Review

AKIS and Sustainable Management of Natural Resources: Current Trends and Future Research Priorities

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AKIS and Sustainable Management of Natural Resources: Current Trends and Future Research Priorities

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Abstract: The new Common Agricultural Policy of the European Union (EU) (2023-2027) envisages a stronger Agricultural Knowledge and Innovation System (AKIS) that will unite all relevant actors in a co-creation process to ensure knowledge flows within and across Member States. A significant and increasing body of literature focuses on the strategy and processes of strengthening AKIS. However, there is a relative gap in research related to the role of AKIS in achieving sustainability in the farming sector. The purpose of this paper is to provide an extensive overview of the advancements so far of AKIS across the EU when it comes to facilitating the sustainable management of natural resources (SMNR). The paper builds upon a comprehensive review of relevant literature during the last 15 years covering all 28 EU countries (including the United Kingdom until 2019). We conclude that AKIS architecture in most EU countries lacks a comprehensive structure promoting SMNR. Based on the results we identify countries with relatively high intensity of research and development projects linking AKIS to SMNR and where SMNR is better integrated to AKIS. Our results can be of interest to the design of stronger AKIS during the new programming period.

Keywords: Agricultural Knowledge and Innovation Systems (AKIS); sustainable management; natural resources; agricultural advisory

1. Introduction

The general idea behind Agricultural Knowledge and Innovation Systems (AKIS) is to present an understanding among all the actors throughout modeling, generating and advancing the current knowledge and technology in Agriculture (Busse et al., 2013). The framework focuses on creating the bridging factor among different disciplines within the agricultural sector. Knierim et al. (2015) argued that the fundamental concept of AKIS is the identification, analysis, and sum assessment of various agricultural actors and their substitute sectors. The attempt to drive agricultural innovation and more over to develop a strong and effective AKIS has resulted in the EU formulating targeted rural development and initiatives (such as EIP-AGRI) in specific localities.

Understanding AKIS unearths the participation of multiple actors (Sutherland et al., 2023). On the other hand, institutions enhance a smooth and linear flow of knowledge and information from the researchers (scientists) to the actual implementers, the farmers on the farms. However, the simplified gap contains several middle players ranging from private to publicly positioned individuals and institutions (Vecchio et al., 2020). More so, Ahuja et al. (2016) noted that AKIS also involves other organizations and institutions interested in progress in agricultural technology and its knowledge in general, such as the governments and Farmer Based Organizations (FBOs).

Sustainability concerns are inherent to the development of a well-organized AKIS ecosystem. Agricultural development is dependent on enabling exchanges among actors in a way that secures prosperity and sustainable development. The urge to enhance AKIS, according to Knickel et al. (2017), arises from the need for societies and communities to produce more commodities for populations in a context of limited natural resources, maintaining sustainability in the whole process. Therefore, besides the need to integrate AKIS, there is also a need to maintain a conducive and sustainable environment within which humans survive and thrive (Dale & Polasky, 2007). By promoting sustainable farming practices, such as crop rotation, conservation tillage, and integrated pest management, AKIS can have a direct impact on reducing the environmental footpring of agriculture, including soil erosion, water pollution, and greenhouse gas emissions. In addition, AKIS can help to improve the livelihoods of farmers and rural communities by promoting the use of new technologies, such as improved seeds, fertilizers, and irrigation systems, and by providing access to markets, credit, and other resources. This can help to increase farm productivity, reduce poverty, and promote economic growth.

In this context, the new Common Agricultural Policy has included AKIS as one of its 10 objectives, among the remaining nine which target the three pillars of sustainability (environmental, social, economic). Regulation EC/2021/2115 postulates the implicit links between AKIS and the sustainable management of agriculture, including environmental and climate standards (climate change adaptation and mitigation) and – in their interface - promotes the provision of public goods. The Sustainable Management of Natural Resources (SMNR) is a stand-alone CAP 2023-2027 objective which clearly interrelates with the remaining ones. The relationship between advisory and sustainable management of land, water and pesticides is acknowledged within Reg. EC/2021/2115 and the need to increase farm resilience through new strategies is highlighted.

This paper presents a systematic review of available literature within the European Union (27 countries and United Kingdom until 2019) that focuses on the relationship between AKIS and the promotion of sustainable management of natural resources (SMNR). The idea that triggered the need for this research was that sustainability is fundamental within AKIS ecosystems and that promoting sustainability objectives in agricultural production through advisory is a concept of uttermost importance within a challenging environment. Therefore, this paper aims to examine the degree to which SMNR is indeed embedded in AKIS-related research through the systematic examination of relevant literature from 2010 onwards. In particular, the paper examines whether the available scientific research presents examples and advancements in promoting SMNR through dedicated AKIS-related activities, initiatives, approaches and practices.

The methodological approach in this paper is based on extracting data from existing literature with regards to SMNR under the explicit lens or encouragement and support from AKIS in practice. The analysis focuses specifically on three dimensions of SMNR. The first component includes the use of AKIS for improving the efficient use of water (Mirra et al., 2020). Farm advisory services are expected to contribute specifically towards the implementation of the Water Framework Directive (WFD, Dir. 2000/60/EC). It also incorporates the education process geared toward educating farmers on different methods of conserving water (Curry et al., 2012). AKIS is also scrutinized under its expected usefulness in helping farmers successfully adapt to the present and progressing climate change conditions (Teixeira et al., 2013; Coderoni & Pagliacci, 2023; Salpina & Pagliacci, 2022).

The second component of the analysis in this paper examines the role of AKIS in sustainable soil management (SSM) (Rust et al., 2021) – including nutrient management under the scope of the Farm Sustainability Tool for Nutrients, according to Reg. EC/2021/2115. The topic of AKIS and soil management is discussed under the disciplines of scientific management of soil health, sustaining of soil fertility and understanding the eco-processes of soil conservation through established and new techniques such as soil mapping, and the determination and control of soil salinity as well as erosion and mineral leaching. The role of AKIS is explored from the point of view of training and education of farmers and practitioners combined with advisory from practitioners who are specialized in the field and can communicate efficiently new agricultural knowledge (including organic agriculture) to diverse audiences.

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The third topic of interest in this paper, refers to the use of pesticides within agricultural land and their immediate/long-term effect. The CAP specifically tackles the issue of sustainable use of plant protection and promotes advisory support and training as an effective means of sustainable pest control techniques. The discussion further touches on the role of advisory and training on mitigating the impact of human activities on agricultural land (Giagnocavo et al., 2022). Finally, this topic undergoes transparent scrutiny on managing replaceable and irreplaceable resources within agricultural lands.

For approaching these three dimensions of SMNR, the paper devotes to clustering the European Union countries into groups reflecting the intensity realized in the research and development of projects that bind AKIS to SMNR. Indeed, since Reg. EC/2021/2115 clearly recognizes that advisory should be based on the outputs of research and innovation projects, the paper seeks to provide insights regarding the degree to which such outputs are indeed integrated in the advisory process in EU countries. This topic is analyzed within the 28 countries of the European Union (including the United Kingdom until 2019).

2. Materials and Methods

The paper is based on a systematic review of scientific literature on SMNR and AKIS from 2010 onwards. The selected method was PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) statement, which is a tool that has been designed to assist transparent reporting of systematic reviews (Page et al., 2021). The popularity of PRISMA as a methodological tool for systematic reviews is due to three characteristics: rigorousness, transparency, and objectivity. Indeed, while traditional reviews have their place in the academic literature, they are generally more susceptible to bias, subjectivity, and incomplete coverage of the relevant literature.

2.1. Search Criteria

The search followed a keyword-guided investigation from the public databases SCOPUS and Google Scholar. These databases were upheld for the relevance of their data to the research topic. Secondly, their providers render the databases public, posing no additional cost to this research procedure.

The search also incorporated a few authenticated online websites acting as valuable data resources to back up the attained data, while an interactive investigation has also been carried out in the international Prospective Register of Systematic Reviews to gather information on any study in progress at the current research time. A few manual searches were also included to use some prior printed content on the topics in discussion. The entire physical or electronic examination ensured an exhaustive inspection to retrieve all the valuable data in each bulk literature storage pursued.

Using more than one database and randomly selecting articles were directed towards minimizing bias in retrieving articles from online electronic databases. The review adopted blinded data processing methods that supported randomized links supported the article's data to add to these procedures. More so, there has been made an individualized screening of the pieces to attain a more remote data acquisition procedure from the risk of bias altogether. The terms that used for searching into the above-mentioned data bases, aligned with the review's objectives, were Agricultural Knowledge and Innovation Systems, "SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES," Prefixes such as "SOIL," "WATER," "NATURAL RESOURCES," and suffixes such as "MAINTENANCE," "CONSERVATION" and "PROTECTION. "The geographical specificity also led to the addition of geographical terminologies such as "UNITED KINGDOM," "EUROPEAN UNION," and "THE 28 COUNTRIES IN THE EUROPEAN UNION". The number of the yielded articles along with their results are presented in the "results" section below.

2.2. Study Selection and Data Synthesis

In pursuit of complete information on the subject matter, a transparent and authentic strategy was implemented to survey the best quality article to establish the review. The systematic review

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followed the inclusion and exclusion criteria to analyze the reports considered. This step ensured that the articles considered were all informational and relevant to the study. In addition, a specified keyword search approach was involved to ensure the results obtained were within the expected data. The keyword strategy also confirmed that all the internal subtopics that guided the review were incorporated. The whole system was geared toward avoiding ambiguity throughout the process.

The author used more than one database to ensure a balance in information inclusivity. This consideration provided a mixture of different points of view, which helped reduce the risk of bias in article acquisition or author selection. The reports acquired were all screened individually. The screening process involved reading through the text in each piece and the abstracts to substantiate the information contained in each. The screening process also checked the authenticity of the authors in the field they were reporting. The articles that passed these steps were grouped as viable and helpful in attaining the main objectives of this systematic review.

2.3. Eligibility Criteria

The reviewer assumed an individual screening of the articles obtained from the literature search. Before that, however, a systemized process was put into place to choose specific papers (from all sources considered) based on a previously prepared list of inclusion and exclusion criteria. The articles that were taken up to be used for systematic review fulfilled the criteria below:

- Inclusion criteria.

1. The studies that were carried out or considered the 28 countries in the European Union (including the United Kingdom until 2019)
2. Studies published in the English Language
3. Studies that were published within the past 15 years (critical point the common agricultural policy's 2009 "health check", where the concept in sustainability in natural resources was better defined)
4. Studies covering including a transparent description of the process of data acquisition and interpretation
5. Studies covering a primary or secondary class investigation on the subject matter
6. Studies showcasing the effects of AKIS on agricultural knowledge advancement.

- Exclusion criteria

1. Studies published in a non-English language
2. Studies carried out outside the EU
3. Studies with unclear methodology of data collection and analysis
4. Studies lacking author names and affiliation
5. Studies not covering both the main issues of this review (i.e., AKIS and SMNR)

2.4. Data Analysis

The primary analytical method put in use was the tabulation of each article's data. Tabulation was done through columns and rows, with the rows indicating different themes and the columns showcasing various domains upon which the articles were assessed. The tabulation method was also used with systematic narrative synthesis to create a fully equipped process of analyzing the data obtained.

The review also considered the synopsis method to enable data handling. The synoptic approach ensured there was a clear overview of the subject matter. In addition, it presented a clear path along the data modeling strategy leading to the results obtained and finally revealing the conclusions' credibility.

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3. Results

3.1. Literature Search

The online search that was carried out in the two databases initially yielded 618 articles. However, 114 articles were immediately excluded as duplicates of other reports and 105 more articles were also excluded for not fulfilling the inclusion criteria described in Section 2.3. As a result, 399 articles passed the initial screening. At the following step, the remaining articles were assessed (based on the abstracts and on bibliometric data) according to the exclusion criteria of Section 2.3. This process led to ruling out 186 articles in addition. The remaining 213 articles were downloaded and the inclusion and exclusion criteria were applied once more on the full text of these articles. Based on this process, 159 more articles failed to fulfil the criteria of Section 2.3 (either inclusion or exclusion criteria). In addition, 41 were excluded due to publication in a language other than English; irrelevance of their study to the objective of the analysis (AKIS and SMNR); or unclear description of the methodology or of data acquisition and processing. Therefore, only thirteen (13) articles were finally chosen for this systematic review after passing all the quality and eligibility criteria.

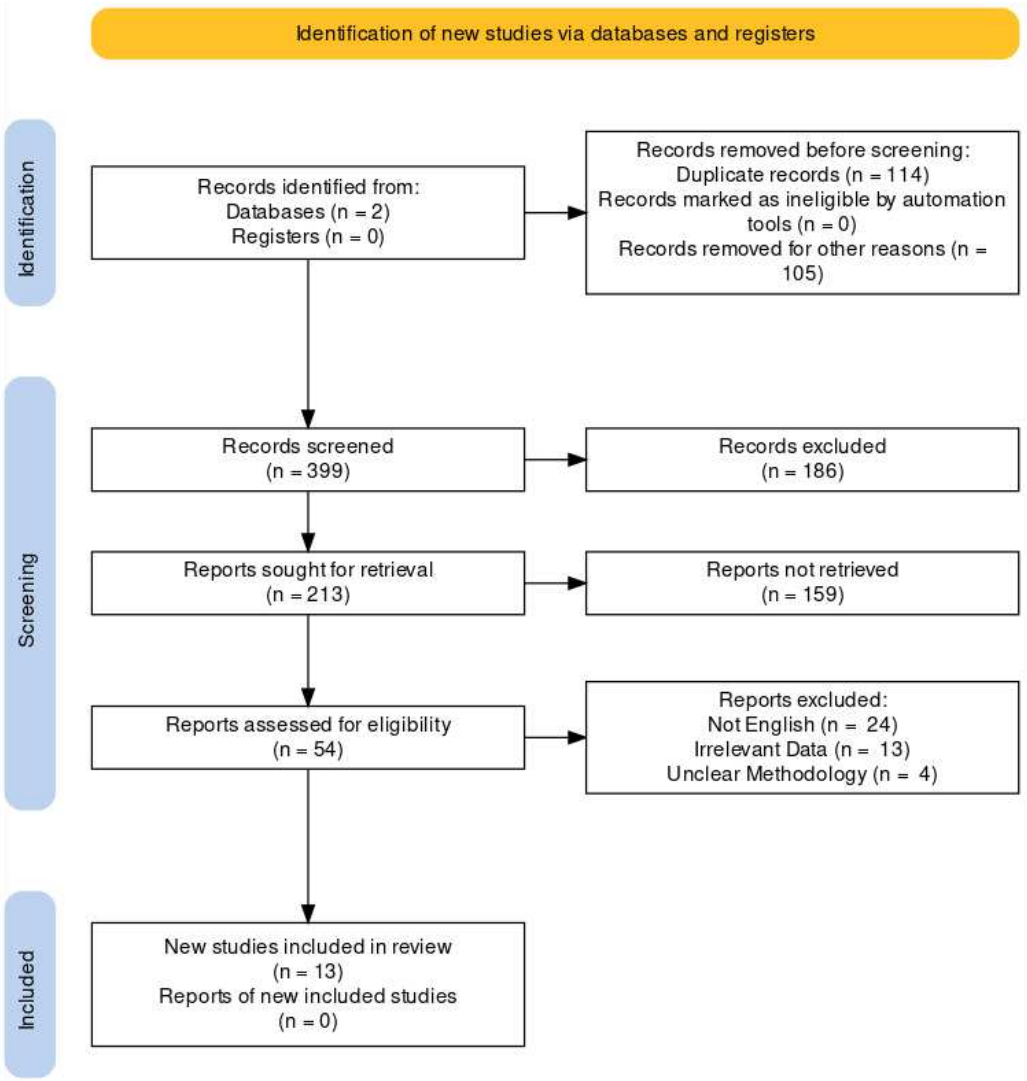

Figure 1. Research methodology flowchart.

3.2. Studies Included

Table 1 presents the main information about the papers that have been considered in this review (Article ID, country, factors investigated, results obtained, and suggested improvements – where

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applicable). The published literature that first related innovation systems in agriculture with SMNR in the EU was dated back in 2009. However, the fact that only 13 papers (2.1% of the papers initially retrieved) passed the inclusion criteria demonstrates the scarcity of literature connecting AKIS and SMNR even in the following period.

Table 1. A comprehensive description of the main references.

Article ID	Country	Factor(s) Investigated	Key Results Obtained	Suggested Improvements
Ingram & Mills, (2019).	European countries.	Advisory services 'fit for purpose' to support sustainable soil management.	1. Regional and national governance systems have failed to achieve Sustainable Soil Management (SSM) in Europe, due to fragmented policy context and focus on single soil functions. This has a negative impact farm-level advisory provision and generates conflicting priorities leading to tensions among advisors. Indeed, due to this complexity, SSM is given low priority by advisory services, such as the promotion of destructive soil practices from productivity-oriented advisors (heavy machinery and dependence on inorganic fertilizers) 2. There are several options offered to farmers by advisors and this variety affects positively some soil functions but affects others adversely. The reliance on these multiple sources has resulted in duplicate information and, at times, conflicting advice to farmers, which end up causing dangerous results to the anticipated SSM.	• The capacities and expertise of advisors is prime for SSM advisory. Improvements are needed, including updating regularly data in private advisory organizations and systematic provision of information to advisors
Bachev, (2022).	Bulgaria.	Governance, Efficiency, and Development of AKIS.	1. Diverse organizations consist AKIS in Bulgaria. Public institutions were outdated while the private sector was underdeveloped. 2. The activities carried out by these organizations needed more reliable information and data including the integration of SMNR in AKIS. 3. There was a decreased trend of the Agricultural resesarch and development (ARD) expenditures as a fraction of total R&D expenditure in the country, especially with regards to AKIS personnel and	• Partial compensation of the missing data by experts' assessment activities while carrying out in-depth as well as representative surveys targeting singled-out components of AKIS. • The country should work towards institutionalizing and regulating the

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			infrastructure, thus continuously reducing the importance and potential of the country's agrarian knowledge and innovation sector. 4. Uneven application of modern technologies in production and management methods in different farms, regions, and subsectors of agriculture.	collection of official statistics and other necessary data and information. • A need to improve knowledge-sharing, and innovations pointed to agricultural development.
Knierim et al., (2019).	Germany.	Farmers' and other stakeholders' perceptions and attitudes toward Smart Farming Technologies (SFT).	1. Although farmers are generally positive with regards to the outcomes of SFT, they are less enthusiastic about the links between SFT and SMNR 2. Unfavorable infrastructure and institutional environments cause adoption barriers to modern technology in agriculture production.	• The multi-actor approach enables the transition from traditional to professional advisory profiles, thus increasing the positive impact of advisory on SFTs to achieve SMNR. • Closer cooperation between practitioners and development agents is needed
Oliveira et al., (2019).	Portugal.	The different views of the concept of innovation within the Program of Operational Groups (Ogs) of the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI).	1. There is an emerging need for more investments directed toward research and innovation. 2. The objectives of the traditional innovation framework in the country are to introduce modern trends in agricultural innovation, focusing on sustainable development, improvement of competitiveness and enhanced production.	• Innovation should be redefined along with its related activities that deserve financial support to improve public investment returns. • Rural development programs are important to enhance agricultural innovation in developed areas.
Rust et al. (2021).	Hungary and the UK.	Knowledge flow on innovations for SSM.	1. Farmers in both countries accessed soil information online. 2. A group of farmers relied on social media farming influencers for information on soil management. 3. Another group of farmers trusted their peer farmers to learn about new soil practices, showing less or no trust in traditional experts	• There should be a trustworthy knowledge exchange path between agricultural stakeholders to ensure increased uptake of SSM

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			academic and government institutions.	
Giagnocavo et al., (2022).	Spain.	Reconnecting Farmers with Nature through Agroecological Transition.	1. Farmers are central to achieving sustainable development through agri-food systems networks but conventional agri-industrial systems have also led to the disconnection of farmers from nature. 2. The farmer's interaction with nature was found to be functional in (SE Spain) in the domains of biological control, ecological restoration, soil health, and pond management.	• Applying agroecological practices would lead to a deeper understanding of the ecosystems in greenhouse landscapes. • The increased connection between farmers and nature can bring more sustainable and innovative agricultural systems.
Knierim et al., (2015)	Belgium, France, Ireland, Germany, Portugal, and the UK.	The AKIS Concept and its Relevance in Selected EU Member States.	1. There is a general appraisal and usefulness of AKIS and sustainability. 2. The AKIS concept helps understand and evaluate the agricultural-induced policies of innovation and sustainable management in all the countries assessed.	
More & Poppe (2013).	EU countries.	AKIS components of research and innovation and the analysis of prime developments made over the recent years together with their drivers.	1. Likely persistence of the institutional arrangement diversity since they are responsive to different socio-economic contexts.	• The European Union (EU) should coordinate the infrastructure for science and research and manage spillovers within EU regions. Should also handle the promotion of market-based instruments and uphold capacity-building. • The governments could encourage innovation and sustainability in the agri-food sector by facilitating many policies and enhancing their coherence.

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Moschitz et al., (2021).	EU countries.	Viability of EU '*Farm to Fork*' strategy to deliver on its sustainability promises.	1. To achieve a sustainable action plan, there should be flexibility in the specification of the objectives for each farming sector. 2. Involving all relevant stakeholders is necessary to achieve a healthy and sustainable diet.	• Member states should train and inform their advisors, researchers, and other knowledge brokers with a view to assist them change their practice and attitudes to upscale their AKIS.
Terziev & Arabska, (2015).	Bulgaria.	Priorities for future sustainable development and assurance of food quality and safety in the agricultural and food sector.	1. To facilitate a prosperous future in terms of food security and SMNR, there is a need to establish AKIS. 2. Distribution of knowledge, innovations across all stakeholders, and networking can increase competitiveness in agriculture and the food industry. 3. AKIS embraces all the individual actors and promoting their interactions along creation and transfer of knowledge in new ways that prove effective and promote sustainability.	• The measurement of inputs, market-focused technology development, and information systems are the three main pillars for sustainable rural development • Agricultural sustainability requires an economy based on knowledge.
Ingram et al. (2022).	Europe countries.	What is the level at which agricultural advisory services can support the transition to healthy soils across Europe?	1. The need of accessing the content of soil management advice and overall support for the transition from traditional farming to the enhancement of healthy soil has increased. 2. Fragmentation compromises soil at the farm level by creating competition for clients and funding projects. 3. There is a noted challenge of funding, equipment, resources, and staff necessary for organizations to give SSM advice effectively. 4. The move to integrate SSM in multiple European commission strategies and the ambitious targets set will result in an increased requirement for building capacities and a knowledge base for improved practices.	• SSM advisors require higher levels of training and also to capitalize on their experience gained in their fieldwork and their general motivation towards the SSM sector. • Member states will be required to enhance their Agricultural Advisory Services (AAS) capacities to achieve the desired transition through an effective combination of national and EU policies. • Future research should cover the incentivizing nature of market drivers and emerging policies

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				toward enhanced capacities in AAS.
Knickel et al., (2009)	Germany and the EU.	Information exchange and learning processes bring forward innovation.	1. Innovation often needs to be clarified as being a linear process. 2. There is an agricultural knowledge system segmentation. 3. The knowledge of agriculture and innovation systems is expected to grow to higher levels, enhancing the assimilation of private and public interests	To adopt a systemic approach from linear models; ● The innovation process should aim SMNR. ● Incorporation of novelty production as a better and more productive system due to its specificity of localities. ● Innovation is brought out as directly proportional to information flows, the social learning process, and its interactional relations. ● All actors, both public and private, should be able to access public and private resources with ease. ● Innovation policies in the rural areas should go hand in hand with any new agricultural objectives in their localities and promote capacity building on innovation
Birke et al. (2022).	28 EU countries.	AKIS in European countries.	1. AKIS concept is used as a guiding principle for modernising agriculture and enhancing SMNR. 2. AKIS guides associated stakeholders, i.e., (politicians, practitioners, the EU, national interested parties, and researchers) through bridging gaps and facilitating cooperation. 3. Europe's land users operate in a huge variety of natural, sectoral, socio-cultural and institutional	● There should be a stipulated AKIS government policy that promotes AKIS through financial and intellectual support.

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	conditions which create particular environments that influence the development and the performance of AKIS services at national and local levels. 4. Significant levels of pluralism seen within the advisory service providers throughout most Europe countries 5. Public advisory organizations have demonstrated their indispensable role in knowledge provision 6. The strong involvement of Farmer Based Organizations (FBOs) in AKIS resulted in a visible decline in the role of NGOs

4. Discussion

The literature review investigated the linkages between AKIS and SMNR with a view to increase understanding on the level to which AKIS has contributed towards higher levels of SMNR and to provide a justification of the new CAP 2023-2027 to include AKIS as one of its 10 objectives, which will facilitate the achievement of the remaining ones – including the three environmental objectives with particular focus on environmental care and SMNR.

4.1. AKIS and SMNR: Friends or Strangers?

Perhaps the most interesting finding of this research was that the research relating AKIS to SMNR remains quite scarce. Out of 618 papers initially extracted from SCOPUS and Google Scholar, only 13 fulfilled all the inclusion criteria (2.1%). This constitutes an important discrepancy, because although training, information and advisory have been highlighted as key elements for achieving SMNR, in fact relevant activities are fragmented and this is reflected in research outputs. Fragmentation is further induced by the presence of many farming-knowledge brokers, as this pluralism has led to competitive relations between advisory services in their attempt to win clients (farmers) and also to low-value information (Compagnone & Simon, 2018). Coherence has been hoighlighted by More and Poppe (2013) as a prerequisite towards smother AKIS across the EU.

There is a general appraisal of AKIS within the EU community, especially since most countries support the idea altogether (Knierim et al., 2015). At this level, most countries from the EU trading block revealed their assurance of the usefulness of AKIS as support to farmers is necessary to play their roles in promoting social, economic and environmental objectives. Nevertheless, AKIS implementation has been a challenge in many countries despite the significant efforts to enhance agricultural extension services and empower the structure of AKIS (Materia, 2012; Cristóvão et al., 2012; Kernecker et al., 2019). The results of this review demonstrate that specific initiatives, structures, activities and efforts to increase the potentialities between AKIS and SMNR have been developed in a small number of EU countries, such as Belgium, France, Ireland, Germany, while countries like Bulgaria experienced a deteriorating level of AKIS incorporation into the agricultural processes and thus weak contribution of AKIS towards SMNR (Bachev, 2022). However, no specific literature connecting AKIS and SMNR was found for most EU countries. Factors such as multiple advisory services (pluralism) have led to significant disruption in the advisory system for farmers (Sutherland et al., 2013; Bourne et al., 2017), while also the lack of AKIS-promoting policies from the government and other powerful institutions has led to standard practice and low incorporation of AKIS strategies in some countries (Klerkx et al., 2019).

There is no doubt that AKIS can serve a great purpose in maintaining SMNR (Knierim et al., 2015; Terziev & Arabska, 2015). This role is evident in the transition from conventional agriculture to agroecological systems that help curb most of the problems experienced in the earlier designs (Giagnocavo et al., 2022). However, some of the strategies formulated by the EU need to be more comprehensive and conclusive. Moschitz et al. (2021) unearth the loopholes left in the European Commission Farm to Fork (F2F) strategy for transforming the food system to a more sustainable form. Despite the fact that AKIS could play an important role facilitating this transition, there is absolutely more room for improvements and this is substantiated by the outcomes of this systematic review. Although some of the targets of the Farm to Fork Strategy were very ambitious – such as shifting about 25% of EU agricultural land to cross toward organic production by 2030 – AKIS could have a significant contribution in focusing more on the essential structural elements and the social pillar rather than on technical aspects. According to Moschitz et al. (2021), this way the targeting could have been better and would increase flexibility in its implementation.

4.2. AKIS for Specific Advancements in SMNR

The review shows that relevant objectives were upheld in very few EU countries, with AKIS operating "top-down" from government agencies to practitioners (Birke et al., 2022). For example, this review highlighted the importance of more cohesive AKIS for SSM. Fragmentation has been reported to have resulted in a competitive and confusing environment for farmers, leading to low-quality duplicate information. In the examples that were found in literature, farmers relied heavily on the knowledge flow either directly (e.g., online) or from researchers to advisors who relayed this information to the farmers that practiced it directly (Keesstra et al., 2018, Kountios, 2022). Ingram and Mills (2019) concluded that the advisory services were fit to facilitate knowledge flows to farmers to promote proper soil management.

With regards to the preferred channels for information and advisory, the study of Rust et al. (2021) revealed knowledge transfer from one farmer to another as the most appreciated in Hungary and the United Kingdom (UK). Most farmers in these two countries relied on their colleagues for SSM knowledge and practices to adapt themselves (Rust et al., 2021). However, also online sources were important. The significant dependence on fellow farmers and social media comes to counterbalance lower trust to professional soil researchers for information on SSM (Chenyang et al., 2021). Ingram et al. (2022) highlighted the need to effectively train advisors and increase their capacities to communicate their experience to farmers.

Social factors have also interfered with the effective implementation of SMNR (Steenwerth et al., 2014). It has been observed that some farmers are used to a particular way of doing things. Therefore, some farmers may hesitate to follow some knowledge-driven practices since they place too much trust in their traditional/ societal ways. Knierim et al., (2019) demonstrated how farmers can be inert towards the adoption of smart farming towards SMNR despite well-structured advisory support. SMNR should be promoted as an innovation process in order to achieve promising and evident results, much like the example described by Knickel et al., (2009) and Oliveira et al. (2019), who focused specifically on the role of Operational Groups of EIP-AGRI.

5. Conclusions

In this paper an effort has been made to assess the advancements of AKIS across the EU in terms of facilitating SMNR. The review focused on specific components of agricultural ecosystems (soil and irrigation water) as well as on the use of pesticides. Based on the outcomes of the review, some EU countries were clustered according to the integration of SMNR to AKIS activities (such as advisory and training) as well as to the intensity of research and development projects linking AKIS and SMNR. It was found that the link between AKIS and SMNR is overall fragmented and weal, as there were no studies retrieved for most EU countries.

The EU has been on its toes in promoting AKIS in most of its countries for driving the agricultural sector towards sustainability and this paper focused on water, soil and pest management, as cutting-edge issues in policy debate. Only a few countries, however, have been reported in this

paper to demonstrate significant efforts in integrating SMNR in their AKIS. For most countries, the need to introduce a modern innovation model was underlined. The process of integrating SMNR in training and advisory can be facilitated if approached as an innovation process.

Nevertheless, perhaps the most important finding was that the relationship between SMNR and AKIS has not been examined adequately and this pinpoints that more significant efforts are required in terms of research and development. There is a dire need to collect and systemize available knowledge related to SMNR to be properly diffused to farmers. This also requires intensive training of advisors. These are the two basic priorities in order to allow AKIS play its fundamental role in the achievement not only of SMNR but also of all CAP objectives. As the new CAP has set ambitious environmental goals, which are expressed – among others – in Conditionality requirements and the Eco-schemes, advisors are expected to be the main agents towards the effective implementation of relevant measures and the achievement of results within the result-based approach of the new CAP. It is thus expected that AKIS should not remain a vague notion linking advisory with SMNR but specific measures and practices should be promoted. Initiatives such as the establishment of common Agricultural Knowledge and Innovation repositories and the active involvement of EIP-AGRI Operational Groups in advisory can be proven important in promoting SMNR as innovation.

In a nutshell, EU Countries should maintain and enhance their efforts for an effective and sustainable AKIS, towards the achievement of increased productivity, sustainable development, economic growth, food security and resilience. More research is, therefore required not only on new effective ways for SMNR but mainly on how to render them acceptable to farmers, compatible to their existing practices, beliefs and expectations and useful to achieve their objectives. Although this study has focused only on one CAP 2023-2027 objective (SMNR) – which is its main limitation – future research can reveal the degree to which other environmental objectives of CAP have been integrated in AKIS-related activities.

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