers.
Opportunities • Contribution to the circular economy model and enhancement of the sustainable agriculture. • Research and innovation in the processing application of these new fertilisers. • Securing organic certification.	Threats • Technical challenges. • Price competition with conventional mineral fertilisers. • Certification under national assurance programmes. • Availability and logistics for bio-waste

3.4.3. Main PEST findings

The main Political, Economic, Social and Technical barriers and drivers identified for **bio-waste** and **biological by-products** as secondary raw materials for producing alternative fertilisers in East Ireland are summarised below:

Table 11. Main findings of PEST analysis as barriers to alternative fertilisers production and usage from bio-waste and biological by-products as secondary raw materials in East Ireland

East Ireland: bio-waste and biological by-products	Barriers
Political • Regulatory framework. • Lack of awareness and information. • Interest of different stakeholders. • Political priorities.	Economic • Economics of scale. • Loss of income. • Infrastructure investment.

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Social • Lack of awareness and education. • Resistance to change. • Perceived effectiveness. • Social pressure and peer influence.	Technological • Product development and formulation. • Nutrient availability and release. • Storage and handling. • Quality control and consistency.

Table 12. Main findings of PEST analysis as drivers to alternative fertilisers production and usage from bio-waste and biological by-products as secondary raw materials in East Ireland

East Ireland: bio-waste and biological by-products	Drivers
Political • Environmental regulations and targets. • Sustainable agriculture policies. • Reduction of dependency on imports. • Climate change mitigation strategies.	Economic • Reduced input costs. • Improved soil health. • Premium markets. • Research and innovation.
Social • Environmental concerns. • Promotion of local agriculture. • Media and social media influence.	Technological • Circular economy and waste recycling. • Precision application technologies. • Resilience.

3.5. Poland – South-East Poland

3.5.1. Regional characterisation

Socio-economic characterisation of the region. Poland, officially known as the Republic of Poland, is a democratic country in Central Europe with a land area of 312 696 km2, Poland is the ninth-largest country in Europe. The population of Poland is 37 654 247 inhabitants, making it the sixth most populous country in Europe. South-east Poland is situated in the eastern part of the country, bordering Ukraine to the east, Slovakia to the south and the Czech Republic to the southwest. It covers a significant portion of the Carpathian Mountains and includes fertile lowlands and river valleys.

In the south-eastern Poland, there are 3 voivodeships - Podkarpackie, Małopolskie and Śląskie. The south-eastern part of Poland, due to its location, is more prone to temperature extremes compared to western and northern parts of the country. Additionally, the presence of the Carpathian Mountains can lead to variations in climate across different elevations. This region experiences distinct seasons with noticeable temperature variations throughout the year.

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The economy of south-east Poland is diverse, with a mix of industries including agriculture, manufacturing, services, and tourism. The region has been experiencing economic growth in recent years, with investments in infrastructure and the development of special economic zones. Key sectors include food processing, automotive, machinery, and IT.

Agriculture. Agriculture plays a significant role in Poland's economy. The fertile soils and favourable climatic conditions support a variety of agricultural activities. Moreover, Poland is one of the main agricultural producers in the EU: it belongs to the three largest producers of basic cereals and root crops and is also the largest supplier of apples and poultry meat. Major agricultural products include cereals (such as wheat, barley and rye), potatoes, sugar beets and vegetables. Livestock farming, including cattle, pigs, and poultry, is also an important part of the agricultural sector.

Fertilising products sector in relation to the waste streams studied in the region: sewage sludge, animal manure and digestate. The agriculture sector employs a considerable portion of the regional workforce, using both conventional and natural fertilisers. The use of fertilisers derived from sewage sludge, animal manure, and digestate can have both positive and negative environmental aspects.

Regulatory and institutional framework. In Poland, there are legal regulations concerning the use of sewage sludge that govern the management of this material. The most important regulations are presented by Waste Act, Regulation of the Minister of Environment on the conditions for Introducing waste to the soil, Regulation of the Minister of Agriculture and Rural Development on natural fertilisers and Administrative decisions issued by relevant administrative authorities, such as environmental agencies.

The use of animal manure as an alternative fertiliser is regulated by several important regulations.The list of regulations consists of Fertilisers and Fertilisation Act, Regulation of the Minister of Agriculture and Rural Development on the conditions for the use of animal manure, Good Agricultural Practices (GAP) and Environmental Protection Act.

In Poland, the use of digestate, which is the residual material left after anaerobic digestion of organic waste, is regulated by several laws and regulations. The main legal framework includes Waste Act, Fertiliser Act, Water Law, Environmental Protection Law.

3.5.2. Main SWOT findings

The main Strengths, Weaknesses, Opportunities and Threats identified for **sewage sludge**, **animal manure** and **digestate** as secondary raw materials for producing alternative fertilisers in South-East Poland are summarised in the following radar diagrams, in which the different attributes are valued from very relevant (5) to not relevant (1):

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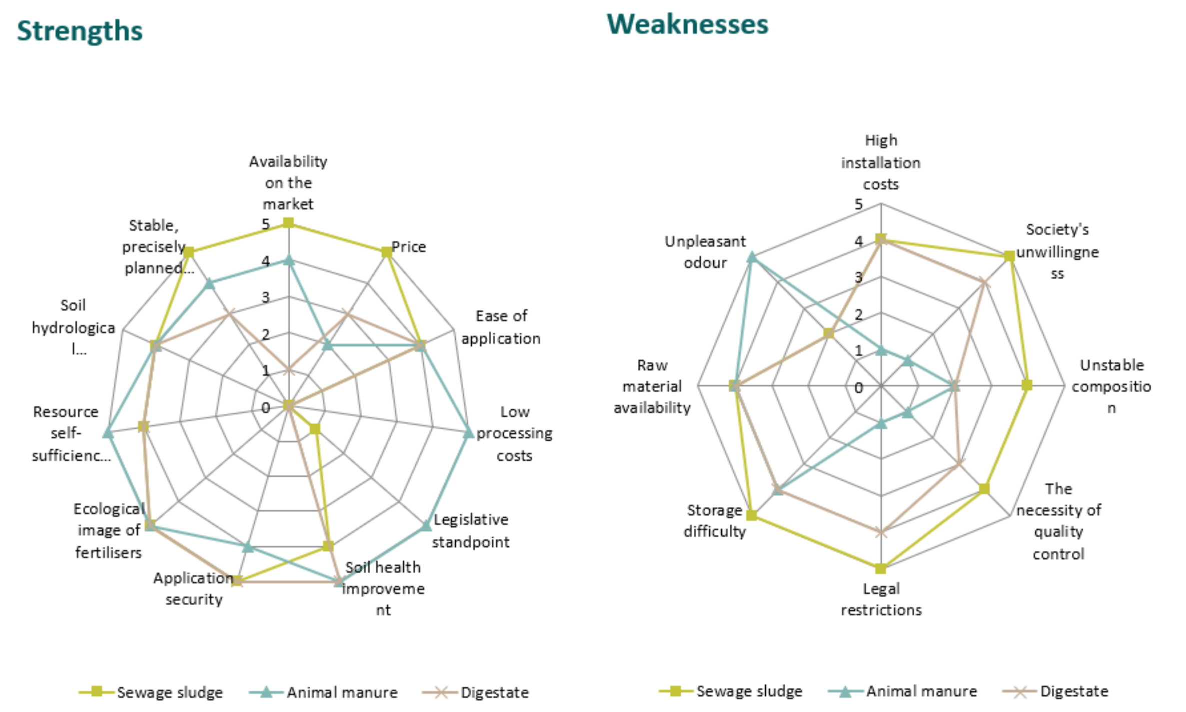

Figure 14. Strengths and weaknesses radar diagrams for South-East Poland region

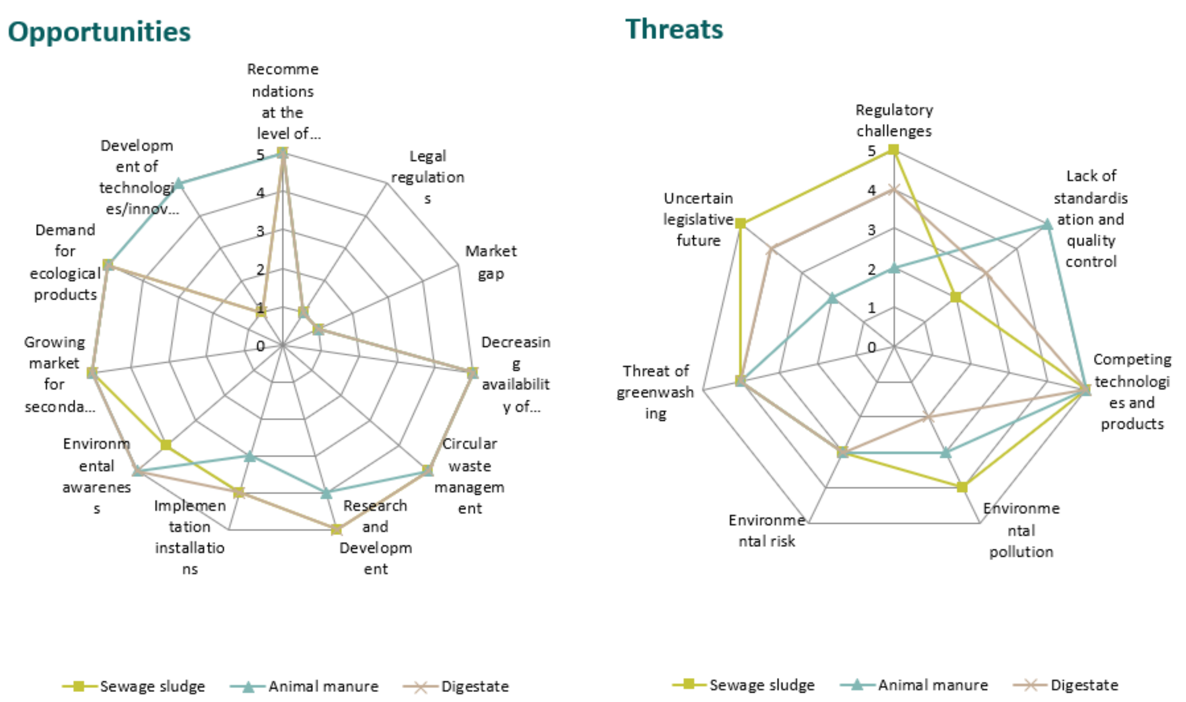

Figure 15. Opportunities and threats radar diagrams for South-East Poland region

The most relevant attributes can be described as follows:

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Table 13. Main findings of SWOT analysis for sewage sludge, animal manure and digestate as secondary raw materials for producing alternative fertilisers in South-East Poland

South-East Poland sewage sludge, animal manure and digestate	
Strengths • Positive ecological image of new fertilisers. • Application security of new fertilisers. • Self-sufficiency. • Soil improvement. • Market availability for sewage sludge and animal manure. • Price of new fertilisers coming from sewage sludge. • Processing costs of animal manure.	**Weaknesses** • Raw material availability. • Storage difficulties. • Certain social reluctance for sewage sludge and digestate. • High costs of installation and need of quality control for sewage sludge and digestate. • Legal restrictions for sewage sludge and digestate. • Odour problems for animal manure.
Opportunities • EU recommendations for the use of alternative fertilisers and demand for ecological products. • Decrease of the availability of critical raw materials and growing market for secondary raw materials. • Contribution to the circular economy model. • Development of innovations and technologies for animal manure.	**Threats** • Existing competence with other technologies and products. • Greenwashing. • Regulatory challenges and uncertain legislative future for sewage sludge and digestate. • Lack of standardisation and quality control for animal manure.

3.5.3. Main PEST findings

The main Political, Economic, Social and Technical barriers and drivers identified for sewage sludge, animal manure and digestate as secondary raw materials for producing alternative fertilisers in South-East Poland are summarised below:

Table 14. Main findings of PEST analysis as barriers to alternative fertilisers production and usage from sewage sludge, animal manure and digestate as secondary raw materials in South-East Poland

South-East Poland sewage sludge, animal manure and digestate	Barriers
Political • Legal restrictions. • Regulatory challenges. • Uncertain legislative future.	**Economic** • High installation costs. • Environmental pollution. • Environmental risk.

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Social • Society's unwillingness. • Unpleasant odour. • Lack of standardisation and quality control. • Threat of greenwashing.	Technological • Unstable composition. • Necessity of quality control. • Storage difficulty. • Raw material availability. • Competing technologies and products.

Table 15. Main findings of PEST analysis as drivers to alternative fertilisers production and usage from bio-sewage sludge, animal manure and digestate as secondary raw materials in South-East Poland

South-East Poland sewage sludge, animal manure and digestate	Drivers
Political • Legislative standpoint. • Recommendations at the level of the European Union. • Legal regulations.	Economic • Price. • Low processing costs. • Soil health improvement. • Resource self-sufficiency (local production). • Soil hydrological improvement. • Stable, precisely planned production stream. • Market gap. • Decreasing availability of critical raw materials. • Growing market for secondary raw materials. • Implementation installations.
Social • Ecological image of fertilisers. • Demand of ecological products. • Environmental awareness. • Circular waste management.	Technological • Availability on the market. • Ease of application. • Application security. • Development of technologies / innovation. • Research and development.

3.6. Spain – Andalusia

3.6.1. Regional characterisation

Socio-economic characterisation of the region. Andalusia is located in the south of Spain, between the African continent and the rest of Europe, and it is the point where the Mediterranean Sea and the Atlantic Ocean converge. To the north, the Sierra Morena is the natural border that separates it from the rest of Spain. In the west, Andalusia limits with the

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Guadiana river and Portugal's border. To the south, with the Atlantic Ocean and the Mediterranean Sea. Andalusia is the second biggest region of Spain with an extension of 87,268 km. 50% of the region is mountainous. Andalusia is Spain's most populated region and the second most extensive with 8,484,804 million inhabitants, 87,598 km^2 and a population density of 96.86 inhabitants/ km^2. Its surface represents the 17.3% of Spain.

Andalusia's GDP is 160,747 million Euros, representing the third largest economy in Spain by volume of GDP. As for GDP per capita, which is a good indicator of life quality, in 2021 was 18,906 €, compared to 25,498 € of GDP per capita in Spain. The main sectors are services , followed by agriculture, construction, manufactured industry and logistics and communication.

Agriculture. The agri-food sector in Andalusia is one of the main sources of wealth and employment within the region, that accounts for 10% of the gross domestic value of the region and participating for 40% of the region's total exports. In comparison to the national context, the Andalusian primary sector accounts for about a quarter of Spanish agricultural production and accounts for over 30% of the added value and employment of the national agricultural sector.

Andalusia is the first Autonomous Community in absolute terms of irrigated area with 1,123,547 ha, 28.97% of the total national irrigated area. In relative terms it accounts for 12.83% of its geographical area and 31.84% of its cultivation area. The main risk of water shortage in Andalusia is drought. This is a gradual circumstance characterised by the periodic water shortage, although the tendency shows how drought periods are becoming more common.

Mediterranean climate, climatic and altitude differences within the Andalusian region make it a very varied and abundant region in agricultural terms. One of the most common sectors in Andalusia is the Olive tree. Andalusia is the main producer of olives and olive oil in the world and this kind of activity is non-irrigated. However, the biggest non-irrigated sector in Andalusia is the herbaceous one.

Fertilising products sector in relation to the waste streams studied in the region: wastewater and sewage sludge. Currently the main source of macronutrients is represented by fertilisers of mineral origin, highly dependent on natural gas for the extraction and their production. Among the three macronutrients (N-P-K) Nitrogen represents the main supply in terms of amount delivered, during the seasonal fertiliser plan it accounts for 220,000 tons for the only Urea that represents the most widespread inorganic fertiliser. It follows the Phosphorus consume through Diammonium phosphate for the most (86 000 tons), while Potassium is delivered thorough mainly Potassium chloride formulation accounting in 2020 for 60,000 tons.

In 2016, the number of sewage treatment plants amounted to 695, considering both those built (668) and those under construction. With a total volume of 698.17 Hm^3/year treated wastewater produced in Andalusian UWWTP, the region has a strong potential to use reclaimed water in agriculture. According to the most recent data (2020), 5.22 % of the treated wastewater was finally reused as reclaimed water in Andalusia (36,49 Hm^3/year).

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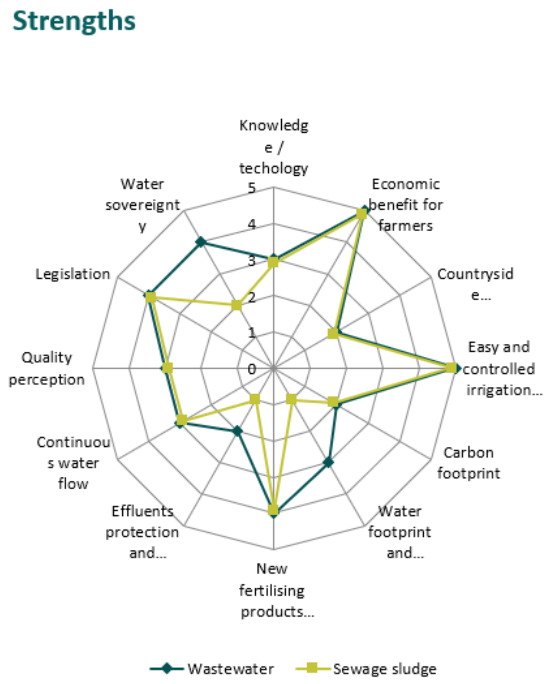
Regulatory and institutional framework. The Spanish regulations for water reuse were approved in December 2007, as a Royal Decree 1620/2007. The RD 1620/2007 defines the practice of "water reuse", introducing the term "reclaimed water", determining the minimum requirements to develop a safe reuse of reclaimed water, setting the protocols to be followed for getting reclaimed water rights, establishing the scope of water reuse practices (with specific prohibition of certain reclaimed water uses) and setting forth the quality requirements associated to each specific water reuse option. The production and supply of reclaimed water for agricultural irrigation requires a permit. Parties concerned must submit an application to the relevant national authority.

Andalusia faces relevant challenges in the wastewater treatment sector and still fails to comply entirely with the Urban Wastewater Treatment Directive. Nevertheless, the wastewater treatment has followed a very positive evolution in this region.

Large volumes of digestate are continuously produced during the purification of unconventional water. Over the years and with the introduction of policies aimed at the circular economy, the digestate has been re-evaluated from waste to resource for the interception of useful substances in agriculture such as organic fertilisers.

3.6.2. Main SWOT findings

The main Strengths, Weaknesses, Opportunities and Threats identified for **wastewater** and **sewage sludge** as secondary raw materials for producing alternative fertilisers in Andalusia region, Spain are summarised in the following radar diagrams, in which the different attributes are valued from very relevant (5) to not relevant (1):



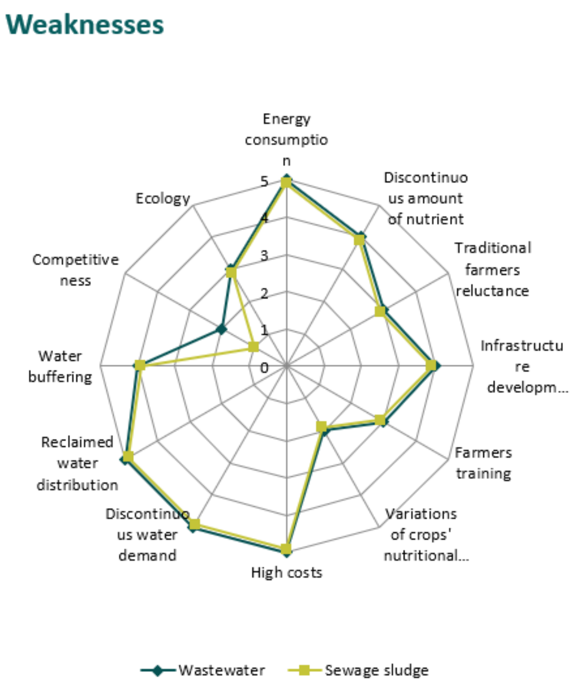


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Figure 16. Strengths and weaknesses radar diagrams for Spain - Andalusia region

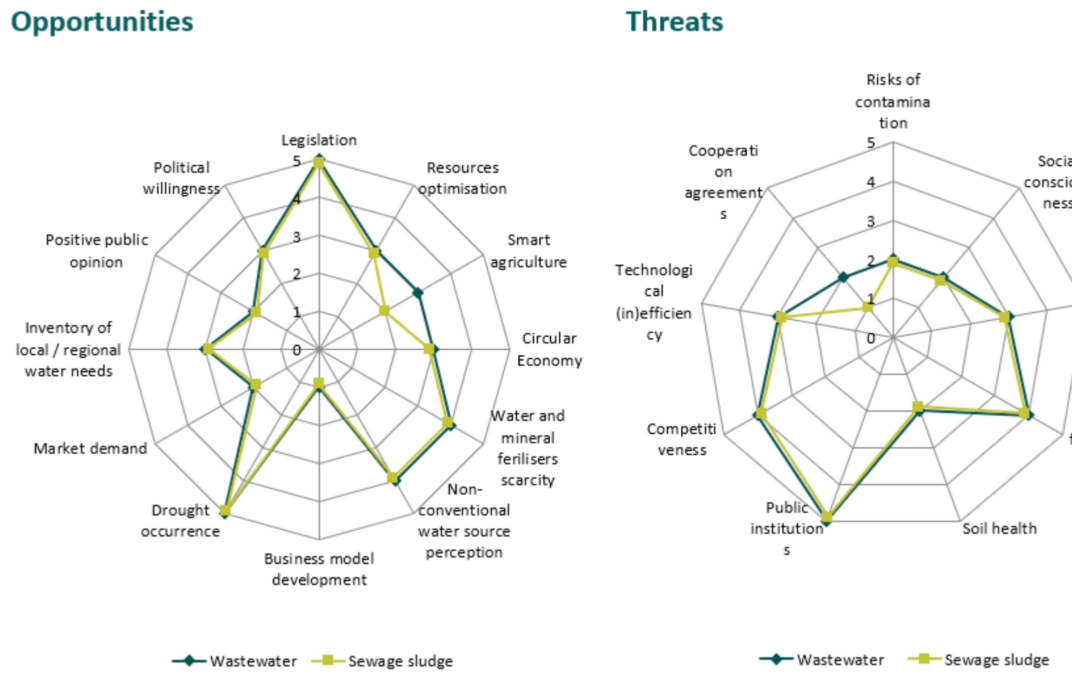

Figure 17. Opportunities and threats radar diagrams for Spain - Andalusia region

The most relevant attributes can be described as follows:

Table 16. Main findings of SWOT analysis for wastewater and sewage sludge as secondary raw materials for producing alternative fertilisers in Andalusia, Spain

Spain – Andalusia: wastewater and sewage sludge	
Strengths • Economic benefit of the new fertilisers' use. • Possibility of elaborated precise irrigation and fertilisation plans with reclaimed water. • Supporting legislation. • Growing fertilising products market. • Water sovereignty for wastewater.	Weaknesses • Energy consumption to deliver the water resource and the associated high costs. • Discontinuous water demand from agriculture. • Reclaimed water distribution. • Discontinuous amount of nutrients of reclaimed water. • Need of infrastructure to buffer water for further distribution.
Opportunities • Legislation on water ruse for irrigation. • Drought occurrence in the region. • Water mineral fertilisers scarcity.	Threats • Slowness in licensing by the public administration. • Extra treatment costs that might imply the legal framework.

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• Current perception of non-conventional water sources.	• Competitiveness of the water source with other users.

3.6.3. Main PEST findings

The main Political, Economic, Social and Technical barriers and drivers identified for **wastewater** and **sewage sludge** as secondary raw materials for producing alternative fertilisers in Andalusia region, Spain are summarised below:

Table 17. Main findings of PEST analysis as barriers to alternative fertilisers production and usage from wastewater and sewage sludge as secondary raw materials in Andalusia, Spain

Spain – Andalusia: wastewater and sewage sludge	Barriers
• Public institutions. • Cooperation agreements. Political	• Energy consumption. • High costs. • Competitiveness. • Legal framework. Economic
• Traditional farmers reluctance. • Farmers training. • Ecology. • Risks of contamination. • Social consciousness. • Smart agriculture practices. Social	• Discontinuous amount of nutrient. • Infrastructure development. • Variations of crops' nutritional requirements. • Discontinuous water demand. • Reclaimed water distribution. • Water buffering. • Soil health. • Technological (in)efficiency. Technological

Table 18. Main findings of PEST analysis as drivers to alternative fertilisers production and usage from bio-wastewater and sewage sludge as secondary raw materials in Andalusia, Spain

Spain – Andalusia: wastewater and sewage sludge	Drivers
• Carbon footprint. • Water footprint and climate change adaptation. • Legislation. • Circular economy. Political	• Benefit for farmers. • New fertiliser products market. • Water sovereignty. • Resources optimisation. Economic

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• Water and mineral fertilisers scarcity. • Drought occurrence. • Inventory of local / regional water needs. • Political willingness.	• Business model development. • Market demand.
Social • Countryside depopulation tackling. • Effluents protection and water quality enhancement. • Quality perception. • Legislation. • Non-conventional water source perception. • Positive public opinion.	Technological • Knowledge / technology. • Easy and controlled irrigation and fertilisation plan. • Continuous water flow. • Smart agriculture.

3.7. Spain – Catalonia

3.7.1. Regional characterisation

Socio-economic characterisation of the region. Catalonia, located in northeastern Spain, is a region characterised by a diverse and dynamic socio-economic landscape. Catalonia covers an area of approximately 32,000 square kilometres. Most of its territory (except the Val d'Aran) lies northeast of the Iberian Peninsula, south of the Pyrenees Mountain range. Catalonia is administratively divided into four provinces: Barcelona, Girona, Lleida, and Tarragona. The capital and largest city, Barcelona, is the second-most populated municipality in Spain and the fifth-most populous urban area in the European Union.

Catalonia boasts a varied landscape, including fertile plains, rugged mountains, and a Mediterranean coastline, contributing to its agricultural productivity. The region's agriculture is known for its focus on high-quality, locally grown products, strongly emphasising sustainable and organic farming practices. Catalonia is renowned for its vineyards, producing world-class wines and sparkling cava. Additionally, it is a significant producer of fruits, mainly citrus fruits, vegetables, and nuts.

Agriculture. The region's agriculture is known for its focus on high-quality, locally grown products, strongly emphasising sustainable and organic farming practices. Catalonia is renowned for its vineyards, producing world-class wines and sparkling cava. Additionally, it is a significant producer of fruits, mainly citrus fruits, vegetables, and nuts.

So far, manure has been directly applied as organic fertiliser in crop fields to produce different types of fruits and cereals, nuts and vegetables. The potential contamination of soil and water created by animal manure could be mitigated using biobased fertilisers derived from manure. However, this is still limited to a reduced number of available products without a clear overview of the numbers.

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Fertilising products sector in relation to the waste streams studied in the region: animal manure. Currently, the primary source of macronutrients is fertilisers of mineral origin, highly dependent on natural gas for extraction and production. Among the three macronutrients (N-P-K), nitrogen represents the main supply regarding the amount delivered. Cataluña required 22.942 T of N, 6.633 T of P2O5 and 22.793 T of K2O in 2022 in form of external mineral fertilisers.

In Catalonia, there are approximately 7.9 million pigs, 637,000 head of cattle, and 44.6 million poultry (DARP, 2020), generating around 9.4 million tons of slurry and 2.8 million tons of manure and hens yearly. The agriculture and livestock sector contributes 12% of the greenhouse gases emitted in Catalonia. Of these emissions, it is estimated that 47% occur while managing livestock manure. The livestock sector is also responsible for the emission of 92% of atmospheric ammonia.

Over the years, excessive application of manure to crops has resulted in the accumulation of phosphorus in the soil and nitrate in the groundwater.

Regulatory and institutional framework. In accordance with the European Directive on nitrates, currently, 33.8% of the total area of Catalonia is declared vulnerable to pollution by nitrates of agricultural origin and affects 422 municipalities, i.e. 45% of all Catalan municipalities (ACA, 2020). Currently, no regulation in Catalonia establishes maximum concentrations of P according to crop and agroclimatic zone, but there are maximum P levels in the soil.

3.7.2. Main SWOT findings

The main Strengths, Weaknesses, Opportunities and Threats identified for animal manure as secondary raw material for producing alternative fertilisers in Catalonia region, Spain are summarised in the following radar diagrams, in which the different attributes are valued from very relevant (5) to not relevant (1):

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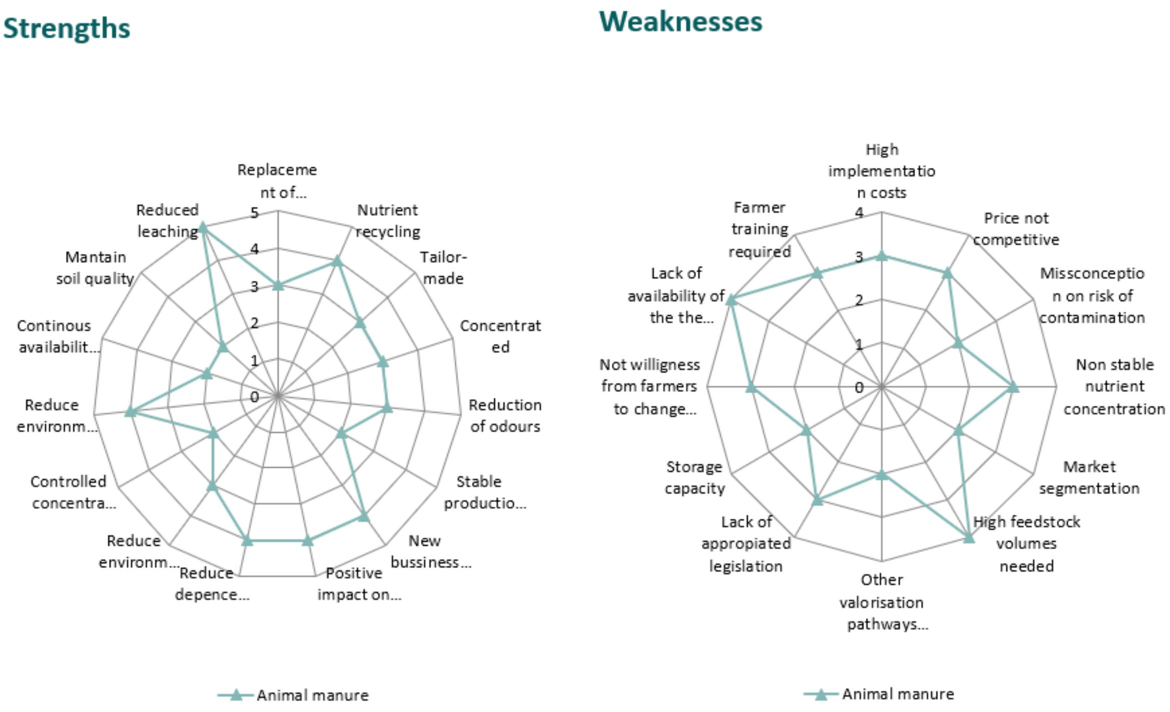

Figure 18. Strengths and weaknesses radar diagrams for Spain - Catalonia region

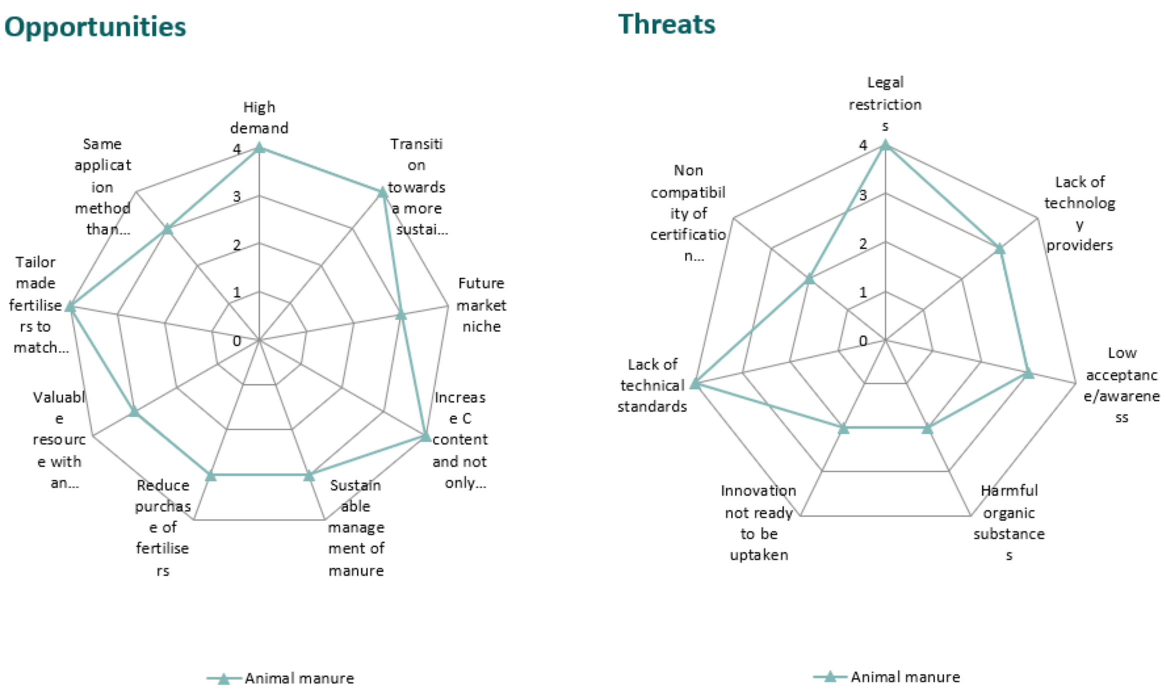

Figure 19. Opportunities and threats radar diagrams for Spain - Catalonia region

The most relevant attributes can be described as follows:

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Table 19. Main findings of SWOT analysis for animal manure as secondary raw material for producing alternative fertilisers in Catalonia, Spain

Spain – Catalonia: animal manure	
Strengths • Decrease of carbon footprint by nutrients recycling, thus reduction of the environmental impact. • Production of fertilisers with the EC label. • Reduction of dependence on raw materials. • Positive impact on soil fertility.	Weaknesses • High feedstock volumes needed, • Lack of needed infrastructures availability.
Opportunities • High demand of sustainable products. • Pressure on agriculture to increase production while respecting the environment. • Reduction of nutrients loss to environment.	Threats • Legal restrictions to use the new fertilisers in the same context as mineral fertilisers. • Lack of consensus on technical standards.

3.7.3. Main PEST findings

The main Political, Economic, Social and Technical barriers and drivers identified for **animal manure** as secondary raw material for producing alternative fertilisers in Catalonia region, Spain are summarised below:

Table 20. Main findings of PEST analysis as barriers to alternative fertilisers production and usage from animal manure as secondary raw material in Catalonia, Spain

Spain – Catalonia: animal manure	Barriers
Political • Legal restriction. • Unclear definitions. • Non-compatibility of certification schemes across the EU. • Regulatory challenges.	Economic • High logistics costs. • Standard pricing. • Lack of real business cases. • Technical training. • Environmental risk / pollution.
Social • Common misconceptions about bio-based fertilisers derived from manure. • No consensual nomenclature. • Disinterest of farmers and fertiliser industry.	Technological • Variability. • Lack of LCA analyses. • Agronomic tests performed under variable weather conditions / soil types. • Scaling up.

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• Harmonisation / standardisation (quality control and consistency). • Lack of successful cases. • Unpleasant odour and appearance.	• Scattered information on nutrient flows from secondary sources in Europe. • Compatibility and machinery. • Technological (in)efficiency. • Storage and shorter shelf-life.

Table 21. Main findings of PEST analysis as drivers to alternative fertilisers production and usage from animal manure as secondary raw material in Catalonia, Spain

Spain – Catalonia: animal manure	Drivers
Political • Replacement of mineral fertilisers. • Circular economy. • Meeting the Green Deal goal. • Political willingness.	Economic • Future market niche. • More efficient fertilisation. • New fertiliser products market. • Nutrient recycling. • Business model development. • Wide spectrum of products.
Social • Preserving soil health and biodiversity. • Solve waste disposal problems, • Support integrated farming. • Positive public opinion.	Technological • Knowledge / technology. • Precision application technologies. • Feedstock availability and low or no cost of input streams. • Research and innovation.

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4. Regional state of the art of the NOVAFERT regions

4.1. Belgium – Flanders

4.1.1. Socio-economic characterisation of the region

Flanders is the Dutch-speaking region of northern Belgium, mostly flat and has a small stretch of coastline on the North Sea. Despite accounting for just 45% of Belgium's land, it has the largest population, with 6,653,062 (or 57%) of the country's 11,431,406 residents. Much of Flanders is agriculturally rich and heavily inhabited, with a population density of 483/km2 (1,250/sq mi). The Flemish Region is organised into five provinces, 22 arrondissements, and 308 cities or municipalities and covers 13,625 km2 (5,261 sq mi).

Figure 20. Present day Flanders (red) shown within Belgium

Climate and Geography

Flanders borders Wallonia to the south, with Brussels being an enclave inside the Flemish Region. The remaining border is shared by the Netherlands (Zeelandic Flanders in Zeeland, North Brabant, and Limburg) in the north and east, and France (French Flanders in Hauts-de-France), and the North Sea in the west.

Flanders is a densely populated region located entirely within the Blue Banana. The major cities in the Flemish Region are Antwerp, Ghent, Bruges, and Leuven. Antwerp is the largest city, with a population of almost 500,000 people; Ghent has a population of 250,000 people; Bruges has a population of 120,000 people; and Leuven has a population of over 100,000 people. Flanders is divided into two geographical regions: the northwestern coastal Yser basin plain and the centre plain.

The first zone consists mainly of sand dunes and clayey alluvial soils in the polders. Polders are regions of land at or below sea level that have been reclaimed from the sea and are protected by dikes or, a little farther inland, by canal-drained fields. The central plain begins with similar soils along the lowermost Scheldt basin, a smooth, slowly rising fertile area

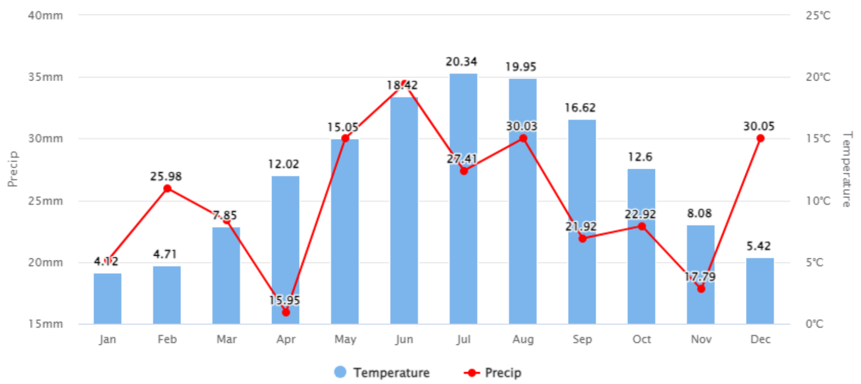

Figure 21. the mean monthly temperature and precipitation of East Flanders in recent years
Source: www.en.climate-data.org

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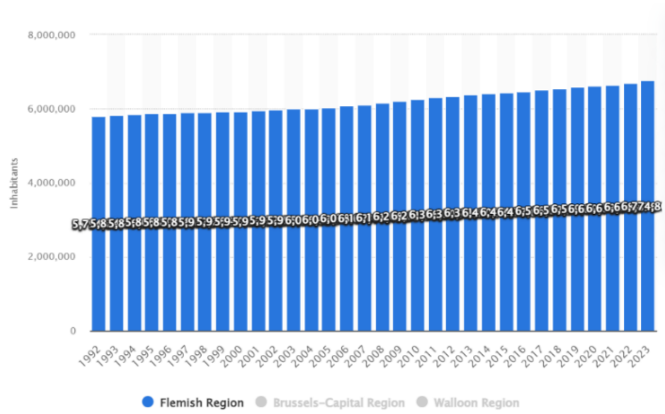
irrigated by many waterways with an average height of about five meters (16 feet) above sea level. The region has wide valleys of its rivers upstream and sandy soils at around thirty meters in the Campine region to the east. Near its southern borders, close to Wallonia, there is significantly harsher ground, richer in calcium, with low hills reaching up to 150 m (490 ft) and small valleys, and marl caves may be found in the Meuse basin on the eastern border with the Netherlands.

Flanders has a Marine west coast and warm summer climate (Classification: Cfb) and is located at a height of 16.26 meters (53.35 feet) above sea level. The yearly temperature in the city is 12.1 °C (53.78 °F), with average temperatures of 3 °C (37 °F) in January and 21 °C (70 °F) in July, which is 0.69% higher than the Belgian norms. Flanders gets around 20.08 millimetres (0.79 inches) of rain each year and has 66.45 rainy days (18.21% of the time).

Population and economics

Flanders has a population of about 6 million people, with Antwerp being the most populous province. Flanders, Belgium's northern region, accounts for 45% of the country's landmass, covering 13,522 km^2. The primary language spoken in the area is Dutch; however, most residents are also fluent in English and French.

In 2022, the Flemish Region had a population of 6,774.807 people. This is an increase over the previous year's figure of 6,698.876 people. 2022 was also characterised in Flanders by a strong population growth of 1.13% or 75,931 inhabitants; the natural balance was negative (-4,244). That year, there were 63,284 births and 67,528 deaths. However, the international migration balance was positive (+64,589). That year, 118,704 immigrants and 54,115 emigrants were recorded. 33,565 of the immigrants were of Ukrainian origin. A third balance plays a role at all geographical levels lower than Belgium: the internal migration balance. The balance presents a summary of the relocation moves that have occurred within Belgium. Internal migration balance, defined as the difference between emigrations and evictions in the Flemish Region, was positive (+15,781). As a result, more individuals have relocated to Flanders from another region (38,617) than from Flanders to another region (22,836).



Population
(number)

	2010	2022
TOTAL	6,251,983	6,698,876
Men	3,085,334	3,316,611
Women	3,166,649	3,382,265
Aged 0-17	1,225,426	1,299,256
Aged 18-66	4,021,563	4,160,140
Aged 67 and over	1,004,994	1,239,480
Belgian	5,852,550	6,040,606
Non-Belgian	399,433	658,270
Inhabitants per km^2	459	492

Figure 22. Population of Flemish region 1992-2022. Source: Statistics Flanders

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The strong population growth in the Flemish Region in 2022 is thus the result of a positive internal migration balance and a strongly positive international migration balance, which compensated for a negative natural balance while ensuring a solid population growth of 1.13%, or 75,931 inhabitants.

Table 22. Economic growth in real terms, Flemish region, Belgium, EU-27 and the neighbouring countries, 2020-2023 (in %)
Source: Statistics Flanders

	2020	2021	2022	2023
Flemish region	-5.5	7.0	2.8	1.3
Belgium	-5.4	6.1	3.1	1.0
EU-27	-5.7	5.4	3.3	0.3
Germany	-3.7	2.6	1.6	-0.6
France	-7.8	6.8	2.6	0.4
The Netherlands	-3.9	4.9	4.7	0.6

Economic growth falls in 2023, although it remains higher above the Belgian and EU norms. The COVID-19 issue caused a severe reduction in economic activity in Flanders in 2020. The decrease was most noticeable in the first half of 2020. Activity began to build up again in the third quarter of 2020. Rising vaccination rates and the gradual relaxation of restrictive restrictions fuelled the economic recovery in 2021. In 2021, real GDP growth was 7.0%, making GDP 1.1% greater in real terms than in 2019 (the year before the COVID-19 pandemic).

In 2022, the real economic growth of the gross domestic product (GDP) in Flanders was 2.8%. In 2021, Flanders' GDP per capita reached EUR 38,200, ranking it in the top half of the EU. In February 2022, war broke out in Ukraine. This added to the already rising commodity and energy costs, as well as creating uncertainty among producers and consumers. The HERMREG model14 predicted that GDP growth in Flanders would be +2.8% in July 2022 and +1.3% in 2023 (due to rising inflation). The most recent Belgian forecast for 2023 was 1.0% in February 2023. The industries with the most economic growth include transportation and communications, health and social services, business services, and equipment manufacturing.

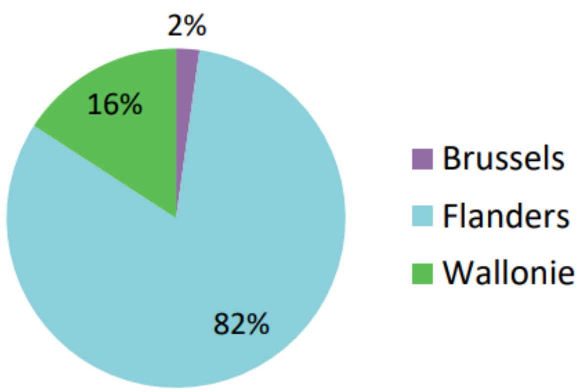

Figure 23. Regional distribution of Belgium export (%) (2021)
Source: Institute for the National Accounts, Department of finance and budget

The Flemish economy is heavily export-oriented. Flanders' exports account for 82.0% of Belgium's total export volume

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(2021). Flemish exports experienced robust growth in 2021 following a decrease in 2020 due to the Covid-19 pandemic. The region's most successful export products include chemicals and pharmaceuticals, transportation equipment and components, machinery and equipment, mineral products, and plastics.

4.1.2. Agriculture

The Agricultural areas are most prevalent in the north, where there are formerly seabeds that have fertile soils. Agriculture benefits from the mild as well. Sugar beets, grains, and potatoes are the most significant crops. Meat and dairy products are key commodities as well. Pig alone contributes to a fourth of agricultural export value. Flanders has the most pig farms, whereas Wallonia has the largest grain output.

The average area of agricultural land per farm grew by 50% between 2005 and 2022, from 18.3 hectares (ha) in 2005 to 27.6 ha in 2022. This suggests that smaller farms are closing, resulting in a continual increase in scale. Between 2017 and 2021, the average cultivated area per farm stabilised, then increased by 2.6% in 2022.

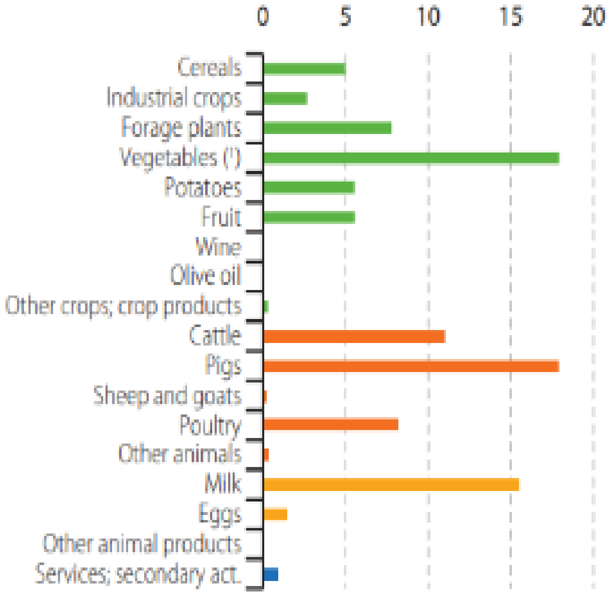

Figure 24. –Output value of the agricultural industry, 2019 (% of the total output)
Source: Eurostat

4.1.3. Fertilising products sector

The evolution of average cattle density per farm also indicates a shift in scale. Between 2005 and 2022, the average number of livestock units per farm and the average herd size of each specialist, a cow's pig and poultry farm, increased steadily.

Flanders's agriculture mainly produces pigs, cattle, milk, vegetables and crops (Eurostat, 2019).

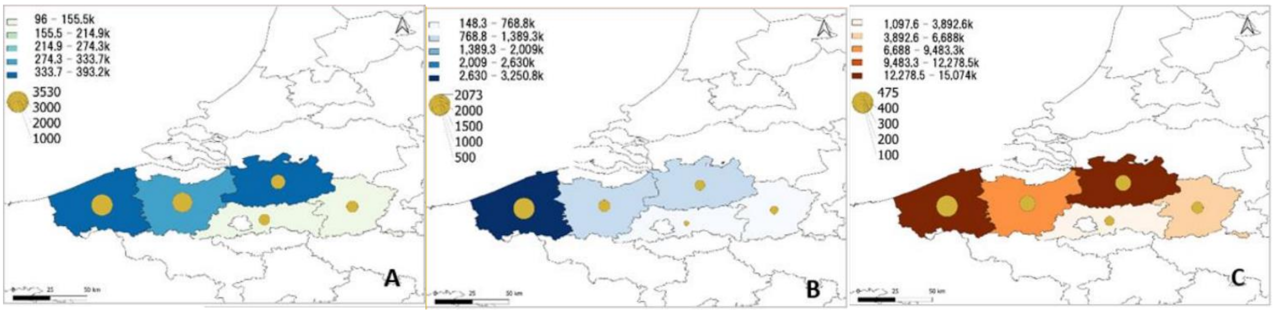

Figure 25. Number of animals (census) per animal type (LSU) per county (NUTS-3). A: Beef & Dairy Cattle; B: Pigs; C: Poultry. Circles represents the number of farms
Source: Eurostat 2019 and Fertimanure EU project

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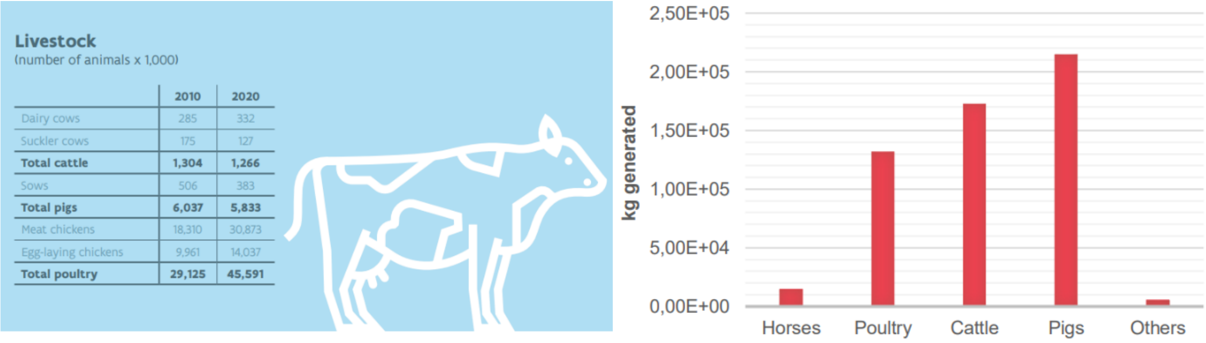
Pig farming is still the most significant economic activity in Flanders' agricultural and horticultural sectors. The nitrogen (N) ranges for cattle, pigs, and poultry are comparable. The distribution varies by province (NUTS-2). Cattle and pig nitrogen output are higher in the west, in accordance with larger animal production.



Livestock
(number of animals x 1,000)

	2010	2020
Dairy cows	285	332
Suckler cows	175	127
Total cattle	**1,304**	**1,266**
Sows	506	383
Total pigs	**6,037**	**5,833**
Meat chickens	18,310	30,873
Egg-laying chickens	9,961	14,037
Total poultry	**29,125**	**45,591**

Figure 26. Number of livestock and total production of nitrogen in total Kg N per animal type
Sources: Department agriculture and Fisheries, Statbel, processed by statistics Flanders.

4.1.4. Regulatory and institutional framework

Manure reuse legal framework

In all Member States, the Nitrates Directive is perceived as a successful legislative tool to reduce the loss of nutrients and to allow for the application of recycled nutrients over unprocessed manure or chemical fertilisers. In Belgium, the implementation of the Directive into national legislation is moving towards stricter monitoring and higher fines. In Flanders, manure use and management is strictly regulated by the manure decree and the manure action plans. All famers with a production of at least 300 kg P_2O_5 have to submit a manure declaration. The whole region of Flanders is designated as a nitrate vulnerable zone, which means that the maximum application standard for manure is 170 kg N per ha, in line with the Nitrate Directive. The implementation of the Nitrates Directive via the Flemish Manure decree since 1991 is rated as having a neutral effect. Digestate products resulting from co-fermented animal manure with plant-based input streams are considered as 'animal manure' and are therefore limited in Nitrate Vulnerable Zones (NVZ) to 170 kg N/ha/y.

According to (EC) 2003/2003, ammonium salts are recognised as 'EC fertiliser' (category C1 n°1, with C1: straight fluid fertilisers and n°1: nitrogen fertilising solution) if the N content is at least 15%. Whereas the ammonium nitrate from stripping/scrubbing from the installations in Flanders, meets the 15 % requirement (because of the use of nitric acid), this is not the case for the ammonium sulphate which is currently mostly produced by air washing ammonia rich air from animal stables. In the new Fertiliser Products Regulation (EC 2019/1009) regulation, active from mid-July 2022, a fertilising product is defined by its product function category (PFC, type of product/fertiliser) and the component material category (CMC, allowed input materials). Ammonium salts correspond to the Product Fertiliser Category (PFC) C.I. (b) (i) Straight liquid inorganic macronutrient fertiliser if the N-concentration > 5 %. Both, produced in Flanders, ammonium nitrate and -sulphate meet that N-content. The same case is for the ammonium water. At the Belgian national level, the Royal Decree of 28^{th} January 2013 includes the regulations on the marketing and use of fertilisers, soil amendments, cultivation substrates, sewage sludge and to any product to which a specific effect to promote plant production is

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attributed (referred to as "products" in this Royal Decree). It is thus a product regulation, defining which products can be considered fertilisers, soil improvers and cultivation substrates. These are the main categories of products that are accepted for trade and marketing in Belgium, as listed in annex I of the Royal Decree (28/01/2013). It includes both the fertilisers with CE label, as included in 2003/2003 (and therefore implements this regulation) and nationally accepted fertilisers.

Products not occurring in Annex I to the Royal Decree of 28 January 2013 can be placed on the market via a so-called derogation (this is an authorisation for fertilisers, soil improvers, growing media and related products). The Minister may authorise national trade in non-Annex I products (pursuant to Article 5) by granting them an exception. The derogation is granted for a period of maximum 5 years and can repeatedly be renewed for a period of maximum 5 years at a time.

If the product for which a derogation is requested is a byproduct, a waste product or a processed waste product, one also needs an authorisation, granted by the Region (in Belgium the 3 regions are: Wallonia, Flanders, Brussels) where the producer is located. In Flanders this authorisation is granted through a "raw materials declaration", granted by OVAM. For this member state we must also consider that the whole region of Flanders is designated as a nitrate vulnerable zone (NVZ). Therefore, according to article 2(g)3 of the EU Nitrates Directive (91/676/EEC), all manure, even in processed form, is considered as animal manure and can be applied up to the maximum limit of 170 kg N/ha/year. On Flemish level this is regulated via Manure Decree that regulates the use of fertilising products. The ammonium salts currently produced from stripping / washing, such as ammonium sulphate and ammonium nitrate, are considered to be animal waste and are therefore in competition with animal manure for land application. However, ammonium sulphate, recovered from scrubbing ammonia rich air from animal stables, is under derogation which means it is not considered as animal manure and can be used as a replacement for synthetic fertilisers. Finally, the newly proposed RENURE criteria (not yet implemented) by Joint Research Centre (JRC) state under which criteria manure-derived N fertilisers could be used in NVZ as replacement for synthetic mineral N fertilisers: a total organic carbon:total N (TOC:TN) ratio ≤ 3 or a mineral N:TN ratio ≥ 90%, (ii) the content of copper (Cu) and zinc (Zn) should not exceed respectively 300 mg kg^{-1} DW and 800 mg kg^{-1} DW. Being BBFs in inorganic form, ammonium sulphate, ammonium nitrate and ammonium water might have the potential to be used in future as replacements for synthetic mineral N fertilisers in NVZ. Finally, it should be highlighted that ammonium sulphate, ammonium nitrate and ammonium water should be applied with low emission techniques: injection or incorporation within 2h from the application are obligatory in Flanders.

VLAREMA is the Flemish legislation dealing with the 'end-of-waste'-statute of biological treated organic biological waste streams. All products originating from digestate from an anaerobic digestion installation treating both manure and organic biological waste streams (co-digester), are subject to this legislation. VLAREMA points out that input streams for the biological treatment processes as well as the end products (being used as fertiliser or soil improver) must comply to strict criteria concerning composition, dosing, etc. for heavy metals and organic pollution. Furthermore, VLAREMA obliges certification for the installations, handed out by VLACO. All RENURE-products coming from digestate from an installation treating also

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organic waste streams, need to comply to the VLAREMA criteria (Annex 2.3.1A/B and 2.3.1.C) and they need a certificate from VLACO.

Trade in the biobased fertilisers and registration as fertiliser trader. Trading of end products of manure processing is regulated at federal level through the Royal Decree of 28th January 2013. If end products of fermentation (digestate) and manure processing are not listed in Annex I of this legislation, an exemption for these products from the Public Health Department; Food and Environmental Safety section (FAVV) is needed. This FOD-exemption is valid for a maximum of 5 years. To trade in fertilisers/soil improvers that are no 'natural products from the farm', companies must have formal FAVV-approval. Annual inspection visits are carried out by FAVV inspectors. Checklist are audited (reporting duties, traceability, infrastructure, equipment, hygiene, packaging, and labelling and auto- checks).

4.1.5. Animal manure and digestate treatment and processing

Every year, the Flemish Coordination Centre for Manure Processing organises an investigation of the state of manure processing in Flanders. In 2021 around 4 250 857 tonnes of animal manure were treated in Flanders. This tonnage equates to 39.8 million kg of nitrogen extracted from cattle manure. In 2020, 4 632 182 tonnes (or 43 474 955 kg N) were processed. Flanders now operates 142 manure processing units.

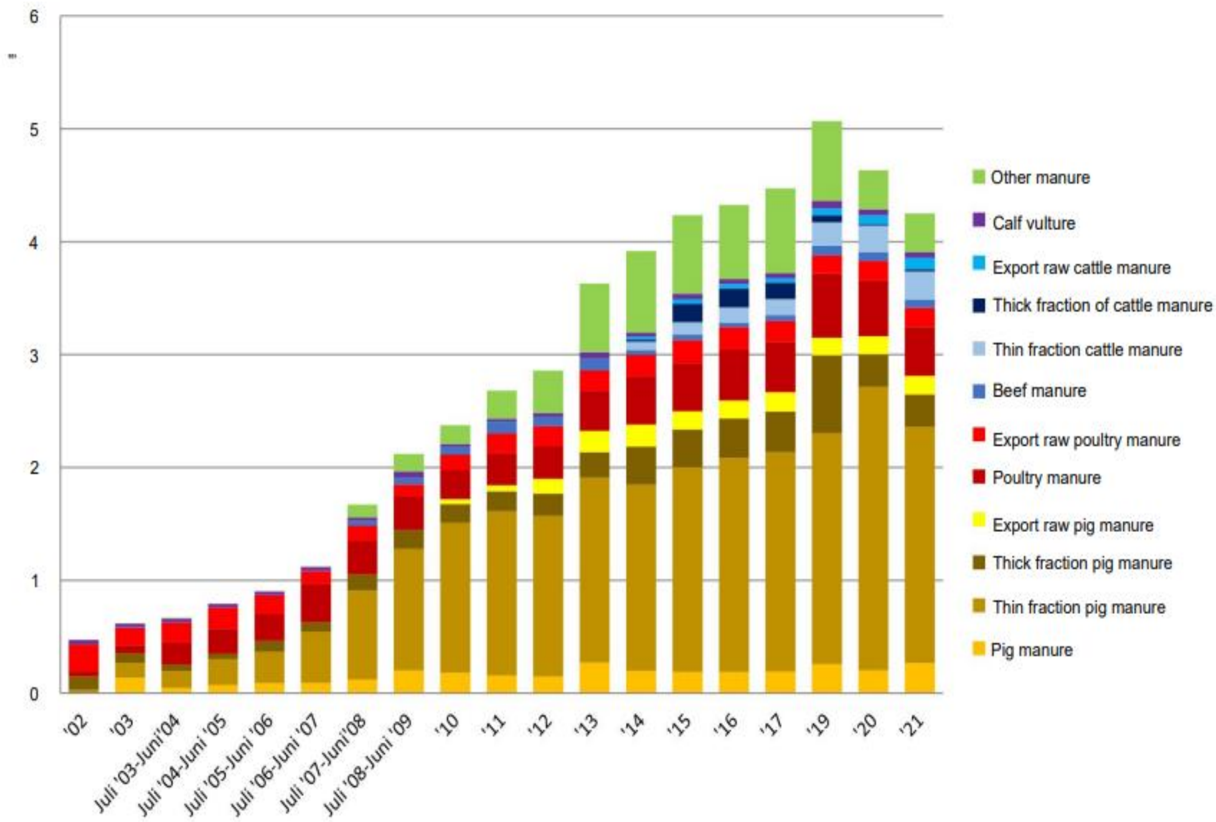

Figure 27. Evolution of the operational manure processing capacity in Flanders (2002-2021) in tonnage of processed manure, including export of raw pig, cattle and poultry manure
Source: Information collected and processed by VCM 2021

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Pig and poultry manure

Regarding nitrogen processing, pig and poultry manure accounted for 88.9% of total manure processing, with 17.1 million kg N (43.0%) and 18.3 million kg N (45.9%), respectively. In terms of quantity, 2 812 050 tonnes of pig manure (66.2%) and 602 041 tonnes of poultry dung (14.2%) were treated. Compared to 2020, operational processing of chicken manure, excluding exports, dropped by 60 619 tonnes. Pig manure operational processing, excluding exports, also decreased by 355 914 tonnes. Raw pig manure direct exports increased by 3% (+5 168 tonnes). Direct raw poultry manure exports decreased by 3.2% (-5 588 tonnes).

Cattle manure

The processing and export of livestock manure, including calf manure, increased by 38 849 tonnes in 2021. Imports of livestock dung from the Netherlands increased by just 1% (+ 281 tonnes) compared to 2020. After a 77% decline in 2020 compared to 2019., processing of the thick fraction of livestock manure scaled by 24% (+ 3 298 tonnes). Raw animal manure exports to the Netherlands increased by 32% (25 733 tonnes). Processing of cattle manure grew by 7% (+ 15 864 tonnes), whereas processing of cattle manure decreased by 16% (- 7 123 tonnes).

Manure processing techniques

Biology (biological nitrogen removal from pig manure, cow manure, or digestate) is still the most widely used approach (99 out of 137 installations, total processors (manure/digestate) not included), followed by biothermal drying (15 plants, total processors not included). Biothermal drying (of farmyard manure, solid fractions, chicken manure, horse manure, and compost) is used in 15 different installations, with two of them additionally drying and granulating manure. Furthermore, there are three mushroom substrate preparers, one of which uses liming of solid fraction and/or digestate. The manure will be dried or thermally hygienised by two companies.

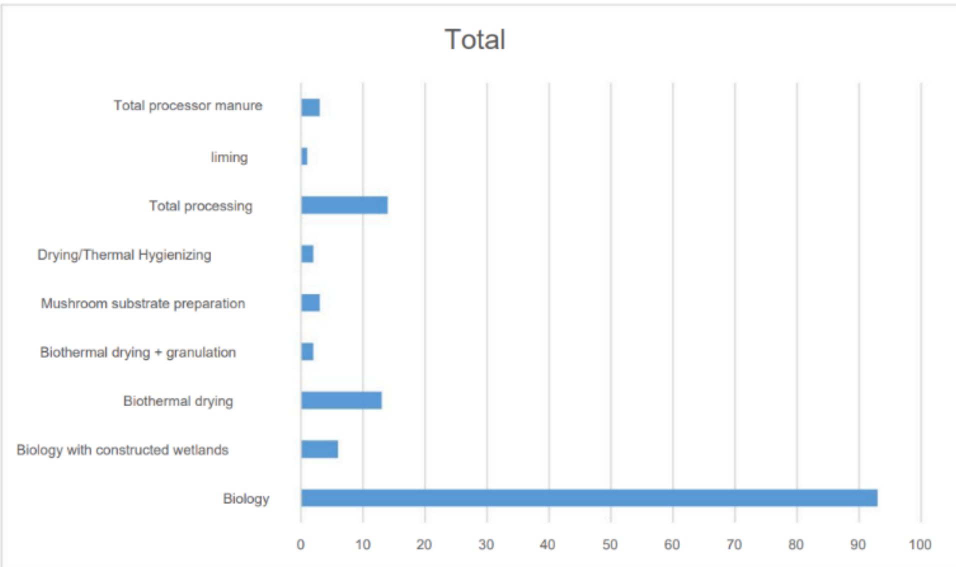

Figure 28. Number of manure processing techniques applied at the 137 Flemish installations. Under total processing are counted the fermentation installations of which the digestate is exported directly and

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integrally after processing or of which the solid fraction is exposed, and the thin fraction is processed on site. Total processors manure process both the thin and thick fraction of manure without prior fermentation
Source: VCM 2021

Flanders has 14 processors in total. Total processors are the fermentation plants that process the full export digestate or use separation, exporting the (dry) solid fraction while processing the thin fraction on-site (for example, using biology). The drying and hygienisation of the Biothermal drying (of farmyard manure, solid fractions, chicken manure, horse manure, and compost) is a thick fraction of the digestate with the heat from the Combined Heat and Power (CHP) at 5 total processors. There are three facilities in Flanders that do entire manure processing without any prior fermentation. These installations either process the thin fraction after separation via a biological process or without a biological process followed by membrane filtration. The solid part of manure is bio thermally dried.

Table 23. Manure management

Type of treatment	Equipment used	Cost
Separation	Centrifuge	1.47 – 3.17 €/m^3
	Screw press	0.64 – 1.44 €/m^3
Drying	Air dry system + air washer	20.2 €/m^3
Precipitation	CAFR-process	18.3 €/m^3
Stripping	SMELOX-installation	4.5 – 5 €/m^3
Composting	Extensive	6.5 €/ton

Table 24. Manure transport costs

Transport type	Type of matter	Hourly cost	Cost per Km
Transport truck (volume not specified)	Liquid	0.18 €/Km.m^3	10 (disposal costs)

In 2021, the largest amount of nitrogen was processed through organic manure processing (13.7 million kg N or 41.7%). However, this represents an 11.7% decrease compared to 2020. Biothermal drying, which previously ranked first in terms of the most nitrogen processed in 2020, processed 11.7 million kg of N (35.5%) in 2021, mostly from chicken manure, horse dung, thick fraction of pig manure, and thick fraction of cattle manure. This represents a 23% drop from 2020. The temporary inactivity of a large biothermal drying facility might explain this.

The largest amount of phosphate (9.6 million kg P_2O_5 or 68.4%) is processed via biothermal drying (whether or not combined with drying and granulation).

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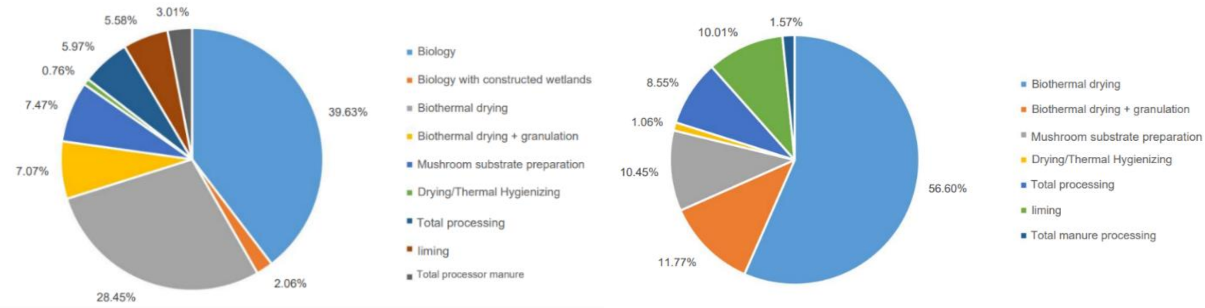

Figure 29. Percentage share of the amount of (a) N and (b) P that is processes via the various primary techniques
Source: VCM 2021

4.1.6. Initial stakeholders identified

Table 25. Initial key actors identified from the quadruple helix

Stakeholder	Sector	Entity
Farmer	Private sector	Family farm Kris Heirbaut
		Family farm Frederique D'hondt
		Family farm Lieven Lafaut
Business-SME	Private sector	DLV
		IVACO
Research centre	Private sector	Inagro
		VCM
Foundation	Private sector	Boerenbond
		ABS
National public administration	Public sector	Nutricycle Vlaanderen

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4.2. Croatia – Continental Croatia

4.2.1. Socio-economic characterisation of the region

Continental Croatia refers to the inland region of Croatia, located away from the country's coastline along the Adriatic Sea. It is characterised by diverse landscapes, rich cultural heritage, and historical significance. Continental Croatia is situated in the central and north-eastern parts of the country. It is primarily a lowland area, with rolling hills, fertile plains, and numerous rivers. In continental Croatia, the types of soil vary depending on the specific geographical location and environmental factors. However, there are several prevalent soil types found in the region. The main soil types in Continental Croatia: Chernozem, Luvisols, Cambisols and Gleysols. Chernozem is a fertile black soil that is rich in organic matter and nutrients. It is found in the agricultural areas of Continental Croatia, especially in Slavonia and Baranja. They are known for their high fertility and suitability for growing crops. Luvisols are characterised by a clay-rich subsoil and are prevalent in many parts of Continental Croatia. These soils typically have good water-holding capacity and are suitable for agriculture, especially when properly managed. Cambisols are relatively young soils with a variable composition. They are formed from the weathering of parent materials such as rock or alluvium. Gleysols are waterlogged or poorly drained soils that occur in areas with high groundwater levels or poor drainage conditions. They are characterised by a grayish colour due to reduced iron content. Gleysols can be found in low-lying areas and floodplains in Continental Croatia.

Croatia is divided in three regions:

- Pannonian region, which occupies 55 % of the area and 67 % of the population.
- Gorsko – kotlinska region, which occupies 14 % of the area and 2 % of the population.
- Jadran region, which occupies 31 % of the area and 31 % of the population.

In continental Croatia, there are 14 (including city of Zagreb) counties that form the administrative divisions of the country. These counties are responsible for local governance, public services, and various administrative functions. Counties in continental Croatia are: Zagreb County, Krapina-Zagorje County, Varaždin County, Međimurje County, Sisak-Moslavina County, Brod-Posavina County, Osijek-Baranja County, Koprivničko-križevačka County, Bjelovar-Bilogora County, Virovitičko–Podravska County, Požeško-Slavonska County, Vukovarsko-Srijemska County, Karlovac County.

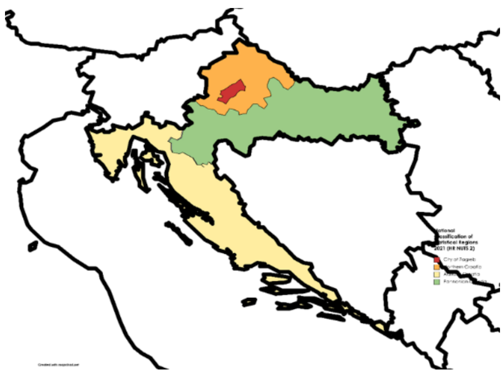

Figure 30. National Classification of Statistical Regions 2021 (HR NUTS 2)
Source: Authors calculation

NUTS Classification in the Republic of Croatia

The Classification of Territorial Units for Statistics (NUTS) has been applied since the Republic of Croatia's accession to the European Union and corresponds to the National Classification of

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Spatial Units for Statistics. The second-level statistical region consists of four non-administrative units formed by grouping counties as lower-level administrative units. According to the second-level classification, Croatia is divided into Pannonian Croatia, Adriatic Croatia, Northern Croatia, and the City of Zagreb.

Climate and geography

Climate in Continental Croatia vary across the region, influenced by its diverse topography and proximity to different climatic zones. The climate in Continental Croatia exhibits a transition between a moderate continental climate in the north-western parts and a more pronounced continental climate in the eastern and south-eastern areas. The climate is influenced by its inland location, with limited maritime influence compared to the coastal regions. Here are the key characteristics of the climate in Continental Croatia:

Summers in Continental Croatia are generally warm to hot, with average temperatures ranging from 25°C to 30°C (77°F to 86°F). However, temperatures can occasionally rise above 35°C (95°F) during heatwaves. The region receives a moderate amount of rainfall during the summer months.

Winters are cold and can be quite harsh in Continental Croatia, especially in the northern and eastern parts. Average temperatures during winter range from -5°C to 5°C (23°F to 41°F). Snowfall is common, particularly in higher elevated areas.

Spring and autumn are transitional seasons with moderate temperatures. These seasons can be unpredictable, with varying temperatures and occasional rainfall.

The amount of rainfall in Continental Croatia varies across the region. In general, the western and north-western parts receive more precipitation compared to the eastern and south-eastern areas. Annual rainfall averages range between 800 mm to 1,200 mm (31 inches to 47 inches). The distribution of rainfall is relatively even throughout the year, although summer months can be drier.

Continental Croatia's climate and geography offer a mix of moderate continental conditions, with distinct seasonal variations.

Population and economics

In 2021 the population of Croatia was estimated to be around 3.8 million people. However, population figures can change over time due to factors such as birth rates, migration patterns, and demographic shifts.

In the first part, we will give insight into the average employment values and an overview of trends in the representation of individual activities at the level of the entire Republic of Croatia.

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In 2021, the recovery of the Croatian economy and the growth of employment was marked after the global crisis in 2020 caused by a pandemic of coronavirus.

The recovery of economic activities in 2021 affected on labour market developments. According to the data CBS's, average unemployment rate in 2021 was 8 %. Compared to previous year, average unemployment rate was decreased for 0.9 %. In 2021 the number of employees was 1 575 837, which is more than the pre-crisis year 2019.

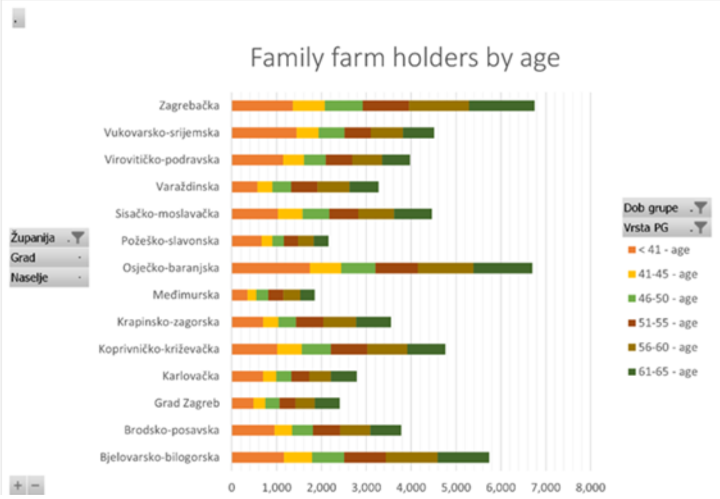

Figure 31. Share of Family farm holders by age of the holder in Continental Croatia in 2022
Source: Author's calculation according to the data from the Register of farmers

Agriculture activity counts 39 522 employees (2,5% of total employees), or 1.5% more in relation to the previous year.

The second part graphically illustrates the age structure of the agricultural holdings, the structure of education and trend of the number of employees at the level of the Continental Croatia.

When analysing the age structure of the family farm holders in Continental Croatia in 2022, out of 56 699 family farms, 76.5% belong to age group of more than 40 years old. The holder's share in the age category up to 41 years is 23.5 %, which is a slight increase compared to the previous years.

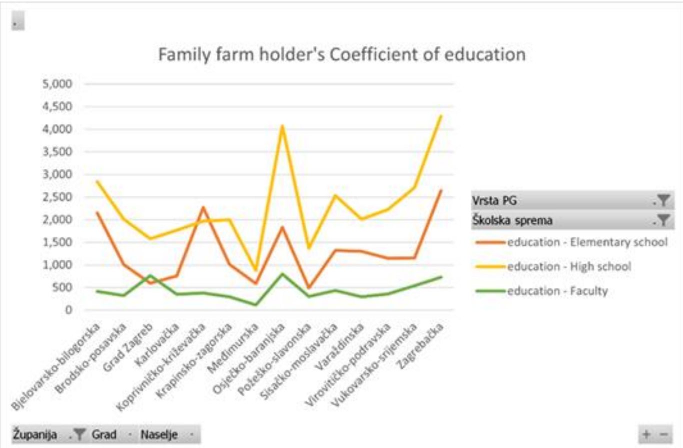

Figure 32. Family holder's coefficient of education
Source: Author's calculation according to the data from the Register of farmers (2022)

With regards to the family farm holder's coefficient of education in Continental Croatia in 2022, the largest number of farmers has high school education, 56.9 % of them. In view of fact that innovations are more easily and quickly accepted by more educated and younger farmers, the educational structure of farmers indicates socio-demographic difficulties in incorporating innovations into their agro management. Therefore, various measures of CAP (Common Agricultural Policy) are on disposal for generational renewal. Croatian agriculture needs a generational renewal that will at the same time contribute to improving the

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educational structure and have a greater focus on livestock production that creates greater added value.

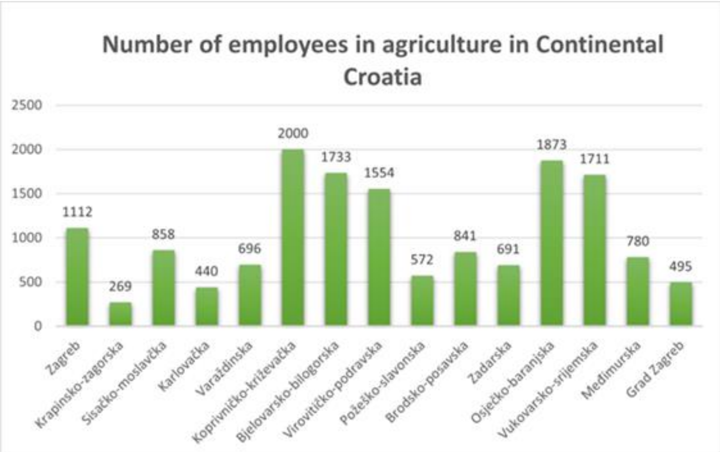

Figure 33. Number of employees in agriculture in Continental Croatia in 2022
Source: CBS, 2022 (Authors calculation)

Regarding the number of employees at the level of the Continental Croatia in 2022, the proportion of employees in Continental Croatia compared to Croatia is 83,3 %.

Continental Croatia contributes significantly to the country's economy. Continental Croatia employs a significant portion of the region's workforce. Agriculture has traditionally been an important economic activity in the region, particularly in rural areas. The year 2021 was marked by the recovery of the Croatian economy and the growth of employment after the global crisis in 2020 caused by the coronavirus pandemic. In 2021, the agricultural sector achieved a production value of 20.7 billion HRK. Compared to 2020, the production value of the agricultural sector increased by 2.4 billion HRK, or 13.3%. The growth in production value, coupled with a significantly lower growth in intermediate consumption, had a positive impact on the growth of gross value added. It reached 11 billion HRK in 2021, which is 26.3% higher than in 2020.

Significant growth in exports of goods and services and growth in household consumption caused increase of gross domestic product for 13.1 % compared to the previous year. Croatia achieved a higher GDP growth rate than the most Member States of the European Union. In 2021, according to the CBS's data gross domestic product amounted 58,2 billion euros. Main growth factors of GDP are investment growth (4.7 %), household consumption growth (9.9 %), export growth of goods and services (36.4 %), import growth of goods and services (17.6 %).

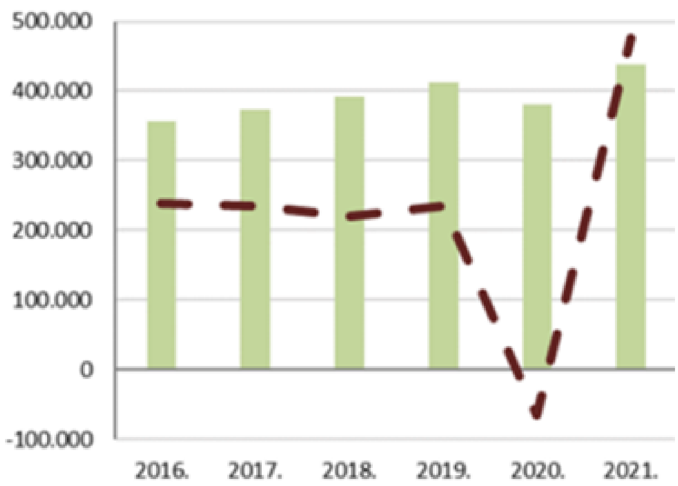

Figure 34. GDP of Croatia from 2016 to 2021 (HRK million)
Source: CBS, 2021

In 2021, GDP of primary activities in agriculture, forestry and fishing increased 8.2 % in reference to the previous year.

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Prices of goods and services for personal consumption are increased 2.6 % (2021). Food consumer prices increased 1.6 %. Price growth was recorded for all groups of food products, except for meat, fish, and seafood.

In 2021, according to the CBS's data total value of foreign trade exchange of goods and services was 46.8 billion euros, which is 23.7 % more than the previous years. The value of exports of goods and services was 18.4 billion euros, and the value of imports was 28.4 billion euros. It is an increase of 23.4 % for export and 23.9 % for import.

The deficit in foreign trade reached the amount of 10 billion euros, which is 24.9 % higher than 2020. Within agricultural food products, percentage of import coverage by export was 73.9 %. The value of foreign trade exchanges of agricultural food products in 2021 represents 14,2 % of the total value of Croatia’s trade.

The highest share of agricultural and food products was exported to Italy (21.0 %), Slovenia (14.6 %), Bosnia and Herzegovina (10.4 %), Germany (7.7 %), and Serbia (6.4 %).

Agricultural and food products were imported from 121 countries. The highest share of agricultural and food products was imported from Germany (14.7 %), Italy (11.2 %), Slovenia (10.1 %), Hungary (9.8 %), and the Netherlands (8.3 %).

4.2.2. Agriculture

Agriculture plays a significant role in Continental Croatia, contributing to the region's economy and cultural identity. Agriculture in Continental Croatia is diverse, embracing both traditional and modern farming practices. The region's fertile lands, favourable climate, and cultural heritage contribute to a thriving agricultural sector that produces a wide range of crops, wines, and livestock products.

The value of agricultural production in Croatia reached 20.7 billion HRK in 2021, which is 13.3 % higher than in 2020. Plant production accounted for 59 % of the total value of agricultural production, while animal production accounted for 35.3 %.

According to the data from the Croatian Paying Agency for Agriculture, Fisheries and Rural Development (PAAFRD) in 2021, there were 170,436 farmers registered, with the majority being family farms, representing 82.9 % of the total number of farmers. The highest number of farmers is in the Zagreb County (14,291), 8.4 % of the total number of farmers in Croatia.

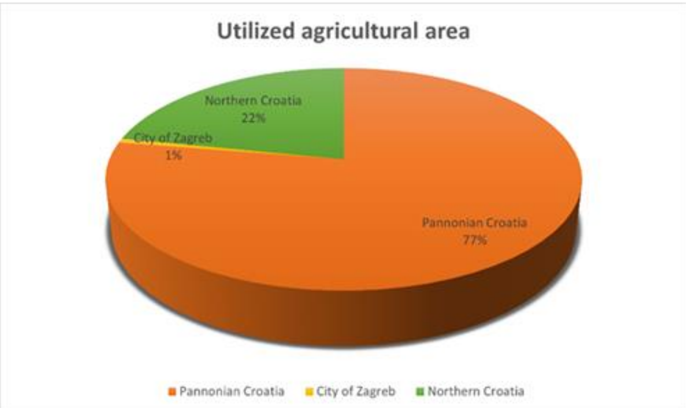

Figure 35. Share of utilised agricultural land in Continental Croatia in 2021
Source: Author calculation

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According to the PAAFRD data in 2021, there were 170,000 farmers registered, utilising 1.16 million hectares of agricultural land. 70 % of farmers use less than 5 hectares of agricultural land, while in average, farmers use 6.8 hectares of agricultural land.

Most of the utilised agricultural land (55 %) is owned by the farmers themselves. 22.1 % is leased, and an additional 8.8% is state-owned land under lease.

Croatia is self-sufficient in cereal production, and in 2020, self-sufficiency in cereal production reached 174.2 %.

Croatia is also self-sufficient in oilseed production, with a self-sufficiency rate of 287.2 % in 2020. Croatia is a significant producer of soybeans within the European Union.

The vegetable production in 2020 amounted to 234,313 tons. The self-sufficiency rate in vegetable production in 2020 was 63.1 % of the domestic market's needs. In 2021, a total of 201,800 tons of vegetables were produced. The most common vegetable types were cabbage (16.2 % of total vegetable production), tomatoes (13.2 %), watermelons and melons (11.6 %), onions and garlic (11.5 %), and peppers (8.5 %).

Croatia is not self-sufficient in potato production, with a self-sufficiency rate of 71.9 % in 2020. The total potato production in 2021 was carried out on 8,786 hectares with an average yield of 14.5 tons per hectare and a total production of 127,826 tons.

There are significant fluctuations in fruit production. Apples (45.3 % of total production, average for the period 2016-2021) and mandarins (29.1 %) dominate the fruit production structure. In 2020, self-sufficiency in fruit production was 44.7 % of the domestic market's needs. In 2021, a total of 129,500 tons of fruit were produced, which is 15.4 % less than in 2020.

Croatia does not produce enough olive oil for domestic consumption, and significant amounts of olive oil are imported. According to the latest available data for 2020, self-sufficiency in olive oil production was 43.2 %.

Croatia is not self-sufficient in sugar beet production, with a self-sufficiency rate of 88.4 % in 2020. In 2021, 707,000 tons of sugar beet were produced on an area of 10,066 hectares, with a yield of 70.2 tons per hectare.

In 2020, self-sufficiency in dried pulses was 36.3 %. The most common dried pulses are field peas (62.8 % of production in 2021) and beans (28.6 %).

In 2021, a total of 2,079,623 tons of fodder were produced on an area of 642,665 hectares, which is the lowest production in the observed period from 2016. Silage corn is the most prevalent feed crop.

The most common seed crops in production are winter wheat, soybeans, winter barley, and corn. The certified seed quantity has been continuously increasing in recent years, and in the 2021/2022 season, it was 9.5 % higher than the previous season.

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4.2.3. Fertilising products sectors

The total number of cattle in 2021 was 427,600, representing an increase of 1.1 % compared to the previous year. The Simmental breed is the most prevalent on Croatian farms, used for milk and meat production.

The total number of pigs in 2021, was 971,000, which represents a decrease of 6 % compared to the same date in 2020.

The total number of sheep in 2021 was 654,000, which was lower by 7,653 compared to 2020. However, the number of sheep is still higher than the five-year average from 2016 to 2020 (by 1.9 %). The same trend was observed in the goat population (85,800); despite a certain decrease compared to 2020 (by 475), it is still above the five-year average (by 7.2 %).

The total poultry population in 2021 was 12.1 million beaks, which represents a decrease of 7.4 % compared to 2020.

According to the data from the Ministry of Agriculture, in 2021, there was an increase in the number of ungulates by 3,804 animals or 12.5 % compared to 2020. The largest number of horses is found in the Sisak-Moslavina County (7,005 animals or 24.2 %).

In Croatia, in 2021, there were 8,949 beekeepers, with a total of 461,501 beehives. Compared to the previous year, there is an increase in the number of beekeepers by 4.8 % and the number of bee colonies by 4.08 %.

Croatia has been experiencing a growth in organic production year after year. In the period from 2016 to 2021, the organic farming area has increased by 28,330 hectares.

With regards to the fertilisers, Croatian fertiliser production is predicted to drop by 2 % each year, on average, from 2021 to 2026. In 2021, it was recorded at 247,820 metric tons, putting Croatia at 15th place in the world rankings. Croatia's fertiliser exports are forecasted to decrease by 2.7 % annually, from 130,020 metric tons in 2021. Since 2007, it has decreased by 1.8 % each year. In 2021, Croatia was at 21st place worldwide. Croatia's fertiliser imports are estimated to rise by an average of 2.5 % each year, from 42,940 metric tons in 2021. Since 2007, the demand for fertiliser in Croatia has decreased by 4.7 %. In 2021, Croatia was ranked 61st.

Advantages and disadvantages of organic fertilisers

Organic fertilisers have favourable effects on the chemical, biological, and physical properties of the soil. They promote an increase in the population of microorganisms (enhancing soil biogenic activity), enhance humification, and increase the humus content in the soil, making the soil more fertile. The release of biogenic elements occurs slowly in forms that plants can absorb, reducing the risk of excessive concentration of any element. Organic matter decomposition is carried out by microorganisms only under favourable conditions (temperature, moisture, pH, etc.). Organic fertilisers contain a smaller quantity of mineral elements, which varies widely depending on the type of organic manure, its age, and application method. This allows for balanced plant nutrition, and due to the low concentration

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of elements, they do not cause nutritional or osmotic stress. They have a long-lasting effect over several years as they prevent the leaching of biogenic elements. They moderately stimulate plant growth over an extended period. They also strengthen plant resistance to diseases and pests. Organic fertilisers are environmentally friendly because, after their decomposition or mineralisation, there are no significant amounts of harmful residues, they are not prone to leaching or losses through surface water movement during heavy rainfall and/or irrigation. They promote soil life from microorganisms (fungi and bacteria) to worms, which feed on organic matter and contribute to better soil aeration and drainage.

Organic fertilisers have certain disadvantages. Firstly, they release nutrients slowly, especially in colder conditions, which may not align with the time of greatest nutrient requirements for plants. Additionally, they can cause environmental pollution during mineralisation outside the growing season, particularly in the case of nitrogen. The release of biogenic elements in forms that plants can absorb depends on microbial activity, and under conditions of low biogenic activity or low microbial activity (high or low temperature, low moisture, unfavourable pH, low biogenic activity), the availability may be insufficient for higher yields. Organic fertilisers are more expensive than mineral fertilisers, considering their low concentration of active substances and the need for applying dozens of tons per hectare. The application is often challenging due to their form, which is loose and often heterogeneous, and pelletising significantly increases the cost of their application. Liquid forms of organic manure, such as liquid manure and slurry, need to be applied using special machinery.

Digestate is a nutrient-rich by-product from anaerobic digestion but can contribute to nutrient pollution without comprehensive management strategies. Digestate has significantly less odour, inactivity of viruses, bacteria and parasites if treated correctly, higher content of nitrogen and phosphorus (P). Soil digested with digestate is richer in oxygen that contributes to humus and increases soil fertility.

The application of digestate as fertiliser in agriculture is one of the simplest management solutions to avoid or minimise negative environmental impacts and improve the economic sustainability of biogas production.

The ecological advantages of digestate are manifested in reduced emissions of ammonia, greenhouse gases, reduced amount of waste and water consumption, and veterinary safety.

The practice of land application of digestate can improve the health of soils. Soil benefits can include:

- Increasing organic matter content.
- Reducing the need to apply chemical fertilisers and pesticides.
- Improving plant growth.
- Reducing soil erosion and nutrient runoff.
- Alleviating soil compaction, and.

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- Helping increase the soil's water retention ability, which reduces the need for irrigation.

The ecological advantages of digestate are also: reduced emission of ammonia and greenhouse gases, reduction of the appearance of unpleasant odours, reduction of the amount of waste and water consumption, and veterinary safety.

- Reduced emission of ammonia.

The concentration of ammonia, which increases during the digestion process, stimulates the emission of ammonia and during storage itself. Therefore, it is recommended that the space in which the digestate is stored, additionally protect it with foil or some other covering.

- Reduced greenhouse gas emissions.

During the production of mineral fertilisers, fossil fuels are used, and produce high levels of harmful CO_2. According to some estimates, the replacement of one ton of mineral fertiliser with digestate would bring savings of 1 ton of mineral oil, 108 tons of water and 7 tons of CO_2 emissions.

- Reduction of the appearance of unpleasant odours.

In contrast to the application of manure, which leaves an unpleasant smell behind, the application of digestate is based on the use of specialised machinery (pipes) that lay the digestate directly on the ground, which significantly reduces the risk of unpleasant odours.

- Reduction of the amount of waste.

One of the main advantages of AD is the utilisation of existing raw materials which would otherwise be considered as waste. Biogas plants are a good way to meet increasingly restrictive national and European regulations in the field of waste management and utilisation of organic waste for energy production. Biogas technology specifically contributes to reducing the volume of waste and disposal costs.

- Reduction of water consumption.

Compared to other biofuels, the production process of biogas consumes the least amount of water. This aspect is just as important as energy efficiency biogas due to the predicted water shortage in many parts of the world.

- Veterinary safety.

In relation to fresh untreated manure and slurry, anaerobic digestion ensures the veterinary safety of the product itself. The literature states that the sanitary treatment of digestate can be carried out on thermophilic digestion temperatures, pasteurisation or sterilisation under pressure depending on the type of raw material.

The value of manure is found in its nutrients, organic matter, solids, energy potential, and fibre. Manure contains nitrogen, phosphorus, and other nutrients that plants need to grow. Adding manure to soils is an excellent way to increase soil organic matter. Soil organic matter

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contributes to overall soil health – the soil's ability and sustainability to function as a living ecosystem. In addition to slowly releasing plant nutrients over time, organic matter improves soil structure and the soil's ability to hold water. Healthier soils improve crop yields and reduce soil loss from both wind and water erosion and protect water quality by reducing contaminated runoff.

When compared to more conventional fertiliser, manure properly applied to land has the potential to provide environmental benefits including:

- Increased soil carbon and reduced atmospheric carbon levels.
- Reduced soil erosion and runoff.
- Reduced nitrate leaching.
- Reduced energy demands for natural gas-intensive nitrogen fertilisers.

Manure contains most elements required for plant growth including N, P, K and micronutrients. However, it is manure's organic carbon that provides its potential environmental value. Organic carbon from manure provides the energy source for the active, healthy soil microbial environment that both stabilises nutrient sources and makes those nutrients available to crops. The ability of manure to maintain or build soil organic matter levels has a direct impact on enhancing the amount of carbon sequestration in cropped soils. Manure organic matter contributes to improved soil structure, resulting in improved water infiltration and greater water-holding capacity leading to decreased crop water stress, soil erosion, and increased nutrient retention.

Using good-quality compost to replace inorganic N P K fertilisers, as well as peat in growing media, has environmental benefits because the production of mineral fertilisers and the harvesting of peat are avoided. Bio-waste is of value for growing media because of its microbial diversity.

Bio-waste is a subcategory of biodegradable waste that consists of biodegradable garden waste and parks, food and kitchen waste from households, offices, restaurants, wholesale, canteens, catering facilities and similar waste from the production of food products. Biowaste is needed to be collected separately to lower the quantities of waste on junkyards and also to lower the greenhouse gas emissions, to protect the environment and to produce compost as a valuable component in agriculture.

4.2.4. Regulatory and institutional framework

EU regulations are binding legislative acts and must be applied in their entirety in all member countries and by themselves do not allow for different interpretations by member states which do exist within the activity area. Also, there are many directives whose goals must be achieved by every member state, but they themselves create the laws with which the given goals will be achieved.

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Some of the most important EU laws in the sector of anaerobic digestion (AD) and digestate processes are: Regulation (EU) 2019/1009 on establishing rules on making EU fertilising products available on the market, Regulation (EU) 1907/2006 on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and the establishment of the European Chemicals Agency and the Nitrates Directive.

In the Croatian legislative framework, the issue of fertilisers and soil improvers is regulated with different rules, strategies and regulations.

Laws related to digestate are:

- Law on fertilising products (NN 39/2023).
- Law on agricultural land (NN 57/22).
- Regulation on protection of agricultural land from pollution (NN 71/2019).

According to Regulation (EU) 2019/1009, digestate can no longer be treated as organic fertiliser and soil improver, meaning it is no longer considered a fertilising product. The criteria for organic soil improvers require a minimum of 20 % dry matter, while liquid digestate has a maximum of 6 % dry matter. It cannot be classified as organic fertiliser because it does not contain sufficient nutrients. If a solid organic fertiliser contains only one declared primary nutrient, the percentage of that nutrient must be at least 2.5 % of the total nitrogen, 2.0 % of the total phosphorus pentoxide, and 2.0 % of the total potassium oxide. If a solid fertiliser contains more than one declared primary nutrient (N, P, K), the sum of the percentages of those nutrients must be at least 4 %. According to the mentioned Regulation, the only place for digestate is to be used as a component in the preparation and production of specific fertilising products or as a component for creating organic soil improvers.

According to the Regulation on by-products and abolition of waste status, anaerobic digestate and anaerobic digestion are defined as:

- Anaerobic digestate: organic fertiliser and soil improver, produced by anaerobic digestion waste.
- Anaerobic digestion: a technological process of waste management which, by means of microorganisms, in anaerobic conditions, in a biogas reactor, processes and stabilises it biodegradable waste with biogas generation.

According to the Regulation on waste management:

- The amount of biodegradable municipal waste that goes into aerobic or anaerobic treatment can be counted as recycled if this processing produces compost, digestate or other output material with a similar amount of recycled content compared to the initial waste, which will be used as a recycled product, material or substance, and if the output material is used on land, it can be counted as recycled only if its use benefits agriculture or brings ecological benefits improvement.

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- Biowaste that is municipal waste and that goes into aerobic or anaerobic treatment can be counted as recycled only if it is collected separately from other waste or separated from another of waste at the place of waste generation.

According to the Law on agricultural land (57/22), the application of digestate on agricultural land that was obtained in a biogas plant in which waste is used except biowaste in accordance with the regulation on fertiliser products, is forbidden.

According to the Regulation on by-products and abolition of waste status (Appendix V), anaerobic digestate is intended for use in agriculture on land not used for food production and in a manner prescribed by a special regulation that governs fertiliser and soil improvers and their use in forests, respectively park land and for the needs of landscaping or recultivation of the land as well as for the creation of the final one recultivation layer of the landfill.

The biggest obstacle to the use of digestate as an organic fertiliser or soil improver in Croatian legislation (Regulation on by-products and disposal of waste status) comes from meeting the legal requirements. It states that digestate:

- Contains heavy metals and certain organic substances in an amount less than the value prescribed.
- Contains at least 15% by weight of organic matter in the dry matter of the anaerobic digestate.
- Does not contain more than 2 germinating plant seeds in a sample volume of 1 litre of anaerobic digestate.
- Does not contain Salmonella sp. in a sample of 25 g of dry matter.
- Contains a maximum of 1000 live bacteria (CFU) of Escherichia coli in a sample of 25 g of dry matter.
- Contains macroscopic admixtures of plastic, metal or glass larger than 2mm in an amount of less than 2% by weight of s.t. sample.
- Contains mineral particles larger than 5 mm in an amount less than 5% by weight of the dry matter of the sample.

According to III. Action program for the protection of water from pollution caused by nitrates of agricultural origin (NN 73/2021), manure is solid manure, slurry and manure as organic manure in a processed form, and compost is organic fertiliser and soil improver produced by controlled biooxidative decomposition of different mixtures composed primarily of different plant residues, sometimes mixed with organic fertilisers and/or animal residues, and contains limited amounts of mineral substances.

Also, in one calendar year, the agricultural holding can fertilise agricultural areas with manure up to the limit value of nitrogen application of 170 kg/ha of N. Manure is applied in such a way as to reduce nitrogen losses to the minimum possible extent. In order to reduce nitrogen losses, manure is applied as follows:

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- Fertilisation with manure is carried out in such a way as to prevent the evaporation of ammonia, while taking into account the stage of vegetation, time intervals of application, temperature and air humidity, and sunlight.
- On unsown areas, it is necessary to introduce manure into the soil as soon as possible.
- Manure should be distributed evenly over the soil surface.
- The slurry should be stirred before fertilising.

In order to reduce nitrogen losses through leaching and evaporation, the following is prohibited:

- Fertilisation with manure and slurry on all agricultural areas, regardless of the cover, in the period from December 15th to March 15th.
- Fertilising with manure and liquid manure by spreading it over the surface without introducing it into the soil on all agricultural areas in the period from May 1st to September 1st.

Table 26. Maximum allowed amount of manure application on the agricultural area

A type of manure	N	P_2O_5	K_2O	Limit values of nitrogen application (N)	The maximum allowed amount of manure according to the limit values	The amount of nutrients contained (kg)		
	(%)	(%)	(%)	(kg/ha)	(t/ha)	N	P_2O_5	K_2O
Cattle	0,5	0,3	0,5	170	34	170	102	170
Horse	0,6	0,3	0,6	170	28	170	85	170
Sheep	0,8	0,5	0,8	170	21	170	106	170
Pig	0,6	0,5	0,4	170	28	170	142	113
Poultry	1,5	1,3	0,5	170	11	170	147	57
Broiler	3,0	3,0	2,0	170	5.5	170	170	110
Cattle compost	2,1	2,2	0,8	170	8	170	180	65
Cattle slurry	0,4	0,2	0,5	170	42 m^3/ha	170	85	210
Pig slurry	0,5	0,4	0,3	170	34 m^3/ha	170	136	102

The management of bio-waste in Continental Croatia is governed by waste management regulations and guidelines. The Croatian government has implemented policies and regulations to promote the separate collection and appropriate treatment of bio-waste. These regulations aim to reduce the environmental impact of organic waste and promote resource efficiency.

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In the Waste Management Plan for the period from 2017 to 2022, the Republic of Croatia prescribed the dynamics of separate collection of municipal bio-waste on an annual level, according to which by 2022, 40% of the produced amount of bio-waste from municipal waste must be separately collected at the national level. In order to achieve the stated goal, the PGO of the Republic of Croatia also prescribed measures that include the development of quality criteria, methods of marking and quality control of compost and digestate, procurement of equipment and vehicles for separate collection of biowaste and construction and equipping of new ones, as well as increasing the capacity and improving the technology of existing ones plants for biological treatment of separately collected biowaste using aerobic or anaerobic procedures.

4.2.5. Bio-waste, animal manure and digestate treatment and processing

Bio-waste

Bio-waste treatment in Continental Croatia focuses on the management and proper disposal of organic waste materials, including food waste, agricultural residues, and green waste. There are several bio-waste treatment ways in the region.

Bio waste collection systems refer to the infrastructure and processes in place for the collection and disposal of organic waste materials. These systems are designed to separate and collect bio waste, such as food scraps, yard waste, and other biodegradable materials, from other types of waste streams. Bio waste collection systems typically involve the use of separate containers or bins specifically designated for organic waste. Once collected, the bio waste is transported to appropriate treatment facilities, such as composting sites or anaerobic digestion plants, where it can be processed and converted into useful products like compost or biogas.

Composting is a widely used method for bio-waste treatment in Continental Croatia. Organic waste, such as food scraps and garden waste, is collected and processed in composting facilities. Composting is a natural biological process that transforms bio waste into nutrient-rich compost, which can be used as a soil amendment or fertiliser. It enriches the soil with nutrients, improves soil structure, retains moisture, and promotes healthy plant growth.

Bio-waste anaerobic digestion is a process that involves the decomposition of organic waste materials, such as food waste, agricultural residues, and sewage sludge, in the absence of oxygen. It is carried out in specialised facilities called anaerobic digesters. Bio-waste anaerobic digestion offers multiple benefits, including waste reduction, renewable energy production, and nutrient recycling. It helps divert organic waste from landfills, reduces greenhouse gas emissions, and contributes to a more sustainable and circular approach to waste management.

Bio waste treatment plants are facilities designed to process and manage organic waste materials in an environmentally friendly manner. These plants utilise various methods, such as composting, anaerobic digestion, and biogas production, to treat bio waste and extract valuable resources from it. The primary goal of bio waste treatment plants is to reduce the

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environmental impact of organic waste and promote the sustainable management of these materials.

The treatment of bio-waste in the industry in continental Croatia involves various processes aimed at managing and utilising organic waste in an environmentally sustainable manner. Some practices for treating bio-waste in the industry are anaerobic digestion, composting, biomethanisation, mechanical-biological treatment (MBT), waste-to-energy facilities and nutrient recovery.

Anaerobic digestion is widely used in various industries as an effective and sustainable waste management and energy production solution. It is biological process in which microorganisms break down organic materials in the absence of oxygen, producing biogas as a by-product. Industrial-scale anaerobic digestion facilities are utilised in continental Croatia to treat bio-waste, particularly food waste and agricultural residues. The biogas generated can be used for electricity or heat production, reducing reliance on fossil fuels. Anaerobic digestion is utilised in agricultural operations to treat animal manure, crop residues, and other agricultural by-products. Farms with anaerobic digesters can process the waste generated from livestock and crop production, simultaneously reducing odour, pathogens, and greenhouse gas emissions, while producing biogas for on-site energy use or sale.

Composting is a common practice in various industries as a sustainable method of managing organic waste. Industrial-scale composting facilities are employed to process bio-waste from various sources, including food processing industries, restaurants, and municipal waste streams. The agricultural sector generates substantial amounts of organic waste, including crop residues, plant debris, and manure. Many farms and agricultural facilities utilise bio-waste composting to manage these waste materials effectively. On-farm composting systems or centralised composting facilities can process the agricultural waste, resulting in nutrient-rich compost that can be applied back to the fields, improving soil health and fertility.

Waste-to-energy facilities in the industry are specialised facilities that utilise bio-waste as a feedstock to generate energy. These facilities employ various technologies to convert organic waste into usable forms of energy, such as heat, electricity, or biofuels. Bio-waste, including food waste, agricultural residues, and other organic materials, is collected from various sources such as households, commercial establishments, and agricultural operations. The waste is then transported to the waste-to-energy facility for further processing. Upon arrival at the facility, the bio-waste undergoes sorting and pre-treatment. One common technology employed in bio-waste waste-to-energy facilities is anaerobic digestion. In this process, the organic waste is broken down by bacteria in an oxygen-free environment, resulting in the production of biogas. Biogas primarily consists of methane and carbon dioxide, which can be captured and utilised as a renewable energy source. The biogas produced during anaerobic digestion is often upgraded to remove impurities and increase its energy content. This process typically involves removing carbon dioxide and other trace gases from the biogas, resulting in a purified methane-rich gas known as biomethane. Biomethane can be used as a substitute for natural gas or as a transportation fuel. Some bio-waste waste-to-energy facilities utilise combustion

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or gasification technologies to convert organic waste into heat or electricity. After the bio-waste undergoes the energy conversion process, there may be residues left behind, such as ash or digestate. These residues are managed appropriately, often through treatment or beneficial reuse. Ash may be further processed and used as construction material or disposed of in a responsible manner. Digestate, the residual material from anaerobic digestion, can be used as a nutrient-rich fertiliser in agriculture or soil amendment.

Bio-waste nutrient recovery in the industry refers to the process of extracting and recovering valuable nutrients, such as nitrogen, phosphorus, and potassium (K), from bio-waste streams. Bio-waste, including food waste, agricultural residues, and other organic materials, is collected separately at the source to ensure minimal contamination and facilitate effective nutrient recovery.

According to the reported data, in 2021, a total of 1,101,925 tonnes of biodegradable municipal waste were produced, which is an increase of 3.9 % compared to 2020 when the quantity of generated biodegradable municipal waste amounted to 1,058,703 tonnes. The largest quantities of generated biodegradable municipal waste are recorded in the city of Zagreb.

Table 27. Quantities of generated biodegradable municipal waste by counties in 2021. (Continental Croatia)
Source: Report on municipal waste 2021. (Authors calculation)

County	Share of the county in the generated biodegradable waste (%)
Zagreb County	6.0
Krapina-Zagorje County	1.5
Varaždin County	2.9
Međimurje County	2.4
Sisak-Moslavina County	2.7
Brod-Posavina County	2.2
Osijek-Baranja County	5.1
Koprivničko-križevačka County	1.7
Bjelovar-Bilogora County	1.6
Virovitičko–Podravska County	1.4
Požeško-Slavonska County	1.0
Vukovarsko-Srijemska County	2.9
Karlovac County	2.3
City of Zagreb	20.3

The total amount of municipal biodegradable waste disposed of in landfills in 2021 amounted to 594,107 tonnes, which represents a negligible decrease compared to the previous year when

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596,013 tonnes were disposed of. The largest quantities were disposed of in the city of Zagreb (17.5%).

Table 28. Quantities of disposed biodegradable municipal waste in 2021 by counties in Continental Croatia Source: Report on municipal waste 2021. (Authors calculation)

County	Share of the county in disposed biodegradable municipal waste (%)
Zagreb County	4.9
Krapina-Zagorje County	1.9
Varaždin County	0.4
Međimurje County	1.6
Sisak-Moslavina County	3.4
Brod-Posavina County	3.0
Osijek-Baranja County	5.1
Koprivničko-križevačka County	2.4
Bjelovar-Bilogora County	2.7
Virovitičko–Podravska County	1.4
Požeško-Slavonska County	1.2
Vukovarsko-Srijemska County	5.5
Karlovac County	3.1
City of Zagreb	17.5

The total quantity of separately collected municipal bio-waste in 2021 amounted to 122,175 tonnes. Within the separately collected quantities of municipal bio-waste, 54% consists of biodegradable waste from gardens and parks, approximately 40% consists of biodegradable waste from kitchens and canteens, around 5% consists of waste edible oils and fats, and 1% consists of market waste.

In 2021, 10 composters received 88,227 tonnes of waste for composting. This represents a 20% increase compared to the previous year. Anaerobic digestion processed 17,295 tonnes of municipal waste in 11 biogas plants. This indicates a significant decrease of approximately 37% compared to the previous year when 27,356 tonnes of municipal waste were processed in biogas plants. The reason for this significant decrease is the high proportion of impurities in the separately collected municipal bio-waste, which resulted in the inability of biogas plants to process the received bio-waste. The biogas plants primarily processed biodegradable waste from kitchens and canteens.

Animal manure

The basic division of animal manure fertilisers is into solid, liquid, and semi-liquid forms, depending on the type of animal and bedding material (such as cow, horse, chicken, or sheep).

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Farmyard manure should be mature, meaning well decomposed, and should be aged for 8-10 months if used in protected spaces, or 6 months if used for cultivation in open fields. Organic matter provides CO_2, which is necessary for photosynthesis, as well as mineral nutrients. Farmyard manure contains all the essential plant nutrients. It also acts as a good regulator of soil physical properties and a source of numerous active microorganisms. It is a mixture of solid and liquid excreta from domestic animals and bedding material processed by microbial activity. The chemical composition varies considerably and depends on several factors, including the type and age of the domestic animal, the quantity and quality of feed, the management practices, the sex and age of the animal, the type and quantity of bedding material, the climate, and the storage method. The average composition of farmyard manure depends on the type of livestock, with the most important plant nutrients being nitrogen, phosphorus, and potassium, which are often deficient in the soil. The maturation time of farmyard manure depends on multiple factors, including climate, moisture content in the manure, storage method, and temperature. It takes about a year to obtain completely decomposed manure.

Animal manure treatment in Continental Croatia is an essential aspect of agricultural waste management and environmental protection. Proper treatment and utilisation of animal manure help prevent water and soil pollution, improve nutrient management, and promote sustainable agriculture. Farms in Continental Croatia typically have dedicated manure storage facilities. These facilities are designed to store animal manure temporarily, allowing for proper handling and treatment. Adequate manure storage helps prevent runoff and leaching of nutrients into water bodies, minimising the risk of water pollution. Animal manure is commonly used as a natural fertiliser in agricultural practices.

Before application, farmers calculate the appropriate amount of manure needed for crop nutrient requirements. This helps prevent over-application and potential nutrient imbalances in the soil. Manure is often spread on fields using specialised equipment, such as manure spreaders, to ensure distribution. Composting is an effective method for treating animal manure. Through the composting process, organic materials, including manure, are decomposed under controlled conditions. This process reduces odour, eliminates pathogens, and turns manure into a stable and nutrient-rich organic amendment. Composted manure can be used as a soil conditioner, enhancing soil structure and fertility. Anaerobic digestion is another option for treating animal manure. It involves the breakdown of organic matter in the absence of oxygen, producing biogas and digestate. Biogas, mainly composed of methane, can be utilised as a renewable energy source, while the digestate can be used as a nutrient-rich fertiliser.

The Croatian government promotes the development and implementation of nutrient management plans for farms. These plans aim to optimise nutrient use efficiency and minimise nutrient losses from animal manure.

The treatment of animal manure in the industry is focused on sustainable waste management, nutrient recovery, and minimising environmental impacts. These practices aim to protect water

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quality, reduce greenhouse gas emissions, and promote efficient utilisation of resources in agricultural systems.

Nutrient recovery technologies, such as separation systems and nutrient concentration processes, can be employed to extract and concentrate these nutrients from the manure. The recovered nutrients can then be used as fertilisers or sold for agricultural or industrial purposes. When using animal manure as a fertiliser, proper application techniques are important to maximise its benefits while minimising environmental impacts. This includes applying manure at appropriate rates and timing, following guidelines for soil conditions and crop nutrient requirements, and employing techniques to reduce runoff and nutrient loss, such as incorporation into the soil or precision application methods.

Digestate

Digestate is a high-value organic fertiliser obtained from manure, agricultural residues, and organic waste through the process of anaerobic digestion. During the anaerobic digestion (AD) process in biogas plants, the raw materials in the biogas reactor are decomposed into simpler particles under the influence of temperature and microorganisms. This mixture from the digester is transformed into digestate, a special type of homogenised processed material similar to manure, which appears in several fractions. The quantity and quality of nutrients in the digestate will largely depend on the raw materials used, the type of anaerobic digestion (temperature reaction thresholds - psychrophilic, mesophilic, thermophilic), and the type of post-treatment of the digestate. The chemical composition of digestate significantly depends on the type of raw material used in biogas production, as well as the type of anaerobic digestion employed. In practice, biogas plants using raw materials from agricultural production have an organic matter degradation rate of approximately 40 % for cattle manure and up to 65 % for pig slurry. Digestate can be found in three primary forms: undigested digestate (a mixture of liquid and solid fractions), liquid fraction of digestate (individual fraction), and solid fraction of digestate (individual fraction).

Some of the most common treatments of digestate will be further described. Through separation technology, the volume of digestate is reduced. It is important to note that previous research has indicated that most of the mineral nitrogen remains bound in the liquid fraction, while most of the organically bound nitrogen and phosphorus is found in the solid fraction of the digestate. Separation serves as a fundamental step in digestate treatment, and additional processing technologies are often applied depending on whether it is the liquid or solid fraction of the digestate. Composting is an aerobic process in which organic waste is degraded into compost. The final product generally has fewer weed seeds and a neutral odor compared to the initial raw material. Just as composting can be performed on organic waste, it can also be carried out on digestate. One of the treatment methods for digestate includes drying technology, which relies on high temperatures. A stream of hot air passes through the material, causing water evaporation and resulting in digestate with increased dry matter content (up to 80 %). Although membrane technology is commonly associated with wastewater treatment, it can also be used for processing the liquid fraction of digestate. Due to its delicate equipment

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with extremely fine pores, the dry matter content of the digestate should not exceed 3 %. The concept of membrane technology is based on separating the liquid digestate into a purified solution and a highly concentrated solution containing most of the nutrients previously present in the digestate. Evaporation technology requires a high consumption of thermal energy and is primarily of interest to larger biogas plants. The technology is typically applied through several processes, including heating the digestate and acidifying the material to prevent ammonia emissions.

Digestate can be utilised for energy production in addition to biogas generation during anaerobic digestion. The residual organic matter in the digestate may have sufficient energy content to be used as a fuel source in thermal or CHP systems. This can contribute to renewable energy production and reduce the reliance on fossil fuels.

Agronomic benefits of digestate are:

- High availability of plant-accessible nutrients.

The nutrients present in digestate are equivalent to those in the raw material, and they simultaneously have the positive characteristic of being in a form that is easily accessible to plants. This effect is particularly prominent in the case of nitrogen since, according to previous research, as much as 60-70 % of the nitrogen present in digestate is in the form of ammonia.

- Destruction of weed seeds and plant pathogens.

Thanks to the anaerobic digestion process, the ability of weed seeds to germinate is significantly reduced. In other words, the reduction in weed germination occurs spontaneously (without additional energy input) and has potential ecological benefits (potentially reducing the need for herbicides and fungicides).

- Sanitisation.

Numerous laboratory analyses have shown that higher amounts of pathogenic microorganisms, such as viruses, bacteria, and parasites, are present in manure and organic waste substrates. As these materials have direct or indirect contact with humans and animals, the European Commission (EC) has established a legal framework prioritising the safety and health of humans and animals.

- Improvement of soil physical structure.

Digestate produced through anaerobic digestion has a biological component that contributes to the formation of a microscopic biofilm, indirectly enhancing the soil's ability to retain moisture and reducing the risk of erosion and compaction.

Technological assessment

Anaerobic digestion is a biochemical process in which the complex organic matter (e.g., carbohydrates, fats, proteins) breaks down to of simpler compounds, i.e. to methane (CH_4) and carbon dioxide (CO_2).

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The final product of anaerobic digestion is biogas – a renewable source of energy that is used for the production of electricity and digestate – residue from biogas production which is used as fertiliser.

Considering the variety of substrates that are added to the plant, there are two basic ones type of digestion:

- Monodigestion (1 substrate - e.g., energy crops).
- Coodigestion (more than 2 substrates, e.g., manure and energy crops, manure and organic food waste industry, etc.).

Today, it is the most widespread type of digestion exactly codigestion, and the reason for that is variety of available raw materials and simpler management of microorganisms (the lack of certain microelements is avoided). The biogas production process takes place in 4 phases: hydrolysis, acidogenesis, acetogenesis and methanogenesis.

Successful biogas production is based on substrates with high biogas potential (BP). Anaerobic digestion can break down different types of plant and animal raw materials/substrate originating from agricultural production, food industry, municipal plants for the treatment of organic waste, plants for the treatment of wastewater.

Below is a description of the technology/patent of some of the alternative fertilising products:

The PHYSIO + patent contains an algae extract, aminopurine, which ensures the development of roots and root hairs which are first to absorb nutrients and water (P – 1 mm from the root). PHYSIO + stimulates and increases the radius of the roots for better tolerance to stressful conditions, such as drought, and the development of the vegetative part of the plant. PHYSIO + contains marine calcium which enables high efficiency of the product. PHYSIO + stimulates and helps the mineralisation of organic matter and better utilisation of nitrogen, with reduced losses and minimal impact on the environment. PHYSIO + increases the uptake of all elements especially those with reduced mobility (Ca, B).

The treatment of bio-waste in the industry in continental Croatia involves various processes aimed at managing and utilising organic waste in an environmentally sustainable manner. Some practices for treating bio-waste in the industry are anaerobic digestion, composting, biomethanation, mechanical-biological treatment (MBT), waste-to-energy facilities and nutrient recovery.

Composting biowaste in one's own garden is a waste prevention measure. A home composting site can be created in one's own garden or even on the balcony. Fruit and vegetable scraps, teabags, coffee grounds, leftover bread, as well as fallen leaves, twigs and other garden waste are suitable for composting.

Composting biowaste results in compost that is an excellent fertiliser for both garden and house plants. Compost helps plants grow, reduces the need for water, other fertilisers and pesticides, improves soil structure and nutrient content, allows to retain larger amounts of

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water, and protects fertile soil from pests and diseases as it supports a complex feeding network. When composting biowaste, an extremely small amount of methane is produced, unlike in landfills where the decomposition of biowaste occurs without sufficient air supply, thus producing methane, a strong greenhouse gas.

Biodegradable waste is composted with the aim of returning separately collected waste to the production cycle as fertiliser or soil improver. There are various composting technologies of different levels of complexity, from the simplest such as "composting in rows" without forced aeration (aeration takes place by regular turning of the material) to high-tech ones with forced aeration (blowing in air), with a working principle based on equalising the composition of waste and aerating it with the eventual need after adding water. The quality of compost directly depends on the quality and composition of separately collected waste, and it is necessary to collect clean food waste, garden waste and wood separately. The composting process begins when the material is homogenised and placed on a pile, when microbiological activity begins, which raises the temperature to 65-75 °C in a few days, after which it slowly decreases. Depending on the approach and applied technology, the compost is ready for use in 3-12 months. Stabilised compost is sifted while using the remaining part as a structural material for the further composting process, or it is disposed of at a non-hazardous waste disposal site if it has large amounts of impurities. It is a relatively economically accessible technology where the recovery of about 40-50% of the mass of the input material is achieved with the possibility of controlling the process and adjusting the composition of the input material. Composting is a successful method of processing separately collected biodegradable waste with the possibility of producing valuable raw materials while simultaneously avoiding the production of methane and leachate with high levels of biological pollution.

Biomethanation is a process similar to anaerobic digestion, but with a focus on methane production. Bio-waste can be treated in biomethanation plants to generate methane, which can be used for energy production or converted into other valuable products. Farms, livestock facilities, and agricultural processing plants generate organic waste, including crop residues, animal manure, and agricultural by-products. Biomethanation is commonly employed to treat these waste streams. Anaerobic digesters can convert the organic waste into biogas, which can be used for on-site energy production or injected into the natural gas grid. Additionally, the digestate produced as a by-product of the process can be used as a nutrient-rich fertiliser.

Mechanical-biological treatment (MBT) is a combination of mechanical and biological processes used to treat mixed waste, including bio-waste. It involves mechanical sorting to remove contaminants and recover recyclable materials, followed by biological treatment to decompose the organic fraction. The first step in MBT involves sorting and preparing the bio-waste for treatment. This may include the removal of non-biodegradable materials, such as plastics and metals, through mechanical processes like shredding, sieving, and screening. The waste is then homogenised to create a consistent feedstock for further treatment. After the waste is sorted and prepared, it undergoes biological treatment. This typically involves the use of microorganisms, such as bacteria and fungi, to break down the organic components of the

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waste. Biological processes like composting or fermentation may be employed to promote decomposition and stabilise the waste. In addition to biological processes, mechanical treatment techniques are utilised in MBT. This can include mechanical agitation, turning, or mixing of the waste to enhance the decomposition process and improve oxygenation. Mechanical processes also help in the separation of the final compost or digestate from any remaining contaminants. Composting is a common method employed in MBT for the treatment of bio-waste. Through controlled aerobic decomposition, organic waste is transformed into compost, which is a nutrient-rich soil amendment. Another option in MBT is anaerobic digestion, which involves the breakdown of organic waste by bacteria in the absence of oxygen. Anaerobic digestion can produce biogas, a valuable energy source, as well as digestate, which can be used as a fertiliser. The process helps in the reduction of organic waste volume and the generation of renewable energy. Once the mechanical and biological treatment processes are complete, the resulting compost or digestate undergoes further treatment to ensure quality and remove any remaining impurities or pathogens. The final product can then be used in various applications, such as agriculture, landscaping, soil improvement, or as a feedstock for energy production.

4.2.6. Initial stakeholders identified

Table 29. Initial key actors identified from the quadruple helix

Stakeholder	Sector	Entity
University	Academic sector	University of Zagreb, Faculty of Agriculture
		Križevci University of Applied Sciences
		Faculty of Agrobiotechnical Sciences Osijek
Non-governmental organisation (NGO)	Civil society	Renewable energy sources Croatia
Farmers	Private sector	Family farm Dario Cenger
		Family farm Marko Pejić
Business – SME	Private sector	ECODIG
		EkoAgro.club
		ConsultAre
		TIMAC AGRO
		VITA KEMIJA
		PRO-ECO

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4.3. Finland – South-West Finland

4.3.1. Socio-economic characterisation of the region

Finland lies between latitudes 60°N and 70°N, and is the sixth largest country in Europe, occupies an area of 338 312 km^2. Finland is bordered on the east and southeast by the Russian Federation, on the west by Sweden and the Gulf of Bothnia, on the north by Norway and on the south by the Gulf of Finland. Most of the country is low but not necessarily flat. Soil is very thin. Mainly moraine deposits from ice age glaciers, finer mineral soils, and organic soil types are common in Finland. One third of the fields contain clay soil types. The clay soils concentrate in Southwest Finland. The share of peatland in the arable land areas of Lapland, Northern Ostrobothnia and Kainuu is 20–40%. A quarter of arable land in Ostrobothnia and Southern Ostrobothnia consists of organic soil types.

Elevations greater than 640 meters are found along the northwestern frontier with Norway, and in the extreme northern region of Lapland. Most of Finland's 60,000 lakes, comprising 10% of the total area, lie in the southern half of the country. An extensive and imposing archipelago, reaching from the Russian border on the south, westward to the Aland Islands and there northward, provides an important fishing and vacation area. Another impressive physical feature and natural resource of Finland is its forests which cover 65% of the land area (the highest percentage in Europe). The forests of Finland are mainly coniferous; a limited area in the south and southwest contains hardwood deciduous trees. In Lapland, the spruce and pines disappear, and dwarf birch usually forms the timberline.

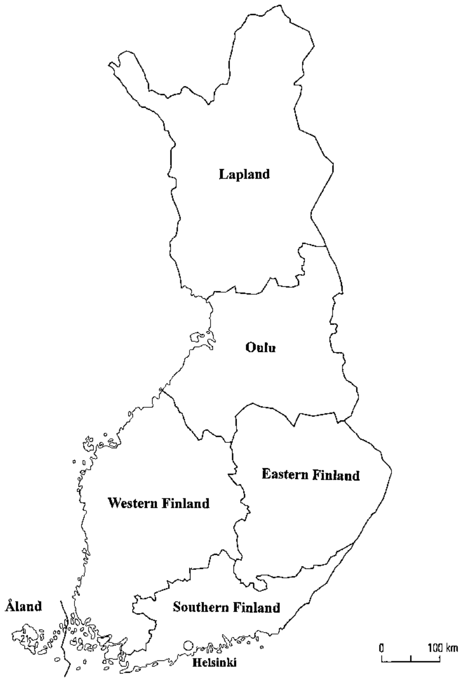

Figure 36. Finnish provinces

Climate

The mean annual temperature is about 5.5°C in southwestern Finland, decreasing towards the northeast. In summer the mean daily temperature is consistently above 10°C. The annual precipitation in southern and central Finland is between 600 and 700 mm. In northern Finland, where about half of the precipitation is snow, the annual precipitation is about 600 mm.

Population and economy

Population of Finland is 5.56 million (2022).

The gross domestic product (GDP) of Finland was 269 billion euros in 2022, an increase of around 18 billion euros compared with the previous year. GDP per capita amounted to 48 345 euros in 2022, which was the ninth highest in Europe. In 2022, GDP share of agriculture in Finland was 2.38%. The largest sector of the Finnish economy is services at 65 percent, followed

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by manufacturing and refining at 31 percent. Finland's main industrial products are paper and board, electronics and metal products. Engineering and high technology industries are the leading branches of manufacturing. On the expenditure side, household consumption is the main component of GDP and accounts for 55 percent of its total use, followed by government expenditure (25 percent) and gross fixed capital formation (20 percent). Exports of goods and services account for 38 percent of GDP while imports account for 39 percent, subtracting 1 percent of total GDP.

4.3.2. Agriculture

Finland is considered the most northerly agricultural country in the world. Finland's agriculture relies heavily on grassland and cereal varieties suited to the northern climate. The total area used for agriculture in Finland comes to about 2.3 million hectares. In recent years, cereal crops have accounted for just over 1 million hectares and grassland for some 0.7 million hectares. In 2021, approximately 14% of arable land area was used for organic production.

Grassland is well suited to our short northern growing season. The large proportion of grassland means that milk production is the most economically significant agricultural sector in Finland. Finland produces approximately 2.3 billion litres of milk each year. Finnish beef production is primarily based on dairy animals. Over the past ten years, beef production has stabilised at around 85 million kg per year, whereas the production of pork has decreased to about 170 million kg per year. Reflecting the general trend, the annual production of poultry meat has increased to 135 million kg. Sheep farming in Finland produces about 1.5 million kg of meat annually. Finland's reindeer husbandry areas in the north of the country produce slightly more meat, about 2 million kg annually.

Finland's most important cereal crops are barley and oats, followed by wheat and rye. The country's fields also grow oilseed crops, for instance, and special crops such as caraway, and sugar beet and potato.

In 2022, there were 44 000 farms in Finland, and nearly all of them were family run (Official Statistics of Finland, 2021). Farmers and their family members perform 80% of all agricultural work in Finland. Agriculture employs 76 000 people. Crop production was the main production activity on 70% of farms and livestock production on 21% of farms. The remainder are mixed farms with no clear main production direction.

According to the Eurostat, agricultural factor income per annual work unit (AWU) was 16 477 euros in December of 2021. The highest AWU reached was 26 399 euros in December of 2010. For crop and animal outputs, the production value at basic price was 2272.29 and 2573.59 million euros, respectively, in December of 2022, according to the Eurostat.

4.3.3. Fertilising products sectors

With regards to the fertilising products, a recent report on the need and potential for phosphorus recycling in Finland estimated the phosphorus demand for crop production on the

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country's 2.3 million hectares of arable land at just over 10 kg/ha (Lemola et al., 2023). Divided evenly according to need, the amount of manure phosphorus would cover 6,7 kg/ha, i.e., 65 % of the need. The need for phosphorus replenishment would be less than 4 kg/ha in the case of even distribution, but the volume of mineral fertiliser phosphorus sold in the last two decades has been around 5 kg/ha. When considering other recyclable biomasses in addition to manure, 90% of the needed phosphorus fertilisation could be covered by nutrient recycling.

Due to regional concentration of livestock production, high cost of manure transportation and subsequent high manure use as fertiliser, local and regional deficits and surpluses of manure phosphorus are significant. At the local (e.g., municipal) level, good cooperation between livestock and crop farms in manure application could meet the phosphorus demand in some regions. However, there are regions where even cooperation between neighbouring farms is not sufficient to solve phosphorus surplus and solutions for processing manure nutrients into concentrated and transportable fertiliser products are needed (Lemola et al., 2023).

4.3.4. Regulatory and institutional framework

This chapter is adapted from the report "D 1.2 Report on the legal framework governing the use of NRSS as BBFs Part B: National legislation" written in LEX4BIO project by Kratz et al. (2023). Report forms part of the deliverables from the LEX4BIO project. LEX4BIO has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 818309 and is coordinated by Natural Resources Institute Finland (Luke).

Fertiliser use of manure and organic fertiliser products is governed via national legislation enacting the EU Nitrates Directive (91/676/EEC) and the EU Fertilising Product Regulation (EU 2019/1009). The Government Decree on Limiting Certain Emissions from Agriculture (1250/2014), known as 'Nitrates Decree', aims to reduce nitrogen emissions caused by the storage and use of manure and other organic fertiliser products and the use of inorganic fertiliser products. In the Decree, the whole of Finland is defined as a nitrate vulnerable zone and thus it controls nitrogen fertilisation in all farms across the country. Legislation on phosphorus fertilisation was renewed in January 2023 when The Government Decree on Use of Phosphorus Containing Fertiliser Products and Manure (205/2022) was laid down under Fertiliser Act (711/2022). It is the first stricter regulation for phosphorus fertilisation in Finland. Previously, phosphorus fertilisation had only a maximum limit in legislation (325 kg/ha/5 yr period), but it did not include manure. Otherwise, limits were then based on a voluntary agri-environmental programme. The Fertiliser Act (711/2022), the Decree of the Ministry of Agriculture and Forestry on fertiliser products (24/2011) and the Decree of the Ministry of Agriculture and Forestry on Activities Concerning Fertiliser Products and Their Control (11/2012) regulate manufacturing fertiliser products, placing them on the market, and their use, transport, import and export, and control. A new Decree on fertiliser products is currently under preparation, which will regulate the quality requirements of fertiliser products, and will replace the previous Decrees on fertiliser products. Additional rules may also apply via the environmental permitting of animal farms and other related legislation.

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The following laws and regulations are related to the use of livestock manure, biowaste and digestates and are described here with respect to their key contents (please note that, where a paragraph (§) consists of several sections and reference is made to a particular section, the section number is given in brackets () following the number of the paragraph).

Fertiliser Act 711/2022 (13.7.2022)

The Fertiliser Act (711/2022) regulates manufacturing fertiliser products, placing them on the market, and their use, storage, transport, import and export, and providing information on fertiliser use for customers and end-users. The Act also regulates manure use in fertilisation. The objectives of the Act are:

- To promote the supply of safe and high-quality fertiliser products suitable for plant production.
- To ensure the safety of plant and food production, and environmental quality.
- To promote the utilisation of manure for fertilising.
- To promote the provision of adequate information on fertiliser products to the buyers and end-users.

Fertiliser products include fertilisers, liming materials, soil conditioners, substrates, microbial products and by-products used as fertiliser products (§4(1)). The Act is applicable to EU fertiliser products regulated in EU 2019/1009 (§4(2)). Fertiliser products must be safe, they must be suitable for the intended use and the requirements in EU Fertiliser Regulation and in this Act must be fulfilled. The products must not contain harmful substances, products, or organisms so that they could not cause any danger to human or animal health or safety, plant health or the environment, when used according to the instructions for use (§5(1-2)). In addition, raw materials must be safe and fulfil the quality requirements (§7).

When using fertiliser products or manure for phosphorus fertilisation, the amount of phosphorus must be equal to plant’s need and taking the soil phosphorus status into account (§6).

The Finnish Food Authority approves the list of ingredients used in fertiliser product. The origin, properties and production process of each ingredient must be verified (§8). The labelling requirements of the products and packaging are also regulated (§9, §11).

Operators are expected to have appropriate premises, facilities and implements for manufacture, storage and transport of fertiliser products and their raw materials (§13). Before an operator commences activity (manufacturing, importing in EU, technical processing or storing), the operations must be approved by the Finnish Food Authority (§14). A new approval must be applied if the operations are changed significantly (§14). A specific notification must be delivered beforehand to the Finnish Food Authority about new operations, essential changes, and termination of operations. This does not apply to the operators in wholesale or retail trade. The authority performs an inspection before the operations are started (§14). An

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operator must annually report the volumes of manufactured fertiliser products, their type designations and trade names, the used raw materials and their origin, the fertiliser products placed on the market, imported, and exported with their volumes and the purpose of use, if needed, to the Finnish Food Authority (§14). The operator is also obliged to keep records (§16) unless it works only in wholesale or retail trade. The manufacturer must conduct an in-house quality control plan (§17(1)). The plan shall cover techniques, processes and measures relating to manufacturing, quality control and quality assurance. In addition, the quality system shall cover inspections and tests carried out before, during manufacture and after manufacture, and their frequency of execution. The quality control plan shall be submitted to the Finnish Food Authority on request (§17(2)).

Decree of the Ministry of Agriculture and Forestry on Activities Concerning Fertiliser Products and Their Control (11/2012, last amended 3.11.2015, new decree in preparation)

The decree gives further provisions in more detail to operators, for example, on the obligation to notify, keep records, conduct in-house control, laboratory approval, internal trade, import of fertiliser products and approval of establishments. It also lays down the provisions on organising the control related to fertiliser products.

Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011, last amendment 8.2.2016, new decree in preparation)

The Decree regulates the types of national fertiliser products, type designation groups and their requirements, and the quality, marking, packaging, transport, storage, use and other requirements related to fertiliser products and their raw materials (§1(1)).

National types of fertiliser products and type designation groups together with their more thorough descriptions and requirements are listed here.

Concerning harmful contaminants, the Decree regulates as follows:

Cadmium (Cd) (§5a):

- A fertiliser product may not contain Cd more than 1.5 mg kg^{-1} in dry matter.
- Ash fertilisers (type designation group 1A7), when used in agriculture, horticulture, green areas and landscaping, may not contain Cd more than 2.5 mg kg^{-1} in dry matter. If an ash fertiliser is used in forests, the maximum content of Cd is 25 mg kg^{-1} dry matter. Raw materials used in the production of ash fertilisers are similarly treated..
- With the minimum phosphorus (P) content of 2.2% (5% as P_2O_5), a fertiliser may not contain more than 50 mg Cd kg^{-1} P (22 mg of Cd kg^{-1} P_2O_5).
- The average maximum Cd load may not exceed 1.5 g Cd ha^{-1} yr^{-1}. The maximum Cd load as used batches during the periods of use can be:
    - In agriculture and horticulture at the maximum of 7.5 g ha^{-1} 5 yr^{-1}.
    - In landscaping and green areas at the maximum of 15 g ha^{-1} 10 yr^{-1}; this does not apply to soil improvers and growing medias.

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- In forestry use ash fertilisers (type designation group 1A7) at the maximum of 100 g ha^{-1} 60 yr^{-1}.

Arsenic (As) (§5b):

- A fertiliser product may not contain As more than 25 mg kg^{-1} in dry matter.
- If an ash fertiliser (type designation group 1A7) is used in forest fertilisation, the maximum content of As is 40 mg kg^{-1} in dry matter. The same applies to the raw materials used in ash fertilisers.
- The average maximum As load from the use of ash fertilisers (type designation 1A7) in forestry may not exceed 2.65 g As ha^{-1} yr^{-1} and 160 g ha^{-1} 60 yr^{-1}.

Selenium (Se) (§6):

- Se can be added as selenate at 15 mg kg^{-1} in dry matter to some fertilisers when permitted in type designation. The maximum amount allowed is 20 mg kg^{-1} in dry matter in a solid fertiliser (not allowed to add on the surface of fertiliser grain).
- To fertilisers sold to livestock farms or farms receiving manure, Se can be added as selenate at 25 mg kg^{-1} in dry matter similarly as described above. The maximum content of Se in a fertiliser can be 30 mg kg^{-1} in dry matter. The aim of Se addition is supplementary fertilisation of grass or cereals for a recognised need when fertilising mainly with manure.

In addition, Annex IV of the Decree regulates other harmful substances, organisms and contaminants in fertiliser products. These requirements apply to all fertiliser products (unless otherwise stated). However, the requirements do not apply to soil improvers, growing media or other fertiliser products utilised in landfill sites or other closed areas or to by-products utilised as such. The maximum allowable harmful metal contents, maximum allowable amounts of pathogenic or disease indicator micro-organisms and impurities are shown below.

Table 30. Threshold values for harmful metals in fertiliser products

Harmful metal	Maximum content (mg kg^{-1} of dry matter)	Maximum content (mg kg^{-1} of dry matter) in ash fertilisers or in ash used as their raw material to be used in forestry
As	25	40
Hg	1.0	1.0
Cd	1.5[1]	25
Cr	300[2]	300

[1] For ash fertilisers or ash used as their raw material to be used in agriculture and horticulture, construction of green areas and landscaping the limit is 2.5 mg Cd kg^{-1} of dry matter.

[2] For steel slag (type designation 2A2/3, a by-product used as a liming material as such) the limit is 2.0 mg soluble Cr^{6+} kg^{-1} of dry matter.

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Cu	600[3]	700
Pb	100	150
Ni	100	150
Zn	1500[3]	4500[3]

Table 31. Threshold values for pathogens and indicator organisms in fertiliser products

Pathogen/Indicator	Limit
Salmonella	Not found in a sample of 25 g
E. Coli	Under 1000 CFU g^{-1} and under 100 CFU g^{-1} in growing media for commercial greenhouse production of plants in which edible plant parts are in direct contact with the growing media.
Root rot fungus (for instance, *Fusarium*; found using a culture test)	Not found in growing media used in seedling production.

Table 32. Special requirements for plant-derived fertiliser products or accompanying topsoil fractions. In addition, pests that are referred in the Act on the Protection of Plant Health (702/2003) or under it may not be present in a fertiliser product

Pest	Limit
Golden nematode (*Globodera rostochiensis)* Pale cyst nematode (*Globodera pallida*) Potato ring rot (*Clavibacter michicanensis*) Potato brown rot (*Ralstonia solanacearum*) Potato wart disease (*Synchytrium endobioticum*) Beet necrotic yellow vein virus "Rhitzomania" Root-knot nematodes (*Meloidogyne spp.)*	Not found in a fertiliser product manufactured from root vegetable, beet and potato raw material or from accompanying topsoil fractions.
Other quarantine pests causing plant diseases	Not found in fertiliser products manufactured from plant waste or growing media from greenhouse production

In the Annex IV of the Decree are also some requirements for the treatment of plant material. By-products and waste from potato, root plant and beet industry and barking and packaging plants, and separately collected biowaste need to be treated either by 1) composting (min temperature 55 °C and moisture 40% for at least two weeks), or 2) heat treating in moist at 70°C for one hour (particle size under 12 mm), or 3) using another method that is approved by the plant protection authority. However, these treatment requirements are not required, if the above-mentioned plant materials originate from a raw material from production sites where pests listed have not been found within no more than 5 years before the production of raw

[3] The limit might be exceeded if there is Cu or Zn shortage based on soil analysis. In forestry, exceeding is allowed only when using Zn in peatland forest in the case of shortage based on soil/leaf/needle analysis. In that case, the limit is 6000 mg Zn kg^{-1} of dry matter.

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material or if pests have not been found in laboratory analyses from raw materials before their use.

Table 33. Limits for impurities in fertiliser products.

Impurity	Limit
Weed seeds • In fertilisers and liming materials • In packaged soil improvers and growing media In soil improvers and growing media sold in bulk	Not found 2 germinated in a litre 5 germinated in a litre or there need to be a description: "product contains weed seeds spread by wind"
Refuse (glass, metal, plastics, bones, rocks) • In packaged products Sold in bulk	0.2% of fresh weight 0.5% of fresh weight
Wild oat	Not found
Parts of plants	No live roots, rootstock or any other parts relating to vegetative propagation

Government Decree on Limiting Certain Emissions from Agriculture and Horticulture (1250/2014, last amendment 15.10.2015)

This Decree implements the Nitrates Directive (91/676/EEC), and it applies to both manure and all fertiliser products (except liming products) specified in the Fertiliser Product Act (539/2006). It also applies to processed or non-processed by-products in farms that are utilised as fertilisers. The entire area of Finland is defined as a nitrate vulnerable zone.

It regulates:

- Placement of storages for manure and organic fertiliser products, exercise areas, and feeding and watering points (§4).
- Manure storage (§5&8) and their minimum capacities (Annex 1 of the Decree).
- Storage of unpackaged organic fertiliser products (§6).
- Constructional requirements (including e.g., storages, composting, permanent feeding points, exercise areas) (§7).
- Fertiliser use (described later) (§10).
- Amount of N fertiliser (described later) (§11).
- Determination of manure nutrient content (§12).
    - Manure must be analysed every 5 years for soluble N, total N and total P.
    - A farmer may choose to use manure analysis result or table values (Annex 2 of the Decree) as basis of fertilisation planning.

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- Buffer zones (§10).

The Decree contains general provisions for fertiliser use in §10: Nutrient runoff into water bodies and risk for subsoil compaction must be prevented in fertiliser spreading. Fertilisers should not be applied on snow-covered, frozen, or water-saturated soil. In addition, the average crop yield, cultivation zone, crop rotation and soil type should be considered. Spreading manure and organic fertiliser products is forbidden between November 1 and March 31. However, deviation is possible until November 30 if exceptional weather conditions have prevented manure spread during growing season. After surface spreading incorporation must be done within 24 hours. On fields with vegetative cover overwinter, manure and organic fertiliser products must be injected below soil surface from September 15 onwards, except in the case of manure application in preparation for autumn sowing. Application of manure and organic fertiliser products is forbidden in plot areas where slope exceeds 15%.

The limit for total N is 170 kg ha^{-1} yr^{-1}, when using farm animal manure and organic fertiliser products (§11(1)). The Decree also regulates on the annual maximum amount of soluble N (kg ha^{-1}) for various crops in mineral and organic soil (§11(2)). If soluble N exceeds 150 kg ha^{-1}, N amount needs to be split into at least two applications at least two weeks in between. After September 1, the amount of soluble N in manure and organic fertiliser products spread may not exceed 35 kg ha^{-1} (§11(3-4)). Regarding manure, fertilisation can be planned either based on manure nutrient analysis or manure nutrient "table (standard) values" that are listed in the Decree's Annex 2 (§12(1)).

Government Decree on Use of Phosphorus Containing Fertiliser Products and Manure (64/2023, adopted 12.1.2023)

Government Decree on Use of Phosphorus Containing Fertiliser Products and Manure (64/2023) laid down under Fertiliser Act (711/2022), is the first stricter regulation for phosphorus fertilisation in Finland. Earlier, phosphorus fertilisation had only a maximum limit in legislation (325 kg/ha/5 yr period), but it did not include manure. Otherwise, the limits have been based on a voluntary agri-environmental support scheme. The Decree regulates the use of phosphorus fertilisation in agriculture, horticulture, green areas, and landscaping.

Fertilisation limits are calculated based on total phosphorus content in manure and fertiliser products with the exceptions; 60% of the total phosphorus in sewage sludge is considered, and 40% of total phosphorus in ash and biochar is taken into account (§3). The specific needs and yield of the crop and the phosphorus status of the soil should be taken into account when applying phosphorus fertilisers. (§4). Maximum level for phosphorus fertilisation is given by crop and soil phosphorus status in the Annex 1 of the Decree. Soil phosphorus status categories are given by soil type and soil organic matter content in the Annex 2 of the Decree. For green areas and landscaping, higher levels of phosphorus fertilisation (given in §10) can be applied.

To promote phosphorus recycling (and manure processing), a maximum of 5 kilograms of phosphorus per hectare can be given where (1) otherwise the fertilisation would be prohibited by high soil phosphorus status (2) phosphorus is derived from the phosphorus separation of

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manure or digestate; and (3) the ratio of total nitrogen to total phosphorus in the fraction generated by the phosphorus separation of manure or digestate is not less than 10 (§5).

Act on organic production

New national Act on Organic Production is in the process of being adopted and serves to implement the European Regulation No 848/2018, which will enter into force on January 1, 2022. The Finnish Food Authority is preparing new guidelines for control and enforcement of organic production. The control will be developed towards electronic inspection methods. Current legislation is based on Regulation (EC) No 834/2007 and consists of Act on Inspection in Organic Production (294/2015) and the Decree on Organic Production (454/2015).

Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011, last amendment 1.9.2011)

In Finland, there are no specific regulations for biowaste treatment in fertiliser use except what is stated in the Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011). The limits for harmful metals, pathogens and indicator organisms and impurities in biowaste-based fertiliser products are same as listed in Tables 3, 4 and 5, as are the issues related to Cd (§5a) and As (§5b). There are no limits for organic contaminants.

In the Annex IV of the Decree (24/2011) are some requirements for the treatment of plant materials. By-products and waste from potato, root plant and beet industry and barking and packaging plants, and separately collected biowaste need to be treated either by 1) composting (min temperature 55°C and moisture 40% for at least two weeks), or 2) heat treating in moist at 70°C for one hour (particle size under 12 mm), or 3) using another method that is approved by the plant protection authority. However, these are not required, if above mentioned plant materials originate from raw material from production sites where pests listed in Table 5 have not been found within no more than 5 years before the production of the raw material or if pests have not been found in laboratory analyses from the raw materials before their use.

Animal by-products: Animal By-Product Act (517/2015, last amendment 18.6.2021) and the Decree of the Ministry of Agriculture and Forestry on animal by-products (783/2015)

Regulation (EC) No 1069/2009 of the European Parliament and Council with its complementary Regulation (EU) No 142/2011 of the European Commission set rules for handling animal by-products and derived products, to prevent and minimise risks to public and animal health arising from those products, and in particular to protect the safety of the food and feed chain. In Finland, the Animal By-Product Act (517/2015) and the Decree of the Ministry of Agriculture and Forestry on animal by-products (783/2015) facilitate the implementation of EU animal by-product regulations regarding the use and disposal of animal by-products and animal-derived products. Some national privileges are given in the Act and Decree. The Act also regulates the supervisory authorities and their functions.

End-of-waste status for particular materials/products

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By the moment, there are no criteria for end-of-waste status of organic materials except by a discretionary evaluation of the authority on a case-by-case decision. Preparations have been started to the future end-of-waste-related regulation on organic materials.

Environmental Protection Act (527/2014) and Environmental Protection Decree (713/2014, last amendment 1.12.2021)

Environmental Protection Act (527/2014) and Environmental Protection Decree (713/2014) apply to all operations that may cause environmental pollution. The act is the foundation of an integrated system for environmental permits and for a pre-approval procedure for operators. The permitting system applies also for intensive farming. Granting a permit is subject to the condition that the operations do not cause harm to health or significant environmental pollution or a risk of such pollution. Environmental permits contain regulations on emissions and their reduction, waste, and waste management, and preventing air, soil, surface water, and groundwater contamination. One important condition for permits is that emissions are limited to the levels obtainable by using Best Available Techniques (BAT). In the decision, due to the local circumstances, stricter provisions can be given than those provided in legislation. Applications for permissions are processed by either the Regional State Administrative Agencies or the local municipal authority depending on the level of activity. The Finnish Food Authority keeps a record of fertiliser product manufacturers to be listed in EU's NANDO database.

Supervision is mainly targeted to operations that involve the greatest risk of causing environmental pollution. Supervision is implemented through planned inspections, by monitoring the load on and the state of the environment, and by carrying out inspections in the event of an accident, harm, or violation.

Government Decree on Water Resources Management (1040/2006, last amendment 1.12.2020)

This Decree serves to implement EU's Water Framework Directive (2000/60/EC) and has a broader approach at reducing diffuse water pollution from agricultural sources. Implementation has been planned and executed in cooperation with national and regional stakeholders. Authorities must consider given water quality targets when environmental permitting process is considered, and for example, manure and phosphorus fertiliser spreading on fields with high soil phosphorus status can be restricted.

Act on Environmental Impact Assessment Procedure (252/2017) and Decree on Environmental Impact Assessment Procedure (277/2017, last amended 1.10.2021)

The Act implements the EU Directive 2014/52/EU and gives regulations on the environmental impact assessment procedure (EIA). EIA is required for activities including, different uses of natural resources, activities affecting water bodies, chemical industry, and energy production. EIA can be required for projects which are not listed in the concerned activities for EIA but have significant impacts based on their context or intensity. EIA legislation includes an assessment of the indirect and cumulative impacts, as well as interactions of several projects.

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National Energy and Climate Strategy for 2030 and Climate Act (423/2022)

The Finnish Government Programme of prime minister Sanna Marin has set the target of Finland being carbon-neutral in 2035 and carbon-negative soon after that. The aim of the Climate Act (423/2022) is to reduce greenhouse gas emissions by at least 60% by 2030 and 80% to 2040 from the level in 1990. The Climate and Energy Strategy is currently under modification and Medium-term Climate Policy Plan was updated in summer 2022.

Common Agricultural Policy in the national law

In new programme period of EU Common Agricultural Policy (CAP) 2023-2027 national actions regarding to fertilisation are proposed to promote circular economy in agriculture.

The proposed agri-environmental agreement commits farmers to perform certain fertilisation practices promoting soil productivity, carbon sequestration, water and air protection, nutrient recycling, and increase of soil organic matter content. The practices are (a) injection or incorporation of slurry manure, urine, liquid fraction of separated slurry manure or liquid bio-based fertiliser or (b) application of organic material (dry matter >20%) on fields that has origin outside of the farm. Organic material means bio-based fertilisers or soil improvers or their mixtures, solid manure or dry fraction of separated manure from another farm. The minimum amount for injected or incorporated slurry or liquid fertiliser on a field is 15 m^3/ha and for organic material (dry matter >20%) 10 m^3/ha. For more concentrated fraction of manure or fertiliser product with high nutrient content, the minimum amount of application is 5 m^3/ha. However, the application amount can be lower if the maximum allowance of nitrogen or phosphorus fertilisation on the parcel will be achieved.

The Decree of Cross-Compliance Standards on Good Agricultural and Environmental State (4/2015, last amendment 22.12.2020)

The Decree serves the implementation of Regulation (EU) No 1306/2013 of the European Parliament and of the Council on the financing, management and monitoring of the common agricultural policy. The cross-compliance standards give the basic requirements to be followed to obtain agricultural subsidies. Regarding fertilisation, organic fertiliser products are not specified distinct from manure. The other requirements are related to public health, animal and plant health, and environmental issues.

4.3.5. Livestock manure, biowaste and digestate treatment and processing

Livestock manure and municipal bio-waste

In total, 13 million tonnes of manure are produced from livestock production in Finland. Livestock and fur animals generate over 73 million kg of nitrogen and 15 million kg of phosphorus yearly. There are large regional differences in manure production due to the high concentration of livestock production in western and southwestern Finland. Biowaste from municipalities yields 484 000 tonnes per year containing 3 000 tonnes of nitrogen and 550

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tonnes of phosphorus. Regional differences in population are reflected in the quantity of municipal biowaste.

Table 34. Production (amounts, organic matter, nitrogen and phosphorus contents) of livestock manure and municipal biowaste in Finland
Source: Lemola et al., 2023

	Amount (t/a)	Organic matter	N (t/a)	P (t/a)
Total livestock manure	***12 960 000***	***1 815 000***	***73 400***	***15 150***
Horse and pony manure	644 000	192 000	2 700	500
Sheep and goat manure	110 000	22 000	800	150
Poultry manure	242 000	109 000	5 700	2 300
Cattle manure	9 752 000	1 318 000	51 000	8 600
Pig manure	2 1000 000	146 000	9 900	2 100
Fur animal manure	112 000	28 000	3 300	1 500
Municipal biowaste	***484 000***	***123 000***	***3 000***	***550***
Total	**13 444 000**	**1 938 000**	**76 400**	**15 700**

Of livestock manure, up to 98% of the total amount is utilised in agriculture (Luostarinen et al., manuscript). However, only 7.2% of manure is processed, which means that most manure is used in agriculture directly without processing. Manure is mainly processed by composting or anaerobic digestion, with a small proportion mechanically separated, thermally dried, or treated in other ways. Most of the processed manure is also utilised in agriculture, but about 30% of it ends up in other uses, mostly horticulture and landscaping.

For municipal biowaste, over 95% is processed (Luostarinen et al., manuscript). Processing is usually a legal requirement to ensure the safe use of end products. Approximately 60% of biowaste is digested in biogas plants, the rest is composted. Half of the processed biowaste ends up in agriculture and half is reused in landscaping and horticulture.

Digestate

In Finland, digestates are currently produced in around 130 biogas plants, including urban and industrial wastewater treatment plants, co-processing plants of various sizes and farm-scale biogas plants. The biogas production was 1 TWh in 2021. An estimation of digestate amounts produced from different biomass origins are shown in the following table, that excludes farm-scale biogas plants, which do not sell the digestate on markets, but use it as a fertiliser for their own fields.

Table 35. Estimation of digestates produced from different origins of biomass and the share of their use in agriculture in Finland
Source: Luostarinen et al., 2023

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Digestate	Amount (t/a)	% utilised in agriculture
Digested livestock manure	311 000	100
Digested municipal biowaste	214 000	70
Digested sewage sludge	302 400 (total solids 25%)	46
Digested residues from food industry	42 500	100
Total	**869 900**	**33**

All the digested manure and residues from the food industry are estimated to be utilised in agriculture. Digested biowaste and sewage sludge are also largely used as soil improvers and fertilisers in agriculture, but there are some legal restrictions. Digested sewage sludge can be used on fields where crops such as cereals, sugar beet, oilseeds or other crops are grown that are not eaten fresh, as a subsoil crop or as animal feed. Slurry can be applied to grassland by establishing the grassland with cover crops.

4.3.6. Initial stakeholders identified

Table 36. Initial key actors identified from the quadruple helix

Stakeholder	Sector	Entity
Governmental body	Authority	Finnish Ministry of Agriculture and Forestry
		Finnish Ministry of Environment
Association	Private sector	Central Union of Agricultural Producers and Forest Owners
Advisory services	Private sector	ProAgria
Fertilisers producers	Private sector	Yara
		Biolan

Key actors identified during the proposal preparation were Finnish Ministry of Agriculture and Forestry, Ministry of the Environment, The Central Union of Agricultural Producers and Forest Owners, advisory services (e.g., ProAgria), fertiliser producers (e.g., YARA and Biolan) and farmers. These actors are relevant in regulating the use of recycled fertilisers, advancing the use of recycled fertilisers among farmers and producing fertilisers from nutrient-rich side-streams. Finally, farmers are the key actors in deciding the use of recycled fertilisers. All these actors have been commonly involved in discussions when preparing new periods for Agri-Environment Schemes. These discussions have commonly included e.g. the fertiliser recommendations (N, P) for different crops and share of P of the total phosphorus in recycled fertilisers that is considered to be available for crops.

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4.4. Ireland – East Ireland

4.4.1. Socio-economic characterisation of the region

Ireland is an island situated in North-western Europe. It is surrounded by the Atlantic Ocean, with the Celtic Sea to the South, the St. George's Channel to the Southeast, and the Irish Sea to the East. Ireland has a temperate maritime climate, characterised by mild winters and cool summers.

Climate

The country experiences frequent rainfall throughout the year averaging 1 230 mm per annum, with the western coastal regions receiving higher amounts. The average annual temperature ranges from 9 degree Celsius in winter to 19 degrees Celsius in the summer. Ireland has a diverse landscape that includes low-lying coastal plains, mountains, and lakes.

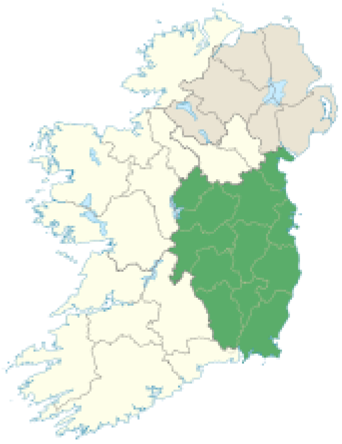

Figure 37. Leinster province of Ireland, where Wicklow / Carlow / Wexford are located

Economy

The current population of Ireland is 5 097 599. Ireland has a developed and modern economy, which has undergone significant growth in recent decades. The country has a strong focus on industries such as pharmaceuticals, technology, financial services, and tourism. The agri-food sector is a hugely valuable part of the economy, and is a key contributor to economic growth. Agriculture in Ireland is responsible for 7.1% of the total workforce on the island. Ireland exports the majority of what we produce to 180 countries around the world.

4.4.2. Agriculture

Irish agriculture is dominated by family-owned farms. There are 140,000 farms, with an average land holding of 32.5 hectares. The Irish climate is capable of growing grass for 9 to 10 months of the year. As a result, the dominant enterprise in Ireland is dairy and beef accounting for two-thirds of gross agricultural output. Ireland is currently one of the fastest-growing dairy producers and exporters in the world. In 2022, there was 1.7 million tonnes of dairy product shipped to 130 markets worldwide. Other than grass, crops such as wheat, barley and oats are also grown in Ireland.

4.4.3. Fertilising products sectors

Ireland is heavily dependent on importing inorganic fertiliser for food production importing over 1.8 million tonnes of fertiliser annually. Ireland imports chemical fertiliser primarily from Russia, United Kingdom, Germany, Spain and Morocco. Ireland is making efforts to reduce

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reliance on chemical fertilisers and explore alternative nutrient sources in agriculture. Irish stakeholders are promoting alternative farming practices which prioritises the use of biological alternative fertilisers such as compost, animal manure, crop residues, food waste, incorporating legume crops such as clover and beans to fix nitrogen. Nutrient management planning is also a key tool being used in Irish agriculture which helps optimise the use of nutrient sources and limit the loss of nutrients to the environment, which involves analysing soil nutrient levels, crop nutrient requirements and using precision application techniques such as low emission slurry spreading.

Bio-waste and biological by-products

Bio-waste and agricultural by products have potential in Ireland to supply nutrients for crop production which will reduce dependence on chemical fertiliser. Therefore, feedstock availability for the use as alternative fertilisers is essential. Approximately 132 million tonnes of agricultural slurries, wastewaters, effluent, and sludge are generated in Ireland on an annual basis. The table below represents estimated annual feedstock availability for agricultural biological by products and other primary sectors in Ireland.

Table 37. Estimated annual tonnes of bio-waste & biological by products produced in Ireland

Feedstock	Annual production (tonnes)
Grass (residual grass)	1,900,000
Straw residues	1,100,791
Mushroom residues	171,390
Cattle co-products and offal	280,000
Dairy cow manure	18,310,513
Pig manure	1,874,200
Poultry litter	250,000
Rapeseed oil	<30,000
Marine discard	72,000
Seaweed	40,000 (harvested only)
Fish processing waste	15,000
Household food waste	250,000
Forestry residues	736,896

There is no single, comprehensive source of data on the capacity and throughput of the organic waste treatment infrastructure in Ireland. Figures displayed here from annual environmental reports for plants, waste collector waste permit returns data and personnel communication with plant managers to quantify the total tonnage, in particular the quantity of bio-waste.

There are approximately 140,686 tonnes of bio-waste processed in the republic of Ireland and 280,496 tonnes processed in Northern Ireland on annual basis. The number of licensed plants

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controlling bio-waste in Ireland is 8 and 5 in Northern Ireland. The total quantity of waste accepted for treatment at composting and anaerobic digestion plants in Ireland in 2020 was 601,482 tonnes and 733,881 tonnes in Northern Ireland. This excludes non licenced on-farm AD plants. The predominant flow between the two jurisdictions is from Ireland to Northern Ireland with 121,289 tonnes of organic waste exported from Ireland to Northern Ireland in 2020 compared to 28,109 tonnes imported from Northern Ireland to Ireland. Most exports from Ireland to Northern Ireland is bio-waste. The EPA estimates that Ireland generates 1 million tonnes of food waste. Of this, 553,000 tonnes were household/commercial food waste and 500,000 tonnes in the food processing and manufacturing sector.

4.4.4. Regulatory and institutional framework

DAFM is the main governmental body responsible for regulating the agricultural sector in Ireland including fertilisers. The department oversees the implementation and enforcement of the regulatory framework and collaborates with other relevant agencies such as the EPA. The EPA's main focus is on environmental protection mainly water quality, it also plays a role in assessing the potential environmental impacts of fertiliser use that the use of fertilisers do not lead to negative effects on the environment. The Health and Safety Authority (HSA) is responsible for the health and safety of workers in the public in Ireland and has a role in evaluating the safety of fertilisers, particularly occupational safety when handling and applying fertilisers. Local authorities in Ireland also have a role in approval and regulation of fertiliser use at a regional level. They may enforce regulations related to land and water management to prevent pollution caused by fertilisers.

Current Irish national fertiliser regulations for biological by products and bio-waste are covered under the fertilisers, feeding stuffs and mineral mixtures act 1955 and the SI No 248 of 1978 (non-EEC fertilisers) which covers mineral fertilisers, organic fertilisers, low nutrient fertilisers and ground limestone. In Ireland, there are currently no national end-of-waste criteria defined for compost and digestate derived from bio-waste and biological by product materials. There are varying quality standards being used by composting and anaerobic digestion plants. Overall, the system needs a uniform set of quality standards for compost and digestate, which would replace existing standards being applied and which would also recommend a strategy on how Ireland should use these new standards in order to create nationally recognised standards which could be used as an end-of-waste criterion, according to a new EPA study.

The current policy of the Department in Northern Ireland is that on farm-based biogas plants using silage and slurry manure as feedstock do not require animal by product approval as these materials can be directly spread to land in their raw states. The vast majority of AD plants currently operating Northern Ireland do not have ABP approval and fall under the remit of the Northern Ireland Environment Agency. The position is different to the Department of Agriculture Food and the Marine in the republic of Ireland who require on-farm biogas plants treating manure and silage to have ABP approval. The EU ABP regulations 1069 of 2009 state in article 24 (g) 'Approval of establishment of plant' is needed if (g) transformation of animal by-products and/or derived products into biogas or compost. Plants processing

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manures/silage in Ireland operating in compliance with EU ABP Regulations should be in a strong position to take advantage of new EU fertiliser regulations which requires digestate processed to the EU standard, to be placed on the market as an EU fertiliser product.

EU regulation 2019/1009 is the most recent amendment to the use of organic fertilisers in Ireland which aims to facilitate nutrient recovery and reduce dependency on critical raw materials, to open the single market for organic fertilisers, promote new and innovative fertilisers, to protect health and the environment, enhanced conformity assessment procedures and to have better information for users. In this area Ireland needs to currently update legislation to reflect the fertiliser product regulation and more expertise is required in new areas. To achieve this Ireland, need to liaise with notified bodies, industry and other competent authorities.

4.4.5. Bio-waste and biological by-products treatment and processing

In Ireland, there are various incentives and support mechanisms in place to promote and encourage the adoption of nutrient recovery technologies. These incentives aim to address environmental concerns, improve resource efficiency, and support the circular economy. Examples include the sustainable energy authority of Ireland grants which offers grants and funding opportunities for renewable energy and energy efficiency projects, including those related to nutrient recovery technologies such as anaerobic digestion and biogas production, which can contribute to nutrient recovery from organic waste. The Irish government provides funding support to other agencies for research and development projects focused on nutrient recovery technologies also, including science foundation Ireland and the environmental protection agency. There are grant schemes available in Ireland that provide financial incentives for the implementation of nutrient recovery technologies. For example, the targeted agricultural modernisation scheme offers grants to farmers for investment in agricultural technologies such as low emission slurry applicators to greater increase the efficiency of nutrient recovery when applying fertiliser to land. Ireland also uses European Innovation Projects (EIP's) which involves collaborative partnerships between farmers, researchers, advisors and other stakeholders to develop and implement innovative practices and solutions in the agricultural sector. The government's circular economy package and associated initiatives aim to support and incentivise businesses and organisations that adapt circular economy practices, including nutrient recovery.

In 2020, there were 63 regulated plants for the processing of controlled organic waste in Ireland. These consisted of 15 in-vessel composting, 7 in-vessel biostabilisation, 14 open windrow, 10 anaerobic digestion plants located on sewage treatment plants, 6 AD plants at food processing plants, 13 AD plants treating controlled waste and 1 AD plant treating manures only. In Northern Ireland there are 47 plants sites regulated by the Department of Agriculture, Environmental and Rural Affairs that treated controlled wastes. Of these 38 are AD plants, 4 in-vessel composting and 5 open windrow plants. There are also approximately 40 on-farm AD plants in Northern Ireland which are probably treating manures and energy crops.

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4.4.6. Initial stakeholders identified

Table 38. Initial key actors identified from the quadruple helix

Stakeholder	Sector	Entity
Governmental body	Authority	Department of Agriculture Food and the Marine (DAFM)
		Environmental Protection Agency (EPA)
Association	Private sector	Composting & Anaerobic Digestion Association of Ireland (Cré)

Farmers are supported in Ireland through key stakeholders such as research and innovation, advisory and education provided by Teagasc, private companies and Universities. Other key stakeholders include the Department of Agriculture Food and the Marine (DAFM), Environmental Protection Agency (EPA), Agricultural Co-operatives, rural development organisations, financial institutions and the Irish Farmers Association.

Cré (composting & anaerobic Digestion Association of Ireland) is one of the main stakeholders in Ireland in this space as composting and anaerobic digestion is the two main nutrient recovery technologies at a large scale in Ireland which deals with bio-waste and biological by products at present. Cré was established in 2001. It was initially set up to represent the fledging composting sector and in later years developed to include anaerobic digestion in the republic of Ireland. Cré represents Irish and non-Irish members supporting their business in the republic of Ireland under the following objectives:

- To promote composting and anaerobic digestion in Ireland.
- To promote the use of quality assured compost/digestate products.
- To infuse best practices into the development of the industry.
- Promote proper management of organic waste in the business community.
- Promote home and on-site composting.
- Promote research in relevant sectors.
- Promote proper management of organic waste to reduce the amount of greenhouse gases generated.
- Inform members on new emerging technologies.

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4.5. Poland – South-East Poland

4.5.1. Socio-economic characterisation of the region

Figure 38. Poland location

Poland, officially known as the Republic of Poland, is a democratic country in Central Europe. Its capital and largest city is Warsaw. With a land area of 312 696 km^2, Poland is the ninth-largest country in Europe and ranks 69th among the world's largest countries. Poland shares its northern border with Russia (Kaliningrad Oblast) and Lithuania, its eastern border with Belarus and Ukraine, its southern border with Slovakia and the Czech Republic, and its western border with Germany. Geographically, Poland is a lowland country. Catholics are by far the largest religion in the country.

The population of Poland is 37 654 247 inhabitants, making it the sixth most populous country in Europe and the 38th in the world. The average population density is 122 inhabitants per square kilometre, although it is strongly varied between the relatively densely populated south and the north. In cities, 22.9 million people live (60.9%), while in rural areas, there are 15.3 million (39.1%). Poland is quite homogeneous in terms of ethnic origin. National minorities, of which there are nine, constitute about 5% of the entire society. The largest ethnic minorities are Ukrainian, German, Belarusian, and Roma. Outside the country, there are about 21 million people of Polish descent, with over 10 million settling in the United States.

Figure 39. South-East Poland

South-east Poland is situated in the eastern part of the country, bordering Ukraine to the east and Slovakia to the south. It covers a significant portion of the Carpathian Mountains and includes fertile lowlands and river valleys. In the south-eastern Poland, there are 3 voivodeships - Podkarpackie, Małopolskie and Śląskie.

Climate and Geography

The south-eastern part of Poland, due to its location, is more prone to temperature extremes compared to western and northern parts of the country. Additionally, the presence of the Carpathian Mountains can lead to variations in climate across different elevations. This region experiences distinct seasons with noticeable temperature variations throughout the year.

- Spring (March - May): Spring is a transitional season with gradually warming temperatures. March and April can still be quite chilly, but by May, temperatures start

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to rise. Average highs in May range from 15°C to 20°C (59°F to 68°F). However, spring can be unpredictable, with occasional temperature fluctuations and precipitation.

- Summer (June - August): Summers in south-eastern Poland are warm to hot. July and August are the warmest months, with average highs ranging from 23°C to 28°C (73°F to 82°F). The region receives a moderate amount of rainfall during this period and thunderstorms.
- Autumn (September - November): Autumn is characterised by gradually decreasing temperatures. September can still have mild weather, but by November, temperatures drop significantly. Average highs in November range from 5°C to 10°C (41°F to 50°F).
- Winter (December - February): Winters in south-eastern Poland are cold and snowy. Average temperatures in January, the coldest month, range from around -5°C to -10°C (23°F to 14°F). Snowfall is common.

Overall, the climate in south-eastern Poland offers a mix of continental and mountain influences, resulting in distinct seasons and occasional weather variations.

The region of south-eastern Poland is bordered by Ukraine to the east, Slovakia to the south and the Czech Republic to the southeast. South-east Poland is characterised by diverse landscapes. The Carpathian Mountains dominate the southern part of the region, with the highest peak being Rysy at 2 499 meters above sea level. The northern part consists of lowlands and rolling hills, with numerous rivers and lakes scattered throughout the area. The major cities in the south-east Poland are Kraków, Katowice, Częstochowa and Rzeszów. Krakow is the largest city, with a population of above 800 000 people, Katowice has a population of 434 670, Częstochowa – above 200 000 people and Rzeszów has a population of almost 200 000 people.

South-east Poland is characterised by numerous rivers and lakes. The main rivers in the region include the Vistula, San and Bug, which provide important water resources for irrigation, hydropower generation, and transportation. The region also has several reservoirs, including Zalew Zegrzyński and Jezioro Solińskie, which serve multiple purposes, including flood control and water supply.

Population and economics

In Poland in 2021, there resided over 38 thousand people (48.3% of the population constituted males, while 51.7% were females). The population density, that is, the number of people per 1 km^2 of the country's surface, amounted to 122 persons (in 2011, it was 123). This signifies that the population of Poland decreased by 476 000 over the course of the decade.

In the 2021, the natural population balance in Poland was negative, amounting to a deficit of 188 006 individuals. In the same year, there were 331 511 births and 519 517 deaths recorded. Nonetheless, during the analysed year, the net international migration balance was positive, with an increase of 3 404 individuals. In this year, there were 15 400 immigrants and 12 000 emigrants reported.

At the level of voivodships in south-east Poland, the largest decrease in the population was recorded in the Śląskie Voivodeship (-25 305 people in 2021; in 2020 it was - 15 930 people.

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South-east Poland covers approximately 14,51% of the country's territory, spanning 45 363 km^2, and the primary language used in this area is Polish. There are also regions, such as the Silesian Voivodeship, where the population speaks a regional dialect. English is also a popular language. Due to the conflict in Ukraine, the immigrating Ukrainian community primarily uses the Ukrainian language. Currently, the Ukrainian population in Poland is mainly located in the Podkarpackie Voivodeship.

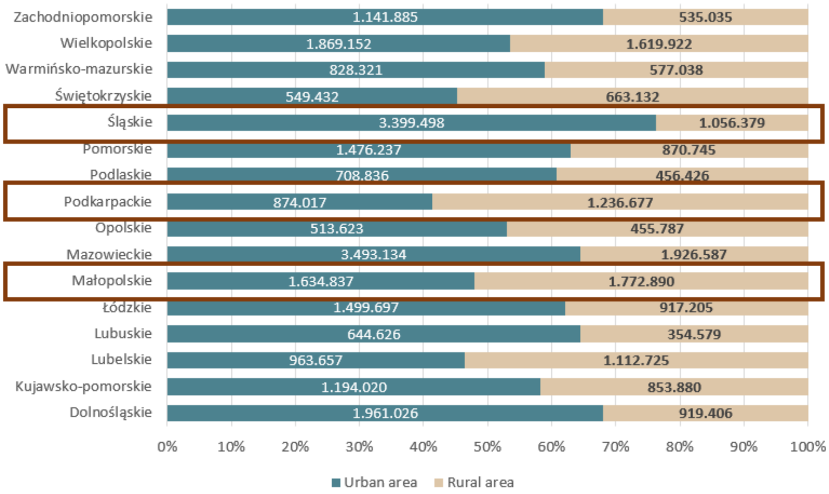

Figure 40. Population living in rural and urban areas by voivodeships (2021)

In 2022, the south-east Poland had a population of 9 892 249 residents (Silesian Voivodeship: 4 375 947, Małopolskie Voivodeship: 3 430 370, Podkarpackie Voivodeship: 2 085 932). This represents a decrease in the population of this region compared to the previous year by 131 751 individuals, which is equivalent to 1,31%.

The largest cities in the region include Kraków, Katowice, Częstochowa and Rzeszów.

On a national scale in Poland, rural areas have a smaller population compared to cities, and this trend is similar in most regions, including the southeastern part of the country. However, the Silesian Voivodeship is an exception because it is one of the most urbanised areas in Poland, with the majority of its population residing in cities.

The gross domestic product (GDP) in constant terms saw a 4.9% increase compared to the previous year. In 2021, following the decline caused by the COVID-19 pandemic, GDP growth reached 6.8%. The primary driver of economic growth was domestic demand, with both consumption and investment demand making positive contributions. Domestic demand was 5.5% higher than in 2021. Final consumption expenditure grew by 2.1%, with a 3.0% increase in the household sector. Gross fixed capital formation rose by 4.6%, an improvement compared to the 2.1% growth observed in the previous year. The investment rate stood at 16.8%, slightly lower than the 17.0% recorded in 2021. Gross value added in the national economy increased by 4.6% compared to 2021, with a significant growth of 7.0% in the industry sector, a 4.5% increase in construction, and a 2.0% rise in trade and motor vehicle repair.

Employment in the national economy saw a modest increase compared to the end of the preceding year. In 2021, employment growth was more substantial, rebounding from a decline, partly attributable to the pandemic. Average paid employment in the corporate sector has been on the rise for two consecutive years, with a greater magnitude than in 2021. Both the number of registered unemployed individuals and the registered unemployment rate at the close of 2022 were lower than the figures from the prior year.

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After a decline in the previous year, the gross agricultural output increased. Crop output was higher than in 2021 and animal output also increased slightly.

Average procurement prices of basic agricultural products were significantly above the level recorded in 2021. Among crop products, the prices of triticale, rye and potatoes increased the most and among animal products – the prices of poultry and milk.

Foreign trade turnover saw a significant increase, reminiscent of the pattern observed in the January to November 2021 period. However, the trade balance ended negatively in contrast to a positive balance the previous year. In terms of current prices, trade turnover expanded with all categories of countries. From January to October 2022, the terms of trade index showed a less favourable trend compared to the previous year. Trade turnover at constant prices in the same period of 2022 increased year-on-year but to a notably lesser extent than during the same period in 2021. There was a substantial decline in the volume of trade with Central and Eastern European nations.

The economy of south-east Poland is diverse, with a mix of industries including agriculture, manufacturing, services, and tourism. The region has been experiencing economic growth in recent years, with investments in infrastructure and the development of special economic zones. Key sectors include food processing, automotive, machinery, and IT.

4.5.2. Agriculture

Agriculture plays a significant role in Poland's economy. The fertile soils and favourable climatic conditions support a variety of agricultural activities. Moreover, Poland is one of the main agricultural producers in the EU: it belongs to the three largest producers of basic cereals and root crops and is also the largest supplier of apples and poultry meat.

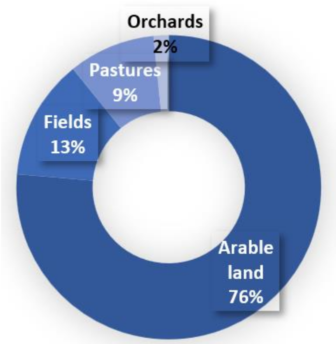

Figure 41. Agricultural land in Poland search

Agricultural land occupies an area of 18,418 thousand hectares, which accounts for 58% of the country's surface. The largest percentage of agricultural land is arable land, as it is as much as 76.4%, followed by fields - almost 13%, then pastures and orchards.

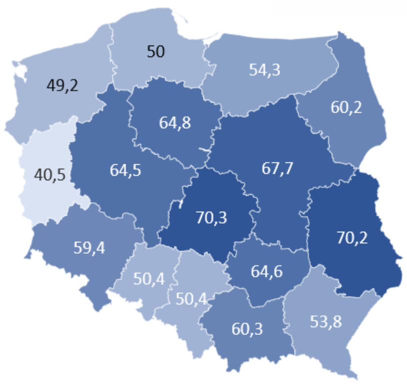

Figure 42. Share of agricultural land in the total area of voivodeship [%]

Major agricultural products include cereals (such as wheat, barley and rye), potatoes, sugar beets and vegetables. Livestock farming, including cattle, pigs, and poultry, is also an important part of the agricultural sector.

Table 39. Production of main crops

Crops	2010	2015	2019	2020	2021
	in kg (per 1 ha of agricultural land				

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Basic cereals	1464	1546	1543	1780	1656
• Wheat	633	753	750	853	810
• Rye	192	138	168	200	169
• Barley	229	204	230	201	202
• Oats	102	84	84	112	111
• Triticale	308	367	312	415	365
Potatoes	551	423	441	526	474
Sugar beet	671	644	942	1000	1021
Rape and tumip rape	150	186	162	209	213
Total vegetables	328	330	342	345	353

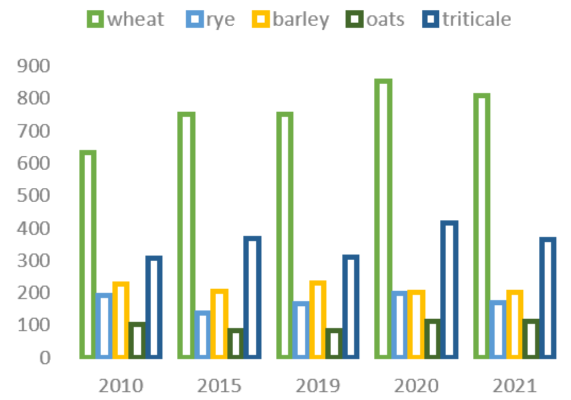

Figure 43. Basic cereals production in Poland

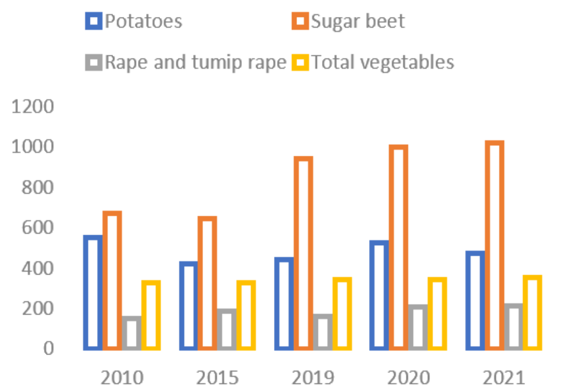

Figure 44. Production of main crops

4.5.3. Fertilising products sector

The agriculture sector employs a considerable portion of the regional workforce, using both conventional and natural fertilisers.

Table 40. Farms using fertilisers by voivodeships in the farming year 2019/2020

Voivodeships	TOTAL										
	Mineral total	Mineral				Lime	Natural				
		Nitrogenous	Phosphate	Potassic	Multicomponent		Total	Solid manure	Poultry manure	Liquid manure	Slurry
POLAND	**940626**	**757323**	**61902**	**75060**	**683217**	**280272**	**575225**	**482756**	**110565**	**86060**	**53312**
Dolnośląskie	36664	28637	1402	2096	28698	11050	11545	9068	2836	806	579
Kujawsko-pomorskie	51499	45961	2882	5953	38478	15614	29327	27422	1769	5894	3667
Lubelskie	131603	105169	9284	10041	103180	47277	55670	44077	15248	3460	2483

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Lubuskie	11062	8714	326	628	6890	2878	5754	4804	1099	236	229
Łódzkie	98195	81087	5415	7692	73538	33784	50398	43810	6711	5871	4814
Małopolskie	**63223**	**43414**	**2087**	**1871**	**49784**	**14313**	**62946**	**48980**	**19069**	**14967**	**4106**
Mazowieckie	148235	120443	14299	14886	93786	45132	93561	84667	8498	12374	9407
Opolskie	22222	18593	758	1445	18902	8135	9394	7924	1523	2769	1077
Podkarpackie	**68045**	**48019**	**2513**	**1732**	**51838**	**17776**	**52033**	**31760**	**25218**	**6265**	**2259**
Podlaskie	53601	45394	8707	6803	36697	14872	46341	41991	3758	8999	9602
Pomorskie	27419	23181	1274	2078	17786	8041	16662	14855	2740	3172	1817
Śląskie	**31333**	**24044**	**1181**	**1420**	**23508**	**8197**	**20196**	**16482**	**4769**	**3306**	**1555**
Świętokrzyskie	58309	44786	3881	3786	42014	12318	32385	24780	10645	3120	1752
Warmińsko-mazurskie	23055	20041	1262	1424	13421	6368	19868	18043	1454	3207	3393
Wielkopolskie	99672	86731	5975	11802	73274	29183	62566	58694	3833	11192	6221
Zachodniopomorskie	16489	13109	656	1403	11423	5334	6579	5399	1395	422	351

Table 41. Consumption of natural fertilisers and area fertilised with natural fertilisers in farming year 2019/2020

Voivodeships	TOTAL							
	Consumption of natural fertilisers				Fertilised area			
	Solid manure	Poultry manure	Liquid manure	Slurry	Solid manure	Poultry manure	Liquid manure	Slurry
	in tonnes		in m^3		in ha			
POLAND	**38608406**	**882615**	**9347907**	**14638475**	**2864385**	**244103**	**602667**	**694106**
Dolnośląskie	614377	55487	113328	278015	68857	15415	7533	13914
Kujawsko-pomorskie	3386470	57506	698200	937768	191238	12163	42551	44642
Lubelskie	2555746	51908	383698	524626	206985	14674	25623	27551
Lubuskie	504994	40310	74538	240107	49784	11222	3563	9220
Łódzkie	3236999	60781	591931	1170288	243306	17398	38508	51696
Małopolskie	**1072057**	**29534**	**499769**	**187840**	**106671**	**11966**	**41352**	**13310**
Mazowieckie	6974605	127945	1799180	2509779	532774	30096	113653	117565
Opolskie	864452	30390	345985	463581	62752	8791	20959	23163
Podkarpackie	**580293**	**36012**	**236044**	**105541**	**68123**	**14219**	**19321**	**8414**
Podlaskie	5322121	41966	1567134	3354212	330697	10411	95827	151372
Pomorskie	1237440	26772	313961	635856	104574	9045	22469	30856
Śląskie	**834180**	**25292**	**288209**	**261590**	**79096**	**9319**	**19337**	**14732**
Świętokrzyskie	1003162	23813	216770	165706	91928	11235	14678	11037
Warmińsko-mazurskie	2329824	49197	543925	1206639	189938	12562	40235	63878
Wielkopolskie	7529357	191137	1479071	2334829	463511	42212	86965	99253

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Zachodniopomorskie	562329	34566	196164	262098	74153	13376	10092	13501

The use of fertilisers derived from sewage sludge, animal manure, and digestate can have both positive and negative environmental aspects.

Positive Environmental Aspects:

- Nutrient Recycling: These fertilisers contribute to the recycling of nutrients from organic waste materials back into the soil, reducing the need for synthetic fertilisers. This helps to close nutrient loops and promotes a more sustainable agricultural system.
- Organic Matter Addition: Fertilisers derived from organic waste sources improve soil organic matter content. Increased organic matter enhances soil fertility, water-holding capacity, and overall soil health, leading to improved crop productivity.
- Reduced Waste Disposal: Utilising sewage sludge, animal manure, and digestate as fertilisers reduces the volume of organic waste that would otherwise require disposal in landfills or incineration. This helps to alleviate the burden on waste management infrastructure and reduces methane emissions from decomposing organic matter.

Negative Environmental Aspects:

- Nutrient Runoff: Excessive application of fertilisers can result in nutrient runoff, particularly nitrogen and phosphorus, which can contaminate surface water and groundwater. This can lead to eutrophication, where excessive nutrients promote algal blooms, causing oxygen depletion and harm to aquatic ecosystems.
- Greenhouse Gas Emissions: The decomposition of organic waste materials can release greenhouse gases such as methane and nitrous oxide. Methane, in particular, has a potent warming effect on the atmosphere. Proper management practices, such as anaerobic digestion, can help mitigate these emissions, but there is still a potential environmental impact.
- Contamination Risks: If sewage sludge, animal manure, or digestate contains contaminants like heavy metals, pesticides, or pharmaceuticals, there is a risk of introducing these substances into the soil and potentially contaminating crops or entering the food chain. Strict regulations and monitoring are necessary to ensure the safe use of these fertilisers.
- Odor and Air Quality: The application of animal manure and certain types of digestate can generate odors, particularly during spreading. This can impact air quality and lead to complaints from nearby communities. Proper storage and application techniques can help mitigate these concerns.

4.5.4. Regulatory and institutional framework

The analysis of regulatory and institutional framework conditions regarding the use of sewage sludge, animal manure and digestate in south-east Poland requires a detailed familiarisation with the applicable legal regulations at the national, regional and local levels.

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Sewage sludge

In Poland, there are legal regulations concerning the use of sewage sludge that govern the management of this material. The most important regulations are presented below:

- **Waste Act**: Sewage sludge is treated as waste and is subject to the provisions of the Waste Act. This law establishes rules for the collection, transport, processing, recovery, and disposal of waste. The use of sewage sludge must comply with the requirements of this law, including the principles of waste segregation and disposal.
- **Regulation of the Minister of Environment on the conditions for introducing waste into the soil**: This regulation pertains to the use of sewage sludge as organic fertilisers or soil improvement agents. The regulation specifies quality standards for the content of harmful substances in sewage sludge and defines the conditions for their application in the soil.
- **Regulation of the Minister of Agriculture and Rural Development on natural fertilisers**: This regulation defines the requirements for the use of sewage sludge as natural fertilisers in agriculture. The regulation governs aspects such as the quality of sewage sludge, requirements related to its introduction into the soil, and methods of application in crops.
- **Administrative decisions**: The use of sewage sludge may also be regulated by administrative decisions issued by relevant administrative authorities, such as environmental agencies. These decisions can impose additional requirements and restrictions regarding the utilisation of sewage sludge.

Animal manure

In Poland, the use of animal manure as an alternative fertiliser is regulated by several important regulations. Below are the key regulations concerning the use of animal manure:

- **Fertilisers and Fertilisation Act**: This act lays down the rules and requirements for the production, marketing, and use of fertilisers, including animal manure. It establishes quality standards, labelling requirements, and restrictions on the content of harmful substances in fertilisers. The act also specifies the obligations of manufacturers, distributors and users of fertilisers, ensuring their safe and effective use.
- **Regulation of the Minister of Agriculture and Rural Development on the conditions for the use of animal manure**: This regulation sets out specific conditions for the application of animal manure as a fertiliser in agriculture. It includes guidelines on the quantity, timing, and methods of application, taking into account factors such as soil type, crop type and environmental protection. The regulation also addresses the storage and handling of animal manure to prevent pollution and ensure proper nutrient management.
- **Good Agricultural Practices (GAP)**: Although not a specific regulation, GAP guidelines play an important role in the use of animal manure as fertilisers. These guidelines promote sustainable and environmentally friendly agricultural practices, including the

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proper management and utilisation of animal manure. They provide recommendations on the storage, application and incorporation of animal manure into the soil, aiming to minimise nutrient losses, protect water quality, and optimise nutrient availability for crops.

- **Environmental Protection Act**: This overarching act includes provisions related to the protection of soil, water and air quality. It sets standards and requirements to prevent pollution and environmental degradation. While not specifically targeting animal manure, this act establishes the general framework for environmental protection, including measures to ensure the responsible use of fertilisers, including animal manure.

Digestate

In Poland, the use of digestate, which is the residual material left after anaerobic digestion of organic waste, is regulated by several laws and regulations. The main legal framework includes:

- **Waste Act**: The Waste Act sets out the general provisions regarding waste management in Poland. It defines digestate as a type of waste and establishes the obligations and responsibilities of waste producers, collectors and operators. The act also covers the requirements for the treatment, storage, and use of digestate.
- **Fertilisers Act**: The Fertilisers Act regulates the production, marketing, and use of fertilisers, including organic fertilisers such as digestate. It defines the quality criteria and labelling requirements for fertilisers, including digestate, and sets out the conditions for their application in agriculture.

- **Water Law**: The Water Law governs water resources management in Poland. It includes provisions related to the use of water for agricultural purposes, including the application of fertilisers and digestate. The law aims to protect water resources from pollution and sets out rules for the proper use and management of fertilisers to prevent water contamination.

- **Environmental Protection Law**: The Environmental Protection Law establishes the principles and mechanisms for environmental protection in Poland. It includes provisions related to the prevention and reduction of pollution, waste management and environmental impact assessment. These provisions indirectly apply to the use of digestate, ensuring that its application does not harm the environment.

In addition to the legal framework, there are also several institutions involved in regulating and overseeing digestate use in Poland. These include:

- **Ministry of Environment**: The Ministry of Environment is responsible for developing and implementing environmental policies in Poland. It plays a key role in formulating regulations related to waste management, including digestate, and ensuring compliance with EU directives and national legislation.

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- **General Directorate for Environmental Protection (GDOŚ)**: The GDOŚ is a central governmental body responsible for implementing environmental protection policies and supervising compliance with environmental regulations. It provides expertise, issues permits, and conducts inspections related to waste management, including the use of digestate;
- **Provincial Environmental Protection Inspectorates (Wojewódzki Inspektorat Ochrony Środowiska, WIOŚ)**: The WIOŚ is a regional-level authority responsible for enforcing environmental regulations at the provincial level. They monitor and inspect waste management activities, including the use of digestate, within their respective jurisdictions.

4.5.5. Sewage sludge, animal manure and digestate treatment and processing

The situation regarding wastewater treatment and its agricultural applications in south-eastern Poland can be characterised as follows:

- **Wastewater treatment**: The region of south-eastern Poland has a well-developed wastewater treatment infrastructure, including both municipal and industrial wastewater treatment plants. These facilities are responsible for removing pollutants from water discharged from households, industry, and agriculture before it is released into the natural environment.
- **Agricultural use of wastewater**: In south-eastern Poland, there is a practice of utilising treated wastewater in agriculture. Treated wastewater, also known as reclaimed water, can be used as a source of organic fertilisers and irrigation water for crops. Farmers who have access to wastewater treatment plants can make use of these resources to improve soil quality and increase yields.
- **Legal regulations**: Wastewater treatment and its agricultural use in south-eastern Poland are subject to legal regulations. There are standards in place regarding the quality of treated wastewater and the guidelines for its application in agriculture. Relevant authorities, such as the Chief Inspectorate of Environmental Protection, monitor compliance with these regulations.

Benefits and challenges

The use of treated wastewater in agriculture can bring benefits such as increased efficiency in water resource utilisation, improved soil structure, and the provision of nutrients for plants. However, there are also challenges associated with proper management and monitoring of wastewater treatment plants, as well as ensuring appropriate cleanliness standards for agricultural use. Responsible and conscious application of treated wastewater is crucial to avoid any negative impact on the environment and human health.

Technological assessment

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Technology assessment in the context of sewage sludge, animal manure, and digestate in Poland involves evaluating the various technologies and methods used for their management and utilisation. Here are some key aspects considered in technology assessment:

- Treatment Technologies: Assessing the effectiveness and efficiency of different treatment technologies for sewage sludge, animal manure, and digestate. This includes anaerobic digestion, composting, thermal drying, and other treatment processes. Factors such as nutrient recovery, pathogen reduction, and energy production potential are evaluated.
- Environmental Impact: Evaluating the environmental impact of different technologies used for managing these organic waste materials. This includes assessing greenhouse gas emissions, potential contamination risks, and nutrient runoff prevention measures. The aim is to identify technologies that minimise negative environmental impacts.
- Nutrient Recovery: Assessing technologies that enable the recovery of nutrients, such as nitrogen and phosphorus, from sewage sludge, animal manure, and digestate. This includes evaluating techniques like struvite precipitation, nutrient extraction and biochar production to maximise the recycling and reuse of valuable nutrients.
- Quality and Safety: Evaluating the quality and safety of the end products derived from sewage sludge, animal manure, and digestate. This involves analysing the presence of contaminants, such as heavy metals and pathogens, and ensuring compliance with quality standards and regulations for their safe use in agriculture.
- Economic Viability: Assessing the economic feasibility and viability of different technologies for sewage sludge, animal manure, and digestate management. This includes analysing the costs associated with treatment, transportation, and utilisation, as well as exploring potential revenue streams from energy generation or fertiliser sales.
- Policy and Regulatory Framework: Considering the policy and regulatory framework surrounding the management and utilisation of these organic waste materials in Poland. Assessing how technologies align with existing regulations, incentives, and support mechanisms, and identifying barriers or opportunities for their implementation.

Technology assessment plays a crucial role in identifying the most suitable and sustainable approaches for managing sewage sludge, animal manure, and digestate in Poland. It helps inform decision-making processes, promote best practices, and support the development of a circular economy approach in the agricultural and waste management sectors.

4.5.6. Initial stakeholders identified

Table 42. Initial key actors identified from the quadruple helix

Stakeholder	Sector	Entity

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Governmental body	Authority	Ministry of Agriculture and Rural Development
Advisory	Private sector	Agricultural Advisory Centre in Brwinów
Business	Private sector	Grupa Azoty

The mission of the Ministry of Agriculture and Rural Development is to ensure optimal conditions for sustainable development of the Polish countryside, agriculture, fisheries, and to ensure food security and high-quality public services.

The Agricultural Advisory Centre, located in Brwinów and with Branch Offices in Kraków, Poznań, and Radom, is a governmental organisation under the supervision of the Ministry of Agriculture and Rural Development. The Centre collaborates with agricultural advisory organisations, government and local administration institutions, professional associations, research and development units, and other entities dedicated to the advancement of agriculture and rural areas in Poland. The primary goal of their current initiatives is to enhance the knowledge and qualifications of advisory personnel while improving and standardising the quality of services offered by advisors to farmers and residents of rural areas.

The Grupa Azoty is the largest chemical corporation in Poland and one of the leading companies in Europe. The Company's domain is manufacturing, services, and trade in the field of engineering plastics, semi-finished products for their production, and nitrogen fertilisers. The company has its own research facilities. It focuses on research and development of new products and technologies, as well as the development of existing products.

4.6. Spain – Andalusia

4.6.1. Socio-economic characterisation of the region

Andalusia is located in the south of Spain, between the African continent and the rest of Europe, and it is the point where the Mediterranean Sea and the Atlantic Ocean converge. To the north, the Sierra Morena is the natural border that separates it from the rest of Spain. In the west, Andalusia limits with the Guadiana river and Portugal's border. To the south, with the Atlantic Ocean and the Mediterranean Sea.

Figure 45. Andalusia region (green) within Spain (red)

Andalusia is the second biggest region of Spain with an extension of 87,268 km. 50% of the region is mountainous. One-third of the mountains are over 600 meters height,

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46% are over 1,000 meters, and Mulhacen and Veleta are the second and the third higher mountains in Spain with an altitude over 3,400 meters.

Climate and Geography

Andalusia's climate is the Mediterranean, characterised by dry and hot summers, warm winters and irregular rainfall. However, due to geographical factors, the region has some areas where the climate is diverse.

The first area (clear green) is important due to its large extension and its Mediterranean climate, with high temperatures, irregular rainfalls and strong insolation. The second one (orange) is influenced by the altitude, thus having lower temperatures, a higher risk to frost and rainfall are more frequent. The influence of the Atlantic Ocean is relevant in the western mountainous areas of Sierra Morena (deep green), especially, in the *Béticas* (Cadiz and Malaga mountain ranges, in orange), that are the areas of maximum rainfall along with the *Sierras of Cazorla and Segura*.

Figure 46. Andalusian climate region
Source: Junta de Andalucía (Andalusian Regional Government)

Near inland and towards the east, as well as on the slopes of the coastal satellites that are not exposed to the Atlantic winds, the levels of precipitation decrease substantially and, therefore, increase the aridity (deep blue). The greater continentality and height of eastern Andalusia, make places like Sierra Nevada, Cazorla, Segura and Filabres, the coldest of the region (clear yellow). A particular case is the eastern highlands of Baza and Los Vélez, in which all features of Mediterranean climate continentality appear (very low rainfall, lower temperatures and a greater presence of frost). The Sierra Nevada area, on the other hand, has special relevance because as a residual form of the southernmost glaciation of the continent, it is the only enclave that receives snowfall that remains most of the year, assuming climatic and ecological uniqueness.

Another significant transition occurs in the coastal strip, where the marine influence and the highest levels of insolation converge (for example, the lower Guadalquivir, with over three thousand hours of sun per year). Within this range, a differentiation between the Atlantic and Mediterranean slopes is established. Guadalquivir valley is open to the Atlantic without significant orographic barriers, favouring the existence of a more humid climate throughout the coast, by allowing the influence of the wet fronts of Poniente (Atlantic). On the Mediterranean slopes of the Baetic systems, the greater aridity is combined with torrential rains that drain through ravines, dry most of the year. The shelter of the coastal mountains allows the mildest average temperatures in the region to be reached here. A fact of enormous

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importance that has favoured, for example, the adaptation of many subtropical plants, or the modern development of mass tourism.

Another example of extreme climatic diversity is found in the arid southeast. The existing conditions (very high insolation and temperature, strong shortage of rainfall) facilitates the advance of desertification, presenting adaptations of species characteristic of the flora and fauna of the Sahara. According to the different geographic areas explained above, the average of temperature, rainfall and dry months are resumed in the following table.

Table 43. Andalusian climate indicators
Source: Junta de Andalucía (Andalusian Regional Government)

Geographic area	Annual Temperature Average	Annual Rainfall Average	Nº rainy days	Nº dry months
Atlantic coast	17-19	500-700	75-85	4 5
Guadalquivir Depression	17-18	500-700	75-100	4 5
Sierra Morena	16-17	60-800	75-100	3 5
Mediterranean coast	17-19	400-900	50-75	4 5
South-east Mediterraean coast	17-21	<300	<50	6 8
Surco Intrabetico	13-15	300-600	60-80	4 5
Sierras Beticas	12 15	400-1000	60-100	3 4

Hydrological data

According to the total annual rainfall, Andalusia can be divided into four large areas: In the rainiest area of the region, 750 mm are exceeded annually (mountains of Aracena, Cazorla-Segura and Grazalema). These are high relays and arranged in the paths most followed by frontal disturbances in their penetration into the region through the Gulf of

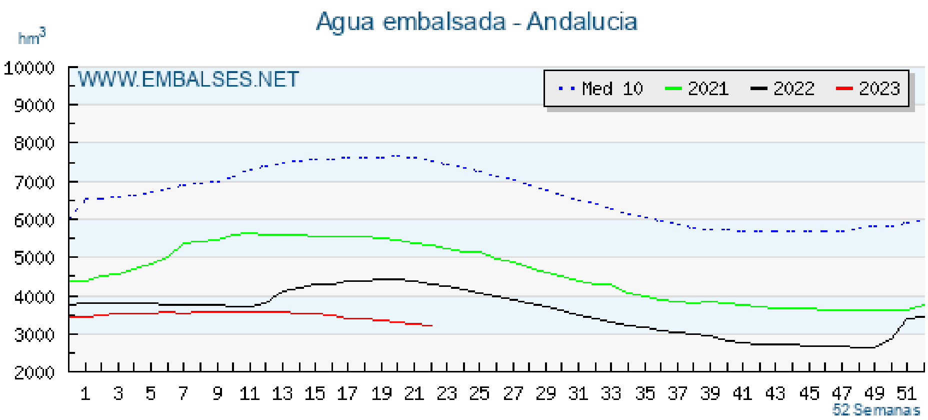

Figure 47. Evolution or water collected in Andalusia (Jan 2021-May 2023) and average for the last 10 years
Source: www.embalses.net

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Cadiz. In the places most benefited by these concepts exceed 1,500 mm, in Grazalema exceeded even 2,000 mm, thus becoming one of the most irrigated places in Spain.

The second area covers most of Andalusia (Guadalquivir valley, almost the entire Sierra Morena, and part of the Mediterranean coast) and it has a total annual rainfall between 750 and 500 mm. The opening and the proximity to the Atlantic Ocean determines that the precipitations are high although in a smaller volume than in previous cases.

Precipitation is collected in water reservoirs along the whole region. The capacity of these reservoirs is 11.941Hm^3 in 2023. The average last ten years for May was 7.525 Hm^3, about 63.02% of the capacity. Currently, its capacity reached 27.13%.

The main water resources in Andalusia are surface water followed by groundwater, although other types of water, such as reclaimed water, are gaining more attention.

Table 44. Water resources (total, Hm^3)
Source: National Institute of Statistics (INE)

Andalusia	Surface water	%	Ground water	%	Other resources	%	Total
2018	3.153.791	68,90%	1.364.049	29,80%	59.505	1,30%	4.577.345
2016	3.060.533	70,60%	1.222.479	28,20%	52.020	1,20%	4.335.032
2015	3.129.850	69,96%	1.294.046	28,93%	49.822	1,11%	4.473.718
2014	3.186.112	70,50%	1.283.483	28,40%	49.711	1,10%	4.519.306
2013	2.857.820	71,77%	1.070.461	26,88%	53.487	1,34%	3.981.768
2012	2.733.248	71,25%	1.058.258	27,59%	44.606	1,16%	3.836.112
2011	2.975.172	71,58%	1.142.852	27,50%	38.150	0,92%	4.156.174
2010	3.538.686	84,42%	628.277	14,99%	24.913	0,59%	4.191.876
2009	3.354.051	80,40%	798.101	19,13%	19.747	0,47%	4.171.899
2008	2.925.341	76,67%	864.633	22,66%	25.691	0,67%	3.815.665
2007	3.089.097	78,11%	845.073	21,37%	20.484	0,52%	3.954.654
2006	3.367.536	80,07%	791.395	18,82%	46.787	1,11%	4.205.718

The Andalusian government, through the Consejería de Medioambiente (Regional Ministry of Environment), published data about the water quality. Andalusia separates the water quality data following the different hydrological areas. The most important areas are Guadalquivir, Mediterranean and Tinto-Odiel-Piedras.

The methodology followed to obtain the information regarding the surface water quality looks for the biological, hydro-morphological and physical-chemical parameters that are the most representative of the quality.

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The nitrates concentration is used to analyse surface and ground water. Specially to identify the existence of wastewater spills or fertilisers. The score given by the regional government is positive, although there is a tendency to aggravate the water quality, there exists an increase of the Nitrates in almost all the different geographical areas. However, the situation of groundwater is worse than the surface water.

While most of the quality detection points for surface water support the existence of Nitrates under 15 mg/l, in the case of groundwaters, the situation is the opposite, with high levels of nitrates.

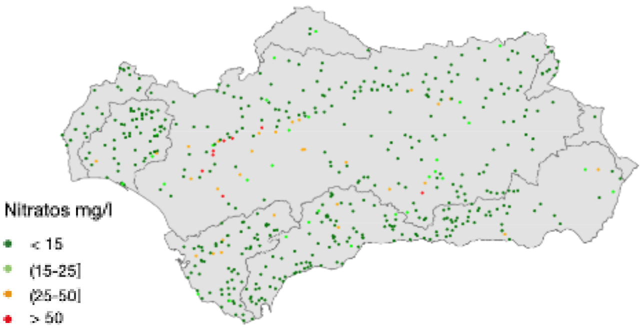

Figure 48. Nitrates concentration in Andalusia
Source: Junta de Andalucía (Andalusian Regional Government)

The main water sources available in Andalusia are surface water, groundwater, desalinated water, and reclaimed water. Desalinated water is the only significant lever available in Andalusia to complement or compete with reclaimed water.

There are four desalination plants in Andalusia, three of them located in Almeria:

- Bajo Almanzora, with a water production of 15 Hm^3/y used for water supply to 140,000 inhabitants and irrigation of 24,000 ha of agricultural crops.
- Carboneras, with a water production of 42 Hm^3/y used for water supply to 200,000 inhabitants and irrigation of 7,000 ha of agricultural crops.
- Campo de Dalias, with a water production of 30 Hm^3/y used for water supply to 300,000 inhabitants.
- The fourth desalination plant, at El Atabal, in Malaga, has a production of 76 Hm^3/y.

Seawater desalination offers an additional and reliable water supply option in coastal basins, providing a net water contribution to the resources available in the basin. Although seawater desalination raises the need to consider the use of renewable energy sources for its sustainable operation, the use of desalinated water for urban supply results in a favourable reduction of dissolved inorganic salts in drinking water, improving its organoleptic properties, reducing its corrosion effects in water conduits and fixtures, and lowering the electrical conductivity of the resulting urban wastewater effluent and ultimately of the reclaimed water produced from it. Low salinity is a very favourable property of reclaimed water when considering it as a water supply for agricultural irrigation. In summary, integrated management of water resources in coastal areas offers the possibility of balancing the economic and environmental requirements of water desalination with the ultimate benefits that a low salinity reclaimed water may offer for agricultural irrigation.

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Population and economics

Andalusia is Spain's most populated region and the second most extensive with 8,484,804 million inhabitants, 87,598 km^2 and a population density of 96.86 inhabitants/ km^2. Its surface represents the 17.3% of Spain.

The population is mainly concentrated in the Guadalquivir Valley and in the coastal strip, while Sierra Morena and the eastern inland regions are the less populated. People under 25 years of age represent 26.8% of the total, compared to the 24.6% of the national average. Half of the Andalusian population (50.9%) is less than 42 years old, and the most represented age segment is the one between 40 to 44 years of age (8.3%).

The urban configuration in Andalusia presents some distinguished traits compared to other European regions that can facilitate the rebalancing in the use of the territory. The settlement system in the region has a hierarchy of urban centres, where the top ten cities with more than 100,000 inhabitants (the eight provincial capitals, plus Jerez de la Frontera and Algeciras) perform basic structuring functions on the whole territory. The urban agglomeration around these ten cities, with different intensity and dimensions, brings together more than 50% of the Andalusian population and an even greater proportion of employment and economic activity.

However, the urban structure of Andalusia is not as unbalanced as other Autonomous Communities: For example, in Catalonia more than 70% of its population lives in the metropolitan area of Barcelona and the city of Zaragoza concentrates more than 50% of the Aragonese population, while the metropolitan area of Seville has 15% of the Andalusian population.

Based on its urban and economic functions, and in the metropolitan, a distinction is established in three ranges:

- Metropolitan areas: Seville and Malaga.
- Regional metropolitan urban areas at the regional level: Granada and Cadiz Bay.
- Urban agglomerations: Almeria, Cordoba, Huelva, Jaen, Jerez and Algeciras Bay.

The incidence of these agglomerations in the regional territory and the configuration of their immediate influence environment is characterised by the presence of a multipolar urban structure in which each of the provincial capitals still represents a directive function in its territorial environment.

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Andalusia's GDP is 160,747 million Euros, representing the third largest economy in Spain by volume of GDP. As for GDP per capita, which is a good indicator of life quality, in 2021 was 18,906 €, compared to 25,498 € of GDP per capita in Spain. Andalusia is ranked 18th with respect to the total of the Autonomous Communities, which indicates that its inhabitants have a lower standard of living compared to the average of the country. Regarding the public debt, despite the economic instability generated by the war in Ukraine and the wide-spread inflation, Andalusia in 2022 represented the Autonomous community that better contained the public debt. In fact, the region observed an increase of the public debt of 0.4% compared to the previous year, in correlation to the average of the Spanish autonomous communities assessed at 1,1%.

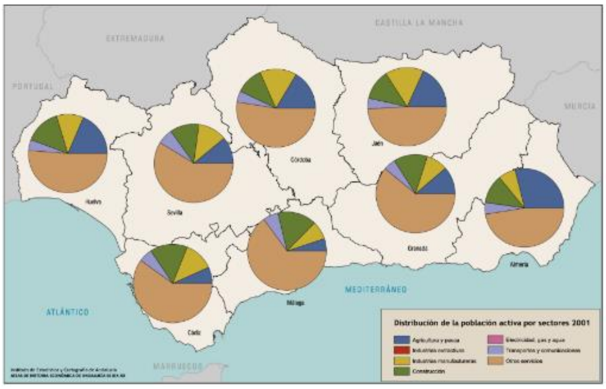

Figure 49. Economic sector per province
Source: Junta de Andalucía (Andalusian Regional Government)

The GDP annual growth rate for Andalusia in 2021 was 5.5%, what makes the region as a growing economy. These data should be compared with those of the GDP of Spain, where the annual variation presents the same trend. The rate of the CPI for March 2021 was 5,5%.

The main sectors are services (brown), followed by agriculture (blue), construction (green), manufactured industry (yellow) and logistics and communication (purple).

4.6.2. Agriculture

The agri-food sector in Andalusia is one of the main sources of wealth and employment within the region, that accounts for 10% of the gross domestic value of the region and participating for 40% of the region's total exports. In comparison to the national context, the Andalusian primary sector accounts for about a quarter of Spanish agricultural production and accounts for over 30% of the added value and employment of the national agricultural sector.

Andalusia, with 4.748.844 hectares of UAA represent the 19.8% of the total Spanish cultivated surface, making the region the leading country together with Castilla y Leon (22%) in terms of extension.

Table 45. Production of Agricultural Sector (PAS) in Andalusia
Source: National Institute of Statistics (INE)

Andalusia	Surface (ha)
HERBACEOUS CROPS	1.229.417
Grain cereals	723.599
Legumes and dry protein crops for grain	76.799

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Roots and tubers	18.122
Green harvested crops	75.137
Industrial crops	278.385
Vegetables, melons and strawberries (excluding seeds and seedlings)	56.290
FALLOWS (including land planted for green manure)	320.865
WOODY CROPS	1.920.786
Citrus trees	80.839
Fruit trees native to temperate climates with pome	1.265
Fruit trees native to temperate climates with stone	6.945
Fruit trees native to tropical and subtropical climates	21.499
Berries (excluding strawberries and wild berries)	3.461
Dried fruit trees	192.610
Olive groves	1.586.194
Vineyards	22.351
Nurseries	807
Other woody crops	4.814
PERMANENT PASTURE	1.230.573
Extensive pasture	1.069.662
Intensive pasture	146.343
Grass not used for production purposes	14.569
VEGETABLES	43.664

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The main way of exploitation is rain-fed, representing 68.4% of the area under regional cultivation, a share that has been decreasing since the beginning of the last decade, and the use of land for irrigation and greenhouse purposes has increased. Andalusia is the Autonomous Community with the greatest significance of the irrigated area, with a total (not including greenhouses) of 1,062,720 hectares, representing 28.3% of the national irrigated area and 30.0% of the total cultivated area within the region. The output of the agricultural sector in Andalusia amounted to €14,482 million in 2021. This accounted for 25.7% of the Spanish SIP and 3.0% of the EU-27.

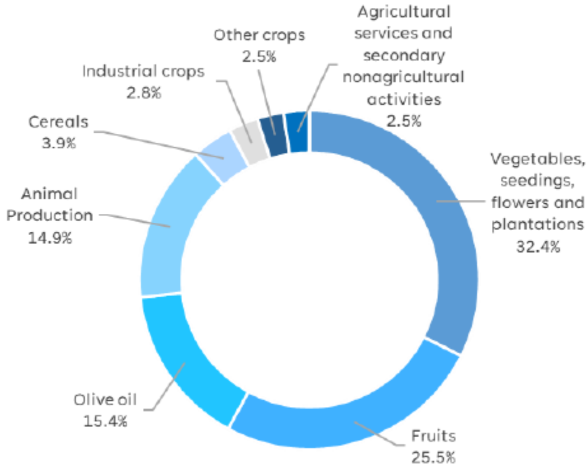

Figure 50. General distribution of crops cultivation area
Source: National Institute of Statistics (INE)

Organic agriculture

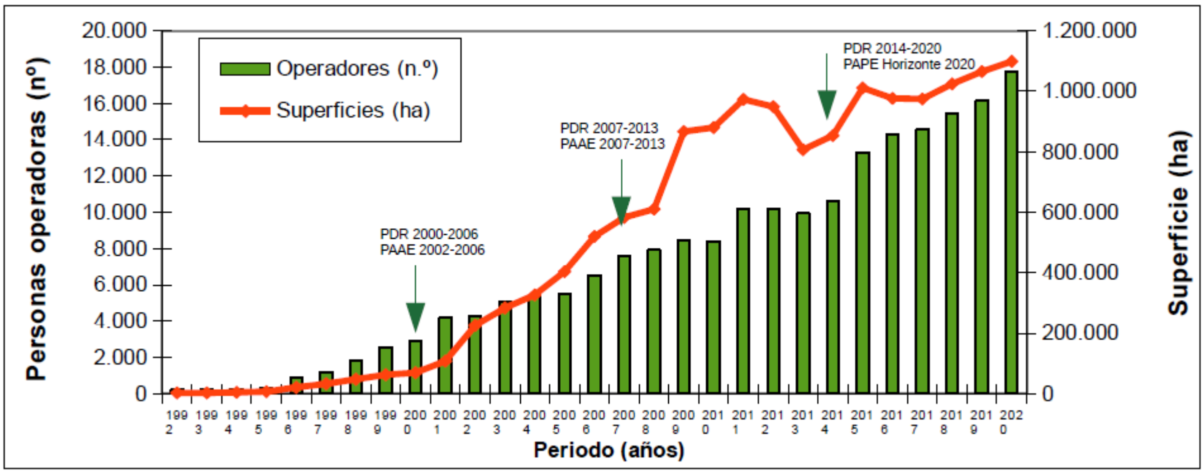

Figure 51. Surface devoted to organic agriculture (ha, in orange) and number of workers involved (nº, in green) by 2020
Source: Junta de Andalucía (Andalusian Regional Government)

Mediterranean climate, climatic and altitude differences within the Andalusian region make it a very varied and abundant region in agricultural terms. Within the primary sector, over the years there has been an increase in surface area with organic practices, involving arising workforce in terms of agricultural operators. Currently 23% of the UAA in the Andalusian territory has been converted to organic farming practices, that lead the region close to the ambitious target of the European Commission. Indeed, under the Green Deal’s Farm to Fork strategy European countries have set a target of ‘at least 25% of the EU’s agricultural land under organic farming by 2030.

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Out of the 1,098,811.66 ha of the current certified organic surface in 2020, just over two thirds are set as pastures, grasslands and forages (64.2%) a third for agricultural crops (30.2%), while the less spread in terms of percentage is represented by the agroforestry sector (5.6%).

Table 46. Main organic crops production in Andalusian regions in 2020
Source: Junta de Andalucía (Andalusian Regional Government)

Provinces / Crops	Pastures, meadows and forages	Agricultural crops	Forest and wild collection crops	Agricultural crops (%)
Almeria	9.958,41	48.014,40	1.302,90	14,46
Cadiz	136.199,36	28.768,92	134,22	8,67
Cordoba	95.065,99	78.483,68	786,41	23,64
Granada	57.857,83	86.005,69	1.649,52	25,91
Huelva	159.486,23	18.901,18	33.531,38	5,69
Jaen	97.319,02	15.494,03	15.667,88	4,67
Malaga	29.537,45	14.829,50	184.17	4.47
Seville	120.085,68	41.500,19	8.047,61	12,50
Total Andalusia 2020	705.509,98	331.997,60	61.304,08	100,00

The area of pastures, meadows and fodder is greater in the Huelva, Cadiz and Seville, followed by Jaen and Cordoba. The agricultural area, however, is more present in Granada and Cordoba, followed by Almeria and Seville. Finally, the forest and wild harvest has its greatest representation in Huelva and, to a lesser extent, in Jaen.

Quantification of water demand

Andalusia is the first Autonomous Community in absolute terms of irrigated area with 1,123,547 ha, 28.97% of the total national irrigated area (see Table 2). In relative terms it accounts for 12.83% of its geographical area and 31.84% of its cultivation area. The significant rise in localised irrigation is evident, accounting for 80.05% of the total main irrigation systems in this region. Also important is the presence of irrigation by gravity, which represents 12.34% of the total. Pressure systems is less used system.

Water shortage risks and effects on agricultural production

The main risk of water shortage in Andalusia is drought. This is a gradual circumstance characterised by the periodic water shortage, although the tendency shows how drought periods are becoming more common. There are different types of droughts: weather-related, hydrological, agronomical or socioeconomic, the differences depend on the intensity, sectors and social groups affected.

Article 63 of the Water Law includes a Special Plan to act in case of drought alert, which allows the Andalusian Government to implement a use limitation with the objective of reducing water consumption.

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The periodic indicators used by the public administration to identify droughts periods are:

- Standardised Index of Rainfall Drought (IESP).
- Normalised Vegetation Index (NDVI).
- Intensity of rainfall drought.

Other reports available to identify drought periods are:

- Analysis of the drought in Andalusia.
- Map of the Standardised Index of Rainfall Drought in Andalusia.
- Monthly Climatological Information.
- Monthly reports on the evolution of climatology in Andalusia.
- Quarterly climatological information.
- ClimaSIG. Weather Indicator Visualiser.

All these reports are available in the Subsystem of Information on Environmental Climatology of the Andalusian Government.

Non-irrigated sector in the region

One of the most common sectors in Andalusia is the Olive tree. Andalusia is the main producer of olives and olive oil in the world and this kind of activity is non-irrigated. However, the biggest non-irrigated sector in Andalusia is the herbaceous one.

Table 47. Non-irrigated field distribution in Andalusia
Source: Junta de Andalucía (Andalusian Regional Government)

Ha.	All rainfed area	Herbaceous crops	Fruit trees	Olive	Vineyard	Others
Total	12,558,099	9,717,923	503,112	1,737,260	573,478	26,327
<1	3,870	2,936	289	339	268	38
1 to <2	131,533	27,476	15,637	76,047	11,695	677
2 to <5	451,259	104,003	52,825	245,927	44,089	4,415
5 to <10	607,040	206,608	69,851	253,897	71,664	5,021
10 to <20	955,482	478,404	90,185	260,449	122,480	3,963
20 to <30	737,382	481,217	58,537	127,501	67,239	2,888
30 to <50	1,225,113	891,276	75,286	177,721	78,110	2,720
50 to <100	2,196,830	1,790,570	63,765	253,748	86,286	2,461
≥100	6,249,590	5,735,432	76,735	341,631	91,647	4,146

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4.6.3. Fertilising product sectors

The use of fertilisers in agricultural practices is an essential requirement to ensure a proper nutritional balance to crops, playing a key role in ensuring food safety. Currently the main source of macronutrients (N-P-K) is represented by fertilisers of mineral origin, highly dependent on natural gas for the extraction and their production. The war between Ukraine and Russia has led to higher energy costs, which in turn have increased the cost of producing organic fertiliser, impacting on food safety and prices. Despite rising prices and environmental risks, as well as the lack of alternatives, mineral fertilisers are the main source of macronutrients and increasingly demanded in the European because of their essential purpose.

Table 48. Mineral fertilisers use (tons) in Andalusia in 2019 and 2020
Source: Junta de Andalucía (Andalusian Regional Government)

Andalusia	2019 (t)	2020 (t)
Ammonium sulphate 21%	109.308	130.919
Ammonium nitro sulphate 26%	5.617	5.727
Calcium ammonium nitrate	32.884	19.674
Ammonium nitrate 33.5%	50.062	65.134
Urea 46%	220.489	234.840
Other nitrogenous compounds	150.934	164.278
Simple superphosphate	9.944	9.958
Concentrated superphosphate	444	748
Other phosphate compounds	31.324	41.280
Potassium chloride	60.522	74.544
Potassium sulphate	15.336	17.238
Monoammonium phosphate	21.455	14.148
Diammonium phosphate	86.248	73.987
N-P complex	9.336	10.840
N-K complex	51.175	54.006
P-K complex	3.070	2.797
N-P-K complex	234.837	234.835

Among the three macronutrients (N-P-K) Nitrogen represents the main supply in terms of amount delivered, during the seasonal fertiliser plan it accounts for 220 000 tons for the only Urea that represents the most widespread inorganic fertiliser. It follows the Phosphorus consume through Diammonium phosphate for the most (86 000 tons), while Potassium is delivered thorough mainly Potassium chloride formulation accounting in 2020 for 60 000 tons.

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4.6.4. Regulatory and institutional framework

Water reuse legal framework in Spain

The Spanish regulations for water reuse were approved in **December 2007, as a Royal Decree 1620/2007**. The RD 1620/2007 defines the practice of "water reuse", introducing the term "reclaimed water", determining the minimum requirements to develop a safe reuse of reclaimed water, setting the protocols to be followed for getting reclaimed water rights, establishing the scope of water reuse practices (with specific prohibition of certain reclaimed water uses) and setting forth the quality requirements associated to each specific water reuse option. That terminology is in complete agreement with the "Article 3 Definitions" of the "Regulation on water reuse for agricultural irrigation", as amended by the EU Parliament during its session of 12 February 2019.

Although the RD 1620/2007 is entirely devoted to regulating the use of reclaimed water, its title includes a direct reference to "treated wastewater", because of its legal dependence from the Spanish Water Code amendment introduced by Law 11/2005, as described in the foreword of the RD 1620/2007. Spanish Water Law establishes that all water resources (surface water and groundwater) are public and consequently any potential water user has to obtain the right water permit (authorisation, concession) for its use, following the protocol within the Water Act and previous legislations.

The RD 1620/2007 allows the use of reclaimed water for five main beneficial uses: 1) urban, 2) agricultural and landscape, 3) industrial, 4) recreational and 5) environmental. Some of them have several subcategories of use, up to 13 in total, depending on the level of contact of reclaimed water with agriculture products, agriculture workers, and the public at large. Water Authority (Basin Agency) is responsible for obtaining a binding report from public health authorities, as a prerequisite for the approval of any water reuse proposal.

The law establishes that before a treated wastewater effluent can be reused, it has to undergo a water reclamation process capable of ensuring that its quality satisfies the health and environmental quality limits associated with the proposed use. Furthermore, the RD 1620/2007 specifically forbids certain uses of reclaimed water, because of the risks regarding public health and the environment, such as 1) human consumption (with the possible exception of natural disasters, when public health authorities will have to establish the water quality required), 2) food industries, as set out in article 2.1 RD 140/2003 with exclusions defined in Appendix I.A.3. 3) hospitals facilities, 4) bivalve mollusc aquaculture facilities 5) swimming water in recreational facilities 6) water supply for cooling towers and evaporative condensers, 7) landscape fountains and ornamental lakes and 8) any other use that public health authorities may consider a source of public health risk.

The RD 1620/2007 sets the administrative procedure that the proponent of a water reuse project has to follow, as to obtain the legal right of using a treated effluent as the influent of a subsequent reclamation process. In particular, the regulation establishes that the recipient of a water right permit will be responsible for all the costs associated to the reclamation process

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necessary to bring reclaimed water quality in accordance with the quality limits included in the regulation. In particular, the regulation contemplates the possibility that State, Regional and Local governments may develop water reuse plans and programs as a way to promote water reuse and integrated water resources management.

Annex I of RD 1620/2007 describes the water quality criteria applicable to the 5 main categories and 13 subcategories of reclaimed water uses. Those quality criteria are considered minimum compulsory requirements. The four basic quality parameters considered in those criteria are 1) intestinal nematodes, 2) E. coli, 3) suspended solids and 4) turbidity. The most restrictive numerical limits for those parameters are associated to the use of reclaimed water for landscape irrigation in private and urban gardens, and are the following: 1 nematode egg/10 L, absence of E. coli (cfu/100 mL), 10 mg SS/L and turbidity of 2 UNT, respectively. The quality limits for agricultural irrigation of unrestricted irrigation of food crops eaten raw are 1 nematode egg/10 L, 100 E. coli (cfu/100 mL), 20 mg SS/L and turbidity of 10 UNT.

That set of water quality parameters was based in the World Health Organisation recommendations and the State of California criteria, where the numerical limits adopted were based on the treatment performance of the reclamation processes regularly applied to reclaim water, mostly representing conventional drinking water treatment processes. None of the quality limits adopted in the RD 1620/2007 was based on risk evaluation assessments, other than the lack of known public health impacts of using reclaimed water of similar quality levels, as reported by water reuse projects conducted in Spain, California and Florida.

Annex I of RD 1620/2007 also includes the minimum number of water samples and analyses applicable to the four main water quality parameters, the maximum deviation of those quality parameters from the applicable minimum requirements, and the analytical methods proposed for evaluating microbiological and chemical parameters.

Annex II of the RD 1620/2007 includes the normalised formulary required for submitting the water right permit application necessary for implementing a water reuse project.

Within the Spanish water reuse legal framework, the Ministry for Ecological Transition and the Demographic Challenge (MITECO) of Spain on the 12 of May 2023 released the **Royal Decree-ley 4/2023** to face the drought and improve water resource availability. The ministry last years had already increased annual investment by 50% from 362 million euros in 2018 to 541 million euros in 2022. The current Hydrological Plans 2022 to 2027 provide investments of 22,844 million and the Recovery Plan, Transformation and Resilience contemplates another 3.167 million, including a PERTE Water Cycle Digitisation. This RDL serves as relief for the agricultural sector and preparation for the momentous challenges that come from climate change, especially in regions like Catalonia and Andalusia that represent most affected areas.

The RDL strengthens this line of work and approves several urgent measures to deal with the current drought situation, with an economic impact of 1400 million that includes:

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- Help measures towards farmers using irrigation systems that suffer a reduction in their water supply by 2023, an exemption will be applied to the regulatory fee and the water use fee. This exemption will be 50% if the allocation falls from 40% to 60%, and 100% if it exceeds 60%. Indirect beneficiaries of the regulatory works of the Guadalquivir basin are directly exempt from 50% of these quotas.
- Actions to encourage the re-use of urban water, the RDL amends the Water framework so as to increase by 150%, from the current 400 Hm3 per year to about 1,000 Hm3 per year in 2027, representing 20 per cent of the volume of water resources used to supply populations.
- The construction of important infrastructure for the basins affected by the drought, such as emergency pumping and the adaptation of outlets to ensure supplies in the coming months, with an estimated budget of 35.5 million.

In this area of new infrastructure, several actions are declared of general interest on the Mediterranean coast, so that the central State will assume the construction of desalination plants in Tordera (Catalonia) -220 million-, in Malaga and Almeria -200 million-, as well as the intensification of reuse in Alicante, with an investment of 224 million.

Likewise, the State Water Society of the Mediterranean Basins (Acuamed) has been given the opportunity to start bidding for the construction of new desalination plants powered by photovoltaic solar parks, within the framework of its second Direct Management Agreement, which has an economic endowment of 600 million.

Table 49. Royal Decree-4/2023 actions within the Guadalquivir basin
Source: Boletín Oficial del Estado (BOE) de España (Spanish Official State Bulletin)

Type of action	Title	Description	Economic value (€)
Guadalquivir hydrographic demarcation			
Taxation	Tax exemption	Exemptions on the regulation fee and water use rate for at-risk users who have had a reduction in supplies greater than 40%	40.000.000,00
Investment	Immediate execution actions	Actions that must be undertaken immediately to alleviate the current and foreseeable shortage situation in the coming months. This includes works to adapt supply intakes or other elements of hydraulic infrastructure, as well as emergency pumping.	14.790.642,00
Investment	Priority actions	Actions that must be undertaken in the coming years to increase the resilience of water resources systems to scarcity situations. This includes actions aimed at the environmental	88.538.000,00

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		recovery of the Doñana natural area and the improvement of drinking water treatment.	
Total for Guadalquivir			143.328.642,00

European Water reuse legal framework

In June 2020, the first European regulation on recycled water was implemented and from 26 June 2023 it will define a broad standardisation guideline on their reuse among European countries. The purpose of the European Commission with **Regulation (EU) 2020/741** is to facilitate the adoption of water reuse whenever it is appropriate and cost-efficient, thereby creating an enabling framework for those Member States who wish or need to practise water reuse. This Regulation should be flexible enough to allow the continuation of the practice of water reuse and at the same time to ensure that other Member States can implement these rules when they decide to introduce this practice at a later stage. The text claims a member state that do not practise water reuse should be duly justified based on the criteria laid down in this Regulation and reviewed regularly. The general European Commission goal is to set out harmonised parameters to guarantee the safety of water reuse in agricultural irrigation, with the aim of encouraging this practice and helping to address droughts and water stress, especially along the most affected Mediterranean countries. This document can even contribute to the UN sustainable development goals, in particular goal 6 regarding the availability and sustainable management of water and sanitation for all and goal 12 on sustainable consumption and production.

The regulation sets out minimum requirements for water quality and monitoring along with rules on risk management, for the safe use of reclaimed water for agricultural irrigation in the context of integrated water management.

It builds on two European Commission's communications:

- The 2012 blueprint to safeguard Europe's water resources
- The 2015 EU action plan for the circular economy, which committed to a series of measures to promote the use of treated waste water and to a legal proposal setting out minimum requirements for water reuse.

The regulation applies whenever treated urban waste water is reused, in accordance with Article 12(1) of Directive 91/271/EEC on urban waste water, for agricultural irrigation. An EU Member State can decide that it is not appropriate to reuse water for agricultural irrigation in one or more of its river basin districts or parts thereof, on the basis of specific criteria:

- The geographic and climatic conditions of the district or parts thereof.
- The pressures on and the status of other water resources.
- The pressures on and the status of the surface water bodies in which treated urban wastewater is discharged.

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- The environmental and resource costs of reclaimed water and of other water resources.

Such a decision must be accordingly justified and regularly reviewed to take into account changing circumstances, such as climate change projections and national climate change adaptation strategies, along with the river basin management plans drawn up in accordance with the water framework directive (Directive 2000/60/EC). The regulation allows for time-limited exemptions from the rules for research or pilot projects, subject to certain conditions.

The reclamation facility operator must ensure that reclaimed water intended for agricultural irrigation complies with the minimum requirements for water quality set out in ANNEX 1 to the regulation, covering **microbiological elements** (such as levels of ***Escherichia coli*** bacteria) and monitoring requirements for routine and validation monitoring; any additional conditions concerning water quality set by the relevant authority in the relevant permit issued.

Risk management

- The relevant national authority must ensure that a **water-reuse risk management plan** to produce, supply and use reclaimed water is drawn up.
- The water-reuse risk management plan can be drafted by the reclamation facility operator, other parties in the water-reuse project or the end users, as appropriate, and it must identify the risk management responsibilities of all parties in the water-reuse project.
- It must, in particular, set out any additional water quality requirements, identify appropriate preventive and/or corrective measures and identify any additional barriers or measures to ensure the safety of the system.

The production and supply of reclaimed water for agricultural irrigation requires a permit. Parties concerned must submit an application to the relevant national authority. The permit sets out the obligations of the reclamation facility operator and, where relevant, of other parties involved in the water-reuse system, which are based on the risk management plan. They must specify a number of elements, including:

- The **reclaimed water quality class or classes** and the agricultural use for which the reclaimed water is permitted, the place of use, the reclamation facilities and the estimated yearly volume of the reclaimed water to be produced.
- Conditions in relation to the minimum requirements for water quality and monitoring.
- Conditions in relation to additional requirements for the reclamation facility operator, set out in the water-reuse risk management plan.
- Any other conditions necessary to eliminate any **unacceptable risks** to the environment and to human and animal health.
- The validity period of the permit.
- The point of compliance.

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- Permits must be regularly reviewed and updated where necessary, and at least when there are significant changes in the treatment processes or in the site conditions.

Agricultural irrigation and landscape irrigation (golf course and urban and private gardens) are frequently conducted using the same water reclamation facility, as well as water distribution and storage facilities. The quality requirements established by the proposed regulation for Class A reclaimed water (≤ 10 *E. coli*, cfu/100 mL) will not satisfy the microbial requirement established in the Spanish regulations for water reuse in urban and landscape irrigation uses (irrigation of private gardens, golf course and parks). Consequently, water reclamation facilities producing water for agricultural irrigation that satisfies the proposed regulation of the EU Parliament would not be suitable for providing reclaimed water that satisfies the Spanish regulations for urban and landscape irrigation.

On the contrary, water reclamation facilities producing water for urban and landscape irrigation that satisfies the applicable Spanish regulations will equally be able to provide reclaimed water for unrestricted agricultural irrigation that comply with the proposed regulation of the EU Parliament, assuming the most likely event that reclaimed water also complies with the BOD_5 limit, and that the reclamation facility complies with the validation process established by the proposed regulation of the EU Parliament.

The EU approved regulation has been directly incorporated into the Spanish legislation, immediately supersede those sections of the RD 1620/2007 referring to irrigation of food crops to be eaten raw. The inception of that legislative adaptation process could be used to update the provisions of the RD 1620/2007, for all the reclaimed water uses included, in accordance to the considerable knowledge and experience gathered during the last decade on the operation and management of water reuse projects.

Waste-based organic fertilisers legal framework

Recently the European Commission has released the awaited **Regulation (EU) 2019/1009** of the European Parliament and of the Council of 5 June 2019 establishes rules on the making available on the market of EU fertiliser products.

With this rule are amended Regulation (EC) No. 1069/2009 laying down health rules for animal by-products and derived products not intended for human consumption and Regulation (EC) n. 1107/2009 on the placing of plant protection products on the market and Regulation (Ce) No 2003/2003 on fertilisers is repealed.

On the assumption that all Member States have national fertiliser rules and mutual recognition allows the sale of national fertilisers, this system has proved particularly difficult to apply. Freedom of movement between Member States through mutual recognition has often been hampered by divergent national rules which have led to additional costs for businesses and difficulties in carrying out checks on products.

- **Open the Single Market to organic and waste-based fertilisers:** the new rules define the conditions under which innovative organic fertilisers can be marketed in the Single

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Market. They address safety, quality and labelling requirements that companies producing and selling such fertilisers will need to comply with before affixing the CE mark, allowing their products to be freely traded across the EU without additional formalities.

- **Establish limit values for toxic contaminants in fertilising products:** the regulation for the first time introduces limits for toxic contaminants such as cadmium, mercury, or arsenic. This will contribute to a high level of soil protection and reduce health and environmental risks.
- **Allow optional harmonisation:** as fertilising products are sometimes produced locally, producers remain free to choose whether they want to apply the new EU rules or continue comply with EU countries' national rules in order to place products on the EU market. Companies that wish to apply national rules without affixing the CE-mark will continue to be able to sell their products in other EU countries under the principle of mutual recognition.

The New Regulation has a different approach: if before it was explained for each fertiliser how to produce it, now a series of constituent materials are defined that can be used, the processes to be undergone and the products that must comply with the essential requirements of quality, safety and labelling described in the annexes to the Regulation. If necessary, the conformity assessment of products must be carried out by notified bodies, otherwise self-certification will be sufficient.

This measure is a novelty for all EU countries and radically changes the functioning of the fertiliser supply chain, introducing the need for CE Conformity as a condition for marketing, while before it was sufficient to comply with legal requirements and proper labelling.

The manufacturer must now have a body accredited by the competent national authorities assess whether the characteristics of the product comply with the requirements of the standard (for example, a fertiliser could be the maximum content in heavy metals, the absence of contaminants, etc.) by carrying out appropriate tests according to certain standards setting out the analytical methods to be adopted.

The New Regulation is therefore divided into 53 articles and 5 annexes concerning:

- The functional categories of the product (Pfc).
- The constituent material categories (Cmc).
- The labelling requirement and tolerances.
- The conformity assessment procedure.
- The EU declaration of conformity.

During the 2022 the fertilisers regulation framework was implemented through the **Regulation 2022/1171 of the European Commission** on the 22nd of March 2022 that amended ANNEX II-III-IV of the Regulation (EU) 2019/1009. Particularly, high purity products were categorised

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as constituent materials for fertiliser production, with a minimum purity requirement of 95% for dry matter.

The high purity materials identified by the JRC (Commission's Joint Research Centre) are ammonium salts, sulphate salts, phosphate salts, elemental sulphur, calcium carbonate and calcium oxide. All those materials are covered by Regulation (EC) No 2003/2003 of the European Parliament and of the Council, have a significant market demand and have proven their high agronomic value during a long history of use in the field. As a first measure to ensure both safety and agronomic efficiency, a minimum purity requirement of high purity materials should be laid down. According to the information available in JRC's assessment report, a 95 % purity, expressed in terms of the dry matter of the material, will ensure high agronomic efficiency with low risks to the environment, health and safety. In addition, it is appropriate to specify that high purity materials are recovered from waste following two types of processes: processes that isolate salts or other elements through (a combination of) advanced purification methods, such as crystallisation, centrifugation or liquid-liquid extraction, often applied in (petro-)chemical industries; and gas purification or emission control processes designed to remove nutrients from off-gases. Therefore, the content of certain impurities, pathogens or contaminants which are specific to those materials, or the content of organic carbon should be limited, based on the JRC assessment report. Such criteria should apply in addition to the safety criteria laid down in Annex I to Regulation (EU) 2019/1009 for the corresponding product function category and without prejudice to Regulation (EU) 2019/1021 of the European Parliament and of the Council.

Standards

ISO 16075-1:2015

ISO (International Organisation for Standardisation) is a worldwide federation of national standards bodies (ISO member bodies). In particular, **ISO 16075-1:2015** contains guidelines for the development and the execution of projects intending to use treated wastewater (TWW) for irrigation, considering climate and soil parameters. The purpose of these guidelines is to provide specifications for all elements of a project using TWW for irrigation, including design, materials, construction, and performance, when used for the following destination of use:

- Unrestricted irrigation of agricultural crops.
- Restricted irrigation of agricultural crops.
- Irrigation of public and private gardens and landscape areas, including parks, sport fields, golf courses, cemeteries, etc.
- Irrigation of private individual gardens.

These guidelines are intended to provide assistance for the benefit of users of TWW for irrigation. The guidelines relate to the widespread and common ranges of water quality rather than exceptional or unique ones and are intended for the use by professionals, such as irrigation companies (designers and operators), agricultural extension officers or advisors,

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water companies (designers and operators), and local authorities. This guideline refers to factors involved in water reuse projects for irrigation regardless of size, location, and complexity. It is applicable to intended uses of treated wastewater in a given project, even if such uses will change during the project's lifetime; as a result of changes in the project itself or in the applicable legislation.

The key factors in assuring the health, environmental and safety of water reuse projects in irrigation are the following:

- Meticulous monitoring of treated wastewater quality to ensure the system functions as planned and designed.
- Design and maintenance instructions of the irrigation systems to ensure their proper long-term operation.
- Compatibility between the treated wastewater quality, the distribution method, and the intended soil and crops to ensure a viable use of the soil and undamaged crop growth.
- Compatibility between the treated wastewater quality and its use to prevent or minimise possible contamination of groundwater or surface water sources. These guidelines suggest the parameters of TWW quality. These parameters include the following:
    - Agronomic parameters: nutrients (nitrogen, phosphorus and potassium) and salinity factors (total salt content, chloride, boron, and sodium concentration).
    - Other chemical element parameters (heavy metals).
    - Microbial parameters. Recommendations for these parameters are provided in the ISO document. These levels have been derived for irrigating fields at seasonal irrigation doses of 500 mm to 600 mm (5 000 m^3/ha to 6 000 m^3/ha) and in relation to the nitrogen and phosphorus consumption of the crops.

ISO/TR 20736:2021(E)

Another important standard guideline to the reuse of water is related to Sludge recovery, recycling, treatment and disposal. These guidelines represent a globally and growing challenge for most countries because:

- Sludge is a by-product of water treatment process produced in large quantities as new wastewater treatment facilities are built and the existing ones are upgraded to keep up with the population growth.
- One of the largest costs associated with water and wastewater processing streams is the treatment and disposal of sludge.
- Stricter regulations on conventional outlets such as beneficial agricultural land, composting, landfilling require more treatment due to concerns about the long-term impacts on public health and environment.

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- Sludge is now being considered as a source of renewable energy, and also a source of valuable components such as carbon and nutrients.

The growing trend to recover energy and resources from waste sludge and stricter regulations on outlets have created interest in a number of thermal treatments and may meet, under certain conditions as the case of circular economy principles.

The objective of this document is to pragmatically present the methods for thermal treatment of sludge by covering the different process fundamentals, the associated technologies and operational aspects, as well as the management of energy, valuables and residues, the aspects related to impacts and integration of installations referring to them.

ISO 23056:2020(E)

This document provides guidelines for the planning, design principles and considerations of a decentralised/onsite water reuse system and water reuse applications in urban areas. This document is applicable to practitioners and authorities who intend to implement principles and decisions on decentralised water reuse in a safe, reliable and sustainable way. This document addresses decentralised/onsite water reuse systems in their entirety and is applicable to any water reclamation system component (e.g. source water collection, treatment, storage, distribution, operation and maintenance and monitoring). The document provides:

- Standard terms and definitions.
- Description of system components and possible models of a decentralised/onsite water reuse system.
- Design principles of a decentralised/onsite water reuse system.
- Common assessment criteria and related examples of water quality indicators, all without setting any target values or thresholds.
- Specific aspects for consideration and emergency response. Design parameters and regulatory values of a decentralised/onsite water reuse system are out of the scope of this document.

4.6.5. Wastewater and sewage sludge treatment and processing

Andalusia faces relevant challenges in the wastewater treatment sector and still fails to comply entirely with the Urban Wastewater Treatment Directive. Nevertheless, the wastewater treatment has followed a very positive evolution in this region. In 1984, 55 treatment plants operated in Andalusia. In 2016, the **number of sewage treatment plants amounted to 695**, considering both those built (668) and those under construction (27). These treatment plants **benefit a population of 7,118,859 people**.

Table 50. Evolution of the number of WWTP built in Andalusia during 2012 – 2016 by province
Source: Andalusian regional office of agriculture, livestock, fisheries and sustainable development

Province/year	2012	2013	2014	2015	2016

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Almeria	135	160	161	161	161
Cadiz	71	72	82	82	83
Cordoba	45	47	49	49	50
Granada	84	88	88	88	88
Huelva	64	67	73	74	74
Jaen	80	80	76	77	77
Malaga	81	80	74	76	76
Seville	55	56	57	57	59
Andalusia	**615**	**650**	**660**	**664**	**668**

This means that 12.40% of the population in Andalusia remain unserved of appropriate treatment of their wastewater. The distribution of the unserved population is not homogenous in the region. It is worth to mention the high percentage of the unserved population in the province of Granada with almost 40% of people without wastewater treatment.

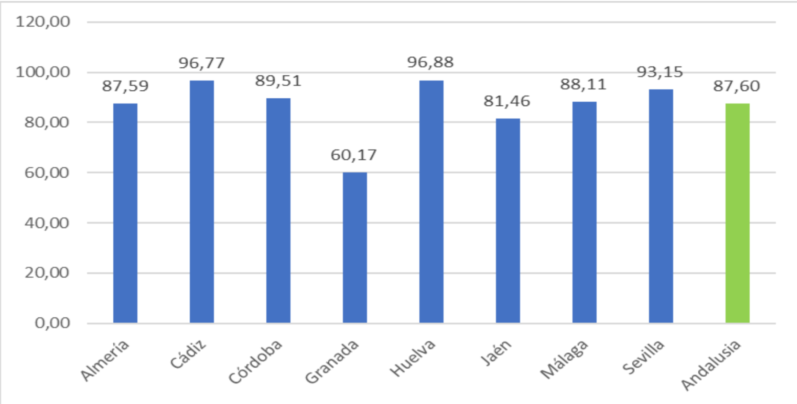

Figure 52. Percentage of population served by WWTP in Andalusia by province
Source: Andalusian regional office of agriculture, livestock, fisheries and sustainable development

The Spanish Ministry of Agriculture has made available a Central Data Repository CDR-EIONET with the reports sent to the European Commission by Spain to comply with the information obligations derived from Directive 91/271 / CEE relative to the treatment of urban wastewater (hereinafter Urban Wastewater Treatment Directive or UWWTD).

In this sense, in 2010 the European Commission (EC) identified that nine Spanish agglomerations did not comply with the requirements of the Urban Wastewater Treatment Directive and brought Spain to the Court of Justice. For this reason, Spain has to pay a lump sum of 12 million euro and a penalty payment of almost 11 million euro for every six-months they do not comply with the Urban Wastewater Treatment Directive. This decision was made by the European Court of Justice in Luxembourg at the end of July 2018. Seven of the nine municipalities that have caused the fine of 12 million imposed this week to Spain by the Court of Justice of the EU are Andalusian.

With a **total volume of 698.17 hm^3/year treated wastewater** produced in Andalusian UWWTP, the region has a strong potential to use reclaimed water in agriculture. In Spain, reuse

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practices are unequally distributed. It is estimated that more than 492.95 cubic hectometres/year are reused in the whole country, which accounts for 10.43% of the treated wastewater (Source: INE). Most of water reuse practices are concentrated in the Valencian Community, Murcia, Andalusia, Canary Islands and the Balearic Islands and large cities such as Madrid or Barcelona (Source: AEDyR).

According to the most recent data (2020), **5.22 % of the treated wastewater was finally reused as reclaimed water in Andalusia (36,49 Hm^3/year)**. This amount is considerably inferior to the percentage of reuse in the most advanced regions in Spain such as Murcia or Valencia community with 71.8% and 47.5% respectively and also lower than the national average, 10.43%.

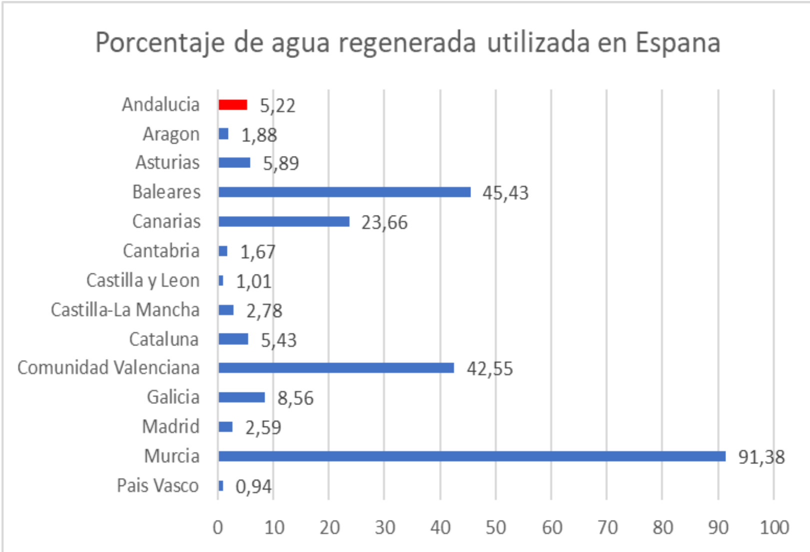

Figure 53. Percent. of reclaimed water reuse in Andalusia compared with other Spanish regions
Source: National Institute of Statistics (INE), 2020

The evolution of water reuse in recent years exhibits a comparable trend to the evolution of treated wastewater volume.

Table 51. Volumes of treated and reused water in Spain and Andalusia in Hm^3/year
Source: National Institute of Statistics (INE), 2020

	Spain		Andalusia	
Year	**Volume of wastewater treated (Hm^3/year)**	**Volume of reclaimed water reused (Hm^3/year)**	**Volume of wastewater treated (Hm^3/year)**	**Volume of reclaimed water reused (Hm^3/year)**
2004	4964.07	367.92	728.81	52.56
2005	5038.79	395.50	637.14	47.73
2006	4880.67	487.33	645.07	45.31
2007	4569.62	500.82	506.35	121.89
2008	4515.60	525.54	543.31	96.69
2009	4672.36	534.46	571.85	119.32
2010	4864.28	491.29	671.05	123.38
2011	4926.59	608.25	823.71	114.54
2012	4961.17	548.45	850.76	87.74

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2013	4998.18	531.26	756.66	62.87
2014	4942.13	530.71	732.10	57.34
2016	4726.41	492.95	698.17	41.42
2018	4994.87	559.95	771.58	37.06
2020	4877.00	532.03	699.17	36.49

Moreover, in Andalusia, most of the treated wastewater (94.8 %) is discharged to either the sea or a river (INE, 2016).

Therefore, 41.42 Hm^3 of reclaimed water was reused in 2016 according to INE. However, only 2.5% of the reclaimed water was used in agriculture. The majority of the reclaimed water produced in Andalusia (69.20 %) was used in non-crop irrigation such as urban gardens or golf courses.

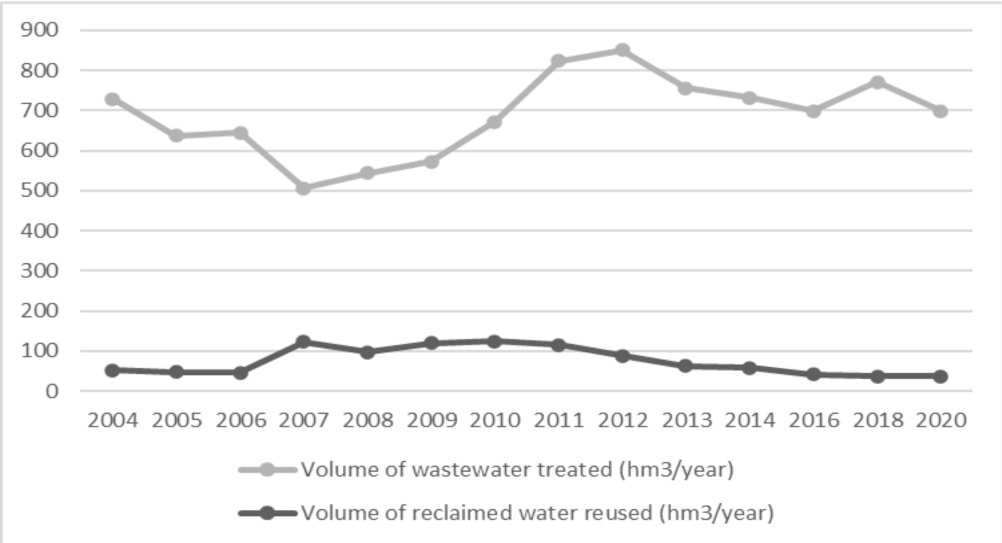

Figure 54. Volume (Hm^3) of wastewater treated and reclaimed water reused in Andalusia in the period 2004-2020
Source: National Institute of Statistics (INE)

Considering the higher percentage of reuse in other Spanish regions such as Murcia and the low percentage of reclaimed water used in agriculture, we can conclude that there is a huge potential for extending the irrigation of agricultural crops with reclaimed water.

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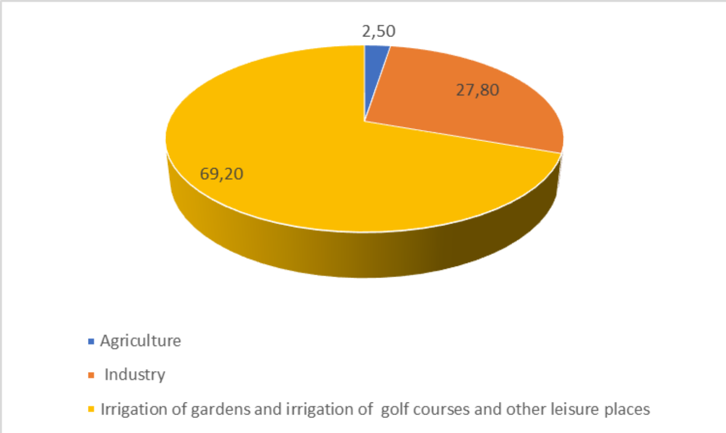

Figure 55. Percentage of use of reclaimed water in Andalusia
Source: National Institute of Statistics (INE)

Large volumes of digestate are continuously produced during the purification of unconventional water. Over the years and with the introduction of policies aimed at the circular economy, the digestate has been re-evaluated from waste to resource for the interception of useful substances in agriculture such as organic fertilisers.

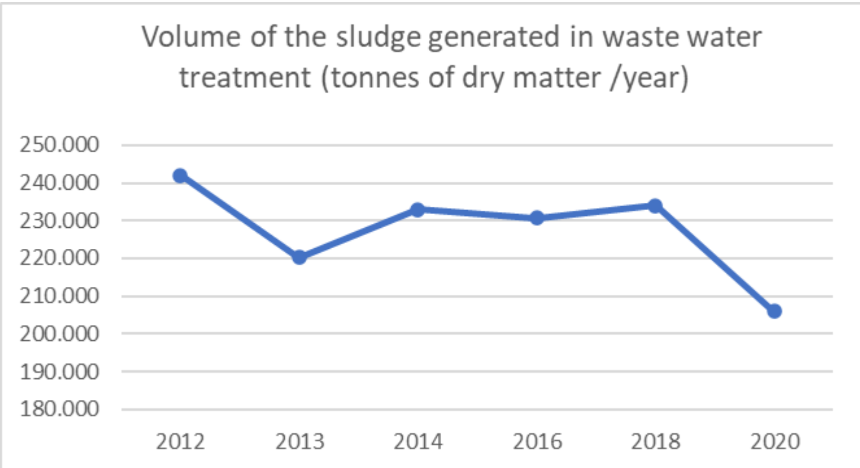

Figure 56. Volume of the sludge generated in wastewater treatment
Source: National Institute of Statistics (INE)

4.6.6. Initial stakeholders identified

A tentative initial list of regional key organisations, as well as several relevant national ones, to be approached when working on the Andalusian Regional Working Group setting up and enlargement, is attached below. The main aim is to gather representatives from the quadruple helix (industry, academy, public government, civil society), and from both water management and agricultural sectors.

Table 52. Initial key actors identified from the quadruple helix

Stakeholder	Sector	Entity
Researchers	Academy	Centre for the New Water Technologies Foundation (CENTA)

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		Andalusian Institute for Agricultural, Fisheries, Food and Organic Production Research and Training (IFAPA)
		Institute for Mediterranean and Subtropical Horticulture "La Mayora" – University of Malaga – Spanish National Research Council (IHSM-UMA-CSIC)
		Institute of Sustainable Agriculture – Spanish National Research Council (IAS-CSIC)
		Department of Agricultural Economics, Finance and Accounting at the University of Cordoba (UCO)
Public Administration	Authorities	Ministry for the Ecological Transition and the Demographic Challenge (MITECO)
		Ministry of Agriculture, Fisheries and Food (MAPA)
		Guadalquivir River Hydrographic Community (CHG)
		Regional Ministry of Agriculture, Fisheries, Water and Rural Development (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural)
		Regional Ministry of Sustainability, Environment and Blue Economy (Consejería de Sostenibilidad, Medio Ambiente y Economía Azul)
		Environment and Water Agency of the Andalusian Regional Government (AMAYA)
Water Utilities	Public sector	Municipal water company of Malaga (EMASA)
		Public water company for the Eastern Costa del Sol Town Council Association – La Axarquia (AXARAGUA)
		Public water company for the Western Costa del Sol Town Council Association (ACOSOL)
Social Agents	Private sector	Global Nature Foundation (GNF)
		New Water Culture Foundation (FNCA)
Technological Agents	Private sector	Experimental Station Cajamar Las Palmerillas (CAJAMAR)
		Cajamar InnovaCentre (CAJAMAR)
		Technnological Water Centre (CETaqua)
Users	Private sector	Union of Small Farmers of Malaga (UPA)
		Union of Consumers of Andalusia (UCAUCE)
Farmers	Private sector	Trops company (TROPS)
		Irrigators community Cuatro Vegas (Cuatro Vegas)
Agronomic products producers	Private sector	Kimitec Group (KIMITEC)
		Biorizon Biotech (BIORIZON)

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4.7. Spain – Catalonia

4.7.1. Socio-economic characterisation of the region

Catalonia, located in northeastern Spain, is a region characterised by a diverse and dynamic socio-economic landscape. Catalonia covers an area of approximately 32,000 square kilometres. Most of its territory (except the Val d'Aran) lies northeast of the Iberian Peninsula, south of the Pyrenees Mountain range. Catalonia is administratively divided into four provinces: Barcelona, Girona, Lleida, and Tarragona. The capital and largest city, Barcelona, is the second-most populated municipality in Spain and the fifth-most populous urban area in the European Union.

Figure 57. Catalonia region within Spain

Climate & Geography

Catalonia experiences a diverse range of climates due to its varied geography. It enjoys a Mediterranean climate along the coast, including Barcelona, with mild, wet winters and warm, dry summers. Inland areas like the Pyrenees Mountains feature a continental climate with colder winters and more pronounced temperature variations.

The region's geography, with its mountains and proximity to the sea, also leads to microclimates, contributing to climatic diversity. Overall, Catalonia offers a pleasant Mediterranean climate along its coastline, while its interior regions exhibit more continental characteristics, providing various climatic conditions across the region.

In the coastal areas, the climate is coastal Mediterranean. It is a mild climate, with warm summers and not very cold winters. Rainfall is abundant, especially in spring and autumn. The inland part of Catalonia is hotter and drier in summer. The temperature may reach 35 °C, some days even 40 °C. Fog is common in valleys and plains; it can be persistent, with freezing drizzle episodes and subzero temperatures during winter, mainly along the Ebro and Segre valleys and in the Plain of Vic. The climate is high mountain in the Pyrenees and Pre-Pyrenees (Pyrenean Mediterranean). Summers are cool, and winters are very cold, with abundant precipitation, often in the form of snow. Finally, the Aran Valley area, with abundant rainfall throughout the year, has an Atlantic climate. Because of this precipitation, summers are cool and winters are cold.

Population and economics

Catalonia has a marked geographical diversity, considering the relatively small size of its territory (32.106,5 Km^2). The geography is conditioned by the Mediterranean coast, with 580 kilometres of coastline, and the towering Pyrenees along the long northern border. As of 2022, the official population of Catalonia was 7,783,392 242 inhabitants/Km^2). Around 1,200,000 residents did not have Spanish citizenship, accounting for about 16% of the population.

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Catalonia is a highly industrialised region. The nominal GDP of Catalonia in 2018 was €228 billion (second after the community of Madrid, €230 billion), and the per capita GDP was €30,426, behind Madrid (€35,041), the Basque Country (€33,223), and Navarre (€31,389). The distribution of sectors is as follows: Primary sector: 3%. The amount of land devoted to agricultural use is 33%. Secondary sector: 37% (compared to Spain's 29%). Tertiary sector: 60% (compared to Spain's 67%).

According to the latest "Report on the Industry, Distribution and Consumption of Agro-food in Catalonia" (DARP, 2018), meat production is the leading food industry sector in Catalonia. Generate a business volume of 9,243 million euros and 35,400 jobs, representing 7% of the turnover and total employment in the Catalan industry. It should also be noted that the meat sector is the largest exporter and principally responsible for improving the trade balance of the agri-food industry, of which 39.6% of exports are concentrated. On the other hand, the meat industry and production-associated livestock stand out for a reasonably decentralised distribution in the territory, with considerable weight in some rural regions contributing to maintaining territorial balance. Behind these data is an intensive industrial livestock production model, based mainly on integration. It stands out for its high production efficiency but also generates a series of critical environmental impacts that have not yet been resolved satisfactorily related to the manure volumes produced.

4.7.2. Agriculture

Catalonia boasts a varied landscape, including fertile plains, rugged mountains, and a Mediterranean coastline, contributing to its agricultural productivity. The region's agriculture is known for its focus on high-quality, locally grown products, strongly emphasising sustainable and organic farming practices. Catalonia is renowned for its vineyards, producing world-class wines and sparkling cava. Additionally, it is a significant producer of fruits, mainly citrus fruits, vegetables, and nuts.

So far, manure has been directly applied as organic fertiliser in crop fields to produce different types of fruits and cereals, nuts and vegetables. The potential contamination of soil and water created by animal manure could be mitigated using biobased fertilisers derived from manure. However, this is still limited to a reduced number of available products without a clear overview of the numbers.

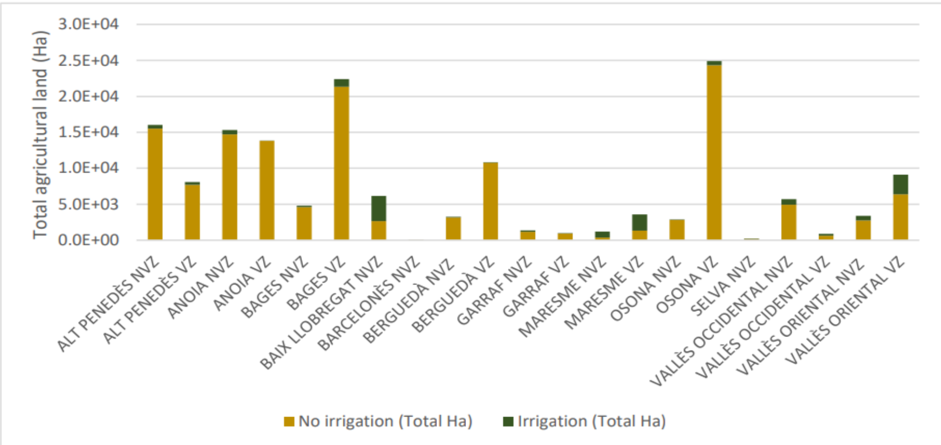

Figure 58. Total agricultural land (Ha) per region. NVZ: Non-vulnerable zone; VZ: Vulnerable zone as designated by Nitrates Directive

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Catalonia is known for its diverse agricultural production, which includes a wide variety of crops. The total area of cultivation in Catalonia is approximately 6,000 square kilometres. Cereal crops such as wheat, barley, and oats are cultivated in Catalonia, accounting for a significant portion of agricultural land. Cereals comprise around 30-35% of the total crop area. Fruit cultivation occupies a substantial portion, around 25-30% of the cultivated area. Vegetables like tomatoes, lettuce, peppers, and cucumbers are also grown in Catalonia. They typically constitute around 15-20% of the cultivated area. Catalonia is a central wine-producing region in Spain. Vineyards, mainly for wine grapes, cover a significant portion, approximately 10-15% of the cultivated area. Catalonia also produces nuts such as almonds, hazelnuts, and walnuts, accounting for a smaller percentage, roughly 5-10% of the cultivated area. Olive cultivation for olive oil production is also significant, with olive groves covering around 5-10% of the cultivated land. Other crops, including legumes, sunflowers, and various speciality crops, comprise the remaining percentage.

Regarding irrigated areas, corn, olive groves, rice, soft wheat, alfalfa and almond trees represent 60.74%. Corn, along with rice, presents practically all of its irrigated surfaces. Alfalfa distributes its surface between 26.75% dry land and 73.25% irrigated. The olive, however, barely exceeds 21% of the irrigated area and barley; although it is the second most irrigated crop in this Autonomous Community in 2021, only 15.61% of its surface is irrigated. For the first time in years, the almond tree surpasses the irrigated area of the peach and nectarine trees, a crop of great relevance in this Community.

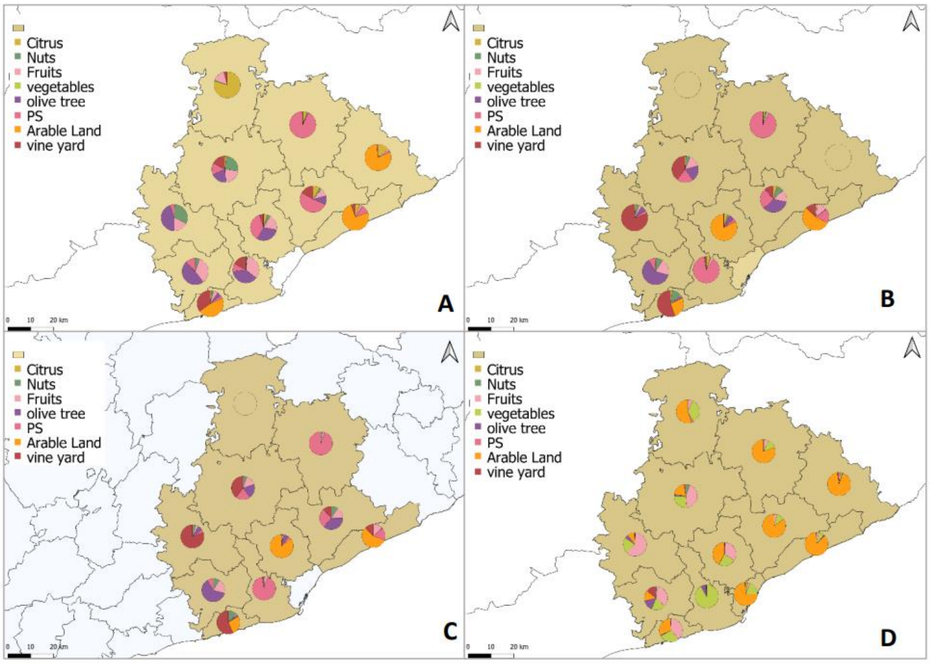

Figure 59. Crop type crossed with the presence or not of irrigation: No irrigation and not nitrate vulnerable (A) and No irrigation and nitrate vulnerable zone (B); Irrigation zone and not nitrate vulnerable (C) and irrigation zone and nitrate vulnerable (D)

4.7.3. Fertilising products sector

Using fertilisers in agricultural practices is essential to ensure a proper nutritional balance in crops, playing a pivotal role in ensuring food safety. Currently, the primary source of

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macronutrients (N-P-K) is fertilisers of mineral origin, highly dependent on natural gas for extraction and production.

Among the three macronutrients (N-P-K), nitrogen represents the main supply regarding the amount delivered. Cataluña required 22.942 T of N, 6.633 T of P_2O_5 and 22.793 T of K_2O in 2022 in form of external mineral fertilisers.

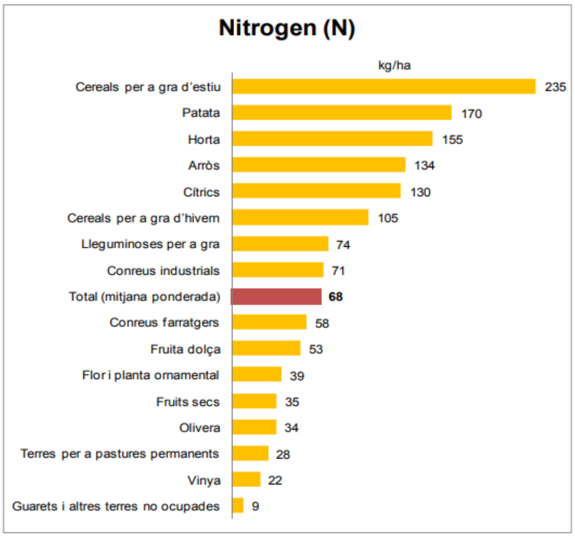

Figure 60. Kg of N per ha needed per type of crop

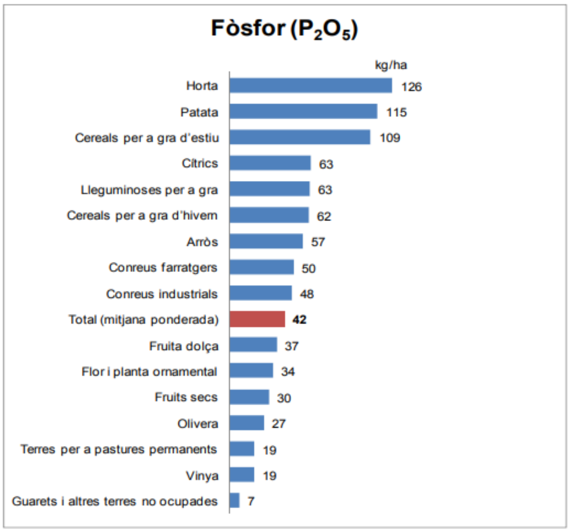

Figure 61. Kg of P per ha needed per type of crop

Quantification of the nutrient demand and possibility of using biobased fertilisers

Livestock manure is characterised by having a heterogeneous composition. For this reason, it is essential to regularly check its composition and, thus, adjust the application dose to the crop's needs. Different analysis tools and techniques allow you to know the nutrient concentration of livestock manure. Each type of manure has different characteristics and different concentrations of nutrients, giving a different market value to each of them.

Figure 62. Current value of livestock manure. A) Pig manure, B) cow manure and C) Poultry manure

It is necessary to evaluate well between the moment of application and when the applied nutrients would be available for cultivation. The manure's composition will influence nutrient availability in the short and medium term. Among the indicators most used to predict how nitrogen would be released, the most used are the % of mineral N (mostly ammoniacal N and/or nitric N), the C/N ratio or the stability of organic materials (e.g. with the degree of

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stability - GE). The product's organic content can also be mineralised in the short term. Thus, the organic forms that are part of livestock manure, treated or not, or any organic-derived product must also be counted as nutrients entering the system. The soil type will also be decisive in the retention of nutrients to make them available for cultivation. Deep soils, with high organic matter and fine textures, will retain more nutrients. Other variables will also play a role in nutrient availability, such as the work of the soil, temperature, or water availability.

Table 53. Summary of organic matter and nutrient content in the manure-derived products
Source: Fertilisation and Livestock Manure Treatment Office, Department of Climate Action, Food and Rural Agenda (DACC), 2023

Product		Dry matter (% ofm*)	Organic matter (Kg/t)	Ammoniacal N/total N (%)	Total N (Kg N/t)	Assimilable P (Kg P_2O_5/t)	Assimilable K (Kg K_2O/t)
Compost	Bovine manure	42.3	266	14	10.8	8.1	15.5
	Composting bed	38.0	275	16	12.4	6.9	15.0
	Pig manure	45.3	263	16	11.6	46.6	6.7
	Poultry manure	62.4	356	15	20.3	26.0	25.8
	Rabbit manure	35.3	230	28	9.8	12.7	12.9
	Composted sludge	77.4	362	30	22.1	26.8	5.9
Solid fraction	Sieve and/or screw press	23.7	201	39	6.4	5.8	3.5
	Centrifuge	23.2	162	43	10.4	15.9	2.6
Dry manure**	Solar drying	81.5	593	12	21.8	22.5	41.7
Digested	Anaerobic digestion	4.3	29	65	4.4	1.9	1.5
Liquid fraction	Sieve and/or screw press	3.8	25	68	3.6	2.4	3.1
	Centrifuge	1.7	10	83	7.0****	0.6	2.3
Ammoniacal solution**	Ammonium sulphate	30.8 (1.2***)	<1	97	15.3****	0.0	0.0
	Ammonium nitrate	39.1 (1.3***)	<1	50		0.0	0.0

*ofm: on fresh matter

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** products with little composition data
in parentheses, the density of the product (Kg/l)
****values corresponding to richness in % P/P and not to total N (Kg/l)

Livestock in Catalonia

In Catalonia, there are approximately 7.9 million pigs, 637,000 head of cattle, and 44.6 million poultry (DARP, 2020), generating around 9.4 million tons of slurry and 2.8 million tons of manure and hens yearly. Over the years, excessive application of manure to crops has resulted in the accumulation of phosphorus in the soil and nitrate in the groundwater. This phenomenon occurs with particular intensity in those areas where the amount of nutrients provided exceeds the needs of the fields.

The meat production density in the Osona province (where BETA centre is located) is among the highest in Spain and Europe. This sector is mainly dominated by pig production, but the meat and beef milk production sector also maintains a significant presence. The importance of each of these is reflected in the generation of nutrient-rich effluents - elements that have an intrinsic value but, in high concentrations, can be pollutants if not managed correctly. For instance, the Osona region has long maintained a nutrient production density that it cannot absorb locally.

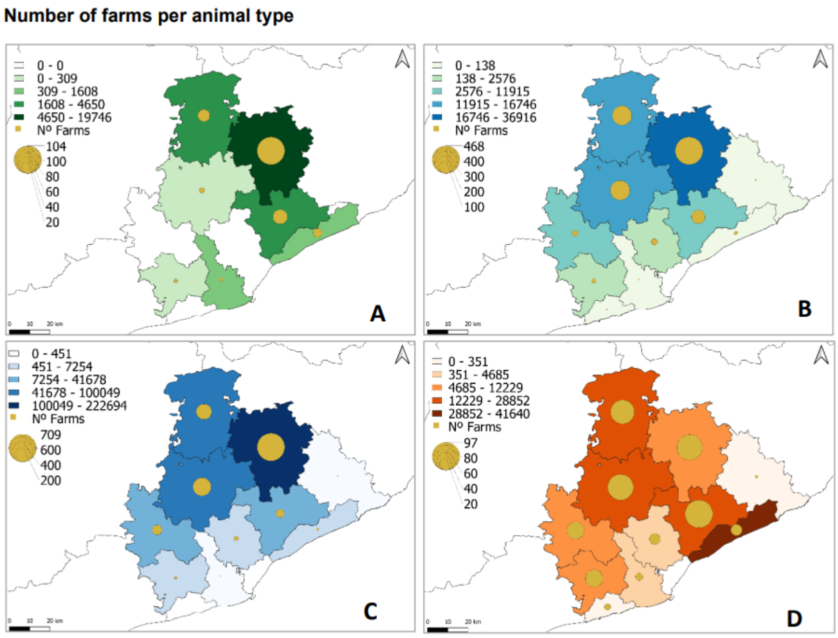

Figure 63. Number of animals (census) per animal type per county. Dairy cows (A) beef cattle (B), pigs (C) and poultry (E)

In terms of animal number, what is seen is that pig rearing dominates the region. Dairy cows are also much more abundant than beef cattle. There is also some regional specialisation, with pigs and cattle concentrated in one area, while poultry is concentrated in the coastal zone. Here, it is interesting to note that poultry animal densities do not reflect the nutrient densities – this probably reflects regional differences in the farming systems, e.g., zones which specialise in chick/hen/broiler raising, etc., and shall be investigated further. Detecting this difference is essential for manure management since this would translate to regional differences in manure chemical properties for the same sector.

Effect of nutrient excess in the environment

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Consequently, to what was exposed above, nutrients derived from pig manures are the most abundant in this region, followed by cows and poultry. Over the years, excessive application of manure to crops has resulted in the accumulation of phosphorus in the soil and nitrate in the groundwater in those areas where the amount of nutrients provided exceeds the needs of the fields. In accordance with the European Directive on nitrates, currently, 33.8% of the total area of Catalonia is declared vulnerable to pollution by nitrates of agricultural origin and affects 422 municipalities, i.e. 45% of all Catalan municipalities (ACA, 2020). On the other hand, in agreement with the Catalan Office of Climate Change, the agriculture and livestock sector contributes 12% of the greenhouse gases emitted in Catalonia. Of these emissions, it is estimated that 47% occur while managing livestock manure. The livestock sector is also responsible for the emission of 92% of atmospheric ammonia, a gas that causes acidification and eutrophication of the ecosystems, and which, in addition, harms the health and productivity of the animals on the farm itself, at the same time which is a loss of a valuable nutrient for agriculture.

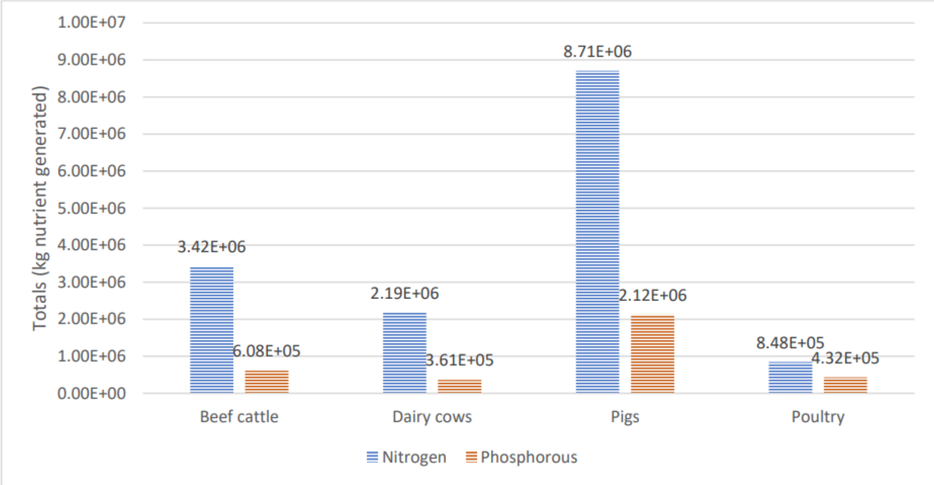

Figure 64. Kg of nutrients generated per animal type

Currently, no regulation in Catalonia establishes maximum concentrations of P according to crop and agroclimatic zone, but there are maximum P levels in the soil.

4.7.4. Regulatory and institutional framework

European framework

The new Regulation (EU) 2019/1009 will apply as of July 16th, 2022 (Briefing EU fertilising products, 2019). The Proposal for a regulation of the European Parliament and of the Council laying down rules on the making available on the market of CE marked fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 – the main elements of new regulation will include:

- Opening the single market for more fertilising products.
- Common rules on safety, quality and labelling requirements for all fertilising products traded across the EU.

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- Introducing limit values for toxic contaminants in fertilising products for the first-time regulation will introduce limits for toxic contaminants to ensure soil protection and reduce health and environmental risks.
- Maintaining optional harmonisation: manufacturer of fertilising products will be given an option to either apply the new regulation and CE-marking the product or complying with national rules and sell the product to other EU countries based on the mutual recognition rules.

According to the Commission, the proposal has two objectives: incentivising large-scale fertiliser production from domestic sources, transforming waste into crop nutrients, and introducing harmonised cadmium limits for phosphate fertilisers.

Furthermore, the proposal defines recovery rules for bio-waste transformed into compost and digestate ("end-of-waste" criteria). It amends the 2009 Animal By-products Regulation to enable derived products no longer posing significant risks to animal health to move freely on the EU market as fertilising products. It also amends the 2009 Regulation on Plant Protection Products to exclude plant bio-stimulants covered by the proposal from its scope. Regulation (EU) 2019/1009 will replace Regulation (EC) No 2003/2003, which does not include fertilisers produced from recovered or organic materials. According to the EU, fertilising products improve plant growth, mainly in agriculture. Fertilisers can be grouped into 2 broad groups: fertilisers – which provide nutrients to plants and other products – whose primary objective is to promote plant growth through other means.

Based on EC's elaborate market research, inorganic fertilisers account for 80 % of the market value and are economically valuable. On the other side, organic and organo – mineral fertilisers account for 6.5%, while plant bio-stimulants and agronomic additives account for only about 3 % of the market. The last category mentioned has been identified as the one with a strong market potential (Briefing EU fertilising products, 2019).

European Commission has now published for public consultation to October 30th 2023, the draft Delegated Regulation to implement "Processed Manure" into the European Fertilising Products Regulation, specifying the CMC10 and labelling criteria as proposed in the draft JRC report.

Nitrates directive

For most of the biobased fertilisers derived from manure resources, restriction of the Nitrates Directive must be considered in case the fields are located within Nitrate Vulnerable Zones (NVZs). Therefore, the mean values of manure-based products, even in processed form, are set at the maximum allowable limit of 170 kg N/ha per year of the utilised agricultural area (UAA). In case of a derogation, higher values apply. However, some products derived from manure will probably be seen as non-manure material and a substitute for synthetic mineral fertilisers if they comply with RENURE criteria (as defined by JRC2, which must still be approved by the commission or by a national provision). The main RENURE criteria are: RENURE materials have

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a mineral N:TN ratio ≥ 90 % or a TOC:TN ratio ≤ 3. This criterion is evaluated by correcting for any N derived from concentrated N materials (> 3 % N, dry matter basis) that classify as products or by-products and not originating from manure. Furthermore, other restrictions can be valid because of the local situation (e.g., drinking water extraction areas, nature-based regions, restrictions related to CAP / farmers funding, to food industry, etc). These restrictions are often more stringent than crop requirements and are defined as maximum values for N or any other element (P). Table 11 shows the nitrogen and phosphorus application restrictions for each crop-soil combination in NVZ according to the Nitrates Directive. The N application standard of manure indicates the total amount of N as manure products that may be applied per ha in NVZ (including derogation if available). The maximum legal N is the total amount of effective nitrogen all fertilisers may apply.

Spanish framework

The current regulation in Spain specifies rules for fertiliser products based on or incorporating humic acids, amino acids, alginic acid, etc. The European Biostimulants Industry Council (EBIC) states that "most fertilisers must be registered before marketing, with clear dossier requirements. It also mentions a group of products called "other means of plant defence". Legislation ORDEN APA/1470/2007 covers the regulation of these products. If a product is in line with provisions in this ORDEN, no registration is necessary before marketing (European Biostimulants Industry Council, 2019). In the case of products with organic components, the manufacturer must ensure that the composition, richness and other guaranteed characteristics of the final product are maintained and that the product continues to meet the conditions specified in the regulations referred to in Annex V of Regulation (EC) No 2019/1009, utilising control analyses at least quarterly in such cases.

Catalan framework

In the Catalan region, nitrogen has received the most attention from the regulations. As explained above, the European Union has addressed the problem of water pollution from agricultural nitrogen sources in its Directive 91/676/EEC of December 12th, 1991, so-called the Nitrates Directive. This one Nitrates Directive obliges member states, among other aspects, to draw up a Code of Good Agricultural Practices, which compliance is mandatory in the designated vulnerable areas and recommended for the rest. This code was established in Catalonia through the Order of October 22nd, 1998. The Directive mentioned above also calls for the establishment of action programs applicable to the designated vulnerable areas, and in this sense, the Regional Government (Generalitat de Catalunya) adopted Decree 136/2009 of September 1st, approving the action program applicable to the vulnerable areas concerning the nitrate pollution from agricultural and management sources livestock manure. At the same time and tied with the implementation of the Nitrates Directive, a series of promotion and training programs and systems of control and inspection were established. The Nitrates Directive set the foundations for defining the vulnerable areas and the measures to be taken to reduce or avoid nitrate pollution, and it is Decree 136/2009 complies with it. Within the vulnerable areas of Catalonia, a grouping is done in different areas with agronomic

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characteristics, soil and climate, as seen in the map below of the 12 areas defined within the vulnerable areas of Catalonia.

Compliance with the Nitrates Directive is also one of the legal requirements of management of conditionality. In this case, the agricultural and livestock farms located in designated areas vulnerable to nitrate pollution must comply with the measures of the Action Program established through Decree 136/2009 if they want to be beneficiaries of specific direct aid from the CAP and the Rural Development Program. The purpose of this Decree 136/2009 of Action Program is to ensure the correct management of livestock manure (slurry, manure, chicken manure, etc.) and nitrogen fertilisers in general (compost, minerals, etc.) to avoid contamination of the waters due to nitrates from sources agrarian. This translates at the level of fertility into two points to highlight: That the applications of nitrogen fertilisers, including livestock manure, must respect, among other aspects, the maximum amounts of nitrogen to apply, the periods of agricultural application, the method of application of nitrogen fertilisers, and the conditions must be taken into account particulars of the land. In addition, the applications must respect certain distances from inhabited areas, watercourses, etc., and maximum terms of incorporation of fertilisers in the soil. Bring a fertiliser management book nitrogenous whenever you have one amount of surface in a vulnerable area that exceeds more than 50 must dry, more than 25 ha of irrigation, more than 5 ha of crops in the open air of horticultural, flower or ornamental plants, or more than 1 ha of crops in vernacular.

Livestock manure is considered in the agricultural framework, regulated by the Directive 91/676/EEC of December 12th, which, in the case of Catalonia, is the Decree 153/2019, of July 3rd. In these treatments at origin, straw and other non-hazardous natural agricultural or forestry materials are possible, but not waste from non-agricultural activities. There will be situations in which the treatment of livestock manure will have to be done through a waste manager and will be considered as management outside the agricultural framework. This will happen when treatment installation is supplied from different livestock farms or when mixed waste. The activity will be subject to the Law State Law 22/2011, of July 28th, on waste and contaminated soil in these cases. Under these circumstances, the waste can be applied directly to agricultural land according to its agronomic value.

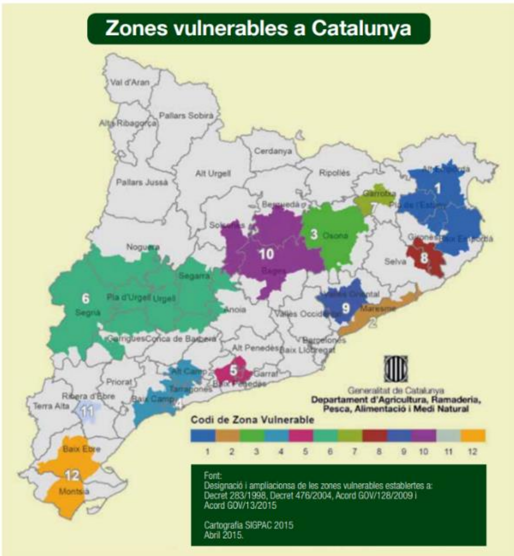

Figure 65. Distribution of the areas designated as vulnerable to nitrate pollution of agricultural origin

4.7.5. Animal manure treatment and processing

Manure treatment technologies: consolidated technologies

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At the end of the 19th century and the beginning of the 20th, with the Industrial Revolution, the composting and anaerobic digestion processes were approached from a scientific and technical perspective, leading them to the current consolidation degree. In addition to these "classic" biotechnologies of treatment, there is one abundant scientific bibliography and application experience with solid-liquid separation processes and nitrification-denitrification. Solar drying is also considered a consolidated technology due to its recent validation with experiences in real farms in Catalonia. When choosing one of these systems for treating livestock manure on the farm, it is necessary to consider the technical and economic limitations, which will vary on each operation.

Solid-Liquid separation

Solid-liquid separation is based on physicochemical processes that allow part of the solids to be separated from the slurry, obtaining two fractions with different characteristics: a more diluted fraction with a low content of solids (liquid fraction) and another more concentrated with a high solids content (solid fraction). Therefore, the solid-liquid separation process allows a redistribution of nutrients between the two fractions, facilitating their final management. The technology of solid-liquid separation of manure is perhaps the most widespread at the Catalan farm level, as it is often applied as a pre-treatment in combination with other processes. For example, this is the case of removing ammoniacal nitrogen from slurry through nitrification-denitrification, a treatment that is necessarily applied to the liquid fraction or in composting of the solid fraction.

Composting

Composting is the biological process of decomposition and stabilisation of organic matter in aerobic conditions (with the presence of oxygen) in an operating regime that allows temperatures to reach thermophiles thanks to the heat generated by the metabolism of the decomposing microorganisms. The compost obtained with this process is a product with stable solid fertilising value and sanitised, free of pathogens and seeds, which have entirely different characteristics from the fresh starting by-products. It is not a putrescible material and does not generate odours when stored. It has a dark colour, and generally, the remains of the initial material cannot be distinguished. Regarding livestock manure, the composting process can be applied to all types of manure: chicken manure, the solid fraction of slurry obtained through the solid-liquid separation process and the digestate from the anaerobic digestion of faeces.

Anaerobic digestion

Anaerobic digestion is a biological process that takes place in the absence of oxygen (anaerobic conditions), during which part of the organic matter is transformed by the action of microorganisms in a mixture of gases known as biogas. Biogas is constituted mainly of methane and carbon dioxide, with a methane content ranging between 60% and 70%, which is why it is a combustible gas (in terms of energy, 1 m3 of biogas is approximately equivalent to 0.6 L of diesel). An organic product, known as digestate, is also obtained, which is more stable and has a volume slightly lower than the input flow of the digester since part of the processed material

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is transformed into biogas but retains the nutrients initially present. Biogas can be valorised in situ via combustion or electrical cogeneration, all taking advantage of thermal energy to heat the digester. There may also be other uses of biogas, such as injection into the natural gas network or as fuel in vehicles. However, it is necessary to consider the legal requirements that require certain thresholds for eliminating unwanted gases (mainly carbon dioxide and hydrogen sulfide). This is achieved through a biogas treatment process known as up-grading, which aims to generate a methane-enriched product known as biomethane. As for the digest, this can be agronomically valued as organic fertiliser, either directly or through its transformation into other products (for example, through composting or solar drying).

Solar drying

Solar drying is a physical process that uses the sun's radiation to evaporate water for different purposes. It is a technology already applied on an industrial scale in areas as diverse as the dehydration of food products, brines and sewage sludge. More recently, this process has also begun to be used to treat livestock manure to reduce the water content. To reach sufficiently high temperatures, the drying process is carried out in a greenhouse with forced aeration to extract the ambient humidity from the interior. In the case of discharges, it is essential to control the emissions of ammonia, greenhouse gases and bad odour. Concentrating the nutrients in livestock manure to facilitate their export can be achieved by applying heat to evaporate the water they contain.

It should be noted, however, that the energy needed to evaporate 1 m^3 of water is 2,442 MJ, an amount that is equivalent to the burn of around 70 litres of petrol or 64 m^3 of natural gas. These high energy requirements mean using conventional energy sources for this purpose is often economically and environmentally unfeasible. On the other hand, solar energy is one of the most abundant resources in the Mediterranean. To give us an idea of the magnitude of this renewable energy source, the annual average of daily irradiation in Catalonia ranges between 12 and 17 MJ/m^2.

Nitrification-Denitrification

Nitrification-denitrification (NDN) treatment is based on a biological process that aims to eliminate nitrogen from the liquid fraction of the slurry, primarily present in the form of nitrogen ammoniacal (NH4+), transforming it into molecular nitrogen (N2). This harmless and inert gas constitutes almost 80% of the atmosphere. Therefore, a solid-liquid separation must be carried out of the slurry before this treatment. It is the only treatment technology that effectively removes ammoniacal nitrogen, but this entails the loss of a resource valued as fertiliser. It is for this reason that the Enforcement Decision (EU) 2017/3027 of the European Commission, which entered into force on 02/21/2017, on the best available techniques (BAT) for the treatment of farm-scale manure state that NDN treatment does not apply to new farms/farms, and is only allowed in existing exploitations.

Manure treatment technologies: emerging treatment technologies

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We are currently at a critical historical moment regarding technological development in diverse areas, including those related to more sustainable food production. It's in this one context of innovation that new ideas can appear on how to treat manure more efficiently, economically and with a lower environmental impact. Some of these technological proposals are based on new concepts, while others consist of making substantial improvements to existing processes.

There are numerous technical publications in which the principles of operation are collected and described for emerging technologies. However, those considered emerging technologies still require specific analysis when establishing the level of nitrogen reduction in the farm where they are or will be. This criterion is due to the lack of accumulated experience in the Catalan context on the specific technology in question in terms of compliance with the claimed efficiency and emissions criteria. To be sufficiently guarantor when presupposing technical feasibility that guarantees specific levels of efficiency and emissions might be better than a currently available technique, which the productive systems and the climatic conditions specific to Catalonia have previously validated. Some of these technologies include stripping-scrubbing, membranes or struvite precipitation.

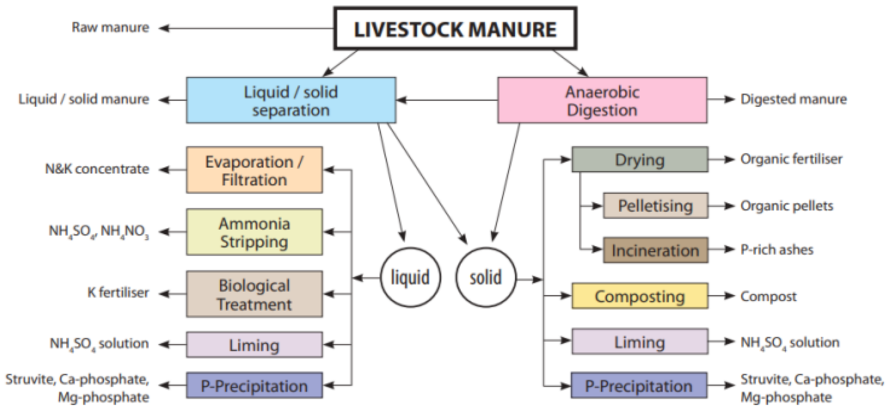

Figure 66. Overview of the main routes for nutrient recovery and reuse and the products obtained (Nutrient Recovery and Reuse)

Development of Biogas facilities in Catalonia and possibilities for nutrient recovery from digestate

Despite Catalonia's high biogas production potential, thanks mainly to a robust agri-food sector, it is far behind European countries such as France, Italy, Germany and Denmark. Biogas can provide environmental benefits, such as decarbonisation and reducing greenhouse gases. It also provides economic benefits, creating new value chains based on the circular bioeconomy and social benefits, such as generating jobs and increasing energy sovereignty. Catalan Biogas and biomethane have a triple effect of mitigating greenhouse gases: reducing emissions by improving the management of organic waste, replacing the use of fossil fuels and reducing the demand for mineral fertilisers thanks to digestate as to organic fertiliser. Biogas is generated thanks to certain microorganisms' natural anaerobic digestion of organic matter. The primary sources of organic matter used are livestock manure, by-products of the food industry, sewage sludge, municipal organic waste and agricultural and forestry biomass. To ensure the sustainability of an anaerobic digestion plant, it is essential to contemplate the management of the digestate, especially in territories with a high generation of organic waste, as is the case in Catalonia. Europe is making a clear commitment to decarbonisation and energy sovereignty.

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One of the strategies to carry this out is the Repower EU Plan to multiply biogas production by 10 by 2030. There are 68 biogas plants in Catalonia, 5 of which produce biomethane. It is necessary that there is political will to promote sustainable growth of the sector in the territory.

37,3% of the Spanish biogas plants are located in Catalonia. Several projects were selected to receive funding from the incentive program of IDAE (Institute for Energy Diversification and Saving) of the Spanish Government.

Table 54. Number of biogas plants per Spanish autonomous region

Spanish autonomous community	Number of plants	Percentage
Catalonia	28	37.3
Aragon	8	10.7
Andalusia	7	9.3
Castilla La Mancha	5	6.7
Castilla y Leon	5	6.7
Murcia	5	6.7
Basque Country	3	4
Canary Islands	3	4
Valencia	3	4
Navarra	1	1.3
Asturias	1	1.3
La Rioja	1	1.3
Cantabria	1	1.3
Extremadura	1	1.3
Madrid	1	1.3
Balearic Islands	1	1.3

As shown in the map produced by the Joint Research Centre of the European Commission of the biogas generation potential in Europe. Catalonia's and part of Aragon's high potential stands out compared with the rest of Spain.

Biogas Plants in Catalonia have different input material. The main typologies are: -Agricultural: Co-digestion of livestock manure and other organic waste (usually from the agri-food sector, mainly sewage sludge, but also others, like SANDACH products, and from the agricultural sector) - Municipal waste (mainly landfills that, to avoid emissions and utilise the methane generated, install a biogas plant) - Sludge from municipal sewage treatment plants - Others: only livestock manure, only agri-food industry, paper industry.

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The map shows the distribution of the plants depending on the waste they manage. As far as the plants of the agri-food industry are concerned, they are located in the north-east and the centre-west (Lleida).

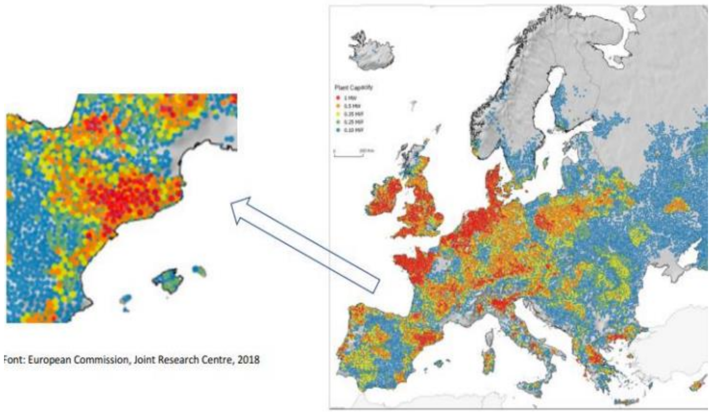

Figure 67. Biogas Generation Potential in Europe Source: EC's Joint Research Centre (JRC)

Figure 68. Distribution of biogas plants in Catalonia from the agri-food industry (including manure treatment)

4.7.6. Initial stakeholders identified

A tentative initial list of regional key organisations and several relevant national ones to be approached when working on the Catalan Regional Working Group setting up and enlargement is attached below. The main aim is to gather representatives from the quadruple helix (industry, academy, public government, civil society).

Table 55. Initial key actors identified from the quadruple helix

Stakeholder	Sector	Entity
Research	Public sector	Institute of Agri-food Research and Technology (IRTA)
		LEITAT technological centre
	Academy	Autonomous University of Barcelona (UAB)
	Public sector	Institute of Sustainable Agriculture – Spanish National Research Council
		Technological Centre of Catalonia (EURECAT)
Public Administration	Authority	Ministry for the Ecological Transition and the Demographic Challenge
	Public sector	ACCIO Agency for bussiness competitiveness https://www.accio.gencat.cat/en/inici/index.html
	Authority	Department of Climate Action, Food and Rural Agenda (DACC)
		Catalan waste agency (https://residus.gencat.cat/)

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	Public sector	Vallès Oriental waste management consortium (Vallès Oriental Waste Management Consortium - SCEA)
		Catalan Institute for the Energy (Inici. Institut Català d'Energia (gencat.cat))
Technological Agents	Private sector	Ecofertbio SL http://www.ecofertbio.es/que-es-el-sistema-ammoneva/
		Sahivo https://sahivo.com/en
		Mecàniques Segalés http://www.segales.net/en/index.htm
		Rotecna https://www.rotecna.com/en/
		Grup Carles https://www.gcarles.com/
		Depurtech https://www.depurtech.com/en/projects/#aigues-residuals
		GEA https://www.gea.com/en/index.jsp
Users	Private sector	FCAC Federació de Cooperatives Agràries de Catalunya (cooperativesagraries.cat)
		ASOPROVAC Catalonia Somos ganaderos | asoprovaccatalunya.com
Farmers	Private sector	Vall Companys Group https://vallcompanys.es/en/
		Agropecuaria de Guissona (BonÀrea Agrupa) https://www.bonarea-agrupa.com/
		Granges Terragrisa, the group managing the Casa Tarradellas' farms
Agronomic products producers	Private sector	Fertinagro Biotech https://www.fertinagrobiotech.com/en/
		P.Labin SL https://labin.net/en/
		Muns SL https://www.muns.es/?lang=en
		Fertiberia https://www.fertiberia.com/en/our-group/

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5. SWOT analysis of the NOVAFERT regions

A SWOT analysis for the use of novel fertilisers produced using secondary raw materials as a basis has been developed for each of the regions considered within NOVAFERT project. This SWOT analysis aims to formulate the Strengths, Weaknesses, Opportunities and Threats affecting the use of such novel fertilisers.

The SWOT analysis has been built based on the initial inputs from the project partners and the initial members of their corresponding Regional Working Group (RWG), what has allowed the definition of the SWOT attributes and their further scoring. The result of this evaluation constitutes the first step to elaborate the Region Specific Action Plans (RSAPs).

Each participant of the RWG, as well as the additional stakeholders contacted, have provided their answer (according to their knowledge and own opinion) to this SWOT. As mentioned in section 2, scoring has been the way of transforming the collected qualitative information into quantitative, giving a value from 1 to 5 to each or the attributes defined.

5.1. Belgium – Flanders

SWOT analysis for Flanders region has been focused on the alternative fertilising products coming from their assigned waste streams:

- Animal manure.
- Digestate.

The results can be graphically presented as follows:

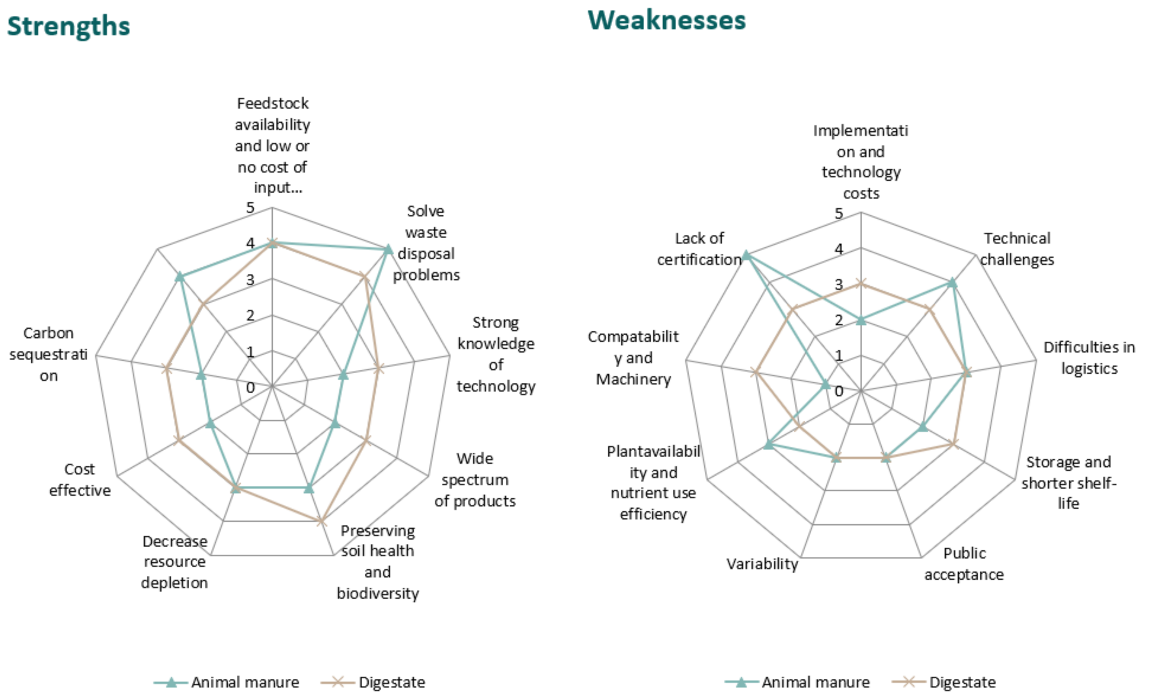

Figure 69. Strengths and weaknesses radar diagrams for Belgium - Flanders region

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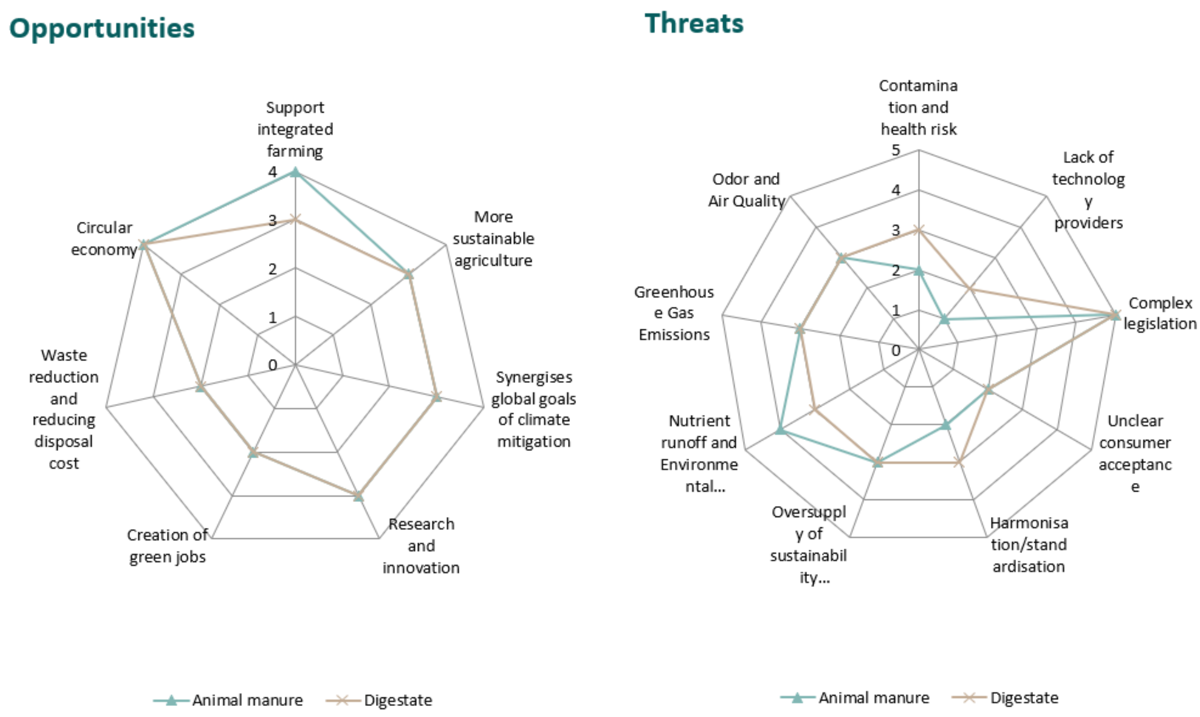

Figure 70. Opportunities and threats radar diagrams for Belgium - Flanders region

5.1.1. Strengths (S)

The strengths identified and the value given to each of them have been the following:

Table 56. Strengths matrix for Belgium - Flanders region

No	Strengths Item	Explanation	Scoring for animal manure	Scoring for digestate
1	Nutrient Recycling	These fertilisers contribute to the recycling of nutrients from organic waste materials back into the soil, reducing the need for synthetic fertilisers. This helps to close nutrient loops and promotes a more sustainable agricultural system	4	4
2	Feedstock availability and low or no cost of input streams	High availability, renewability and minor pollution (4 250 857 tonnes of livestock manure was processed in Flanders in 2021)	5	4
3	Solve waste disposal problems	Utilising animal manure, and digestate as fertilisers reduces the volume of organic waste that would otherwise require disposal in landfills or incineration. This helps to alleviate the burden on waste management infrastructure	2	3

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4	Strong knowledge of technology	In terms of new market and technological challenges, the EU plays a supportive role in developing innovative technologies and improving existing manure processing systems	2	3
5	Wide spectrum of products	Major groups of liquid and solid end and by-products according to their chemical composition, content of plant nutrients	3	4
6	Preserving soil health and biodiversity	Increase crop yield while simultaneously improving soil health. Improve soil organic matter content. Increased organic matter enhances soil fertility, water-holding capacity, and overall soil health, leading to improved crop productivity	3	3
7	Decrease resource depletion	Because of their ability to substitute mineral fertilisers	2	3
8	Cost effective	Bio-waste and biological byproducts are less expensive than synthetic fertilisers. As a result, they are a cost-effective alternative for farmers	2	3
9	Carbon sequestration	As organic compounds decompose, they store carbon in the soil	4	3

The most relevant strength identified for animal manure as a potential source for alternative fertilising products in Flanders region is the high feedstock availability at low or no cost. In addition to that, the potentiality of recycling nutrients by using this waste stream as alternative fertilising product is also very high, as well as the capacity of storing carbon in the soil as organic compounds decompose.

On the other hand, other strengths identified has not been considered so relevant, such as the alleviation of the waste management infrastructure, the lower price in comparison with synthetic fertilisers or the strong knowledge on the existing technology for its valorisation.

Digestate strengths result quite similar to those identified for animal manure. The most relevant strengths identified have been the capacity of recycling nutrients, the feedstock availability at low or no cost and the spectrum of end and by-products according to their chemical composition. Furthermore, the stakeholders consider its relevance in solving waste disposal problems is slightly higher than in the case of animal manure, as well as it happens with the knowledge of technology and the products spectrum. On the contrary, its relevance regarding carbon sequestration is lower.

Thus, the key strengths to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of both animal manure and digestate, are:

- Feedstock availability at very low or even no cost.
- Great potentiality of nutrients recycling by their direct injection back to the soil.
- At a lesser extent, carbon sequestration in the soil as organic compounds decompose and the variety of end and by-products according to their composition.

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5.1.2. Weaknesses (W)

The weaknesses identified and the value given to each of them have been the following:

Table 57. Weaknesses matrix for Belgium - Flanders region

No	Weakness Item	Explanation	Scoring for animal manure	Scoring for digestate
1	Implementation and technology costs	High investment in technology implementation. The implementation of new technologies is of course linked to high investments which companies are not necessarily willing to make	2	3
2	Technical challenges	Considering the costs of owning and operating a manure-processing systems (structures, equipment and labour required to handle and/or store manure for an extended period of time)	4	3
3	Difficulties in logistics	Transportation can be the limiting factor and treatment processes must be modulated to decrease its cost	3	3
4	Storage and shorter shelf-life	Can be difficult to store and may have much shorter shelf-life	2	3
5	Public acceptance	Concerns regarding safety, odour, aesthetics, or perception of quality compared to synthetic fertilisers can influence public acceptance	2	2
6	Variability	The nutrient availability varies depending on factors such as the source, processing methods, and seasonal variations	2	2
7	Plant availability and nutrient use efficiency	The availability and nutrient use efficiency is entirely dependent on the speciation of nutrient	3	2
8	Compatibility and Machinery	Machinery issues related to some products spreading in the field uniformly	1	3
9	Lack of certification	To have the confidence and trust in the product	5	3

The most significant weakness of animal manure waste stream for producing alternative fertilising products is the lack of certification, what makes more difficult for the stakeholders to trust the product followed by the existing technical challenges, as the operation of manure processing systems requires some technical work.

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Surprisingly, initially foreseeable weaknesses like the investment costs for the technology implementation, the difficulties related to the storage vs. the product shelf-life and the public acceptance of the resulting fertilising products have not resulted very relevant for the consulted stakeholders.

With regards to the digestate, it does not show any serious weakness. It shows slightly stronger relevance regarding the implementation and technology costs, the storage vs. shelf-life of the project and the compatibility with machinery than animal manure.

Thus, the key weaknesses to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of both animal manure and digestate, are:

- Lack of certification, that results in lower confidence in the resulting fertilising product.
- Technical challenges related to structures, equipment and labour required.

5.1.3. Opportunities (O)

The weaknesses identified and the value given to each of them have been the following:

Table 58. Opportunities matrix for Belgium - Flanders region

No	Opportunities Item	Explanation	Scoring for animal manure	Scoring for digestate
1	Support integrated farming	The integration between animal farming, crop production, and industrial waste could be implemented for optimisation of energy resources	4	3
2	More sustainable agriculture	Biofertilisers can also help reduce the need for chemical fertilisers by providing a sustainable alternative	3	3
3	Synergises global goals of climate mitigation	Using BBFs have the potential to mitigate climate change due to the utilisation of organic fertilisers over mineral ones and thus increase soil organic matter content (draw down atmospheric CO2)	3	3
4	Research and innovation	A lot of scientific work has been done in the past decades on the subject; regulations set a framework to increase the safety perception of this resource. Ongoing research may focus on improving processing methods, increasing nutritional content and availability, producing new products, and investigating innovative approaches for successfully using these resources in various agricultural systems	3	3

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5	Creation of green jobs	There is plenty of room for moving forward that will provide opportunities to create green jobs	2	2
6	Waste reduction and reducing disposal cost	Growing cost of conventional fertilisers and waste reduction thus reducing disposal costs	2	2
7	Circular economy	Contributing to a circular economy model by transforming waste materials into valuable sources of nutrients	4	4

From those opportunities identified for animal manure, the support of integrated farming (animal farming + crop production + industrial waste generation and reuse) and the contribution to circular economy (transformation or a waste material into a valuable source of nutrients), which actually are quite related topics, have resulted to be the most relevant opportunities for the stakeholders consulted. However, green jobs creation and the reduction of waste disposal costs have resulted to be less attractive opportunities.

Regarding digestate as waste stream, the stakeholders have scored all attributes practically the same as for animal manure. The only difference has been the support to integrated farming, which has resulted slightly less relevant in the case of the digestate.

Thus, the key opportunities to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of both animal manure and digestate, are:

- Contribution to integrated farming, in which animal farming, crop production and waste generation and reutilisation are complementary and feed each other.
- In the same sense, contribution to circular economy practices, with which nutrients circulate through the system.

5.1.4. Threats (T)

Table 59. Threats matrix for Belgium - Flanders region

No	Thread Item	Explanation	Scoring for animal manure	Scoring for digestate
1	Contamination and health risk	Heavy metals, Antibiotic and microplastic residues, pathogen exposure, salt accumulation; and their possible transfer into the food chain, or increased antibiotic resistance in agricultural soils	2	3
2	Lack of technology providers		1	2
3	Complex legislation	Challenging EU and national regulations and policies, Lack of knowledge and uncertainty on the certification and regulatory framework	5	5

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4	Unclear consumer acceptance		2	2
5	Harmonisation/standardisation	Difficulties in harmonisation/standardisation of bio-based fertilisers as well as uncertainty in products sustainability	2	3
6	Oversupply of sustainability programs	There is a tendency for vested interests to attempt to bring their own recycling technique or greenwashing, and farmers are over-inquired about such projects, making it difficult to convince them to participate in the next workshop or idea	3	3
7	Nutrient runoff and Environmental impact	Excessive application of fertilisers can result in nutrient runoff, particularly nitrogen and phosphorus, which can contaminate surface water and groundwater. This can lead to eutrophication, where excessive nutrients promote algal blooms, causing oxygen depletion and harm to aquatic ecosystems	4	3
8	Greenhouse Gas Emissions	The decomposition of organic waste materials can release greenhouse gases such as methane and nitrous oxide. Methane, in particular, has a potent warming effect on the atmosphere. Proper management practices, such as anaerobic digestion, can help mitigate these emissions, but there is still a potential environmental impact	3	3
9	Odor and Air Quality	The application of animal manure and certain types of digestate can generate odours, particularly during spreading. This can impact air quality	3	3

With regards to the threats, there is one that clearly constitutes a concern for the stakeholders consulted, both for animal manure and digestate: the complex legislation. All products originating from digestate from an anaerobic digestion installation treating both manure and organic biological waste streams (co-digestion), are subject to strict criteria of VLAREMA, the Flemish legislation on waste.

Nutrient runoff and related environmental impact are more threatening in case of animal manure due to the excessive application of fertilisers. Both waste streams show similar results in greenhouse gas emissions and odour and air quality.

Thus, the key threats to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of both animal manure and digestate, are:

- Complex legislation; EU and national legislation may be challenging and present uncertainties.

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- Nutrient runoff due to an excessive application of fertilisers, which can pollute the water bodies and cause eutrophication, as well as other harms to aquatic ecosystems.

5.2. Croatia – Continental Croatia

SWOT analysis for Continental Croatia region has been focused on the alternative fertilising products coming from their assigned waste streams:

- Animal manure.
- Digestate.
- Bio-waste.

The results can be graphically presented as follows:

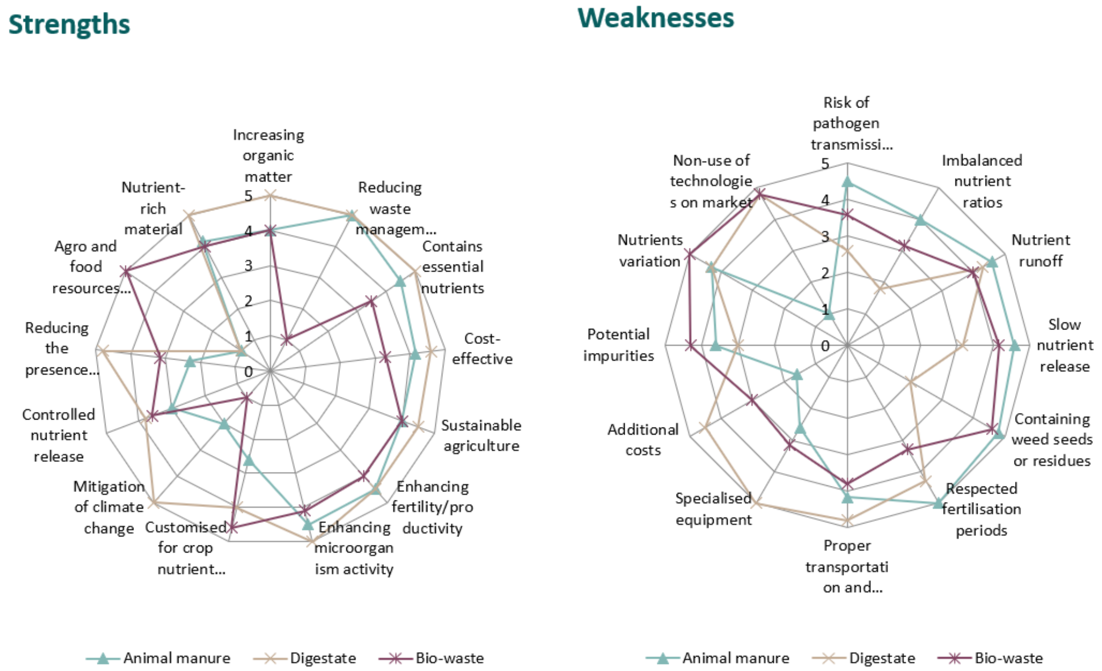

Figure 71. Strengths and weaknesses radar diagrams for Continental Croatia region

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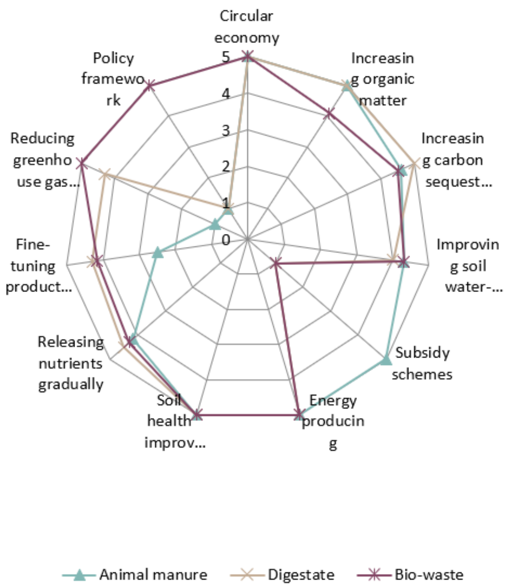
Opportunities



Threats

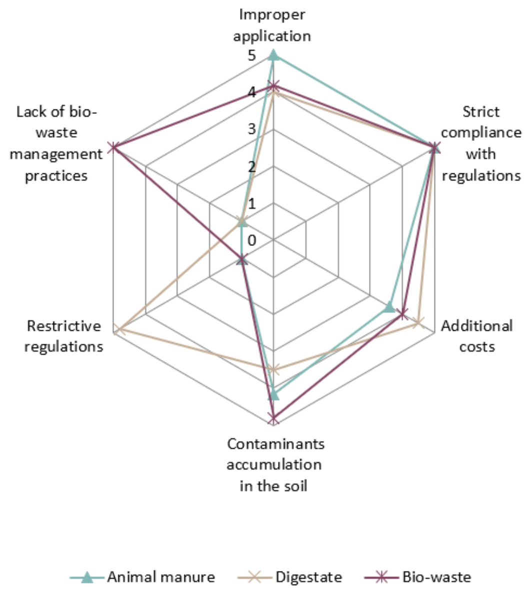


Figure 72. Opportunities and threats radar diagrams for Continental Croatia region

5.2.1. Strengths (S)

Table 60. Strengths matrix for Continental Croatia region

No	Strengths Item	Explanation	Scoring for animal manure	Scoring for digestate	Scoring for bio-waste
1	Increasing organic matter	Fertilisers can contribute organic matter to the soil	4	5	4
2	Reducing waste management issues	Reducing waste management issues associated with large-scale livestock production	5	5	1
3	Contains essential nutrients	Contains essential nutrients which provide a steady supply to plants	5	5	4
4	Cost-effective	Cost-effective, reducing the need to purchase commercial fertilisers	4	5	3
5	Sustainable agriculture	Minimising the ecological footprint associated with chemical fertiliser production and fosters a more balanced nutrient cycle	4	5	4
6	Enhancing fertility/productivity	Regular application can enhance soil fertility and productivity over time	5	5	4

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7	Enhancing microorganism activity	Enhances soil physical properties and microorganism activity	5	5	4
8	Customised for crop nutrient requirements	The nutrient content can be adjusted and customised to meet specific crop nutrient requirements	3	4	5
9	Mitigation of climate change	Mitigation of climate change by reducing methane emissions	2	5	1
10	Controlled nutrient release	Controlled nutrient release which reduces the risk of nutrient leaching or runoff	3	4	4
11	Reducing the presence of pathogens	Reducing the presence of pathogens, resulting in lower risk of disease transmission	2	5	3
12	Agro and food resources recovery	Supporting agro and food processing resources recovery. Utilising bio-waste as a basis for fertilisers provides a sustainable solution for managing organic waste materials, such as food waste and agricultural residues	1	1	5
13	Nutrient-rich material	Nutrient-rich material, which can be used as a soil amendment or fertiliser	4	5	4

The most relevant strengths common to all waste streams (animal manure, digestate and bio-waste) according to the stakeholders consulted are the contents of essential nutrients that the alternative fertiliser products can provide to the crops and the enhancement of soil fertility and productivity that regular application can cause, which is also directly linked to the enhancement of microorganisms activity.

Some other relevant issues for all waste streams, although in some cases at lesser extent, are the cost effectiveness, as using the alternative fertilisers consequently provokes a reduction of the commercial fertilisers needed, the possibility of adjusting the nutrient contents depending on the crops needs and the soil amendment effect their use has.

However, there are a couple of surprising results, as the differences between waste streams are significant. One of the strengths identified has been the reduction of waste management needs. This strength has been considered completely relevant for animal manure and digestate waste streams, while is has been scored as not relevant at all for bio-waste. The contrary happens with the strength defined as agrifood resources recovery; is has been considered very relevant for bio-waste but not relevant at all for animal manure and digestate.

Thus, the key strengths to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of animal manure, digestate and bio-waste, are:

- Organic matter and essential nutrients contents that alternative fertiliser products can provide to the crops, what enhances microorganisms activity, hence the soil fertility and productivity.

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- Possibility of adjusting the nutrient contents, what is also related to cost effectivity of these products.
- Waste management needs reduction for animal manure and digestate.
- Agrifood resources recovery for bio-waste.

5.2.2. Weaknesses (W)

Table 61. Weaknesses matrix for Continental Croatia region

No	Strengths Item	Explanation	Scoring for animal manure	Scoring for digestate	Scoring for bio-waste
1	Risk of pathogen transmission	Risk of pathogen transmission due to improper handling, storage or application	5	3	4
2	Imbalanced nutrient ratios	Potential of having imbalanced nutrient ratios (high concentration of N relative to P and K)	4	2	3
3	Nutrient runoff	Excessive application can lead to nutrient runoff into water bodies	5	4	4
4	Slow nutrient release	Slow nutrient release during the early stages of plant growth or in nutrient-deficient soils	5	3	4
5	Containing weed seeds or residues	Containing weed seeds or residues which can potentially affect crop growth and quality	5	2	5
6	Respected fertilisation periods	Fertilisation periods need to be respected to reduce nitrogen losses (leaching, evaporation)	5	4	3
7	Proper transportation and storage infrastructure	Requiring proper transportation and storage infrastructure. This can add to the overall cost and complexity of using such fertilisers, especially for large-scale agricultural operations	4	5	4
8	Specialised equipment	Using specialised equipment to ensure equal distribution	3	5	3
9	Additional costs	Involving additional costs compared to conventional fertilisers	2	5	3
10	Potential impurities	Contains potential impurities depending on input streams (e.g. heavy metals, trace elements and organic pollutants)	4	3	4

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11	Nutrients variation	Variation of nutrients depending on the type of waste, its source and processing methods used	4	4	5
12	Non-use of technologies on market	Not all technologies currently available on the market are being used/applied on a national level due to different reasons (economic, technical)	1	5	5

The most relevant weakness for all waste streams according to the stakeholders consulted is the nutrient runoff into water bodies and the nutrient variations depending on the type of waste, the processing methods use, etc. Another relevant weakness is the need of a proper transportation and storage infrastructure, that can add costs and also complexity to obtain and use the fertilisers.

There are some differences between waste streams. A weakness identified by the stakeholders has been the slow nutrient release during the early stages of the crops growth, as well as the risk of pathogen transmission due to improper handling, storage or application, have revealed as very relevant weaknesses for animal manure, although they are a little bit less relevant for bio-waste and even less relevant for the digestate. Fertilisation periods have to be respected to reduce nitrogen loses is another of the identified weaknesses, which is especially relevant for animal manure. However, the need of specialised equipment and the consequent additional costs it entails are a very relevant weakness for digestate.

Furthermore, there are a couple of weakness that present very different results from one waste stream to another. The potential content of weed seeds or residues, that could affect the crop growth and quality, has been considered very relevant for animal manure and bio-waste, but not much relevant for digestate. Furthermore, the lack of use of the existing available technologies constitutes a very relevant weakness for digestate and bio-waste, but it seems to be not relevant at all for animal manure.

Thus, the key weaknesses to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of animal manure, digestate and bio-waste, are:

- Nutrient runoff into water bodies.
- Need of transportation and storage infrastructure, what leads to a need of an additional investment.
- Non-use of the technologies available in the market for digestate and bio-waste.
- Content of weed seeds or residues for animal manure and bio-waste.
- Need of specialised equipment for digestate.

5.2.3. Opportunities (O)

Table 62. Opportunities matrix for Continental Croatia region

No	Opportunities Item	Explanation	Scoring for animal manure	Scoring for digestate	Scoring for bio-waste

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1	Circular economy	Contributing to a circular economy by recycling organic waste and utilising it as a valuable resource	5	5	5
2	Increasing organic matter	Increasing organic matter content in the soil contribute to long-term soil fertility and productivity, leading to improved crop yields and sustainability	5	5	4
3	Increasing carbon sequestration	Properly managed application can increase carbon sequestration in agricultural soils	5	5	5
4	Improving soil water-holding capacity	Improving soil water-holding capacity by reducing water runoff and increasing water infiltration into the soil	4	4	4
5	Subsidy schemes	Opportunities for farmers to obtain subsidy schemes if using manure	5	1	1
6	Energy producing	Producing energy from renewable sources. The co-production provides an opportunity for farmers to generate on-site energy	5	5	5
7	Soil health improvement	Contributing to long-term soil productivity, fertility, and sustainability	5	5	5
8	Releasing nutrients gradually	Releasing nutrients gradually, providing a sustained and balanced nutrient supply to plants	4	5	4
9	Fine-tuning production process	Fine-tuning production process results in fertilisers with desired nutrient ratios	3	4	4
10	Reducing greenhouse gas emissions	By diverting organic waste from landfills, it helps prevent the release of methane, a potent greenhouse gas	1	4	5
11	Policy framework	Policy framework promotes the separate collection and appropriate treatment of bio-waste	1	1	5

From all opportunities identified, the stakeholders considered several of them are very relevant for all waste streams: the contribution to circular economy practices, the increase of carbon sequestration in agricultural soils, the energy production from renewable sources available onsite and the improvement of soil health that contributes to long-term productivity and sustainability. Other opportunities like the improvement of soil water-holding capacity and the gradual release of nutrients are also considered quite relevant for all waste streams.

However, there are relevant differences between waste streams for some other opportunities identified. Subsidy schemes dependent on the use of manure are obviously very relevant for animal manure, but there are not relevant for digestate and bio-waste. In the same sense, the policy framework that promotes the selective waste collection and the appropriated bio-waste

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treatment is very relevant for bio-waste, but not for animal manure and digestate. Furthermore, the use of organic waste avoids its discharge in landfills, what prevents the release of methane, thus contributes to the reduction of greenhouse gases emissions; this opportunity is very relevant for bio-waste and digestate, but not for animal manure.

Thus, the key opportunities to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of animal manure, digestate and bio-waste, are:

- Contribution to circular economy practices.
- Increase of carbon sequestration in agricultural soils.
- Renewable energy production onsite.
- Improving of soil health.
- Subsidy schemes for animal manure.
- Selective waste collection and appropriated treatment for bio-waste.
- Reduction of greenhouse gases emissions for bio-waste and digestate.

5.2.4. Threats (T)

Table 63. Threats matrix for Continental Croatia region

No	Opportunities Item	Explanation	Scoring for animal manure	Scoring for digestate	Scoring for bio-waste
1	Improper application	Improper application can lead to nutrient imbalances in the soil	5	4	4
2	Strict compliance with regulations	If subsidy schemes are being used, then strict compliance with regulations is needed	5	5	5
3	Additional costs	Additional costs associated with proper storage, transportation, and application	4	5	4
4	Contaminants accumulation in the soil	Accumulation of contaminants in the soil, potentially affecting soil quality and crop safety	4	4	5
5	Restrictive regulations	Restrictive regulations that govern management, quality, and application of digestate on EU and national levels	1	5	1
6	Lack of bio-waste management practices	Lack of bio-waste management practices in some regions (e.g. lack of infrastructure etc.). There is still a lot of place to improve bio-waste management	1	1	5

The stakeholders consulted considered that the most relevant threat for all waste streams is strict compliance with regulations. Other relevant threats for all waste streams are the improper

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application of the fertilising product, that can lead to nutrients imbalance in the soil, the additional costs that the proper storage, transportation and application entails and the potential contaminants accumulation in the soil.

However, some differences and be also observed between the different waste streams. While existing restrictive regulations for digestate management and application are very relevant for digestate as obvious, they are not for animal manure and bio-waste.

In the same sense, the lack of bio-waste management practices in some regions is a very important threat for bio-waste evidently, but not for animal manure and digestate.

Thus, the key threats to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of animal manure, digestate and bio-waste, are:

- Strict compliance with regulations.
- Improper application that leads to nutrient imbalances.
- Additional costs associated with transport and application.
- Possibility of nutrients accumulation in the soil.
- Restrictive regulations for digestate.
- Lack of management practices for bio-waste.

5.3. Finland – South-West Finland

SWOT analysis for South-West Finland region has been focused on the alternative fertilising products coming from their assigned waste streams:

- Animal manure.
- Digestate.
- Bio-waste.

The results can be graphically presented as follows:

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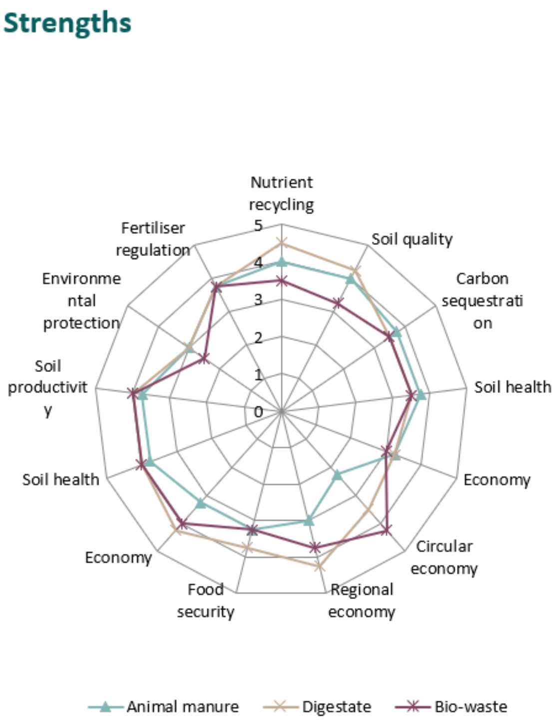


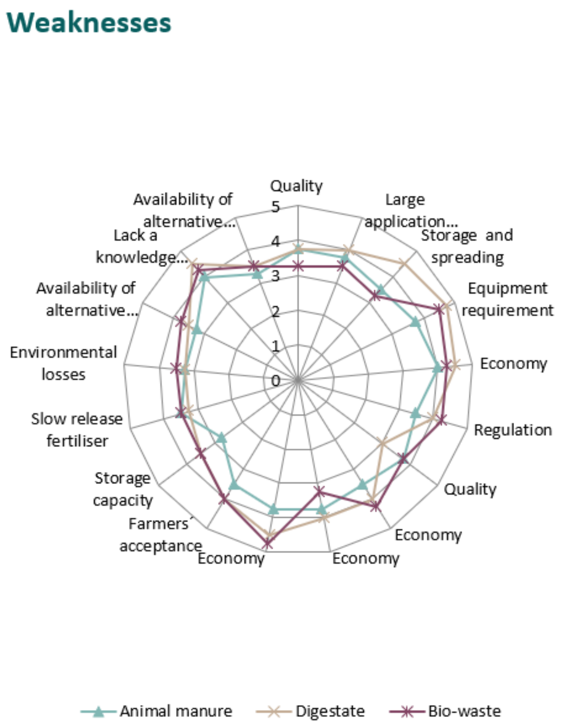
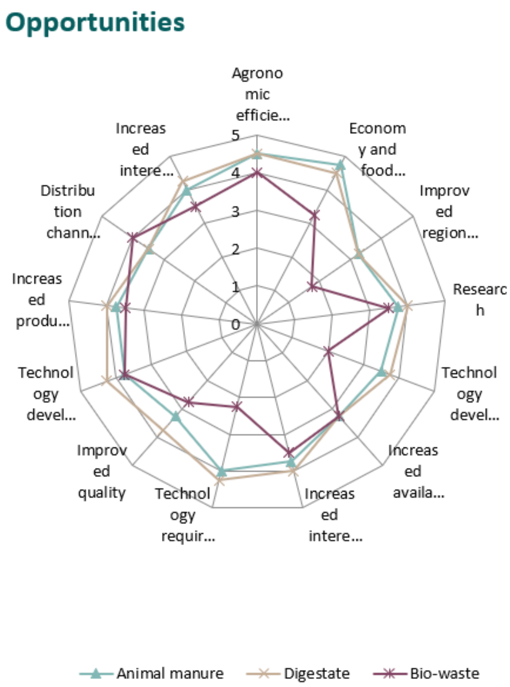


Figure 73. Strengths and weaknesses radar diagrams for Sout-West Finland region



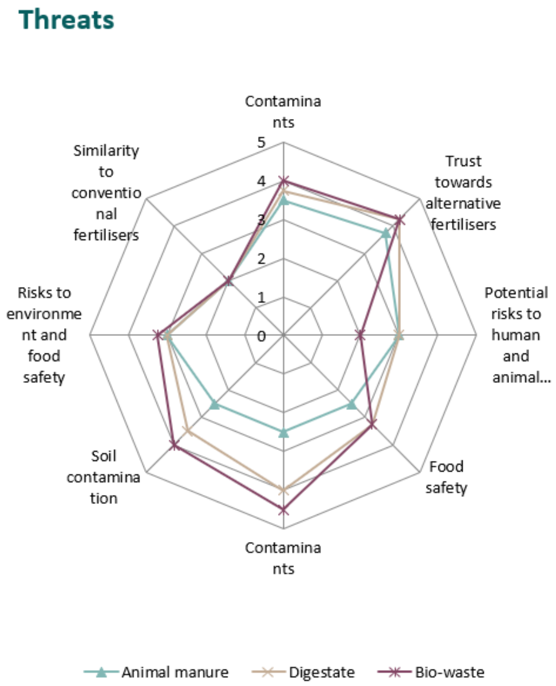


Figure 74. Opportunities and threats radar diagrams for South-West Finland region

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5.3.1. Strengths (S)

Table 64. Strengths matrix for South-West Finland region

No	Strength Item	Explanation	Scoring for animal manure	Scoring for digestate	Scoring for bio-waste
1	Nutrient recycling	Optimal use of alternative fertilisers decreases use of mineral fertilisers	4	5	4
2	Soil quality	Use of alternative fertilisers improves soil productivity	4	4	3
3	Carbon sequestration	Use of alternative fertilisers increases soil carbon content	4	4	4
4	Soil health	Use of alternative fertilisers improves soil resilience against extreme weather events	4	4	4
5	Economy	Use of alternative fertilisers increases self-sufficiency in farms	3	3	3
6	Circular economy	Use of alternative fertilisers decreases total amount of waste	2	4	4
7	Regional economy	Nutrients produced in organic side-streams in a region have an advantage over other regions	3	4	4
8	Food security	Use of alternative fertilisers improve food security	3	4	3
9	Economy	Alternative fertilisers offer multiple business opportunities (production, supply, spreading)	3	4	4
10	Soil health	Use of alternative fertilisers increases soil microbial population and diversity	4	4	4
11	Soil productivity	Alternative fertilisers contain versatile nutrients including micronutrients	4	4	4
12	Environmental protection	Use of alternative fertilisers may decrease phosphorus leaching into the watercourses	3	3	3
13	Fertiliser regulation	Strict regulations ensure the safety use of alternative fertilisers	4	4	4

From all strengths identified by the stakeholders consulted, the decrease of mineral fertilisers due to the optimal use of alternative fertilisers produced via nutrients recycling has resulted to be the most relevant one, especially for digestate.

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Other very relevant strengths for all waste streams are carbon sequestration in the soil, soil resilience and health improvement, soil productivity and strict regulations to ensure the safety use of alternative fertilisers.

There are no strengths from those identified that are actually considered as not relevant by the stakeholders. The in this sense, the contribution to circular economy practices is quite relevant for digestate and bio-waste, but not that much for animal manure. The same happens with the contribution to regional economy.

Thus, the key strengths to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of animal manure, digestate and bio-waste, are:

- Nutrients recycling and the consequent decrease in the use of mineral fertilisers.
- Carbon sequestration in the soil.
- Soil health, resilience and productivity.
- Strict regulation for the use of alternative fertilisers.

5.3.2. Weaknesses (W)

Table 65. Weaknesses matrix for South-West Finland region

No	Weakness Item	Explanation	Scoring for animal manure	Scoring for digestate	Scoring for bio-waste
1	Quality	Alternative fertilisers contain low nutrient concentration	4	4	3
2	Large application rates	Application volumes (in fertilisation) are high in alternative fertilisers due to low nutrient concentration	4	4	4
3	Storage and spreading	Alternative fertilisers have high moisture content	4	5	3
4	Equipment requirement	Alternative fertilisers and mineral fertilisers need different spreader equipment	4	5	5
5	Economy	Logistics of alternative fertilisers is challenging	4	5	4
6	Regulation	Regulations on alternative fertilisers are complex	4	4	4
7	Quality	Nutrient ratios of alternative fertilisers are not optimal for plant growth	4	3	4
8	Economy	Optimisation of nutrient ratio needs high processing inputs and external nutrient sources	4	4	4

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9	Economy	Processing of organic side-streams is expensive and has high energy demand	4	4	3
10	Economy	Small scale production of alternative fertilisers is not profitable	4	5	5
11	Farmers´ acceptance	Price per nutrient kilogram is high in alternative fertilisers	4	4	4
12	Storage capacity	Storage of alternative fertilisers is challenging	3	4	4
13	Slow release fertiliser	Plant availability of nutrients in alternative fertilisers may be lower than in conventional mineral fertilisers	4	3	4
14	Environmental losses	Organic nutrients may turn into soluble form after growing season and increase nutrient leaching into the watercourses	3	3	4
15	Availability of alternative fertilisers	Markets for alternative fertilisers are small and local	3	4	4
16	Lack a knowledge about alternative fertilisers among farmers	Marketing of alternative fertilisers should be targeted directly to farmers	4	5	4
17	Availability of alternative fertilisers	Availability of alternative fertilisers does not meet the demand of farmers in sense of amount and timing	3	4	4

All weaknesses identified have been considered relevant, going from medium to very relevant. Above them all, the most relevant ones for all waste streams according to the stakeholders are the equipment requirements, as the use of alternative fertilisers require specific ones, the economy logistics and the lack of knowledge about alternative fertilisers' use among farmers.

Storage and spreading are problematic in case of digestate and animal manure due to their high moisture content, but it is not so relevant for bio-waste. However, there is contradictory reference, as it is also stated that the storage capacity problems for animal manure have a medium relevance.

Environmental loss is the weakness considered as less relevant (scored as medium relevance) for all waste streams.

Thus, the key weaknesses to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of animal manure, digestate and bio-waste, are:

- Equipment requirements for the production and application of alternative fertilisers.
- Knowledge about the alternative fertilisers by the farmers.
- Storage for animal manure.

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5.3.3. Opportunities (O)

Table 66. Opportunities matrix for South-West Finland region

No	Opportunity Item	Explanation	Scoring for animal manure	Scoring for digestate	Scoring for bio-waste
1	Agronomic efficiency	Growing tests show similar agronomic efficiency between alternative fertilisers and mineral fertilisers	5	5	4
2	Economy and food security	Alternative fertilisers improve self-sufficiency and food security	5	5	3
3	Improved regional economy	Alternative fertilisers increase farmers' business opportunities	3	3	2
4	Research	Research can offer innovations and develop the processing technologies and production of alternative fertilisers	4	4	4
5	Technology development	Simple solutions (e.g. slurry manure sedimentation (solids settle by gravity)) may improve nutrient balance s regionally	4	4	2
6	Increased availability	Large scale processing in centralised plants is profitable to produce alternative fertilisers	3	3	3
7	Increased interest towards alternative fertilisers	Better utilisation of nitrogen rich side-streams can be beneficial to alternative fertiliser production	4	4	4
8	Technology requirement	Efficiency of alternative fertiliser production can be enhanced by separation of nutrient fractions in source location (e.g. separation of solids and liquids in the farm)	4	4	2
9	Improved quality	Quality of alternative fertilisers can be an advantage in markets instead of high production volume	3	4	3
10	Technology development	Granulation or pelletising may increase the demand for the alternative fertiliser product	4	4	4
11	Increased productivity	Willingness to pay for alternative fertilisers is higher in organic farming than among conventional farming	4	4	4

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12	Distribution channels	Dealers are needed to ensure that the distribution channel between the producer and the crop farmer is complete	4	4	4
13	Increased interest towards alternative fertilisers	Pricing of alternative fertilisers will be developed in the future	4	4	4

From all opportunities identified, agronomic efficiency of alternative fertilisers shows the highest relevance for all waste streams. Research and technological development, together with the increased interest towards alternative fertilisers and even the willingness of the current users to pay for the products, especially in the organic farmer sector (and not that much in the conventional one), are also relevant for all waste streams.

Apart from this, the stakeholders have considered that self-sufficiency and food security improvement are very relevant for animal manure and digestate, but not that much for bio-waste. The same happens with the technology development.

Thus, the key opportunities to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of animal manure, digestate and bio-waste, are:

- Research and technological development linked to the willingness to pay for a good product.
- Food security improvement for animal manure and digestate.
- Technology development for animal manure and digestate.

5.3.4. Threats (T)

Table 67. Threats matrix for South-West Finland region

No	Threat Item	Explanation	Scoring for animal manure	Scoring for digestate	Scoring for bio-waste
1	Contaminants	Low concentration of contaminants may accumulate in soils and pose a threat to future generations	4	4	4
2	Trust towards alternative fertilisers	Origin of ingredients in alternative fertilisers must be known	4	4	4
3	Potential risks to human and animal health	Alternative fertilisers may pose a risk for the spreading of animal diseases	3	3	2
4	Food safety	Contaminants in alternative fertilisers may transfer from soil to eatable plants	3	3	3
5	Contaminants	Alternative fertilisers may pose a risk to contaminate soils by pharmaceuticals,	3	4	5

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		heavy metals, pathogens, or microplastics			
6	Soil contamination	High application volume of alternative fertilisers increase the risk of soil contamination	3	4	4
7	Risks to environment and food safety	Heavy metals in alternative fertilisers may turn into a soluble form in acidic soils	3	3	3
8	Similarity to conventional fertilisers	Alternative fertilisers may lose their attraction if nutrients are concentrated as high as they are in mineral fertilisers	2	2	2

According to the stakeholders consulted, the main threat is related to contaminants. Alternative fertilisers can pose a risk in accumulating contaminants in soils, especially pharmaceuticals, heavy metals, pathogens, or microplastics that can be present in bio-waste. Furthermore, soil contamination can be also caused by high values of application of all waste streams.

Another significant threat shared by all waste streams is the lack of trust towards alternative fertilisers when origin is not well acknowledged.

With regards to low relevant threats, it was also discussed the possibility of not having an impact if their performance or composition was similar to that of conventional mineral fertilisers. If that happened, the farmers would not be willing to replace something that works already by something they do not now and, moreover, seems quite similar to what they use already. This threat was considered as low relevant.

Thus, the key threats to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of animal manure, digestate and bio-waste, are:

- Contaminants accumulation in soils.
- Lack of trust when the origin of the alternative fertiliser is not clearly stated.

5.4. Ireland – East Ireland

SWOT analysis for Wicklow / Carlow / Wexford region has been focused on the alternative fertilising products coming from their assigned waste streams:

- Bio-waste.
- Biological by-products.

The results can be graphically presented as follows:

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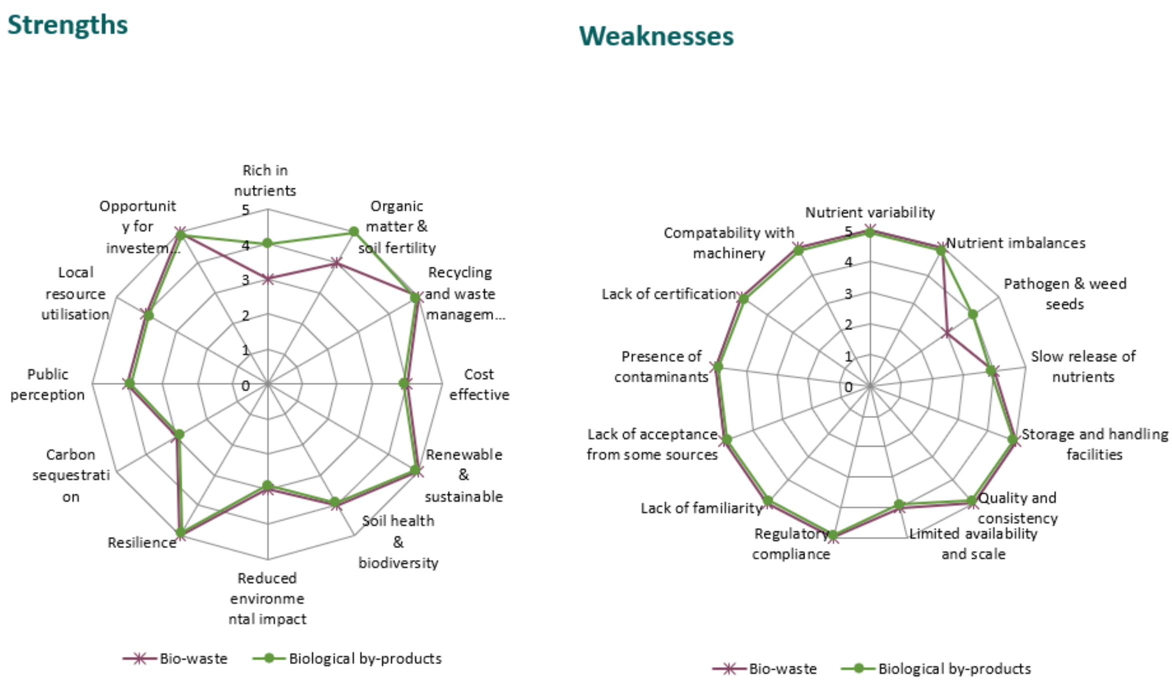

Figure 75. Strengths and weaknesses radar diagrams for Ireland – Wicklow/Carlow/Wexford region

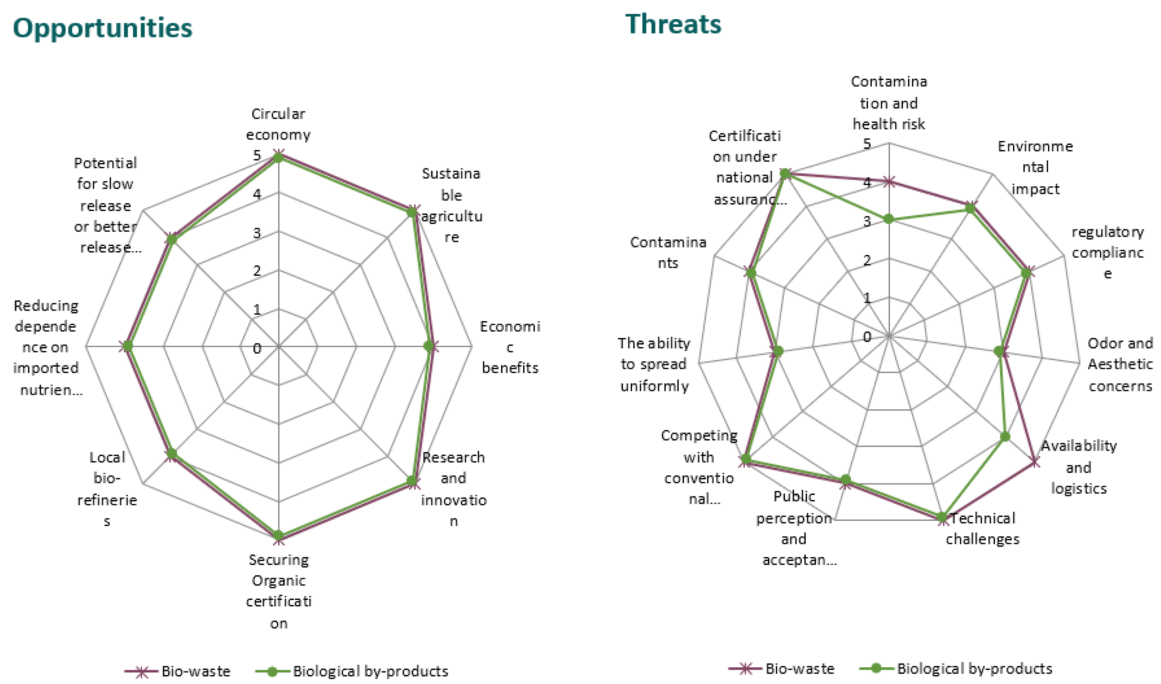

Figure 76. Opportunities and threats radar diagrams for Ireland – Wicklow/Carlow/Wexford region

5.4.1. Strengths (S)

Table 68. Strengths matrix for Ireland – Wicklow/Carlow/Wexford region

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No	Strengths Item	Explanation	Scoring for bio-waste	Scoring for biological by-products
1	Rich in nutrients	Products such as animal manure, food waste, crop residues, compost etc contains valuable nutrients such as N, P & K	3	4
2	Organic matter & soil fertility	Products listed above are rich in organic matter. When added to the soil, they improve soil structure, increase water retention capacity, and enhance nutrient availability	4	5
3	Recycling and waste management	Recycling nutrients from bio-waste and biological by products reduces the environmental impact of waste disposal, and promotes a circular economy approach	5	5
4	Cost effective	Bio-waste and biological by products can be obtained at lower costs compared to synthetic fertilisers. This makes them a cost-effective solution for farmers	4	4
5	Renewable & sustainable	Unlike synthetic fertilisers derived from non-renewable resources, bio-waste & biological by products are renewable and sustainable sources of nutrients. They reduce the dependence on fossil fuel-based inputs in agriculture	5	5
6	Soil health & biodiversity	The nutrients and organic matter available from these types of fertilisers promotes a balanced soil ecosystem, which enhances biodiversity and supports the growth of beneficial insects, microorganisms and earthworms	4	4
7	Reduced environmental impact	The use of alternative sources of fertilisers in replace of synthetic fertilisers reduces the potential negative impacts associated with the overuse or misuse of synthetic fertilisers such as runoff into water bodies	3	3
8	Resilience	Farmers can avail of their own sources of nutrients from their animals & crops and recycle them back to the land reducing the reliance on imported inputs for their system making their system more resilient to any changes to market and policy of synthetic fertilisers	5	5

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9	Carbon sequestration	As organic materials break down, they store carbon in the soil, helping mitigate climate change	3	3
10	Public perception	The use of alternative fertilisers aligns with consumer demands for sustainable and environmentally friendly agricultural practices. It can improve the public perception of food production and contribute to marketing products as environmentally conscious	4	4
11	Local resource utilisation	Bio-waste & biological by products can be often available locally. This reduces the need for long transportation	4	4
12	Opportunity for investment	Nutrient recovery companies may avail of the opportunity to further invest in technologies to refine raw sources of bio-waste and biological by products into more stable and usable forms for land application	5	5

According to the stakeholders consulted, the most relevant strength of bio-waste and biological by-products to produce alternative fertilisers is the possibility they offer to recycle nutrients, what reduces the environmental impact of waste disposal. In addition to this, the renewable and sustainable nature of these waste streams also constitutes one of the most relevant strengths. Moreover, there are two other strengths that have received the maximum scoring, i.e., that have been considered very relevant. One of them is the resilience they provide to the system, as these waste streams are own-produced, and the other is the opportunity they constitute for further investments on new technologies in the region.

Another very relevant strength identified especially for biological by-products is the richness of this waste stream in organic matter, what improves the soil structure, increases the water retention capacity and enhance nutrients availability.

All strengths identified are actually considered relevant, being scored from medium, to very relevant for both waste streams.

The strengths with lower relevance (medium relevance in this case) are the potentiality to reduce the environmental impact because of the replacement of synthetic fertilisers and the capacity of carbon sequestration in the soil.

Thus, the key strengths to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of bio-waste and biological by-products, are:

- Potentiality to recycle nutrients from renewable, sustainable and resilient waste streams.
- Opportunity to invest on technological development in the region.
- Richness in organic matter that benefits the soil and the crops for biological by-products waste stream.

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5.4.2. Weaknesses (W)

Table 69. Weaknesses matrix for Ireland – Wicklow/Carlow/Wexford region

No	Weakness Item	Explanation	Scoring for bio-waste	Scoring for biological by-products
1	Nutrient variability	The nutrient content of bio-waste and biological by products can vary widely, depending on factors such as the source, processing methods, and seasonal variations	5	5
2	Nutrient imbalances	Bio-waste and biological by products contain essential nutrients, their composition may be imbalanced in terms of specific nutrients. It may require blending with other fertilisers to achieve balanced nutrient levels	5	5
3	Pathogen & weed seeds	Bio-waste and biological by products may contain pathogens, weed seeds, or unwanted organisms. If not properly treated or processed, these contaminants can be transferred to the soil, potentially causing plant diseases or weed infestations	3	4
4	Slow release of nutrients	Organic sources of fertilisers generally release nutrients slowly over time. Slow release of nutrients can be beneficial for long term soil fertility, it may not provide immediate nutrient availability during critical growth stages of plants	4	4
5	Storage and handling facilities	Bio-waste and biological by products, especially in raw and untreated forms, can be bulky, odorous, and challenging to store and handle. Proper storage facilities needs to be in place to prevent odour, nutrient losses, and potential environmental contamination	5	5
6	Quality and consistency	Ensuring consistent quality and composition of bio-waste and biological by products can be challenging, especially when multiple sources are involved. Variations in feedstock, processing methods, and storage conditions can lead to inconsistencies in nutrient content	5	5
7	Limited availability and scale	The availability and quantity of bio-waste and biological by products in Ireland may be limited in some areas during specific seasons. Scaling up the production and distribution of these materials from areas where it is more	4	4

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		available to areas where it is less available can pose logistical challenges		
8	Regulatory compliance	This can be a barrier for the use of some raw materials for food production in Ireland and can impose additional burden and cost on farmers	5	5
9	Lack of familiarity	Farmers may not be familiar with using these products and may not be willing to accept them, particularly struvite, biochar, and ash	5	5
10	Lack of acceptance from some sources	Farmers are less willing to accept novel fertilisers from sewage sludge and household food waste sources	5	5
11	Presence of contaminants	Farmers are concerned about the presence of heavy metals, glass, plastics, PCBs, antibiotics that could contaminate their land	5	5
12	Lack of certification	Farmers are looking for the products to be certified, to give them confidence and trust in the product	5	5
13	Compatibility with machinery	Farmers want novel fertilisers to have a texture, similar to the fertilisers they presently use that are compatible with their farm machinery	5	5

There are several weaknesses that stakeholders consider very relevant for both bio-waste and biological by-products. Nutrient contents variability and specific nutrient imbalances may require blending this source with other fertilisers, what is also very related to another weakness, the quality and consistency of the waste stream, as the desired one may not be always easy to get. Storage and handling facilities are also very relevant, especially when dealing with raw and untreated waste, that can be voluminous, difficult to handle, odorous, etc.

Lack of familiarity and, maybe consequently, acceptance from farmers is considered as another very relevant weakness, and it is related to their concerns regarding potential land contamination and their reluctance to use these new products that may contain such contaminants and may not be fully compatible with their machinery. Furthermore, regulatory compliance can constitute another important barrier and it is also perceived as a very relevant weakness, as it could impose additional burdens and costs to the farmers.

Curiously, none of the weaknesses identified are perceived as low relevant; all of them are considered from medium to very relevant.

Thus, the key weaknesses to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of bio-waste and biological by-products, are:

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- Quality and consistency of the bio-waste and the biological by-products, strongly related to their nutrient contents variability and the imbalance of specific nutrients.
- Storage and handling, strongly related also with the compatibility of these new fertilisers with their machinery.
- Lack of familiarity and, consequently, acceptance from farmers to the new fertilising products, also related to the possibility of containing contaminants.
- Regulatory compliance, that could impose additional burdens and costs to the farmers.

5.4.3. Opportunities (O)

Table 70. Opportunities matrix for Ireland – Wicklow/Carlow/Wexford region

No	Opportunities Item	Explanation	Scoring for bio-waste	Scoring for biological by-products
1	Circular economy	The utilisation of bio-waste and biological by products in Ireland is contributing to a circular economy model by transforming waste materials into valuable sources of nutrients	5	5
2	Sustainable agriculture	Bio-waste and biological by products offer an opportunity to enhance the sustainability of agriculture in Ireland. By providing organic nutrients and improving soil health, they support environmentally friendly farming practices	5	5
3	Economic benefits	The use of bio-waste and biological by products in Ireland can generate revenue streams for waste management companies, farmers, and agricultural enterprises involved in the production, processing, and distribution of these materials	4	4
4	Research and innovation	Utilising bio-waste and biological by products in Ireland opens the opportunity for research and innovation. Ongoing research can focus on optimising processing methods, improving nutrient content and availability, developing new products and researching different techniques for utilising these materials effectively in different agricultural systems	5	5
5	Securing Organic certification	Recycled nutrients could increase options for organic farmers	5	5
6	Local bio-refineries	Local jobs and the rural economy	4	4

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7	Reducing dependence on imported nutrients - security		4	4
8	Potential for slow release or better release profile of nutrients		4	4

The main opportunities identified by the consulted stakeholders for both bio-waste and biological by-products and considered as very relevant are the contribution to the circular economy model by extracting nutrients form waste streams, as well as the enhancement of the sustainable agriculture in the region. Moreover, the use of these waste streams also opens a door for research and innovation, what is also considered as a very relevant opportunity. Ongoing research focuses on the optimisation of the processing methods, the improvement of nutrient content and availability, etc. Last but not least, securing organic certification is also considered a very relevant opportunity that could favour organic farmers.

As it happened with the weaknesses, none of the opportunities identified are perceived as low relevant; all of them are considered from relevant to very relevant.

Thus, the key opportunities to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of bio-waste and biological by-products, are:

- Contribution to the circular economy model and enhancement of the sustainable agriculture.
- Research and innovation in the processing application of these new fertilisers.
- Securing organic certification.

5.4.4. Threats (T)

Table 71. Threats matrix for Ireland – Wicklow/Carlow/Wexford region

No	Opportunities Item	Explanation	Scoring for bio-waste	Scoring for biological by-products
1	Contamination and health risk	Bio-waste and biological by products may contain contaminants such as heavy metals, pathogens, pharmaceutical residues or pesticide residues. If not properly treated or processed, these contaminants can pose risks to human health, animal health, and the environment	4	3
2	Environmental impact	Improper management and application of bio-waste and biological by products can lead to nutrient loss to the environment causing pollution	4	4

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3	regulatory compliance	The use of bio-waste and biological by products in Ireland may be subject to specific regulations and guidelines. Ensuring compliance with these regulations, such as proper handling, treatment, storage, and application practices, can be challenging for producers and users	4	4
4	Odor and Aesthetic concerns	In Ireland many farms are located near local villages and towns. Some biological by products have strong odours, which may affect public perception. Adequate application techniques can mitigate these existing concerns	3	3
5	Availability and logistics	The consistent availability and reliable supply of bio-waste and biological by products to farmers in Ireland can be a problem along with the logistics of handling and transporting bulky materials	5	4
6	Technical challenges	Processing raw sources of nutrients into high quality fertilisers may require specialised equipment, infrastructure and expertise. Developing efficient and cost-effective processing methods, such as anaerobic digestion, can be technically demanding, require significant investments and require policy support	5	5
7	Public perception and acceptance	The utilisation of bio-waste and biological by products in Ireland may face public scepticism. Concerns regarding safety, odour, aesthetics, or perception of quality compared to synthetic fertilisers can influence public acceptance	4	4
8	Competing with conventional mineral fertiliser on price	The conventional fertiliser price at a given time will set the bar in terms of the business case viability/ attractiveness	5	5
9	The ability to spread uniformly	What form the fertiliser is in granular, powder, etc	3	3
10	Contaminants	Are there issues with chemical or bacterial contaminants	4	4
11	Certification under national assurance programmes e.g. an Bórd Bia	Irish farmers have to abide by certain farming practices to gain a quality assurance bonus on the produce they produce. Certain alternative fertilising products may be prohibited for use under such programmes, which may be a	5	5

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		barrier for farmer uptake of these alternative products		

From all threats identified by the stakeholders, three resulted to be the most relevant ones. These are the technical challenges the processing of these new fertilisers present, the price competition with conventional mineral fertilisers and the certification under national assurance programmes, as certain alternative fertilising products may be prohibited for use under such programmes and this may constitute a limitation for the farmers.

The availability and logistics may also be a very relevant threat for those fertilisers produced from bio-waste, although a little bit less than for biological by-products.

Other relevant threats are the potential contaminant content, their environmental impact and the compliance with related regulations and guidelines, public perception is also considered as a relevant threat.

Once more, none of the opportunities identified are perceived as low relevant; all of them are considered from relevant to very relevant.

Thus, the key threats to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of bio-waste and biological by-products, are:

- Technical challenges.
- Price competition with conventional mineral fertilisers.
- Certification under national assurance programmes.
- Availability and logistics for bio-waste.

5.5. Poland – South-East Poland

SWOT analysis for South-East Poland region has been focused on the alternative fertilising products coming from their assigned waste streams:

- Sewage sludge.
- Animal manure.
- Digestate.

The results can be graphically presented as follows:

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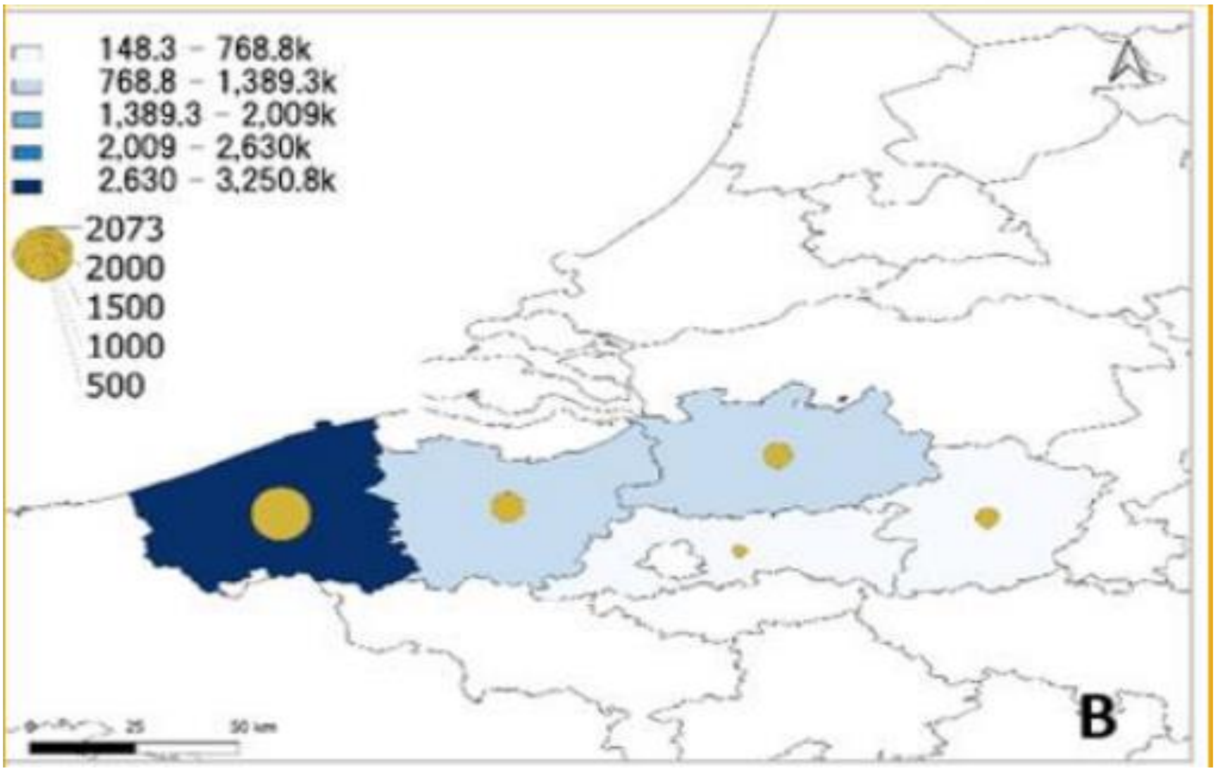

Figure 77. Strengths and weaknesses radar diagrams for South-East Poland region

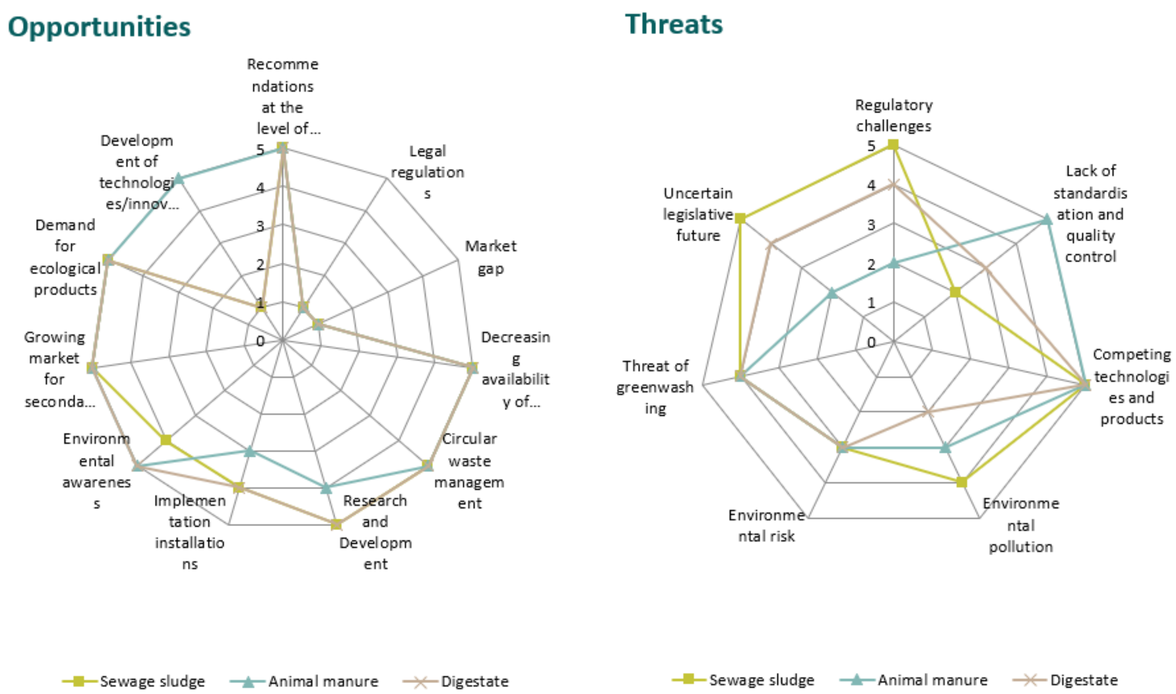

Figure 78. Opportunities and threats radar diagrams for South-East Poland region

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5.5.1. Strengths (S)

Table 72. Strengths matrix for South-East Poland region

No	Strengths Item	Explanation	Scoring for sewage sludge	Scoring for animal manure	Scoring for digestate
1	Availability on the market	In Poland, sewage sludge, digestate, and animal manure are available in the market. Poland has a well-developed wastewater treatment sector, which translates into the availability of sewage sludge. Animal manure is commonly used in agriculture in Poland, particularly in cereal crops and animal husbandry Digestate, is also available in Poland, but on a smaller scale	5	4	1
2	Price	The price of fertilisers from secondary sources such as sewage sludge, animal manure and digestate in Poland is relatively low. The most expensive is fertiliser made from animal manure, followed by digestate and sewage sludge	5	2	3
3	Ease of application	The application of fertilisers derived from sewage sludge, digestate and animal manure is relatively easy in Poland and does not require advanced technology	4	4	4
4	Low processing costs	Processing costs are low for manure as opposed to sewage sludge and digestate	1	5	1
5	Legislative standpoint	From a legislative standpoint, the application of fertilisers derived from sewage animal manure is straightforward in Poland, unlike digestate and sewage sludge, where the procedures are complicated	1	5	1
6	Soil health improvement	Fertilisers from sewage sludge, digestate and animal manure enrich the soil by enhancing its nutrient content and improving microbial activity. They contain beneficial microorganisms, increase nutrient availability, and enhance soil structure	4	5	5
7	Application security	The application of fertilisers derived from sewage sludge, digestate and animal manure is safe because regulated by law	5	4	5

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8	Ecological image of fertilisers	Society is increasingly paying attention to the ecological aspects of fertilisers. Fertilisers made from sewage sludge, digestate and animal manure are part of the idea of ecological products	5	5	5
9	Resource self-sufficiency (local production)	The possibility of producing fertilisers from waste at their place of generation	4	5	4
10	Soil hydrological improvement	Reducing the adverse effects of drought	4	4	4
11	Stable, precisely planned production stream	The amount of biomass produced in a treatment plant, fermentation plant or farm is easy to plan	5	4	3

The stakeholders consulted have considered that the most relevant strength for fertilisers coming from sewage sludge, animal manure and digestate is the positive ecological image of new fertilisers, as society is increasingly paying attention to the ecological aspects of fertilisers. The application security, regulated by law, is also a very relevant strength, as well as their effects in soil improvement and their self-sufficiency.

However, there are some strengths that are very relevant for a concrete waste stream and not relevant at all for other(s).

The availability on the market is very relevant for sewage sludge and animal manure, as their availability is high, but it has low relevance for digestate, as it is also available, but on a smaller scale.

The price of new fertilisers results to be a relevant strength for those coming from sewage sludge, as the price is relatively low, but the price for those coming from animal manure and digestate are higher. However, processing costs of animal manure result to be a very relevant strength, as they are very low. It does not happen the same with sewage sludge and digestate. The situation is very similar regarding the legislative standpoint.

Thus, the key strengths to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of sewage sludge, animal manure and digestate are:

- Positive ecological image of new fertilisers.
- Application security of new fertilisers.
- Self-sufficiency.
- Soil improvement.
- Market availability for sewage sludge and animal manure.
- Price of new fertilisers coming from sewage sludge.

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- Processing costs of animal manure.

5.5.2. Weaknesses (W)

Table 73. Weaknesses matrix for South-East Poland region

No	Strengths Item	Explanation	Scoring for sewage sludge	Scoring for animal manure	Scoring for digestate
1	High installation costs	High installation costs for sewage sludge and digestate	4	1	4
2	Society's unwillingness	Society often shows reluctance towards products made from waste	5	1	4
3	Unstable composition	The difficulty of maintaining a stable composition of fertilisers derived from sewage sludge, digestate and animal manure	4	2	2
4	The necessity of quality control	Products made from sewage sludge, digestate and animal manure must undergo quality control	4	1	3
5	Legal restrictions	There are legal restrictions on the use of fertilisers from sewage sludge, animal manure and digestate	5	1	4
6	Storage difficulty	There is a difficulty in storing products made from waste	5	4	4
7	Raw material availability	Sewage sludge cannot be transported between voivodeships. Additionally, production must be located close to the place of generation	4	4	4
8	Unpleasant odour	The unpleasant odour discourages consumers from buying and using waste fertilisers	2	5	2

With regards to the weaknesses, storage difficulty appears to be a very relevant weakness for sewage sludge, animal manure and digestate according to the stakeholders consulted. Raw material availability also results to be a relevant weakness, as transportation between voivodeships is not easy.

Society's unwillingness is also a very relevant weakness for sewage sludge and digestate, not being relevant for animal manure. This contrasts with one of the main strengths detected, i.e., the increasing attention that society is paying to the ecological aspects of fertilisers. In addition, other weaknesses common for sewage sludge and digestate are the high cost of the installation, the need of quality control and the legal restrictions, what is not relevant for animal manure.

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However, there is a very relevant weakness for animal manure which is not relevant for sewage sludge and digestate: the odour.

Thus, the key weaknesses to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of sewage sludge, animal manure and digestate, are:

- Raw material availability.
- Storage difficulties.
- Certain social reluctance for sewage sludge and digestate.
- High costs of installation and need of quality control for sewage sludge and digestate.
- Legal restrictions for sewage sludge and digestate.
- Odour problems for animal manure.

5.5.3. Opportunities (O)

Table 74. Opportunities matrix for South-East Poland region

No	Opportunities Item	Explanation	Scoring for sewage sludge	Scoring for animal manure	Scoring for digestate
1	Recommendations at the level of the European Union	Recommendations at European Union level on the use of fertilisers from waste	5	5	5
2	Legal regulations	Legal regulations at the national and European level regarding fertilisers from waste	1	1	1
3	Market gap	Market gap regarding the rising price of mineral fertilisers	1	1	1
4	Decreasing availability of critical raw materials	Biogenic nutrients, including phosphorus, are on the list of European critical raw materials, but also key critical raw materials for Poland	5	5	5
5	Circular waste management	Possibility to reduce waste generation and the opportunity to implement circular economy solutions in practice	5	5	5
6	Research and Development	Continued investment in research and development can lead to the development of more effective and specialised fertilisers based on waste tailored to the specific needs of Polish soils and crops	5	4	5
7	Implementation installations	Financial support for implementation installations	4	3	4

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8	Environmental awareness	Increasing ecological awareness among Polish society	4	5	5
9	Growing market for secondary raw materials	Increasing use of secondary raw materials	5	5	5
10	Demand for ecological products	Growing demand for ecological products by consumers	5	5	5
11	Development of technologies/innovation	Due to the prohibition of sludge storage, technologies for the production of fertilisers are being intensively developed	1	5	1

Many of the opportunities identified have been considered very relevant by the stakeholders consulted for all waste streams. Sewage sludge, animal manure and digestate share plenty of significant opportunities, such as the recommendations at EU level to use new fertilisers, the decreasing availability of critical raw materials, the contribution to the circular economy model, the growing market for secondary raw materials and the demand for ecological products. Research and development and environmental awareness are also relevant opportunities.

On the other hand, there are two opportunities that have been identified but have not been considered relevant by the stakeholders: legal regulations and the market gap.

It is relevant to highlight that all waste streams share approximate values in the scoring, except from one concrete opportunity, that has been considered as very relevant for animal manure and not relevant for sewage sludge and digestate. This concrete opportunity is the development of innovations and technologies.

Thus, the key opportunities to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of sewage sludge, animal manure and digestate, are:

- EU recommendations for the use of alternative fertilisers and demand for ecological products.
- Decrease of the availability of critical raw materials and growing market for secondary raw materials.
- Contribution to the circular economy model.
- Development of innovations and technologies for animal manure.

5.5.4. Threats (T)

Table 75. Threats matrix for South-East Poland region

No	Opportunities Item	Explanation	Scoring for sewage sludge	Scoring for animal manure	Scoring for digestate

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1	Regulatory challenges	The regulatory landscape surrounding biofertilisers, including registration, certification, and labelling requirements, can pose challenges for manufacturers and distributors	5	2	4
2	Lack of standardisation and quality control	The production and distribution of biofertilisers may face challenges related to quality control and standardisation. Ensuring consistent quality and efficacy of biofertilisers is essential to gain trust from farmers and promote their wider adoption. Any lapses in quality control can undermine the credibility and hinder the growth of the biofertiliser industry	2	5	3
3	Competing technologies and products	Fertilisers from waste face competition from other agricultural technologies and products, including synthetic fertilisers, precision farming techniques, and genetically modified crops. The availability and aggressive marketing of these alternatives may pose challenges to the widespread adoption of biofertilisers	5	5	5
4	Environmental pollution	Risks of environmental pollution from microplastics, pharmaceuticals and other substances	4	3	2
5	Environmental risk	Possibility of environmental pollution due to improper storage, processing and use of secondary raw materials	3	3	3
6	Threat of greenwashing	The appearance of false information about other technologies that are considered greener and cheaper than sewage sludge, digestate and animal manure treatment methods	4	4	4
7	Uncertain legislative future	The sewage sludge directive has been revised and will most likely be updated. There may be more stringent quality requirements. In addition, the law on the control of micropollutants is tightened	5	2	4

From all threats identified by the stakeholders, the existing competence with other technologies and products constitute a very relevant threat for sewage sludge, animal manure and digestate. The appearance of false information about green technologies, i.e., greenwashing, constitute another important threat.

Sewage sludge has other very relevant threats, like the regulatory challenges and the uncertain legislative future. This also relevant for digestate, but not for animal manure.

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On the other hand, the lack of standardisation and quality control has been defined as a very relevant threat for animal manure, but its relevance is lower for sewage sludge and digestate.

Thus, the key threats to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of sewage sludge, animal manure and digestate, are:

- Existing competence with other technologies and products.
- Greenwashing.
- Regulatory challenges and uncertain legislative future for sewage sludge and digestate.
- Lack of standardisation and quality control for animal manure.

5.6. Spain – Andalusia

SWOT analysis for Andalusia region has been focused on the alternative fertilising products coming from their assigned waste streams:

- Wastewater.
- Sewage sludge.

The results can be graphically presented as follows:

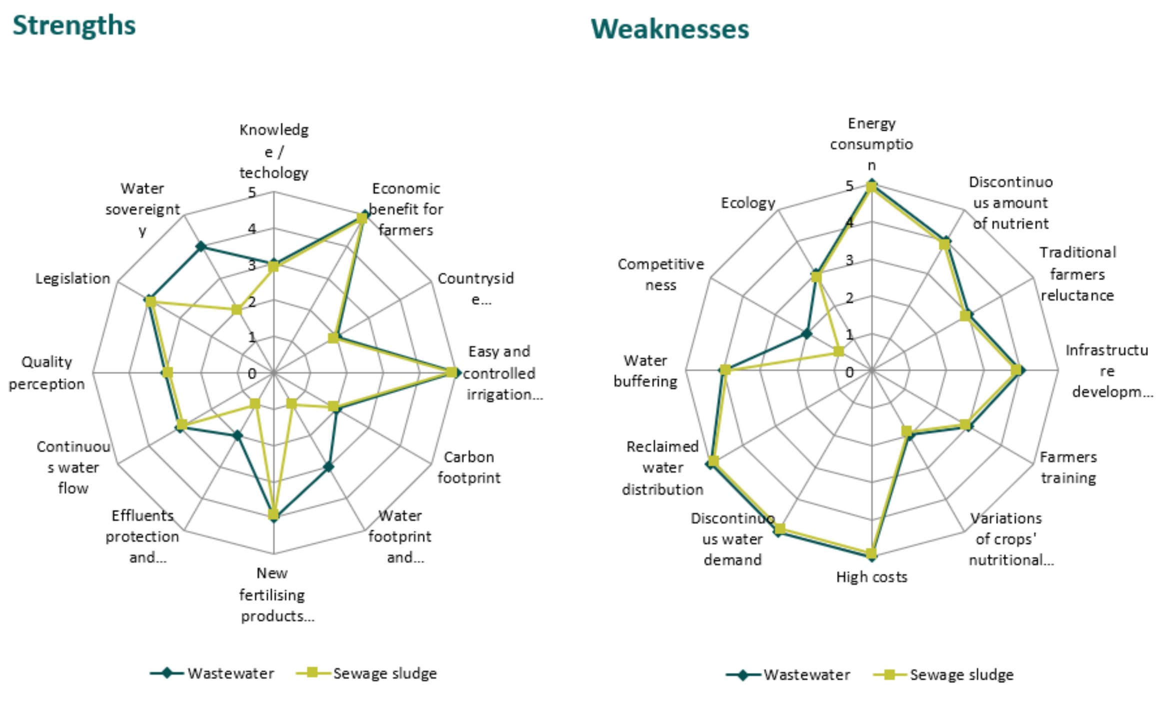

Figure 79. Strengths and weaknesses radar diagrams for Spain - Andalusia region

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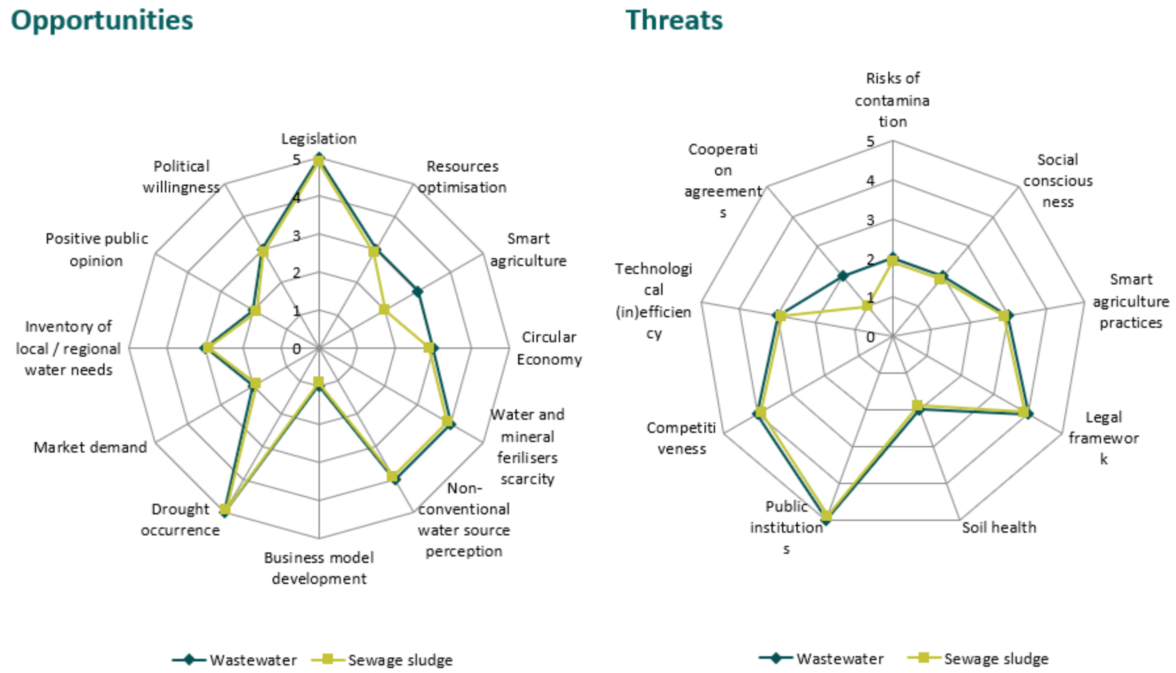

Figure 80. Opportunities and threats radar diagrams for Spain - Andalusia region

5.6.1. Strengths (S)

Table 76. Strengths matrix for Spain - Andalusia region

No	Strengths Item	Explanation	Scoring for wastewater	Scoring for sewage sludge
1	Knowledge / technology	The knowledge and technology for further treatment of reclaimed water is available	3	3
2	Economic benefit for farmers	Depending on the source of wastewater and type of treatment, a farmer can save 10 – 30% of N and P, and in some occasions higher amounts of K, as this nutrient is almost not removed in the treatment process (not dangerous to environment)	5	5
3	Countryside depopulation tackling	Water treatment and nutrient recovery may encourage countryside population to stay within drought areas	2	2
4	Easy and controlled irrigation and fertilisation plan	Reclaimed water together with alternative fertilising products may be applied on crops by means of a precise and controlled delivery	5	5

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5	Carbon footprint	Alternative fertilisers use contribute to decrease the carbon footprint in comparison to the inorganic fertilisers supply chain (can be applied directly onsite (zero-kilometre application), for example)	2	2
6	Water footprint and climate change adaptation	Reclaimed water reduces the pressure on conventional water streams	3	1
7	New fertilising products market	The alternative fertilisers developed will be incorporated to the market, constituting a new option in the sustainable economy context	4	4
8	Effluents protection and water quality enhancement	The recovery of nutrients will protect water bodies from nitrate contamination	2	1
9	Continuous water flow	Even in periods of droughts, a predictable baseline amount of reclaimed water will be always available, as the wastewater source is urban wastewater	3	3
10	Quality perception	According to the current legislation, no extra treatment for reclaimed water is needed to be used for irrigation	3	3
11	Legislation	Farmers show interest in making use of this water source, as water scarcity is one of the most relevant problems in the region (positive attitude of farmers)	4	4
12	Water sovereignty	Optimal use of agricultural land, with no need of on-farm buffering (compared to water basins for rainwater)	4	2

From those strengths identified by the stakeholders consulted, the ones scored as very relevant for both wastewater and sewage sludge are the economic benefit the use of new fertilisers may constitute for farmers and the precise irrigation and fertilisation plan that can be elaborated with reclaimed water as new fertiliser. The supporting legislation and the growing fertilising products market are also relevant strengths.

Water sovereignty, which arises in the optimal use of agricultural land with no need of on-farm buffering, is relevant for wastewater, but it is not for sewage sludge.

On the other hand, the effluents protection and wate quality enhancement has not resulted to be very relevant strengths for the stakeholders for both wastewater and sewage sludge. The same that happens with carbon footprint and countryside depopulation tacking.

Thus, the key strengths to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of wastewater and sewage sludge, are:

- Economic benefit of the new fertilisers' use.

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- Possibility of elaborated precise irrigation and fertilisation plans with reclaimed water.
- Supporting legislation.
- Growing fertilising products market.
- Water sovereignty for wastewater.

5.6.2. Weaknesses (W)

Table 77. Weaknesses matrix for Spain - Andalusia region

No	Weaknesses Item	Explanation	Scoring for wastewater	Scoring for sewage sludge
1	Energy consumption	High energy consumption to deliver the water resource	5	5
2	Discontinuous amount of nutrient	Depending on the wastewater treatment process applied and the raw wastewater used (it may be not only urban wastewater), the reclaimed water obtained can contain a higher or lower amount of nutrients	4	4
3	Traditional farmers reluctance	Traditional farmers may resist the use of these alternative fertilisers because the fertilisers they currently used show optimal results	3	3
4	Infrastructure development	The establishment of new infrastructures takes time and constitute an expenditure the farmers may not be willing to make	4	4
5	Farmers training	The farmers need to learn how to properly manage this resource to solve potential problems, like the appearance of incompatibilities between the fertilising plan and the reclaimed water composition	3	3
6	Variations of crops' nutritional requirements	Nutritional requirements of the crops vary over the cropping period, depending on the phenological stage; reclaimed water shall be used in combination with other water sources in order to balance their requirements	2	2
7	High costs	High price of the final water resource (to the farmer). The cost of "classic" water resources is still very cheap, and the treatment cost can be relatively high	5	5
8	Discontinuous water demand	Discontinuous demand from agriculture (especially during period of droughts, when other sources are not available)	5	5

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9	Reclaimed water distribution	Bad availability of water resources to the farms, as there is not a distribution net available for water reuse (and the cost of distribution network is expensive), and road transport is not optimal	5	5
10	Water buffering	Need of infrastructures to buffer water for its further distribution	4	4
11	Competitiveness	High competitiveness for the water source with other users (industry, households, etc.). The industry, for example, needs water during the whole year, and at the same time has more capital for investments and less risks for food security or environmental contamination	2	1
12	Ecology	The use of reclaimed water reduce the water discharge in water bodies	3	3

From all weaknesses identified by the stakeholders from both wastewater and sewage sludge, those that have been considered as very relevant are the energy consumption to deliver the water resource and the associated high costs, the discontinuous water demand from agriculture (especially during period of droughts, when other sources are not available) and the reclaimed water distribution, as there is not a distribution net available for water reuse. Other relevant weaknesses are the discontinuous amount of nutrients the reclaimed water may contain and the need of infrastructures to buffer water for further distribution.

With regards to the less relevant weaknesses, the stakeholders have considered the variations of crops' nutritional requirements and the competitiveness for the water soured with other users are not relevant.

Thus, the key weaknesses to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of wastewater and sewage sludge, are:

- Energy consumption to deliver the water resource and the associated high costs.
- Discontinuous water demand from agriculture.
- Reclaimed water distribution.
- Discontinuous amount of nutrients of reclaimed water.
- Need of infrastructure to buffer water for further distribution.

5.6.3. Opportunities (O)

Table 78. Opportunities matrix for Spain - Andalusia region

No	Opportunities Item	Explanation	Scoring for wastewater	Scoring for sewage sludge
1	Legislation	Regulation on reuse of water for irrigation (EU/Andalusian level)	5	5

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2	Resources optimisation	There is a need to decrease the use of fertilisers because of the costs for the farmers and pollution problems they cause	3	3
3	Smart agriculture	Digitalisation is key for the European Commission, that appoints water and agriculture as the sectors on which efforts must be focused in terms of digital transformation	3	2
4	Circular Economy	Transition from linear to circular economy is a priority supported by the European Commission and the national government	3	3
5	Water and mineral ferilisers scarcity	Drought and mineral fertilisers supply are crucial points to face agriculture in the next years	4	4
6	Non-conventional water source perception	A lot of scientific work has been done in the past decades on the subject; regulations set a framework to increase the safety perception of this resource	4	4
7	Business model development	Great efforts in research concerning cost-effective implementation (technologies, distribution, etc.) of reclaimed water possibilities	1	1
8	Drought occurrence	Increased drought occurrence affects the urgency for alternative water sources	5	5
9	Market demand	The demand of the agricultural sector for the use of reclaimed water can lead to economies of scale	2	2
10	Inventory of local / regional water needs	Inventory would help to have a precise view on the local and regional water needs and supplies	3	3
11	Positive public opinion	Positive attitude of consumers	2	2
12	Political willingness	Willingness of the local and regional governments to look for solutions to cope with water scarcity and implement them	3	3

The stakeholders consulted have also defined the opportunities for wastewater and sewage sludge. The most relevant ones for both waste streams are the legislation, concretely the regulation on water reuse for irrigation, and the drought occurrence.

Water and mineral fertilisers scarcity and the current perception of non-conventional water sources have also been considered as relevant.

Thus, the key opportunities to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of wastewater and sewage sludge, are:

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- Legislation on water ruse for irrigation.
- Drought occurrence in the region.
- Water mineral fertilisers scarcity.
- Current perception of non-conventional water sources.

5.6.4. Threats (T)

Table 79. Threats matrix for Spain - Andalusia region

No	Opportunities Item	Explanation	Scoring for wastewater	Scoring for sewage sludge
1	Risks of contamination	Heavy metals, nanoparticles, plastics,…	2	2
2	Social consciousness	Social reluctance due to lack of awareness, information, training	2	2
3	Smart agriculture practices	Digital technologies implementation may be difficult for some traditional farmers	3	3
4	Legal framework	It might imply extra treatment costs, thus a higher cost per unit of supplied water	4	4
5	Soil health	Lack of evidence of how the use of reclaimed water (nutrient rich) could affect the soil health	2	2
6	Public institutions	Slowness in licensing by the public administration	5	5
7	Competitiveness	High competitiveness for the water source with other users (industry, households, etc.)	4	4
8	Technological (in)efficiency	Uncertainty about the effective treatment for emerging risk nanoparticles, antibiotics, etc.	3	3
9	Cooperation agreements	Disagreements between different implied parties (farmers, producers, distributors, etc.)	2	1

From those threats identified by the stakeholders, the most significant threat for wastewater and sewage sludge is the slowness of licensing alternative fertilisers by public institutions. Another very relevant threat is the extra costs that might appear due to the legal framework for extra treatment costs, thus causing higher costs per unit of supplied water, and another very relevant threat is the high competitiveness for the water source with other users (industry, households, etc.).

Threats that have been identified and catalogued as low relevant by the stakeholders have been the risk of contamination, the social consciousness, the soil health and the cooperation agreements.

Thus, the key threats to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of wastewater and sewage sludge, are:

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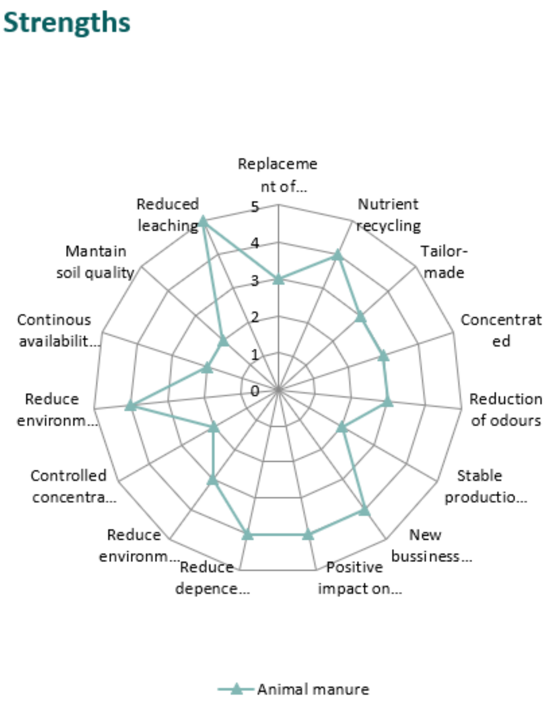
- Slowness in licensing by the public administration.
- Extra treatment costs that might imply the legal framework.
- Competitiveness of the water source with other users.

5.7. Spain – Catalonia

SWOT analysis for Catalonia has been focused on the alternative fertilising products coming from their assigned waste streams:

- Animal manure.

The results can be graphically presented as follows:



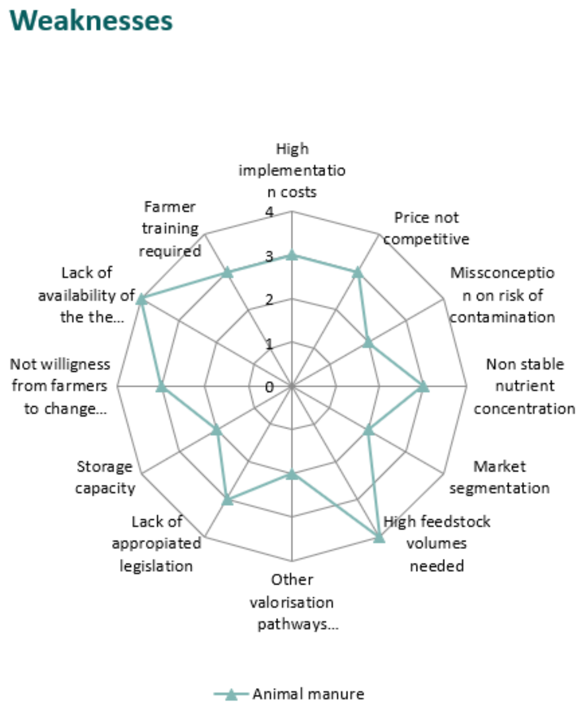


Figure 81. Strengths and weaknesses radar diagrams for Spain - Catalonia region

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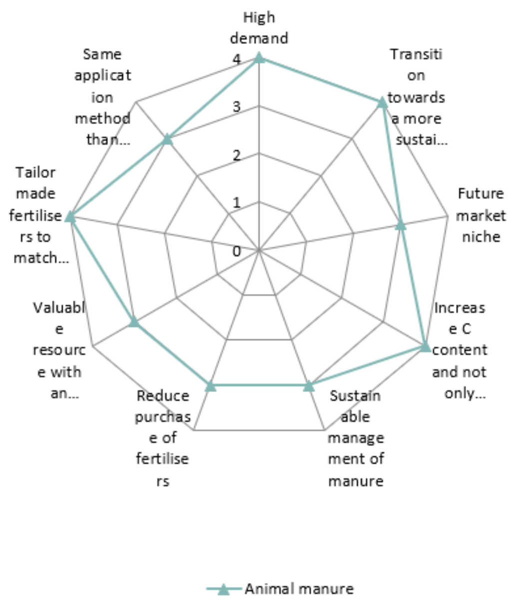
Opportunities



Threats

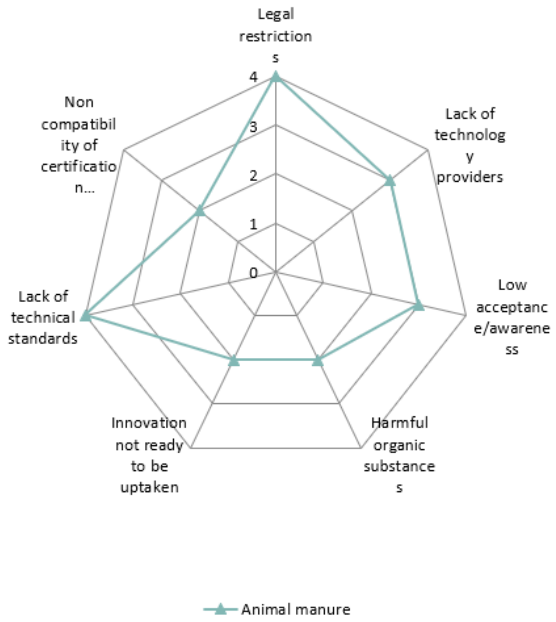


Figure 82. Opportunities and threats radar diagrams for Spain - Catalonia region

5.7.1. Strengths (S)

Table 80. Strengths matrix for Spain - Catalonia region

No	Strengths Item	Explanation	Scoring for animal manure
1	Replacement of mineral fertilisers	Use of non-renewable sources	3
2	Nutrient recycling	The use of recycled fertilisers contributes to decreasing the carbon footprint in comparison to the inorganic fertilisers supply chain.	4
3	Tailor-made	Tailor-made fertilisers using several recovered products to fulfil the nutrients demand of a concrete crop.	3
4	Concentrated	Easier transport.	3
5	Reduction of odours	Reduction of odours in comparison with the direct application of the manure.	3
6	Stable production costs	The price is more stable in comparison with mineral fertilisers, whose price is fluctuant.	2
7	New business opportunity	Possibility of producing fertilisers with the EC label.	4

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8	Positive impact on soil fertility	They do not provide nutrients only, but also C in some cases.	4
9	Reduce dependence on raw materials	Reduction of the dependence on mineral fertilisers from outside the region, direct application in the farm in which they are produced.	4
10	Reduce environmental impacts and contribute to sustainability	In comparison to the application of manure without any treatment.	3
11	Controlled concentration of pathogens and heavy metal	Heavy metals detected in some cases in which manure is directly applied.	2
12	Reduce environmental impact	Reduction of the N loss to water bodies when applying recovered fertilisers, as they have a slower release.	4
13	Continuous availability of the organic feedstock	There is a surplus of manure in the region, what secures the availability of raw material.	2
14	Maintain soil quality		2
15	Reduced leaching		5

From all strengths identified by the stakeholders consulted, those considered as more relevant are the contribution to decrease the carbon footprint by nutrients recycling, the possibility of producing fertilisers with the EC label, the positive impact on soil fertility, the reduction of dependence on raw materials and the reduction of the environmental impact.

On the other hand, the strengths valued as less relevant are the stable production costs, the controlled concentration of pathogens and heavy metals, the continuous availability of the organic feedstock and the maintenance of soil quality.

Thus, the key strengths to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of animal manure are:

- Decrease of carbon footprint by nutrients recycling, thus reduction of the environmental impact.
- Production of fertilisers with the EC label.
- Reduction of dependence on raw materials.
- Positive impact on soil fertility.

5.7.2. Weaknesses (W)

Table 81. Weaknesses matrix for Spain - Catalonia region

No	Strengths Item	Explanation	Scoring for animal manure

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1	High implementation costs	High initial investment needed.	3
2	Price not competitive	In comparison with the mineral fertilisers in the market and the direct application of manure to increase the organic matter of the soil.	3
3	Misconception on risk of contamination	Fear to a non-complete depathogenisation.	2
4	Non stable nutrient concentration	Non stable concentration, as it depends on the type of manure used.	3
5	Market segmentation	Different industries for the production of fertilisers, organic amendments or biostimulants recovered from the manure.	2
6	High feedstock volumes needed	Need of centralising production to make the process economically viable in some cases.	4
7	Other valorisation pathways are more efficient/feasible	Different from nutrients recovery, such as compost production to be used as stable organic matter.	2
8	Lack of appropriated legislation	Some products are still under the restrictions of the nitrates directive, like the untreated manure.	3
9	Storage capacity	Difficult storage, as some products need a post-treatment.	2
10	Not willingness from farmers to change the fertilisation techniques	Reluctancy to change something that is currently working.	3
11	Lack of availability of the infrastructure needed	It requires time and investment.	4
12	Farmer training required	The products' use also requires new application practices that need to be learnt.	3

With regards to the weaknesses identified by the stakeholders consulted, the ones considered as most relevant are the high feedstock volumes needed, as production has to be centralised to make the process economically viable in some cases, and the lack of needed infrastructures availability.

On the other hand, the less relevant weaknesses are the fear to a non-complete depathogenisation, the market segmentation, the difficulties in storage and the existence of other valorisation pathways more feasible.

Thus, the key weaknesses to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of animal manure are:

- High feedstock volumes needed,
- Lack of needed infrastructures availability.

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5.7.3. Opportunities (O)

Table 82. Opportunities matrix for Spain - Catalonia region

No	Opportunities Item	Explanation	Scoring for animal manure
1	High demand	It increases the demand for sustainable products.	4
2	Transition towards a more sustainable agriculture	Big pressure on agriculture to increase production, while respecting the environment.	4
3	Future market niche	Due to the fertilisers' price increase, the demand of new recovered products will also increase.	3
4	Increase C content and not only soil fertility	Many products are interesting because they also increment the amount of C apart from nutrients.	4
5	Sustainable management of manure	Manure production exceeds the storage capacity and local application, what results in a careless disposal and its associated risks.	3
6	Reduce purchase of fertilisers	It is related to the increase of the mineral fertilisers prices due to socio-politic fluctuations.	3
7	Valuable resource with an added value helping to decrease environmental impact	More ecological ways to promote the plants growth and improve the crops.	3
8	Tailor made fertilisers to match crop needs	Reduce the risk of nutrients loss to the environment.	4
9	Same application method than conventional fertiliser	No new investment is needed.	3

From the opportunities identified by the stakeholders contacted, those considered as more relevant are the high demand for sustainable products, the pressure on agriculture to increase production while respecting the environment, and the reduction of the risk of nutrients loss to the environment.

However, all opportunities have been scored as medium-relevant, i.e., the weight differences among all of them are not so significant.

Thus, the key opportunities to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of animal manure are:

- High demand of sustainable products.
- Pressure on agriculture to increase production while respecting the environment.
- Reduction of nutrients loss to the environment.

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5.7.4. Threats (T)

Table 83. Threats matrix for Spain - Catalonia region

No	Opportunities Item	Explanation	Scoring for animal manure
1	Legal restrictions	It is not clear if these products could be used in the same context as mineral fertilisers.	4
2	Lack of technology providers	Lack of innovative technologies developers at industrial scale.	3
3	Low acceptance/awareness	Low acceptance/awareness of the final products from the farmers.	3
4	Harmful organic substances	Like antibiotics that could be transferred to the food chain.	2
5	Innovation not ready to be uptaken	That can be difficult to implement at some scales.	2
6	Lack of technical standards	Lack of consensus.	4
7	Non compatibility of certification schemes across the EU	Trading obstacle.	2

From the threats identified, the ones considered as more relevant by the stakeholders are the legal restrictions, as it is not clear enough the products can be used exactly in the same context as mineral fertilisers, and the lack of consensus on technical standards.

On the other hand, the threats considered as less relevant are the potential existence of harmful organic substances that could be transferred to the food chain, the possibility that the innovations are not ready to be uptaken and the potential non compatibility of certification schemes across the EU, what could constitute a trading obstacle.

Thus, the key threats to be further taken into account for the elaboration of the RSAP, according to the SWOT analysis of animal manure are:

- Legal restrictions to use the new fertilisers in the same context as mineral fertilisers.
- Lack of consensus on technical standards.

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Novafert

6. PEST analysis of the NOVAFERT regions

6.1. Belgium – Flanders

6.1.1. Barriers to alternative fertilisers production and usage in Flanders, Belgium

Table 84. PEST analysis: barriers to alternative fertilisers production and usage from animal manure and digestate as secondary raw materials in Flanders, Belgium

Political	**Legal restriction**: There are legal restrictions in using the fertilisers from animal manure and digestate.
	Regulatory challenges: Challenging national regulations and policies, Lack of knowledge and uncertainty on the certification and regulatory framework.
Economic	**Environmental risk/pollution**: Heavy metals, Antibiotic and microplastic residues, pathogen exposure, salt accumulation; and their possible transfer into the food chain, or increased antibiotic resistance in agricultural soils. Polluting the environment may occur because of inappropriate storage, processing, and use of secondary raw materials.
	High installation costs: High investment in technology implementation; The implementation of new technologies is of course linked to high investments which companies are not necessarily willing to make.
Social	**Unclear consumer acceptance**: Concerns about safety, odour, appearance, lack of certification or quality perception in comparison to synthetic fertilisers can all impact public acceptability.
	Farmers awareness and training: The farmers need to learn how to properly manage this resource to solve potential problems. Limited public awareness and understanding of the benefits of alternative fertilisers could lead to resistance in adopting these products. Lack of public knowledge and comprehension of the benefits of alternative fertilisers could lead to resistance in adopting these products.
	Harmonisation/standardisation (Quality control and consistency): Difficulties in harmonisation/standardisation of bio-based fertilisers as well as uncertainty in products sustainability. Quality control and standardisation issues may arise during the manufacture and distribution of biofertilisers. It is critical to ensure constant quality and performance of biofertilisers to acquire farmer trust and promote their wider use.
	Effectiveness perceived by the public: Farmers may be sceptical of alternative fertilisers' advantages if they have not been widely researched or proved to be as successful as chemical fertilisers.
	Unpleasant odour: The unpleasant odour discourages consumers from buying and using waste fertilisers.
Technical	**Oversupply of sustainability programs**: There is a tendency for vested interests to attempt to bring their own recycling technique or greenwashing, and farmers are over-inquired about such projects, making it difficult to convince them to participate in the next workshop or idea.

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	Variability: The nutrient availability varies depending on factors such as the source, processing methods, and seasonal variations.
	Compatibility and Machinery: Machinery issues related to some products spreading in the field uniformly.
	Technological (in)efficiency: Uncertainty about the effective treatment for emerging risk nanoparticles, antibiotics, etc.
	Storage and shorter shelf-life: Can be difficult to store and may have much shorter shelf-life.

6.1.2. Drivers to alternative fertiliser production and usage in Flanders, Belgium

Table 85. PEST analysis: drivers to alternative fertilisers production and usage from animal manure and digestate as secondary raw materials in Flanders, Belgium

Political	**Reducing dependency on imports**: Policymakers may view the use of alternative fertilisers as a means of reducing the country's reliance on imported fertilisers, so improving self-sufficiency. Because of their ability to substitute mineral fertilisers.
	Circular Economy: Contributing to a circular economy model by transforming waste materials into valuable sources of nutrients.
	Mineral fertilisers scarcity: Mineral fertiliser availability is one of the most pressing issues facing agriculture in the next years, and biobased fertilisers have the potential to replace/substitute mineral fertilisers.
	Political willingness: Willingness of the local and regional governments to look for solutions to cope with water scarcity and implement them.
Economical	**Creation of green jobs**: There is plenty of room for moving forward that will provide opportunities to create green jobs.
	Preserving soil health and biodiversity: Increase crop yield while simultaneously improving soil health. Improve soil organic matter content. Increased organic matter enhances soil fertility, water-holding capacity, and overall soil health, leading to improved crop productivity.
	New fertiliser products market: The alternative fertilisers developed will be incorporated to the market, constituting a new option in the sustainable economy context.
	Nutrient recycling: These fertilisers contribute to the recycling of nutrients from organic waste materials back into the soil, reducing the need for synthetic fertilisers. This helps to close nutrient loops and promotes a more sustainable agricultural system.
	Business model development: Great efforts in research concerning cost-effective implementation (technologies, distribution, etc.).
	Wide spectrum of products: Major groups of liquid and solid end and by-products according to their chemical composition, content of plant nutrients.

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Social	**Synergises global goals of climate mitigation**: Using BBFs have the potential to mitigate climate change due to the utilisation of organic fertilisers over mineral ones and thus increase soil organic matter content (draw down atmospheric CO_2).
	Solve waste disposal problems: Utilising animal manure, and digestate as fertilisers reduces the volume of organic waste that would otherwise require disposal in landfills or incineration. This helps to alleviate the burden on waste management infrastructure.
	Support integrated farming: The integration between animal farming, crop production, and industrial waste could be implemented for optimisation of energy resources.
	Positive public opinion: Positive attitude of consumers.
Technical	**Knowledge / technology**: The knowledge and technology for further treatment is available.
	Precision application technologies: Advanced technology, such as precision agricultural instruments and sensor-based systems, enable the farmers to apply fertiliser more precisely and in real time, based on soil and crop conditions.
	Feedstock availability and low or no cost of input streams: High availability, renewability and minor pollution (4 250 857 tonnes of livestock manure was processed in Flanders in 2021).
	Research and innovation: A lot of scientific work has been done in the past decades on the subject; regulations set a framework to increase the safety perception of this resource. Ongoing research may focus on improving processing methods, increasing nutritional content and availability, producing new products, and investigating innovative approaches for successfully using these resources in various agricultural systems.

6.2. Croatia – Continental Croatia

6.2.1. Barriers to alternative fertilisers production and usage in Continental Croatia

Table 86. PEST analysis: barriers to alternative fertilisers production and usage from animal manure, digestate and bio-waste as secondary raw materials in Continental Croatia

Political	**Restrictive regulations**: Restrictive regulations that govern management, quality, and application of digestate on EU and national levels.
	Strict compliance with regulations: If subsidy schemes are being used, then strict compliance with regulations is needed.
	Legislative obstacle: The biggest obstacle to the use of digestate as an organic fertiliser or soil improver in Croatian legislation (Regulation on by-products and disposal of waste status).
	Government support: Lack of government support for research and development of alternative fertilisers
Economic	**High production costs**: production costs of alternative fertilisers (digestate) may be higher than conventional fertilisers, making them less economically valuable for both producers and consumers

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	Lack of subsidies schemes: for promotion the alternative fertilising products
	Market demand: If there is low demand for alternative fertilisers, producers might be reluctant to invest in alternative fertiliser production.
	Additional costs: Additional costs associated with proper storage, transportation, and application.
Social	**Consumer preferences**: Consumer preferences for well-established products may deter them from trying unfamiliar alternative fertilisers.
	Unpleasant odour: The unpleasant odour discourages consumers from buying and using waste fertilisers (NIMBY).
	Lack of management practices: Lack of bio-waste management practices in some regions (e.g. lack of infrastructure etc.). There is still a lot of place to improve bio-waste management.
	Limited awareness: Limited public awareness and understanding of the benefits of alternative fertilisers could lead to resistance in adopting these products.
Technical	**Unstable composition**: The difficulty of achieving standardised and maintaining a stable composition of fertilisers.
	Strict application: Improper application can lead to nutrient imbalances in the soil.
	Storage and transportation difficulty: Requiring proper transportation and storage infrastructure.
	Non-use of technologies on market: Not all technologies currently available on the market are being used/applied on a national level due to different reasons (economic, technical).
	Environmental pollution: Risks of environmental pollution from microplastics, pharmaceuticals and other substances.
	Specialised equipment: Using specialised equipment to ensure equal distribution.

6.2.2. Drivers to alternative fertiliser production and usage in Continental Croatia

Table 87. PEST analysis: drivers to alternative fertilisers production and usage from animal manure, digestate and bio-waste as secondary raw materials in Continental Croatia

Political	**Policy framework**: Policy framework promotes the separate collection and appropriate treatment of bio-waste.
	Recommendations at the level of the EU: EU policies promote sustainable farming practices and encourage the use of alternative fertilisers.
	Subsidy schemes: Opportunities for farmers to obtain subsidy schemes if using manure.
Economi c	**Cost-effective**: Cost-effective, reducing the need to purchase commercial fertilisers.
	Resource self-sufficiency: The possibility of producing fertilisers from waste at their place of generation.

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	Circular economy: Contributing to a circular economy by recycling organic waste and utilising it as a valuable resource (e.g. subsidies and incentives)
	Market demand for secondary raw materials: Increasing use of secondary raw materials.
Social	**Sustainable agriculture**: Minimising the ecological footprint associated with chemical fertiliser production and fosters a more balanced nutrient cycle.
	Change of consumer preferences: It can increase demand for alternative fertilisers.
	Environmental awareness: Increasing ecological awareness among society.
	Agro and food resources recovery: Supporting agro and food processing resources recovery. Utilising bio-waste as a basis for fertilisers provides a sustainable solution for managing organic waste materials, such as food waste and agricultural residues.
Technical	**Application technologies**: More accessible application technologies can encourage the use of alternative fertilisers and incorporation into agro practices.
	Energy production: producing energy from renewable sources. The co-production provides an opportunity for farmers to generate on-site energy.
	Technological agro-innovations: Development of the technologies can lead to development of new and more effective alternative fertilisers.
	Research and Development: Continued investment in research and development can lead to the improvement of alternative fertilisers making them more effective and accessible.
	Optimal application: Calculation of the appropriate amount of manure needed for crop nutrient requirements. This helps prevent over-application and potential nutrient imbalances in the soil.

6.3. Finland – South-West Finland

6.3.1. Barriers to alternative fertilisers production and usage in – South-West Finland

Table 88. PEST analysis: barriers to alternative fertilisers production and usage from animal manure, digestate and bio-waste as secondary raw materials in South-West Finland

Political	**Regulation**: Regulations on alternative fertilisers are complex.
Economic	**Processing:** Optimisation of nutrient ratio needs high processing inputs and external nutrient sources/Small scale production of alternative fertilisers is not profitable.
	Availability: Markets for alternative fertilisers are small and local.
Social	**Lack of knowledge**: Marketing of alternative fertilisers should be targeted directly to farmers.
	Trust towards alternative fertilisers: Origin of ingredients in alternative fertilisers must be known.

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	Potential risks to human and animal health: Alternative fertilisers may pose a risk for the spreading of animal diseases/potential heavy metals may turn into a soluble form in acidic soils.
Technical	**Quality:** low nutrient concentration/nutrient content not optimal for crop growth/agronomic efficiency may be lower than in mineral fertilisers/potential contaminants/soil contamination.
	Large application rates: Application volumes (in fertilisation) are high in alternative fertilisers due to low nutrient/high moisture concentration.
	Equipment requirement: Alternative fertilisers and mineral fertilisers need different spreader equipment.
	Storage: Storage of alternative fertilisers is challenging.

6.3.2. Drivers to alternative fertiliser production and usage in – South-West Finland

Table 89. PEST analysis: drivers to alternative fertilisers production and usage from animal manure, digestate and bio-waste as secondary raw materials in South-West Finland

Polit ical	**Fertiliser regulation**: Strict regulations ensure the safety use of alternative fertilisers.
Economic	**Nutrient recycling:** Optimal use of alternative fertilisers decreases use of mineral fertilisers.
	Farm economy: Use of alternative fertilisers increases self-sufficiency in farms/ In many cases similar agronomic efficiency between alternative fertilisers and mineral fertilisers.
	Rural areas: Nutrients produced in organic side-streams in a region have an advantage over other regions/Alternative fertilisers offer multiple business opportunities (production, supply, spreading).
	Soil productivity: Alternative fertilisers contain versatile nutrients including micronutrients.
	Quality of bio-based fertilisers (BBFs): Quality of alternative fertilisers can be an advantage in markets instead of high production volume.
	Organic farming: Willingness to pay for alternative fertilisers is higher in organic farming than among conventional farming.
	Distribution channels: Dealers are needed to ensure that the distribution channel between the producer and the crop farmer is complete.
	Price development: Pricing of alternative fertilisers will be developed in the future.
Social	**Waste reduction**: decreases total amount of waste.
	Food security: Use of alternative fertilisers improve food security.
	Environmental protection: Use of alternative fertilisers may decrease phosphorus leaching into the watercourses.
	Research: Research can offer innovations and develop the processing technologies and production of alternative fertilisers.

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Technical	**Soil quality:** Use of alternative fertilisers improves soil productivity/carbon content/ soil resilience against extreme weather events.
	Soil health: Use of alternative fertilisers increases soil microbial population and diversity.
	Technology development: Simple solutions (e.g. slurry manure sedimentation (solids settle by gravity)) may improve nutrient balances regionally/Large scale processing in centralised plants is profitable to produce alternative fertilisers/Efficiency of alternative fertiliser production can be enhanced by separation of nutrient fractions in source location (e.g. separation of solids and liquids in the farm)/ Granulation or pelletising may increase the demand for the alternative fertiliser product.

6.4. Ireland – East Ireland

6.4.1. Barriers to alternative fertilisers production and usage in Ireland

Table 90. PEST analysis: barriers to alternative fertilisers production and usage from bio-waste and biological by-products as secondary raw materials in East Ireland

Political	**Regulatory framework**: The use of alternative fertilisers may be hindered by existing agricultural and environmental regulations that are designed for chemical fertilisers.
	Lack of awareness and information: Policy makers might not be well informed about the benefits and drawbacks of alternative fertilising products.
	Interest of different stakeholders: Balancing the interest of different stakeholders, including farmers, environmental groups, consumers, and industry associations, can be challenging. Different groups may have conflicting opinions.
	Political priorities: Depending on the political climate and current priorities, issues related to agriculture and fertilisation might not receive sufficient attention or resources.
Economic	**Economics of scale**: If alternative fertilisers are produced on a smaller scale, their production costs could be higher.
	Loss of income: If the perceived benefits of using alternative fertilising products such as maintaining crop yields and improving soil health is not well demonstrated, farmers might be reluctant to use them in fear of loss of income.
	Infrastructure investment: Shifting to other sources of fertilisers may require changes to distribution and application methods.
Social	**Lack of awareness and education**: One of the primary social barriers is the lack of awareness and education among farmers and the general public about the benefits and efficacy of alternative fertilisers.
	Resistance to change: Agriculture is often deeply rooted in tradition, and farmers might be hesitant to adapt new alternative fertilisers due to concerns about potential risks.
	Perceived effectiveness: If alternative fertilisers have not been widely tested or demonstrated to be as effective as chemical fertilisers, farmers might be sceptical about their benefits.

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	Social pressure and peer influence: Farmers often rely on peer networks to make decisions. If the majority of farmers in a community are using chemical fertilisers, there might be pressure to conform to these practices.
Technical	**Product development and formulation**: Formulating alternative products that deliver nutrients efficiently and consistently can be a technical challenge.
	Nutrient availability and release: Alternative fertilisers may have different nutrient release patterns compared to traditional fertilisers. Ensuring that nutrients are available to plants when needed while minimising losses to the environment.
	Storage and handling: Alternative fertilisers might have specific storage and handling requirements. Ensuring their stability and preventing degradation during storage is important.
	Quality control and consistency: Maintaining consistent quality and nutrient content across batches of alternative fertilisers can be challenging, especially if they are produced using unconventional methods.

6.4.2. Drivers to alternative fertiliser production and usage in Ireland

Table 91. PEST analysis: drivers to alternative fertilisers production and usage from bio-waste and biological by-products as secondary raw materials in East Ireland

Political	**Environmental regulations and targets**: Political commitments to reduce greenhouse gas emissions, improve water quality, can drive the adaption of alternative fertilisers because they have lower environmental impacts compared to traditional fertilisers.
	Sustainable agriculture policies: Governments and policymakers focusing on sustainable agriculture are likely to promote practices that prioritise soil health, reduce nutrient runoff, and minimise ecosystem disruption.
	Reduction of dependency on imports: Policy makers may see using alternative fertilisers as a way to reduce the country's dependence on imported fertilisers, enhancing national security and self-sufficiency.
	Climate change mitigation strategies: Alternative fertilisers that help sequester carbon or reduce nitrous oxide emissions can contribute to national climate change mitigation strategies, which may drive policy support.
Economic	**Reduced input costs**: Alternative fertilisers that are locally sourced or produced from waste materials can potentially offer cost savings to Irish farmers compared to imported traditional fertilisers.
	Improved soil health: Alternative fertilisers that contribute to improved soil structure, nutrient retention, and microbial activity can lead to better long-term productivity.
	Premium markets: There might be market demand for crops produced with sustainable and environmentally friendly practices. Farmers who use alternative fertilisers could access premium markets that value such products.

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	Research and innovation Investment in research and innovation in the field of alternative fertilisers can create economic opportunities, stimulate job growth, and lead to the development of new products and technologies.
Social	**Environmental concerns**: Growing awareness of environmental issues in Ireland, can drive demand for sustainable agricultural practices. Alternative fertilisers that have reduced environmental impacts might align with the Irish public concerns.
	Promotion of local agriculture: The movement to support local and sustainable agriculture in Ireland is driving interest in alternative fertilisers produced within the region, contributing to local economic development.
	Media and social media influence: Public perception of agricultural practices in Ireland is influenced by media coverage and social media discussions. Positive stories and information about the benefits of alternative fertilisers can generate interest and support.
Technical	**Circular economy and waste recycling**: Irish farmers utilises organic waste materials, such as compost, animal manure and food waste which supports the principles of the circular economy.
	Precision application technologies: Advanced technologies, such as precision agriculture tools and sensor-based systems, allows Irish farmers to apply fertilisers more accurately, and based on real time soil and crop conditions.
	Resilience: Irish farmers are looking at alternative fertilisers as a way of becoming more resilient to adverse weather conditions by increasing organic matter content to improve water-holding capacity which helps crops withstand extreme weather events associated with climate change.

6.5. Poland – South-East Poland

6.5.1. Barriers of alternative fertilisers production and usage in Poland

Table 92. PEST analysis: barriers to alternative fertilisers production and usage from sewage sludge, animal manure and digestate as secondary raw materials in South-East Poland

Political	**Legal restrictions:** There are legal restrictions on the use of fertilisers from sewage sludge, animal manure and digestate.
	Regulatory challenges: The regulatory landscape surrounding biofertilisers, including registration, certification, and labelling requirements, can pose challenges for manufacturers and distributors.
	Uncertain legislative future: The sewage sludge directive has been revised and will most likely be updated. There may be more stringent quality requirements. In addition, the law on the control of micropollutants is tightened.
Economic	**High installation costs:** High installation costs for sewage sludge and digestate.
	Environmental pollution: Risks of environmental pollution from microplastics, pharmaceuticals and other substances.

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	Environmental risk: Possibility of environmental pollution due to improper storage, processing and use of secondary raw materials.
Social	**Society's unwillingness**: Society often shows reluctance towards products made from waste.
	Unpleasant odour: The unpleasant odour discourages consumers from buying and using waste fertilisers.
	Lack of standardisation and quality control: The production and distribution of biofertilisers may face challenges related to quality control and standardisation. Ensuring consistent quality and efficacy of biofertilisers is essential to gain trust from farmers and promote their wider adoption. Any lapses in quality control can undermine the credibility and hinder the growth of the biofertiliser industry.
	Threat of greenwashing: The appearance of false information about other technologies that are considered greener and cheaper than sewage sludge, digestate and animal manure treatment methods.
Technical	**Unstable composition:** The difficulty of maintaining a stable composition of fertilisers derived from sewage sludge, digestate and animal manure.
	Necessity of quality control: Products made from sewage sludge, digestate and animal manure must undergo quality control.
	Storage difficulty: There is difficulty in storing products made from waste.
	Raw material availability: Sewage sludge cannot be transported between voivodeships. Additionally, production must be located close to the place of generation.
	Competing technologies and products: Fertilisers from waste face competition from other agricultural technologies and products, including synthetic fertilisers, precision farming techniques, and genetically modified crops. The availability and aggressive marketing of these alternatives may pose challenges to the widespread adoption of biofertilisers.

6.5.2. Drivers of alternative fertilisers production and usage in Poland

Table 93. PEST analysis: drivers to alternative fertilisers production and usage from bio- sewage sludge, animal manure and digestate as secondary raw materials in South-East Poland

Political	**Legislative standpoint:** From a legislative standpoint, the application of fertilisers derived from sewage animal manure is straightforward in Poland, unlike digestate and sewage sludge, where the procedures are complicated.
	Recommendations at the level of the European Union: Recommendations at European Union level on the use of fertilisers from waste.
	Legal regulations: Legal regulations at the national and European level regarding fertilisers from waste.
Econo mic	**Price:** The price of fertilisers from secondary sources such as sewage sludge, animal manure and digestate in Poland is relatively low. The most expensive is fertiliser made from animal manure, followed by digestate and sewage sludge.

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	Low processing costs: Processing costs are low for manure as opposed to sewage sludge and digestate.
	Soil health improvement: Fertilisers from sewage sludge, digestate and animal manure enrich the soil by enhancing its nutrient content and improving microbial activity. They contain beneficial microorganisms, increase nutrient availability, and enhance soil structure.
	Resource self-sufficiency (local production): The possibility of producing fertilisers from waste at their place of generation.
	Soil hydrological improvement: Reducing the adverse effects of drought.
	Stable, precisely planned production stream: The amount of biomass produced in a treatment plant, fermentation plant or farm is easy to plan.
	Market gap: Market gap regarding the rising price of mineral fertilisers.
	Decreasing availability of critical raw materials: Biogenic nutrients, including phosphorus, are on the list of European critical raw materials, but also key critical raw materials for Poland.
	Growing market for secondary raw materials: Increasing use of secondary raw materials.
	Implementation installations: Financial support for implementation installations.
Social	**Ecological image of fertilisers:** Society is increasingly paying attention to the ecological aspects of fertilisers. Fertilisers made from sewage sludge, digestate and animal manure are part of the idea of ecological products.
	Demand for ecological products: Growing demand for ecological products by consumers.
	Environmental awareness: Increasing ecological awareness among Polish society.
	Circular waste management: Possibility to reduce waste generation and the opportunity to implement circular economy solutions in practice.
Technical	**Availability on the market:** In Poland, sewage sludge, digestate and animal manure are available in the market. Poland has a well-developed wastewater treatment sector, which translates into the availability of sewage sludge. Animal manure is commonly used in agriculture in Poland, particularly in cereal crops and animal husbandry. Digestate, is also available in Poland, but on a smaller scale.
	Ease of application: The application of fertilisers derived from sewage sludge, digestate and animal manure is relatively easy in Poland and does not require advanced technology.
	Application security: The application of fertilisers derived from sewage sludge, digestate and animal manure is safe because regulated by law.
	Development of technologies/innovation: Due to the prohibition of sludge storage, technologies for the production of fertilisers are being intensively developed.
	Research and Development: Continued investment in research and development can lead to the development of more effective and specialised fertilisers based on waste tailored to the specific needs of Polish soils and crops.

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6.6. Spain – Andalusia

6.6.1. Barriers to alternative fertilisers production and usage in Andalusia, Spain

Table 94. PEST analysis: barriers to alternative fertilisers production and usage from wastewater and sewage sludge as secondary raw materials in Andalusia, Spain

Political	**Public institutions**: Slowness in licensing by the public administration.
	Cooperation agreements: Disagreements between different implied parties (farmers, producers, distributors, etc.).
Economic	**Energy consumption**: High energy consumption to deliver the water resource.
	High costs: High price of the final water resource (to the farmer). The cost of "classic" water resources is still very cheap, and the treatment cost can be relatively high.
	Competitiveness: High competitiveness for the water source with other users (industry, households, etc.). The industry, for example, needs water during the whole year, and at the same time has more capital for investments and less risks for food security or environmental contamination.
	Legal framework: t might imply extra treatment costs, thus a higher cost per unit of supplied water.
Social	**Traditional farmers reluctance**: Traditional farmers may resist the use of these alternative fertilisers because the fertilisers they currently used show optimal results.
	Farmers training: The farmers need to learn how to properly manage this resource to solve potential problems, like the appearance of incompatibilities between the fertilising plan and the reclaimed water composition.
	Ecology: The use of reclaimed water reduces the water discharge in water bodies.
	Risks of contamination: Heavy metals, nanoparticles, plastics,...
	Social consciousness: Social reluctance due to lack of awareness, information, training..
	Smart agriculture practices: Digital technologies implementation may be difficult for some traditional farmers.
.Technical	**Discontinuous amount of nutrient**: Depending on the wastewater treatment process applied and the raw wastewater used (it may be not only urban wastewater), the reclaimed water obtained can contain a higher or lower amount of nutrients.
	Infrastructure development: The establishment of new infrastructures takes time and constitute an expenditure the farmers may not be willing to make.
	Variations of crops' nutritional requirements: Nutritional requirements of the crops vary over the cropping period, depending on the phenological stage; reclaimed water shall be used in combination with other water sources in order to balance their requirements.
	Discontinuous water demand: Discontinuous demand from agriculture (especially during period of droughts, when other sources are not available).

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	Reclaimed water distribution: Bad availability of water resources to the farms, as there is not a distribution net available for water reuse (and the cost of distribution network is expensive), and road transport is not optimal.
	Water buffering: Need of infrastructures to buffer water for its further distribution.
	Soil health: Lack of evidence of how the use of reclaimed water (nutrient rich) could affect the soil health.
	Technological (in)efficiency: Uncertainty about the effective treatment for emerging risk nanoparticles, antibiotics, etc.

6.6.2. Drivers to alternative fertiliser production and usage in Andalusia, Spain

Table 95. PEST analysis: drivers to alternative fertilisers production and usage from bio- wastewater and sewage sludge as secondary raw materials in Andalusia, Spain

Political	**Carbon footprint**: Alternative fertilisers use contribute to decrease the carbon footprint in comparison to the inorganic fertilisers supply chain (can be applied directly onsite (zero-kilometre application), for example).
	Water footprint and climate change adaptation: Reclaimed water reduces the pressure on conventional water streams.
	Legislation: Regulation on reuse of water for irrigation (EU/Andalusian level).
	Circular Economy: Transition from linear to circular economy is a priority supported by the European Commission and the national government.
	Water and mineral fertilisers scarcity: Drought and mineral fertilisers supply are crucial points to face agriculture in the next years.
	Drought occurrence: Increased drought occurrence affects the urgency for alternative water sources.
	Inventory of local / regional water needs: Inventory would help to have a precise view on the local and regional water needs and supplies.
	Political willingness: Willingness of the local and regional governments to look for solutions to cope with water scarcity and implement them.
Economical	**Benefit for farmers:** Depending on the source of wastewater and type of treatment, a farmer can save 10 – 30% of N and P, and in some occasions higher amounts of K, as this nutrient is almost not removed in the treatment process (not dangerous to environment).
	New fertiliser products market: The alternative fertilisers developed will be incorporated to the market, constituting a new option in the sustainable economy context.
	Water sovereignty: Optimal use of agricultural land, with no need of on-farm buffering (compared to water basins for rainwater).
	Resources optimisation: There is a need to decrease the use of fertilisers because of the costs for the farmers and pollution problems they cause.

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	Business model development: Great efforts in research concerning cost-effective implementation (technologies, distribution, etc.) of reclaimed water possibilities.
	Market demand: The demand of the agricultural sector for the use of reclaimed water can lead to economies of scale.
Social	**Countryside depopulation tackling**: Water treatment and nutrient recovery may encourage countryside population to stay within drought areas.
	Effluents protection and water quality enhancement: The recovery of nutrients will protect water bodies from nitrate contamination.
	Quality perception: According to the current legislation, no extra treatment for reclaimed water is needed to be used for irrigation.
	Legislation: Farmers show interest in making use of this water source, as water scarcity is one of the most relevant problems in the region (positive attitude of farmers).
	Non-conventional water source perception: A lot of scientific work has been done in the past decades on the subject; regulations set a framework to increase the safety perception of this resource.
	Positive public opinion: Positive attitude of consumers.
Technical	**Knowledge / technology**: The knowledge and technology for further treatment of reclaimed water is available.
	Easy and controlled irrigation and fertilisation plan.: Reclaimed water together with alternative fertilising products may be applied on crops by means of a precise and controlled delivery.
	Continuous water flow: Even in periods of droughts, a predictable baseline amount of reclaimed water will be always available, as the wastewater source is urban wastewater
	Smart agriculture: Digitalisation is key for the European Commission, that appoints water and agriculture as the sectors on which efforts must be focused in terms of digital transformation.

6.7. Spain – Catalonia

6.7.1. Barriers to alternative fertilisers production and usage in Catalonia, Spain

Table 96. PEST analysis: barriers to alternative fertilisers production and usage from animal manure as secondary raw material in Catalonia, Spain

Political	**Legal restriction**: Lack of appropriate legislation on national or regional level. Lack of technical standards.
	Unclear definitions: In terms of organic waste streams used for recovering BBFs, the current regulation uses too broad definitions that are not always clear and some of the most commonly used materials are not adequately considered.

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	Non-compatibility of certification schemes across the EU: Differences and (trading obstacle).
	Regulatory challenges: EU standards and regulations make it difficult for producers to sell BBFs in different countries.
Economic	**High logistics costs**: High investment in technology implementation; Application of BBFs brings numerous technological challenges, uncertainties on quality control or higher logistic costs**.**
	Standard pricing: There is a clear need on establishing standard and agreed methodologies for pricing BBFs.
	Lack of real business cases: There is a lack of real business cases on nutrient recovery and marketability of BBFs. New business models should be promoted, including a real cross-linking with other relevant sectors.
	Technical training: Is needed an initial investment to train the farmers to produce and apply the products and to learn about their nutrient availability and content.
	Environmental risk/pollution: Harmful organic substances could transfer to the food chain. Heavy metals, Antibiotic and microplastic residues, pathogen exposure, salt accumulation; and their possible transfer into the food chain or increased antibiotic resistance in agricultural soils.
Social	**Common misconceptions about biobased fertilisers derived from manure**: Common misconceptions that organic fertilisers have slow nutrients release effect, have higher cost or cause storage/odour problems. Limited public awareness and understanding of the benefits of alternative fertilisers
	No consensual nomenclature: There is no consensual nomenclature and definition for bio-based fertilisers. Defining terminology is currently considering the origin of the organic waste, but it does not recognise the level of refinement that will distinguish different recovered products with distinct grades of processing (e.g., digestate vs struvite).
	Although information on the satisfactory operation of nutrient recycling technologies (either for consolidated or emerging technologies) exists, this information remains unknown primarily as it is not easily accessible.
	Disinterest of farmers and fertiliser industry: Not looking for new opportunities. The farmers need don't want to learn how to manage a new resource.
	Harmonisation/standardisation (quality control and consistency): Fill in the knowledge gaps related to the most appropriate analytical methodologies to characterise bio-based fertilisers in different types of matrixes and soils. Consensus is needed in this regard to make quality parameters of BBFs comparable to allow benchmarking. Likewise, developing an appropriate analytical methodology for emerging pollutants such as microplastics, pesticides or pharmaceuticals, and veterinary products is still missing, as well as establishing appropriate sampling and monitoring methodologies for gaseous emissions during the application of BBFs.
	Lack of successful cases: Lack of public knowledge and comprehension of the benefits of alternative fertilisers could lead to resistance in adopting these products. They need

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	Unpleasant odour and appearance: The unpleasant odour and texture discourage consumers from buying and using waste fertilisers.
Technical	**Variability**: The nutrient availability varies depending on factors such as the source, processing methods, and seasonal variations.
	Lack of LCA analyses: There are methodological gaps in how to integrate the application stage of BBFs in LCA. Lack of knowledge in social aspects of BBFs and nutrient recovery technologies as well as a low spreading degree of the Social-LCA methodologies.
	Agronomic tests performed under variable weather conditions/soil types: Lack of conclusions of BBF efficiency due to agronomic tests performed under variable weather conditions/soil types. There is a lack of proper guides to harmonise the assessment of BBFs in the field. Lack of long-term field trials to test BBFs.
	Scaling up: There are critical constraints limiting the scaling up of technologies that need to be addressed, mainly related to mass- and cost-effectiveness of the technologies assessed.
	Scattered information on nutrient flows from secondary sources in Europe: Incomplete, non-comparable
	Compatibility and machinery: Machinery issues related to some products spreading in the field uniformly.
	Technological (in)efficiency: There is still room for improvement in the performance efficiency of conventionally implemented nutrient recycling technologies.
	Storage and shorter shelf-life: Can be difficult to store and may have much shorter shelf-life.

6.7.2. Drivers to alternative fertiliser production and usage in Catalonia, Spain

Table 97. PEST analysis: drivers to alternative fertilisers production and usage from animal manure as secondary raw material in Catalonia, Spain

Political	**Replacement of mineral fertilisers**: The use of recycled fertilisers contributes to a lower carbon footprint compared to the inorganic fertiliser supply chain.
	Circular Economy: Contributing to a circular economy model by transforming waste materials into valuable sources of nutrients.
	Meeting the Green Deal goal: Mineral fertiliser availability is one of the most pressing issues facing agriculture in the next years, and biobased fertilisers have the potential to replace/substitute mineral fertilisers and help to meet the goal of reducing the use of mineral fertilisers by 20% in 2030.
	Political willingness: Willingness of the local and regional governments to look for solutions to cope with water scarcity and implement them.
Economic	**Future market niche**: Demand is increasing. There is plenty of room for moving forward that will provide new market opportunities and will create new jobs.

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	More efficient fertilisation: using the biobased fertilisers as raw materials to produce tailor made fertilisers.
	New fertiliser products market: The alternative fertilisers developed will be incorporated to the market, constituting a new option in the sustainable economy context.
	Nutrient recycling: These fertilisers contribute to the recycling of nutrients from organic waste materials back into the soil, reducing the need for synthetic fertilisers. This helps to close nutrient. loops and promotes a more sustainable agricultural system.
	Business model development: Great efforts in research concerning cost-effective implementation (technologies, distribution, etc.)
	Wide spectrum of products: Major groups of liquid and solid end and by-products according to their chemical composition, content of plant nutrients,
Social	**Preserving soil health and biodiversity**: Increase crop yield while simultaneously improving soil health. Improve soil organic matter content. Increased organic matter enhances soil fertility, water-holding capacity, and overall soil health, leading to improved crop productivity.
	Solve waste disposal problems: Utilising animal manure, and digestate as fertilisers reduces the volume of organic waste that would otherwise require disposal in landfills or incineration. This helps to alleviate the burden on waste management infrastructure
	Support integrated farming: The integration between animal farming, crop production, and industrial waste could be implemented for optimisation of energy resources
	Positive public opinion: Positive attitude of consumers
Technical	**Knowledge / technology**: The knowledge and technology for further treatment is available
	Precision application technologies: Advanced technology, such as precision agricultural instruments and sensor-based systems, enable the farmers to apply fertiliser more precisely and in real time, based on soil and crop conditions.
	Feedstock availability and low or no cost of input streams: High availability, renewability and minor pollution (4 250 857 tonnes of livestock manure was processed in Flanders in 2021)
	Research and innovation: A lot of scientific work has been done in the past decades on the subject; regulations set a framework to increase the safety perception of this resource. Ongoing research may focus on improving processing methods, increasing nutritional content and availability, producing new products, and investigating innovative approaches for successfully using these resources in various agricultural systems.

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7. General conclusions for the 7 target regions

The SWOT and PEST analysis have been initial steps to define the regions situation regarding their associated waste streams use to produce alternative fertilisers.

There are similarities, and also differences, between the regions. One of the main attributes appearing independently from the region and the waste stream analysed is the regulatory framework, both as negative and positive aspect. This is due to the fact that current legislation may be restrictive, but at the same time new and upcoming policies, existing recommendations and political willingness constitute an opportunity to change this fact.

Another relevant transversal issue is the lack of information for consumers and information and/or training of farmers, what constitutes an important barrier, but this is also being confronted with increasing demand or ecological products and environmental awareness.

The need of high investment and/or maintenance costs (because of energy consumption, for example) is also a transversal concern, but at the same time the decreasing availability of critical raw materials is forcing the approach to these alternatives, as well as the existence of a market gap that can be filled with secondary raw materials.

The last relevant transversal topic is the need of improving the quality of alternative fertilisers and of storing options, what is being currently confronted with research and development to improve these aspects.

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