NUTRI•KNOW

Inventory of current farming practices on nutrient management

D1.2

June 2023

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Executive Summary

Deliverable 1.2 (D1.2) Inventory of current farming practices on nutrient management is part of the NUTRI-KNOW work package (WP) 1. The main objective of this WP is to identify, compile and analyse all the knowledge and outcomes generated by the engaged 12 EIP-AGRI OGs from 4 Member States (Spain, Italy, Belgium and Ireland) in the theme of nutrient management.

The D1.2 aims to collect information about the current farming practices, broader than the screening of practices beyond the 12 engaged OGs, based on other EIP-AGRI OGs and EU projects which already put in practice their primary outcomes. This information will serve for Task 1.3 (Cost-benefit and sustainability analysis) and 1.4 (Summary meta-database) of WP1 and other WPs. The compilation will be made from public information on EIP-AGRI OGs and project databases, research websites, and complementary information from the partners involved in the different OGs.

The D1.2 is divided into 6 chapters: Introduction, Objectives, Methodology, Results, Current farming practices and Conclusions.

Disclaimer

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Table of Abbreviation

BAT	Best available technology
EEC	European Economic Community
EU	European Union
GHG	Green House Gasses
N	Nitrogen
NDN	Nitrification-Denitrification
$N\text{-}NH_4^+$	Ammoniacal Nitrogen
OG	Operational Groups
P	Phosphorous
PLF	Precision Livestock Farming
PLF	precision livestock farming

1. Introduction

Over the past few years, numerous research projects funded by the European Union (EU) have made significant strides in developing knowledge and strategies for nutrient management in agriculture. These projects have aimed to test, develop, and introduce new and improved practices, as well as identify best practices for practitioners to adopt in the primary sector. However, despite the continuous flow of knowledge and the efforts made by these projects, the uptake and implementation of these managing choices by practitioners have not met the anticipated level of adoption.

NUTRI-KNOW project aims to broaden EIP-AGRI Operational Groups (OG) outcomes across borders, to modernise and dynamise the agri-food sector by collecting, translating, and sharing easy-to-understand and practice-oriented knowledge. NUTRI-KNOW wants to assure the appropriate adoption of innovative solutions on nutrient management best practices by farmers, practitioners, and other relevant end-users. In this sense, NUTRI-KNOW is focused on **Nutrient Management** and considers 6 main steps of the Nutrient Management value chain: livestock farming, storage systems, fertiliser production, processing technologies, transport, and application. To this end, 12 OGs have been selected to ensure that all the steps of the value chain are efficiently covered.

Work Package 1 has the main objective to identify, compile and analyse all the knowledge and outcomes generated by the engaged 12 EIP-AGRI OGs from 4 EU Member States (Spain, Italy, Belgium, and Ireland) in the theme of nutrient management. Building upon the findings of Task 1.1 (as descripted in deliverable 1.1 Inventory and analyses of selected OGs), Task 1.2 delves deeper into the current farming practices and challenges related to nutrient management activities across various stages of the agricultural value chain, i.e., livestock farming, storage systems, fertiliser production, processing technologies, transport, and application. This inventory will lead to the deliverable 1.2 (D1.2), with an aim to gain a comprehensive understanding of the existing practices and identify the obstacles and bottlenecks that hinder the widespread adoption of improved nutrient management practices.

Therefore, this deliverable aims to broaden the knowledge about the current farming practices in the 4 Member States **beyond** the outcomes of the 12 selected OGs, by screening into other EIP-AGRI OG and EU projects which already put into practice their primary outcomes to showcase their good performance. Information about challenges at each value chain step will also be collected from involved partners and compared between the 4 Member states. This holistic approach will contribute to a more thorough and practical understanding of state-of-the-art that align with the specific needs and challenges of different stakeholders along the value chain. Results of the deliverable will support the follow-up tasks to develop targeted strategies and recommendations to overcome these barriers, and foster knowledge exchange of innovative practices among practitioners.

2. Objectives

The objective of this deliverable is to collect information on nutrient management, to identify the current farming practice and challenges on nutrient management activities for different steps of the value chain and make an inventory of these current farming practices. This information will be broadened with other EIP-AGRI OGs and EU projects that have successfully implemented their primary outcomes, highlighting their exemplary performance.

3. Methodology

To determine the prevailing nutrient management practices in the 4 involved EU Member states, an extensive information search was conducted. This search involved not only the NUTRI-KNOW partners directly engaged in the execution of the 12 studied OGs, but also sought their active participation in gathering knowledge on the current situation in each country. Additionally, a comprehensive review of literature was undertaken to include insights from other OGs and European projects, providing a more comprehensive understanding of current practices, the challenges they present, and the various approaches adopted by different countries to tackle these challenges. Figure 1 illustrates the implementation of this methodology.

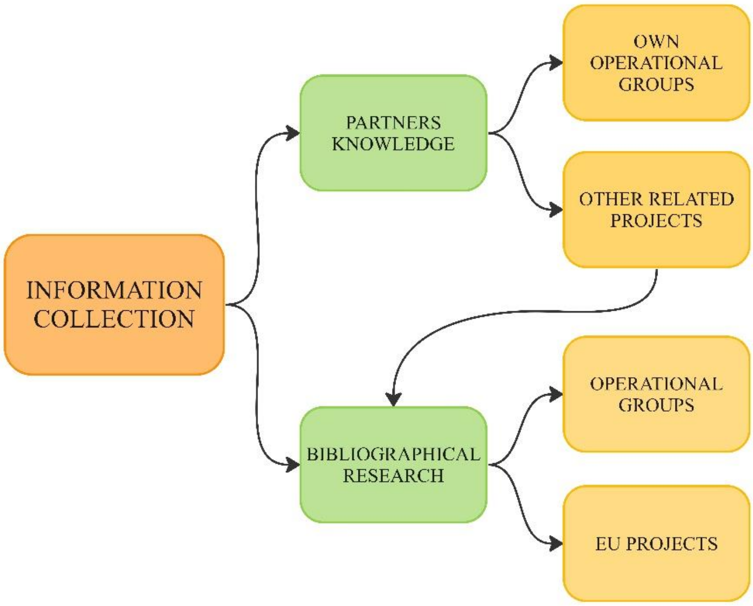

Figure 1. Methodology used for the data collection in D1.2

3.1. Knowledge beyond NUTRI-KNOW's 12 engaged EIP-AGRI Operational Groups

To obtain information regarding current farming practices, specifically in nutrient management, a comprehensive literature review was performed, with a particular focus on the innovations related to the 12 selected OGs within the NUTRI-KNOW project. The information obtained was then used to compile a list of keywords for each individual OG, as detailed in Table 1.

The keywords listed in Table 1 served as specific terms or phrases that represented key concepts or aspects related to nutrient management in farming practices. They were employed to refine the search process, identify relevant literature, and gather additional insights from other OGs and projects associated with nutrient management. Essentially, the keywords played a crucial role in guiding the exploration of related information and expanding the understanding of current practices in the field.

Table 1. List of keywords for each NUTRI-KNOW's engaged EIP-AGRI Operational Group

	Operational Group	Keywords
1	Development of a slurry concentrator with continuous total nitrogen data collection	Fertilisation and nutrients management Livestock manure Slurry concentrator Manure transportation
2	Development of tools to optimise coordinated manure management and to improve soil fertilisation, crop quality and environmental protection	Fertilisation and nutrients management Livestock manure management Soil analysis Organic fertiliser Digital fertilisation tools Emission reduction in slurry storage
3	FERTICOOP-GO - Innovations to adapt to the best available techniques (BAT) in the Catalan cooperative agricultural sector	Fertilisation and manure management Best available techniques (BAT) Greenhouse Gas (GHG) and ammonia emissions reduction (spreading phase) Phosphorus reduction Manure valorisation Appling fertilisation methods
4	Livestock manure and digestates treatment to reduce emissions and produce Struvite	Digestates treatment Greenhouse Gas (GHG) and ammonia reduction (storage and spreading phase) Farming equipment and machinery Organic fertilisers Livestock manure treatment Struvite Slow-release renewable recovery fertiliser
5	SOS-AQUAE - Sustainable farming techniques and renewable fertilisers to combine agriculture, water and environment	Farming equipment and machinery Fertilisation and nutrients management Renewable fertilisers Reduce of pollution Water quality Livestock effluents and digestates treatment
6	Gas Loop - Emissions capture for a virtuous nitrogen cycle in pig livestock	Fertilising solutions Nitrogen virtuous cycle (Loop) in pig farming Ammonia and GHG emissions reduction

		Ammonia Washing Machine Circular economy
7	RENURE - REcovered Nitrogen from manURE	RENURE - REcoverd Nitrogen from manure Ammonium salts Liquid fraction of manure or digestate Fertilisation and nutrients management Stripping-scrubbing
8	POCKETBOER 2 - More performant operation of pocket digesters	Pocket digesters and biogas Farm scale anaerobic digesters Energy management Knowledge exchange
9	Grass2Algae - From grass juices to the cultivation of microalgae	Grass juices and grass valorisation Microalgae cultivation and animal feed use Fiber fraction as composting Circular economy
10	Biorefinery Glas - Small-scale Farmer-led Green Biorefineries	Small-scale mobile grass biorefinery Grass valorisation (as animal feed and fertiliser) Farm-to-farm bioeconomy Climate and climate change Farming/forestry competitiveness and diversification Bioeconomy Circular economy Carbon footprint
11	MOPS - Maximizing Organic Production Systems Through integrated cropping systems	Organic horticulture production Soil and plant analysis Organic cropping programmes Green manures Effective use of approved organic materials and organic fertilisers Reduce reliance on imported nutrients Biodiversity and nature management

12	Duncannon Blue Flag Farming & Communities Scheme	Bacterial quality of streams Duncannon beach Reduction of agricultural and domestic pollution Sustainable management of catchments Water environment and biodiversity Leaching

The predominant themes that emerged from the keywords revolve around fertilization and nutrients management, livestock manure utilization, soil analysis, organic fertilizers, emission reduction, farming equipment and machinery, circular economy principles, and water quality. These themes reflect the project's commitment to sustainable farming practices, optimizing nutrient utilization, reducing emissions, and promoting a circular economy approach. By integrating these key concepts, the NUTRI-KNOW project aims to enhance nutrient management strategies and improve the overall sustainability of farming practices.

Based on the identified keywords and the data collected from our partners, a comprehensive search was conducted for projects related to nutrient management and animal husbandry. The specific focus was on projects that had already yielded tangible results and demonstrated impacts on the agricultural sector. The resultant projects have been compiled and presented in Table 2.

Table 2. List of projects related to nutrient and animal husbandry management

Country	Title of project	Link
Spain	Treatment of slurries by fixation of ammoniacal nitrogen (N-NH_4^+) using magnesium by-products	https://grupsoperatius.cat/fitxes/2016_2_2.pdf
	Treatment and management of excrement in nitrogen surplus areas: adaptation of the treatment to the surplus to be managed and agronomic valorisation of the resulting liquid effluents	https://grupsoperatius.cat/fitxes/2016_2_45.pdf
	Valorisation of waste and material recovery of cattle excrement	https://grupsoperatius.cat/fitxes/2017_2_13.pdf
	Demonstration of the efficiency of a nutrient concentrator	https://betatechcenter.com/projects/demonstration-of-the-efficiency-of-a-nutrient-concentrator/
	FERTIMANURE: is a project dedicated to the innovative nutrient recovery from secondary sources for the production of high-added value FERTIlisers from animal MANURE.	https://www.fertimanure.eu/en/

Italy	Circular Agronomics_Circular solutions for carbon and nutrient management	https://www.circularagronomics.eu/case-studies/
	Biogas_N_Management systems and valorisation of nitrogenous fractions in digestates: evaluation of technologies and nitrogen balance	https://www.crpa.it/nqcontent.cfm?a_id=16401
	BATtAIA_Nitrogen balance self-monitoring tools for BAT application in pig farming	http://battaia.crpa.it/nqcontent.cfm?a_id=16491
	Less_Low EmiSSion farming	https://www.fondazionecrpa.it/prodotto/less/
Belgium	DemoProject Boost pocket digestion and post-processing	https://www.biogas-e.be/index.php/node/1242
	Nitroman: extracting nitrogen from surplus manure in the Flemish-Dutch border region	https://www.vcm-mestverwerking.be/nl/kenniscentrum/20262/nitroman
	Grassification: valorisation of roadside grass clippings as a renewable resource to produce biobased products	https://www.biorefine.eu/projects/grassification/
	Pocket power: Increasing the potential of anaerobic digestion at farm scale	https://www.biorefine.eu/projects/pocket-power/ ; https://www.nutri2cycle.eu/lighthouse/farm-scale-anaerobic-digestion-of-agro-residues-pig-manure-to-increase-local-nutrient-cycling-improve-nutrient-use-efficiency-inagro-ghent-university/
Ireland	CRiBZ – Culdaff Riparian Buffer Zone Scheme	https://ec.europa.eu/eip/agriculture/en/find-connect/projects/culdaff-riparian-buffer-zone-cribz-scheme.html
	National Farm Survey of Manure Application and Storage Practices on Irish Farms	https://www.teagasc.ie/media/website/publications/2011/TeagascNationalFarmSurveyOfManureApplication.pdf

	Farm-Gate Nitrogen Balances on Intensive Dairy Farms in the Southwest of Ireland	https://www.jstor.org/stable/25564584
	ReMIX_ Redesignin european cropping systems based on species MIXtures	https://www.remix-intercrops.eu/

Table 2 exhibits the projects that have been undergone in a more extensive analysis within this task, although there exist additional projects that are highly innovative, they are less aligned with prevailing farming practices. Nevertheless, it is beneficial to acknowledge and compile information about these projects as they contribute to the understanding and documentation of contemporary farming practices.

Through this bibliographic search, it becomes apparent that various EU countries face challenges when it comes to acquiring organic fertilizers for soil nutrition. Livestock manure emerges as a highly nutritious form of organic fertilizer that has been utilized for many years to nourish agricultural fields. Nevertheless, the application of manure and mineral fertilizers has been restricted to prevent soil and water contamination caused by leaching. Moreover, the expansion and consolidation of farms, driven by factors like population growth, farm profitability, and specialization, have exacerbated the ongoing struggle of managing livestock manure. Consequently, numerous countries are actively endeavouring to enhance practices and technologies in soil nutrition management. Their objectives include developing organic fertilizer production methods, implementing livestock manure recovery systems, and promoting the advancement of circular bioeconomy principles.

As a result, numerous initiatives have been undertaken to address the different challenges related to increase the nutrients in soil. These endeavours encompass the extraction of essential nutrients such as nitrogen, phosphorus, and potassium from diverse by-products, the establishment of pilot biorefinery plants, exploration of biogas as a potential resource, implementation of treatments to enhance waste quality, and the development of technologies aimed at identifying organic fertilizers like grass whey. Furthermore, recommendations have been formulated to improve agricultural practices, boost the efficiency of fertilizers and crop production, and tackle related challenges.

By examining these projects and their objectives, it can be seen that the current different scenarios of various countries and the strategies they employ to confront the diverse obstacles associated with soil enrichment.

3.2. Data collection from partners

In addition to the information collected through EIP-AGRI OGs and EU Projects, partners actively involved in the 12 committed NUTRI-KNOW OG provided complementary information. To gather this data, a straightforward database was established, encompassing the "state-of-the-art" information, including key problems identified by the OGs, current practices relevant to the respective OGs, and pertinent references. Furthermore, the primary challenges encountered at each step of the value chain were also incorporated into the database. Figure 2 illustrates the methodology employed to collect data from our partners, showcasing the process involved.

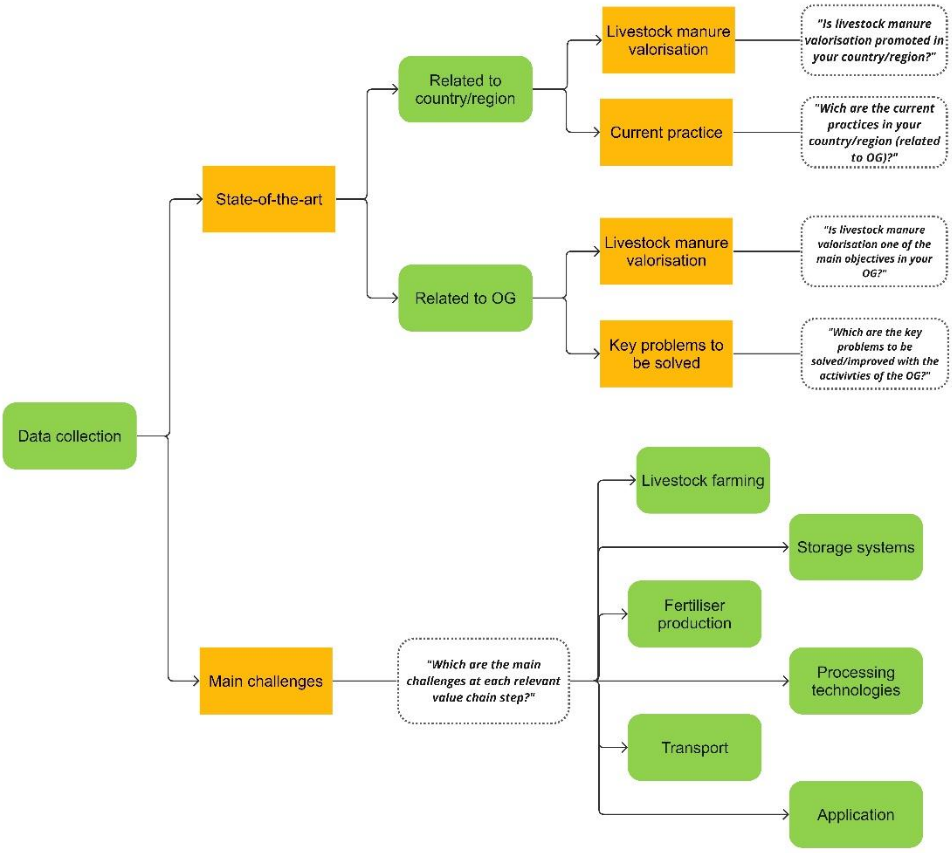

Figure 2. Methodology of data collection from partners

By collating the knowledge and expertise of NUTRI-KNOW partners regarding agricultural practices in their respective countries, it allowed to compare and contrast this information with the findings obtained through bibliographic research. The comprehensive presentation of this combined knowledge can be found in sections 3.2.1 and 3.2.2. On the one hand, Section 3.2.1, titled "State-of-the-art," provides an overview of partners' insights into the problems associated with livestock manure valorization in each OG and country/region, highlighting the significance of addressing manure management. On the other hand, Section 3.2.2, "Value chain steps," focuses on the challenges encountered at various stages of the value chain, acknowledging that these challenges are as crucial to the current practices as the problems faced by each country.

3.2.1. State-of-the-art

The partners' input regarding the "state-of-the-art" primarily turns around the challenges encountered by each of the selected OGs, country, or region and their link to the valorisation of livestock manure.

During the data collection process involving partners (as depicted in Figure 2), a series of questions were posed. In response to the query, *"Has there been an increase in the valorisation of livestock manure in your country/region?"* all partners responded affirmatively, thereby corroborating the findings obtained through the literature review. This substantiates the fact that livestock manure management presents a significant challenge in numerous EU countries, prompting concerted efforts to convert it into a high-quality by-product that effectively nourishes the soil with essential nutrients[1]. However, it is important to note that not all OGs examined in this project prioritize manure valorisation; only half of them actively pursue research and initiatives in this domain.

It is apparent that while the valorisation of livestock manure is vital for preventing soil and water pollution, it is not the sole focus within the realm of nutrition management. Different regions present varying scenarios: some face the challenge of excessive manure quantities surpassing the capacity of the crop area, while others encounter the opposite predicament, necessitating the search for organic fertilizers to enhance soil nutrition. Consequently, to gain insights into the distinct challenges encountered by the 12 analysed OGs, the following question was posed to NUTRI-KNOW partners: "What are the key problems that need to be addressed or improved in the implementation of your OG?" Figure 3 showcases the identified key problems that require resolution or enhancement within each region/country.

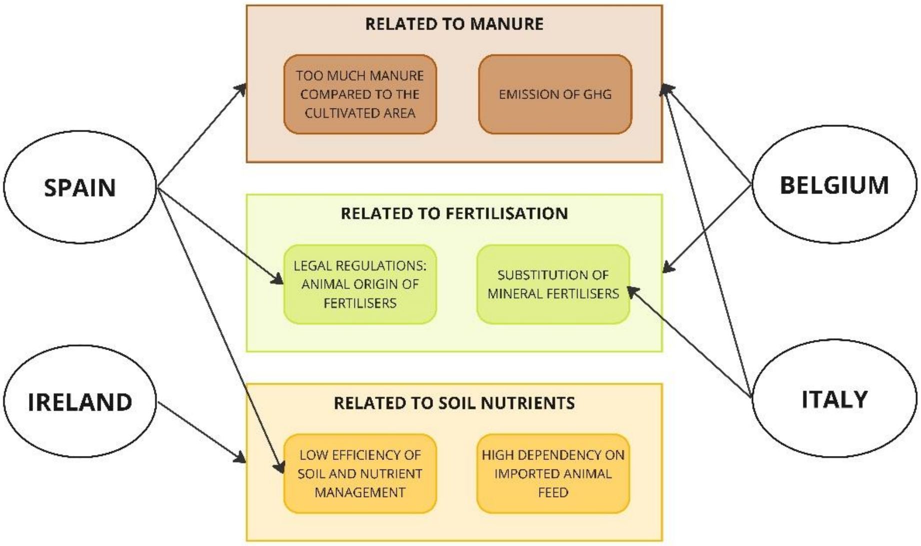

Figure 3. Key problems that need to be solved or improved in each region/country.

Chapter 4 elucidates the outcomes derived from the state-of-the-art analysis and provides a comprehensive exploration of the identified key problems. Specifically, it focuses on the key problems faced by the 4 member states (Spain, Italy, Belgium, and Ireland) in relation to livestock farming, storage systems, fertilizer production, processing technologies, transport, and application. The chapter highlights common challenges shared by these countries, including excessive manure production, limited availability of organic material, GHG emissions during manure management, the need to replace mineral fertilizers with organic alternatives, low soil fertility, and legislation issues. The results emphasize the importance of improving manure management, promoting sustainable practices, adapting technologies, reducing emissions, and addressing legislative barriers to minimize environmental impact and enhance the efficiency of nutrient application throughout the value chain.

[1] European Commission. (2020). Future of EU livestock: how to contribute to a sustainable agricultural sector. Retrieved from [https://op.europa.eu/en/publication-detail/-/publication/04af47b0-0c38-11eb-bc07-01aa75ed71a1/language-en]

3.2.2. Value chain steps

The challenges experienced by each country are crucial aspects of their current agricultural practices, just as the obstacles encountered at each stage of the value chain hold significance. In order to gather insights into these challenges, the NUTRI-KNOW partners were consulted, seeking their input regarding the main hurdles observed at each relevant step of the value chain. This consultation involved the collection of data through a questionnaire that asked partners to identify the primary challenges.

According to the insights gathered from the NUTRI-KNOW project partners, a range of challenges has been identified across different stages of the value chain in the different 12 OGs. The partners have highlighted key obstacles encountered in livestock farming, storage systems, fertilizer production, processing technologies, transport, and application, shedding light on the complexities faced by the agricultural sector.

Livestock farming poses challenges related to mitigating GHG emissions, preventing soil and water contamination, and addressing issues of odours. Managing livestock manure and dealing with limited nutrient concentrations in soils have also been identified as significant difficulties.

Regarding to storages systems, the NUTRI-KNOW partners expressed concerns about staying compliant with changing regulations and farmers' hesitancy to invest in structures that may become outdated. Poor stability of slurry, limited accessibility to technologies, and water content in storage systems have been recognized as additional challenges.

Fertiliser production faces hurdles such as limited technology access, slurry instability, and transportation issues. Proposed solutions include complying with regulations, encouraging the use of recovered fertilizers, and refining raw materials. Enhancing liquid fractions, relaxing regulations, and promoting sustainability are important considerations. Addressing grass juice properties, soil acidification, and on-farm composting requirements are also crucial.

Processing technologies for fertiliser production encounter challenges such as rudimentary systems, limited availability, and high prices. Farmers require assurance of technology availability and functionality before investing. Treatment technologies for digestate and slurry face obstacles such as high costs, reliability issues, and the need for tailored solutions. Investment, research funding, and policy coherence are needed for infrastructure development and advancing biorefinery processes.

In terms of transport, challenges include reducing slurry transport costs and minimizing associated emissions. Solutions like digestate stripping and microfiltered digestate offer more convenient and efficient transport by reducing water content and focusing on nutrient-rich components. Considerations include corrosion risks, cross-border transport costs, and ammonia emissions.

Finally, the application of fertilisers and manure-derived materials presents its own set of challenges. The project partners have emphasized the need to develop criteria for ensuring that manure-derived materials meet fertiliser standards. Furthermore, the lack of machinery for in-season application has been identified as a limitation. The partners are actively exploring ways to reduce ammonia emissions, promote non-tillage agricultural systems, and minimize soil compaction during application.

In summary, the insights provided by the NUTRI-KNOW project partners shed light on the common challenges faced in the agricultural sector. These challenges encompass reducing environmental impacts, complying with regulations, improving technologies and accessibility, and promoting the use of recovered fertilisers.

4. Results

4.1. The state-of-the-art

The methodology for collecting information from partners has been explained in the Section 3.2.1. In this section, the information obtained will be presented. Figure 3 displays the key problems of the four NUTRI-KNOW member states, which have been summarized into three different categories:

a) Manure

a.1) High amounts of manure for the arable area where this manure could be applied to as a fertiliser.
a.2) In certain areas, access to organic material, including manure and other organic waste is fragmented due to the concentration and specialisation of farms.
a.3) Needs to reduce GHG emissions during manure management and storage.

b) Fertilization

b.1) Current regulation limited the use of manure as organic fertiliser.
b.2) Needs to replace mineral/inorganic fertilisers with organic fertilisers.

c) Soil health

c.1) Low level of soil management and soil fertility, as well as a renewed emphasis on improving soil structure and biological activity, making a necessary crop rotation plan for better efficiency of nutrient application.
c.2) Imports of cattle feed, which makes necessary improve the nutrition of crops, in order to increase the number of crops and be able to decrease these imports.

Figure 3 also shows how different countries share common problems to be solved:

- **Spain:** (1) high amounts of manure are being produced in relation to the arable farmland where it can be applied; (2) low availability of tools for manure management; (3) high level of GHG emissions in storage systems; (4) a lot of bureaucracy that slows down the adaptation processes of farmers and hinders the emergence of new technologies and processes; (5) low quality of soil on phosphorus levels.
- **Italy:** (1) high amounts ofmanure are being produced, which leads to a need to manage it as a by-product; (2) areas with low level of nitrogen and phosphorus; (3) high level of GHG emissions in storage systems; (3) needs to replace mineral/inorganic fertilisers with organic fertilisers.
- **Belgium:** (1) low availability of tools and technologies for manure management; (2) lack of knowledge; (3) needs to replace mineral/inorganic fertilisers with organic fertilisers.
- **Ireland:** (1) needs to improve crops and increase the use of perennial and annual legumes to reduce dependency of cattle feed imports; (2) improve soil and nutrient management; (3) improve the management of manure and river discharges to improve water quality.

Arguably, current challenges can be addressed by enhancing manure management practices to reduce their environmental impact and capitalize on their potential as organic fertilizers, thereby improving soil management and nutrition. Additionally, it is essential to enact changes in existing legislation to classify manure as a by-product rather than waste, enabling its use as a valuable fertiliser. The aforementioned issues faced by farmers and producers are intricately linked to the practices they employ. These practices play a vital role in their daily operations and overall management strategies.

4.2. Challenges along the value chain steps

Livestock farming

Table 3. Main challenges at "livestock farming" step of value chain, by each country

Country	Main challenges at "livestock farming" step
Spain	1. Manure management 2. Pollution (odours, GHG emissions, nitrate leaching, etc.) 3. Legislation (too strict and not updated in relation to by-products, e.g., manure used as fertiliser)
Italy	1. Nutrients management: relocate the surplus manure to areas with low levels of N and P 2. Pollution (odours, GHG emissions, nitrate leaching, etc.) 3. Manure management 4. Increase the sustainability of biogas plants
Belgium	1. Manure management 2. Pollution (odours, GHG emissions, nitrate leaching, etc.) 3. Macro farms management (due to the high level of intensification in livestock farming) 4. Legislation (too strict and not actualized about by-products)
Ireland	1. Nutrient management planning 2. Livestock feed (dependency on imports) 3. Limited avaliability of manure and its appropriate use and management 4. Pollution of livestock manure to air and water

Table 3 depicts the primary challenges encountered by the four NUTRI-KNOW member states in the livestock farming phase, with pollution emerging as a prominent concern. This issue is intricately linked to the management of manure, which stands as the second most prevalent challenge. Presently, manure management poses difficulties in terms of GHG emissions, odours, nitrate leaching, and other related problems. These complications also have implications for soil management, such as excessive nutrient accumulation in certain soils and inadequate availability in others where livestock is absent. Consequently, the transportation and relocation of these nutrients become necessary.

Additionally, the countries face the challenge of modifying legislation to ease its stringency and reclassify manure as non-waste, thereby enabling its use as fertilizers after appropriate treatment. This dual-purpose resolution tackles the issues of manure disposal and the demand for organic fertilizers.

Furthermore, some of them confronts the task of enhancing the sustainability of biogas plants from social, environmental, and economic perspectives. This challenge is likely to arise in other countries in the future, as evidenced by the literature review highlighting the establishment of such biogas plants across various European Union member states.

Storage systems

Table 4. Main challenges at "storage systems" step of value chain, by each country

Country	Main challenges at "storage systems" step
Spain	1. Reduce the emissions of GHG, odours and ammonia 2. Legislation (in constant changes, what makes it difficult for farmers and producers to act accordingly)
Italy	1. Reduce the emissions of GHG, odours and ammonia 2. Need to introduce new storage systems (due to the use of recovered fertilisers) 3. Introduce BATs to produce less manure with less amount of N
Belgium	1. Reduce the emissions of ammonia increase the tolerance of containers to the corrosive ammonium sulphate solutions 2. Reduce the oudour
Ireland	1. Need to have large spaces including for the recycling and composting organic materials 2. Legislation (strict on the minimum storage requirements for livestock manures) that requires water quality standards to be meet 3. Need to storage dirty water apart from manure to avoid contamination

Table 4 highlights the prevalent challenge of reducing emissions, particularly GHG emissions, as well as addressing issues related to odours and ammonia emissions. The primary objective is to enhance air quality and storage systems.

Efforts are underway to implement the BATs to address the aforementioned challenge by reducing emissions and improving storage system management. Although the specific techniques employed by their counterparts are not explicitly mentioned, our literature research indicates that other countries are also implementing similar measures.

Lastly, the challenge of legislation arises, characterized by its stringent nature and frequent changes over time. This dynamic environment poses difficulties for farmers in making decisions aimed at improving their management practices.

Fertiliser production

Table 5. Main challenges at "fertiliser production" step of value chain, by each country

Country	Main challenges at "fertiliser production" step
Spain	1. Lack of knowledge on which technologies are available to produce fertilisers 2. Low availability of technologies 3. Low stability of manure for its transport to the production plants
Italy	1. Need to increase use of organic fertilisers and its production 2. Legislation (about origin of fertiliser: there are limitations by Nitrates Directives on the manure application rate that doesn't allow fertilisers coming from manure) 3. High standards of quality from EU

	4. Make farmers producers of fertilisers so they can increase their economic and environmental sustainability
Belgium	1. High standards of quality from EU for fertilising products 2. Make sure the sustainability of organic fertilisers 3. Improve tecnologies for manure processing
Ireland	1. Increase availability and acces to high quality organic fertilisers 2. Increase their quality in order to decrease soil acidification

In this step of the value chain, Table 5 shows there is more diversity in terms of challenges that each country faces. In general, it is noticed that there is a need to increase and adapt existing technologies in order to improve the processes of transforming manure into organic fertilisers.

Several countries also agree that the high-quality standards required for the production of fertilisers make these processes difficult. Thus, there is a low availability of organic fertilisers, forcing farmers and producers to use mineral fertilisers.

Finally, the need arises for these fertiliser productions to be more sustainable in three areas: social, economic and environmental. Therefore, some countries seek to encourage the farms themselves to produce fertilisers, with a strong focus on composting and the recycling of organic materials, solving different problems such as transport, availability, manure management, etc.

Processing technologies

Table 6. Main challenges at "processing technologies" step of value chain, by each country

Country	Main challenges at "processing technologies" step
Spain	1. Improve technologies: more availability, less production costs, low acquisition costs, better efficiency, etc.
Italy	1. Improve technologies: more availability, less production costs, low acquisition costs, better efficiency, etc. 2. Give a chance to those investigations who want to increase technologies but cannot afford the investigations or lack of infrastructure. 3. Enhance those pilots that are already working and seems to be sustainable
Belgium	1. Lack of technologies and knowledge 2. Legislation (short length of time to propose and execute changes, difficulties to obtain permissions, etc.) 3. Obtain by-products with enough level of nutrients to be efficient
Ireland	1. Lack of technologies and knowledge 2. Give a chance to those investigations who want to increase technologies but cannot afford the investigations or lack of infrastructure.

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Table 6 shows that, in contrast to the previous value chain stage, there are several shared viewpoints among countries. They unanimously acknowledge the absence of adequate technology and knowledge concerning various technologies. Consequently, it becomes imperative to incentivize governmental authorities to conduct further research, thereby providing farmers with additional options and opportunities.

Transport

Table 7. Main challenges at "transport" step of value chain, by each country

Country	Main challenges at "transport" step
Spain	1. Difficulty on the transport due to the characteristics of manure (high content of water) 2. High elevated costs of transport
Italy	1. High elevated costs of transport 2. GHG emissions during the transport
Belgium	1. High elevated costs of transport 2. Concerns in the GHG emissions 3. Risk of corrosion of the containers due to the corrosive nature of ammonium sulphate 4. Legislation (differences between each country that affects the importations and exportations) 5. Difficulty on the transport due to the characteristics of manure (high content of water)
Ireland	1. Long distances between specialist farms and/or processing and managment facilities

In Table 7 provides insights into the challenges associated with the transportation of manure and its derived products. One prominent obstacle is the high cost of transportation. This issue is exacerbated by the high-water content present in manure, necessitating the use of more suitable containers and increased truck capacity for efficient transport. Moreover, transportation contributes to GHG emissions, highlighting the imperative to reduce these emissions and improve overall sustainability.

In the context of Belgium, farmers face additional challenges related to legislation and the corrosive properties of manure-derived ammonium sulphate, such as its potential to cause damage to tanks.

Lastly, within the specific case of Ireland's Biorefinery Glas project, there is a need for immediate spreading of the grass whey produced as a fertilizer product. Consequently, on-site production with minimal or no transportation becomes essential.

Application

Table 8. Main challenges at "application" step of value chain, by each country

Country	Main challenges at "application" step
Spain	1. Legislation (limitation of 170 kg N/ha) 2. Characteristics of fertiliser (that makes specific techniques necessary to apply it)
Italy	1. Emissions of GHG, odours, ammonia, and nitrate leaching 2. Improve the fertigation technologies to make sure needed areas get fertilised 3. Promote agricultural system based on crop rotation
Belgium	1. Emissions of GHG, odours, ammonia, and nitrate leaching 2. Costs due to lack of available machinery for application given the characteristics
Ireland	1. Legislation (limitation of 170 kg N/ha) and 2. Understanding of nutrients moving on and off-farm 3. Widespread knowledge of relevant agri-ecological practices 4. Fresh grass whey needs to be spread immediately

Table 8 reveals that the four countries encounter similar challenges. Firstly, the existing EU legislation restricts the application of animal manure and its derived products to a maximum of 170 kg of nitrogen per hectare per year. This limitation compels farmers to explore alternative outlets for their generated manure. In the case of Ireland, organic agriculture must adhere to rigorous standards regarding fertilizer application. Moreover, challenges arise concerning the emissions of GHGs, odours, ammonium, and nitrate leaching caused by excessive nutrient accumulation in the soil.

Finally, some of the 4 countries face the necessity of identifying and adapting appropriate techniques and technologies to facilitate the application of fertilizers based on their specific physical characteristics, such as high-water content and the requirement for fresh application. These endeavours aim to minimize costs while ensuring effective fertilizer utilization.

5. Current farming practices

Through a comprehensive analysis of the data provided by NUTRI-KNOW partners and the information obtained from the bibliographic research, it can be compiled a comprehensive list of agricultural practices currently being implemented across various EU countries.

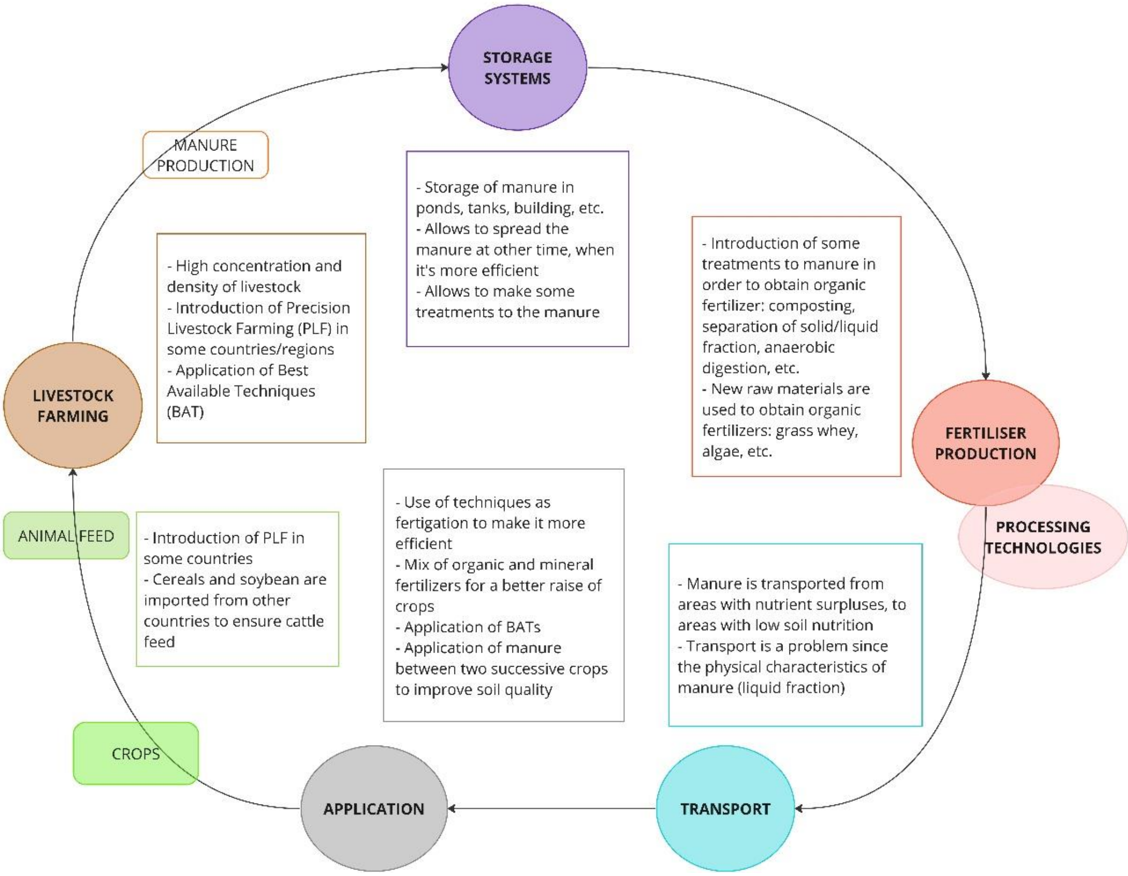

Figure 4. Current farming practices employed at each stage of the value chain.

Figure 4 illustrates a circular value chain wherein livestock consumes crops grown on the land, resulting in the production of livestock manure. This manure is subsequently stored, processed, and transformed through various processing technologies to obtain organic fertilizer. The fertilizer is then transported and applied to crops that can serve as animal feed, continuing the cycle.

However, the agricultural economy model is not entirely closed, leading to surpluses or inefficiencies. Consequently, there is a need to seek outlets for excess manure, explore alternative sources for organic fertilizer production, and even import food for livestock, among other measures. Building upon this model, it can be elucidated the current agricultural practices being implemented at each stage of the value chain within the EU[2].

[2] European Commission (2021). The post-2020 Common Agricultural Policy: environmental benefits and simplification. Retrieved from [https://agriculture.ec.europa.eu/system/files/2021-01/cap-post-2020-environ-benefits-simplification_en_0.pdf]

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Livestock farming

In the last few years, there has been a significant population increase, accompanied by drivers such as specialization and concentration, resulting in heightened food production demands. Consequently, farms have intensified and expanded in size.

This intensification has given rise to challenges in managing livestock manure. Traditionally, manure has been utilized as a field fertilizer; however, its improper and excessive use has resulted in pollution issues affecting the air, soil, and water systems. Nutrient leaching occurs when these nutrients are not retained in the soil for plant utilization. Therefore, effective management of surplus manure is crucial to enhance nutrient efficiency and prevent environmental pollution. To address this concern, the European Union (EU) introduced the Nitrates Directive (Council Directive 91/676/EEC), which imposes limits on the amount of nitrogen that can be applied to the soil (170 kg N/ha per year). Consequently, various practices are implemented across EU countries to manage surplus manure within these prescribed limits: (i) **introduction of the BATs (best available techniques,** such as the use of easy-to-clean surfaces for the storage of manure, the use of an outdoor tank for a slurry storage**,** the monitoring of water, energy, feed and fertiliser consumption, nitrogen recovery from manure, the reduction of GHG emissions to air, and nitrate leaching to water body, the reduction of the amount of wastewater, the efficient use of the energy, and the reduction of odour emissions[3]**, (ii) introduction of the Precision Livestock Farming** (**PLF)** that seeks to apply a management approach that focuses on (near real-time) observation, measurement, and responses to variability in crops, fields and animals. It can help increase crop yields and animal performance, reduce costs, including labour costs, and optimise process inputs[4]**, (iii) development of nutrient budget to better** to monitor nutrient surpluses and deficits both at farm and regional scale and inform nutrient management strategies[5]. **And (iv) adoption of agroecological systems and practices** such as organic farming that seek to ensure a greater balance between the animals reared and the carrying capacity of the land as well as other practices including the use of legumes[6].

Storage systems

The substantial volume of manure generated, coupled with restrictions on its quantity for use as fertilizer and legislative requirements, force farmers to store the manure to treat it and/or use it as fertilisers during the appropriate periods of the year.

Manure is commonly stored in various facilities such as ponds, tanks, and treatment plants for subsequent use or processing. Typically, this storage takes place on the same farm where the manure is produced. However, in cases where livestock concentration is observed in specific

[3] European Commission (2021). Report from the Commission to the Council and the European Parliament on the implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources based on Member State reports for the period 2016–2019 Retrieved from [https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?from=ES&uri=CELEX%3A52021SC1001]

[4] EIP-AGRI (2022). Inspirational idea: Using data to manage environmental impact of livestock farming. Retrieved from [https://ec.europa.eu/eip/agriculture/en/news/inspirational-idea-using-data-manage-environmental.html]

[5] EIP-AGRI (2022). EIP-AGRI Focus Group Digital tools for sustainable nutrient management. Retrieved from [https://ec.europa.eu/eip/agriculture/sites/default/files/eip-agri_ws_digital-tools-nutrient-management_final-report_2022_en.pdf_0.pdf]

[6] European Commission (202). Farm to Fork Strategy. Retrieved from [https://food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf]

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regions, a centralized treatment plant is established[7]. This facility serves as a collection point where multiple producers bring their manure for treatment and management.

Fertiliser production and processing technologies

Livestock manure is used as a primary source of nutrients in the field (also as a source of biogas). However, as mentioned earlier, treatment is essential to mitigate soil pollution and degradation.

Various technologies and processes have been developed to enhance the quality of manure as a fertilizer. Nevertheless, it is widely recognized among different countries that **further research and efforts are needed.** The existing technologies found in most of the agricultural areas are often rudimentary, and **finding the most suitable and efficient processes remains a challenge**. Considering this, it has been compiled a list of the most common practices currently implemented:

The **separation of the liquid fraction from the solid component of manure** is achieved through either physicochemical or physical processes. This separation process enables improved management of manure and, when combined with other treatments, results in the production of higher-quality fertiliser. **Anaerobic digestion** is a process utilized to enhance the quality of fertiliser, minimize odours and pathogens, and generate a renewable fuel known as biogas. This biological process occurs in an oxygen-free environment, where microorganisms transform a portion of the material into a gas mixture primarily composed of CH_4 and CO_2, referred to as biogas. This biogas can then be harnessed as an energy source[7].

Composting involves the aerobic decomposition of manure, meaning it occurs in the presence of oxygen, resulting in the production of a stabilized product called compost. This process offers several benefits, including the reduction of manure weight and volume, elimination of foul odours, pathogens, and weeds, as well as the transformation or removal of specific organic pollutants. Additionally, composting helps reduce phytotoxic components, which vary depending on the original raw materials used. It is crucial to have a comprehensive understanding of the organic materials' characteristics, including their nutrient content, availability, and contribution to enhancing soil structure and biological activity. This knowledge aids in optimizing the composting process and utilizing the resulting compost effectively. Nevertheless, livestock manure is not the sole material source to produce organic fertilisers, and alternative options are being increasingly explored to address the demand for biologically derived fertilisers. For instance, the different OGs studied in this project have considered various organic materials as potential alternatives. **A wide range of organic sources are already being utilized to produce organic fertilisers, including algae, grass whey, sewage sludge, solid urban waste, agricultural waste, and more.** By tapping into these resources, which are often considered waste, it can be extracted their value and reduce reliance on mineral-based fertilisers[8]. This approach fosters sustainable practices by promoting the reuse and valorisation of organic materials.

Nitrification-Denitrification (NDN) is a process primarily aimed at removing nitrogen from manure. This process effectively eliminates polluting nitrogen and converts it into harmless nitrogen gas. Additionally, NDN helps reduce GHG emissions and foul odours associated with manure. However, there is a common misconception that NDN entails high investment costs and significant electricity consumption, which has limited its widespread adoption across the EU. Implementing this manure management technique allows for the reutilization of waste material as organic

[7] European Commission (2020) Technical proposals for the safe use of processed manure above the threshold established for Nitrate Vulnerable Zones by the Nitrates Directive (91/676/EEC). Retrieved from [https://publications.jrc.ec.europa.eu/repository/handle/JRC121636]

[8] European Environmental Agency (2020) Bio-waste in Europe — turning challenges into opportunities. Retrieved from [https://www.eea.europa.eu/publications/bio-waste-in-europe]

fertiliser, mitigating its pollution potential and decreasing farmers' reliance on mineral fertilisers. This transition has numerous advantages, including improved soil structure, reduced emissions and minimized leaching. By embracing NDN and optimizing manure management, it can be fostered sustainable agricultural practices while concurrently addressing environmental concerns[7].

Transport

Transport plays a crucial role in the value chain, particularly when farms are unable to handle manure management themselves and rely on external entities, such as treatment plants. Consequently, direct application of fertilizers from the farm to the fields is not feasible. Instead, manure needs to be transported to treatment plants, and subsequently, the resulting fertilizer must be transported to the agricultural fields. This situation is particularly common in densely populated regions, where the ratio of livestock farming to available crop surface is high, or in small farms lacking the necessary infrastructure and capacity for on-site treatment processes. To facilitate the transportation of these products, **tanks are commonly employed to transport manure from livestock farms to agricultural fields**[9].

Another significant aspect related to transport involves addressing nutrient imbalances in different areas. In some regions, soil may experience an excess of nutrients due to their proximity to or sharing of boundaries with livestock farms. As a result, these areas often receive enough fertilisers. On the other hand, there are agricultural regions exclusive to crop cultivation where soil fertility may be insufficient. Consequently, it becomes necessary to transport fertilisers from areas with nutrient surpluses to regions lacking these essential components. By strategically moving fertilizers between locations, it can effectively manage nutrient distribution, optimize soil fertility, and support sustainable agricultural practices across diverse geographic areas[3].

Application

The application of fertilizers directly to the soil, whether in liquid form using a hose or in solid form through broadcasting, is a commonly adopted practice in agriculture. However, it has been demonstrated that this approach leads to several issues, including ammonia GHG emissions, unpleasant odours, and reduced nutrient efficiency for the crops[10].

In order to ensure the efficient application of fertilisers to the soil and prevent air pollution (caused by GHG emissions), water pollution (due to leaching), and soil degradation (caused by excessive nutrient accumulation), various techniques are employed: (i) **Implementation of BATs:** These include timing the fertiliser application based on the specific crop requirements, applying fertilisers between two successive crop cycles, and accurately calculate the nutritional needs of the crops. By adopting these practices, farmers ensure that the introduced nutrients are optimally utilized by the crops[11]. **(ii) Use of fertigation:** This method enables the precise delivery of the required amount of nutrients to the crops, ensuring efficient uptake. Fertigation also minimizes the emission of ammonia, GHGs, and unpleasant odours, as the fertiliser is applied in a concentrated form[11]. **(iii) Combination of organic and mineral fertilisers:** In some countries, it is common to mix organic and mineral fertilisers. This approach improves soil structure and enhances nutrient

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[9] European Commission. Commission Decision (EU) 2018/813 Retrieved from [https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX%3A32018D0813]

[10] Joint Research Centre (2021). Manure management and soil biodiversity, towards more sustainable food systems in the EU. Retrieved from [https://publications.jrc.ec.europa.eu/repository/handle/JRC124903]

[11] Joint Research Centre (2017). Best Available Techniques (BAT) Reference Document for the Intensive Rearing of Poultry or Pigs. Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control). Retrieved from [https://publications.jrc.ec.europa.eu/repository/handle/JRC107189]

availability for the crops, while staying within established limits[12]. **(iv) Soil/plant testing for assessing soil health:** Regular soil and plant testing allows farmers to make informed decisions regarding nutrient management. By analysing the test results, corrective actions can be taken in areas where nutrient imbalances or deficiencies are identified[11]**. (v) Optimization of crop rotations:** Designing more effective crop rotation patterns that incorporate the use of legumes and green manures can enhance nutrient management. These practices contribute to soil health and nutrient cycling. And **(vi) Enhanced utilization of cover crops and intercropping:** Implementation of catch crops, cover crops, and intercropping strategies improves soil health and nutrient utilization[13].

6. Conclusions

Based on the analysis of the information gathered in this report, it is evident that the four member states of the EU (Spain, Italy, Belgium, and Ireland) employ similar practices in nutrient management across the entire value chain.

- The growing population and the resultant increase in food demand has led to the concentration and the number increase of farms, which has led to different problems. As for livestock**, large quantities of manure are produced that must be managed to avoid soil, water and air pollution.**
- To minimize the impact of this manure, **farmers put into practice precision livestock farming (PLF) and the best available techniques (BATs)** as well as converted to organic farming**.**
- **There is a great dependence of farmers on mineral fertilisers, which must be eliminated and replaced with organic fertilisers and as well as the use of legumes,** that improve the quality of the soil, provide more efficient nutrients, and reduce the risk of pollution.
- Manure receives **treatments to be used as organic fertilisers: anaerobic digestion, composting, NDN, etc.,** although the technologies are still quite rudimentary.
- Manure is not the only source for the manufacture of organic fertilisers, and **several countries have begun to study techniques and technologies to valorise other by-products (such as whey grass) that can nourish and improve soil quality.**
- **Most of the treatments for the manure to transform it into fertilisers are done on site at the farms,** but there are cases where they are taken to treatment plants**. In these cases, transport is necessary, which is difficult due to the characteristics of the droppings and has a high cost.**
- It is also common to find a situation where the livestock area has a surplus of nutrients in the soil and can no longer apply more manure as fertiliser, therefore **the surplus manure is transported to other crop areas where there is a lack of these nutrients.**

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[12] European Commission (2018) Expert Group for Technical Advice on Organic Production. Final Report. Retrieved from [https://agriculture.ec.europa.eu/system/files/2019-01/final-report-egtop-fertilizers-iii_en_0.pdf]

[13] Eurostat (2020) Agri-environmental indicator - soil cover. Retrieved from [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_soil_cover]

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- **To avoid contamination at the time of application, farmers apply BAT**, such as fertigation and mixing of organic and mineral fertilisers.
- Usually, it can be found the situation that a region needs to introduce raw materials for livestock feed, which is why **different countries have begun to investigate techniques to use by-products and other alternative products as a source of livestock feed.**
- **PLF is applied in animal feed in order to improve the life quality of livestock and be more efficient in their management.**

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