State-of-play Climate Smart Agriculture Research in Europe

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List of Abbreviations

AKIS	Agricultural Knowledge and Innovation System
CAP	Common Agricultural Policy
CGIAR	Consultative Group on International Agricultural Research
CSA	Climate Smart Agriculture
CIP	Competitiveness and Innovation Programme
CSR	Climate Smart Research
EEA	European Environment Agency
ERS	Experimental Research Station
WP	Work Package
CFD	Climate Fram Demo
FAO	Food and Agriculture Organization
FP7	Seventh Framework Programme
GACSA	Global Alliance for Climate-Smart Agriculture
GHG	Greenhouse Gas
CH4	Methane
CO2	Carbon dioxide
H2020	Horizon 2020
IFAD	International Fund for Agricultural Development
IoT	Internet of Things
InnovatERS	Innovating Experimental Research Stations
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
N2O	Nitrous oxide

N-P-K	Nitrogen-Phosphorus-Potassium balance
OECD	Organization for Economic Co-operation and Development
PioneERS	Pioneering Experimental Research Stations
RPG	Research Practice Gap
R&I	Research and Innovation
S1	Survey 1
S2	Survey 2
SI	Sustainable Intensification
USAID	United States Agency for International Development

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Summary

This deliverable provides a state-of-play analysis of climate smart agriculture (CSA) research in Europe by combining an exploratory literature review with survey data collected from experimental research stations (ERSs) across Europe. Together, these analyses provide insight into the evolution of CSA as a scientific field, the current research priorities of European ERSs, the methodological approaches underpinning climate smart research, and the capacities required to strengthen future research and innovation.

The literature review demonstrates that CSA has evolved from a global policy concept into an increasingly established field of European agricultural research. Within Europe, CSA research is primarily oriented towards keeping productivity stable while improving resource-use efficiency. It is also oriented on climate change mitigation, and adaptation through technological innovation and sustainable farming practices. Nevertheless, the literature highlights several persistent challenges. European CSA research remains geographically uneven, continues to prioritize technological solutions over social and institutional dimensions, and often studies individual practices rather than whole-farm systems and interactions. Recent scholarship increasingly argues for more participatory, system-oriented and context-specific approaches that better account for synergies, trade-offs and the complexity of agricultural systems.

The survey results indicate that European ERSs already undertake a broad portfolio of climate smart research. Productivity, adaptation and mitigation are generally well represented across research activities, while ecosystem services receive comparatively less attention. Research spans diverse thematic areas, including soil management, livestock systems, precision agriculture, water management and greenhouse gas mitigation, illustrating the breadth of expertise available within the European research infrastructure.

The findings further show that many ERSs are already incorporating elements of climate smart research and innovation design as described by the Climate Smart Research (CSR) framework. Researchers report relatively strong engagement with transdisciplinary collaboration, systems thinking and, to a lesser extent, reflexive research practices. Stakeholder involvement is common during agenda setting, research implementation and dissemination, although participation remains less consistent during data interpretation and evaluation. Similarly, systems-oriented design is recognized as important, yet practical implementation is often constrained by the complexity of agricultural systems, limited resources and methodological challenges. Reflexive practices are present across many research stations but are interpreted inconsistently, indicating a need for greater conceptual clarity and methodological support.

The report also identifies the research practice gap (RPG) as a widely recognized challenge among ERSs. Respondents consistently emphasize that translating scientific knowledge into practical implementation remains difficult due to limited long-term funding, institutional incentives that favor scientific publications over societal impact, fragmented collaboration across the Agricultural Knowledge and Innovation System (AKIS), and insufficient opportunities for continuous interaction with farmers and advisors. Although ERSs already engage in a wide range of dissemination and knowledge exchange activities, researchers recognize that communication alone is insufficient to

ensure uptake when research is not co-developed throughout the innovation process. Institutional support, sustained funding, and stronger collaboration across research, advisory and farming networks were repeatedly identified as prerequisites for increasing the societal impact of climate smart agricultural research.

Finally, the capacity assessment demonstrates that European ERSs possess substantial scientific expertise to conduct climate smart research but also identifies clear opportunities for strengthening future capacities. Respondents expressed particular interest in developing skills related to systemic research design, on field trials, and participatory research methodologies.

1. Introduction

Introduced in 2020, the Green Deal formulated the ambitious plan to steer Europe towards climate neutrality by 2050. The “Fit for 55” package concretely aims to reduce EU greenhouse gas emissions (CO2, CH4, N2O) by at least 55 percent by 2030 compared to 1990 (Counsil of the European Union, 2026). In addition, the Farm to Fork strategy addresses the need for the food sector to accelerate its transition towards sustainable food systems.

However, agriculture does not only contribute to climate change, it is also highly vulnerable to climate change impacts. In 2025, the European Environmental Agency (EEA) reported that in the EU-27 agriculture was responsible for about 11 percent of the domestic greenhouse gas emissions (not including energy use, imported animal feed, or fertilizer production) (EEA, 2025). At the same time it is also reported by the European Commission and the European Investment Bank that climate-related losses in agriculture are estimated at an average €28.3 billion per year (about 6 percent of production) and are expected to increase sharply by mid-century without stronger adaptation measures (OECD, 2020).

The vision of CSA is thus promoted and increasingly accepted by policy makers to address the challenges of climate change (Chandra et al., 2018). It aims to sustainably maintain or increase productivity, while building its adaptive capacity and reducing GHG emissions (FAO, 2013). The Climate Smart Research project (CSR) aims to accelerate this transition in Europe by developing new climate smart agricultural knowledge, by connecting existing research stations, and by building their capacities to produce high quality and actionable research output.

This deliverable 2.1., within WP2 in CSR is a part of this first step by giving insight into the state of play of climate smart agricultural research in Europe. First, it aims to sketch the evolution of climate smart agricultural research worldwide and in the European scientific community. Secondly, it describes ongoing research on ERSs across Europe. Combining the two, we arrive at an idea of ongoing research, the capacities and gaps in ongoing research on CSA by research stations across Europe. Finally, the report is a first step toward building and strengthening the network between these ERSs by facilitating peer to peer learning and capacity building activities. ERS within and beyond the project will be invited to these activities, the approach and content will be informed by the results of this deliverable.

1.1. Definitions

Climate smart research

In a previous CSR deliverable, a conceptual framework for conducting climate smart agricultural research was developed (Ziv et al., 2026). This framework aims to conceptualize CSA from a holistic, whole-farm perspective, incorporating the pedoclimatic context as well as synergies and trade-offs at the farm level.

The framework was developed in response to the current tendency within European agricultural research to focus on isolated solutions, such as validating a single crop, adaptation measure, or mitigation technique, often without adequately considering interactions with the broader farming system and its context. Within CSR, research and knowledge development attempts to integrate a holistic whole-farm perspective that includes pedoclimatic context, interactions, synergies and trade-offs at farm scale into research design.

The framework builds on the idea that research should move beyond just understanding the problem, towards questioning how to create real actionable, transformative change (Fazey et al., 2018). This means it ought to be relevant and suitable to farmers' and advisors' realities who wish to incorporate climate smart practices in the future. For this reason, transdisciplinary and system-oriented research design are central to this research framework (Rossing et al., 2021; Ziv et al., 2026). The framework also stresses the need for reflexivity of the researcher and capacity building to improve skills in research and innovation design with the goal to close the Research Practice Gap (RPG). Lastly, it is important to intentionally set priorities when designing climate smart research covering all three pillars (adaptation, productivity, mitigation) as well as the role of ecosystem services (Thornton et al., 2018; Ziv et al., 2026).

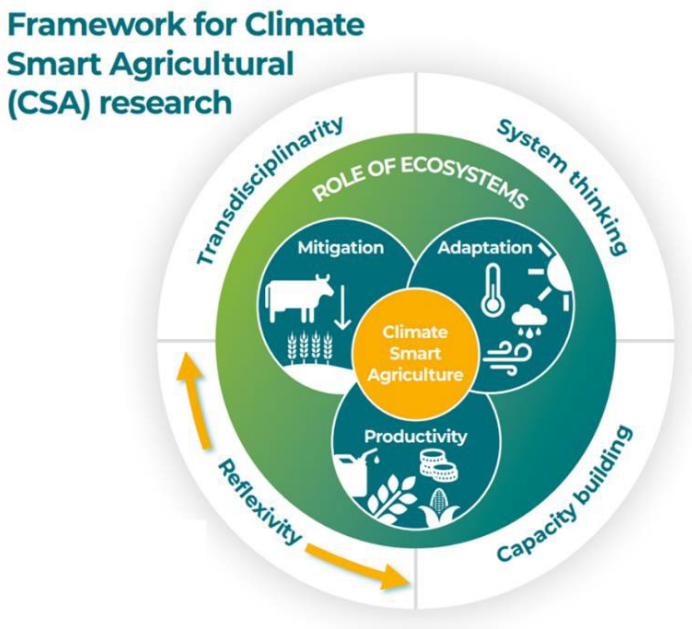


Figure 1. Principles for Climate Smart Agriculture research (Ziv et al,. 2026).

To strengthen the capacity of the ERSs involved in this project, as well as those beyond it, this framework is used as the blueprint for understanding climate smart research for the present report. Building on this foundation, we assess the extent to which current research designs align with a holistic climate smart approach and describe their key strengths and weaknesses in the design and implementation of climate smart agricultural research.

Climate smart research and innovation design

The framework for conducting 'good' climate smart research requires certain methodological approaches. Climate smart research and innovation design refers to the methodological approaches through which ERS generate, and test knowledge and innovations addressing climate change

mitigation, adaptation, and the possible synergies or trade-offs between these pillars. Following the abovementioned framework this speaks to transdisciplinary design of research, systemic-oriented design (i.e. the susceptibility of interactions such as trade-offs between measures, scales or pillars) and the incorporation of reflexivity into the design of the study.

Capacities

Capacities are the specific knowledge, skills, and attitudes that enable researchers to develop and implement climate smart agricultural research and innovation initiatives that accelerate the uptake of research findings in practice and contribute to the transition toward climate-neutral farming with resilient and dependable production outcomes. The capacities that we focus on in this report are transdisciplinary, system-oriented and reflexive study design with the objective of closing the RPG.

Experimental research station

An ERS is an agricultural research infrastructure where empirical research and innovation activities are conducted under conditions that are relevant to real farming systems, generating scientific evidence on CSA practices and supporting their validation, adaptation, and uptake in commercial agriculture. Within CSR we partner with 29 ERSs to help build their capacities to conduct climate smart agricultural research. The two surveys are a first exploration into their current CSA research practices.

2. Methodology

2.1. Exploratory literature review

This study employs an exploratory literature review to give insight into the concept of CSA giving insight into the origin of the concept just as evolvement on global and European level. It answers the question: *"How has the concept of climate smart agriculture emerged and evolved within global institutional discourse, and how has it been translated into European agricultural research and innovation?"* Given the multiple objectives of this exploratory literature review, an iterative search strategy was adopted, combining multiple search queries to identify both conceptual and empirical literature. The literature search was conducted in July 2026 using Google Scholar. Multiple search queries, each serving a distinct purpose, were employed.

The initial search aimed to gather literature on CSA from a global, policy, and historical perspective. It was conducted using the keywords *"climate-smart agriculture"* and related variations. Search results were presented according to Google Scholar's relevance ranking and screened by the researchers based on title and abstract, up to page 50. This cut-off was applied because the search produced more than 17,000 results and the relevance of the retrieved articles to the global, policy and historical dimensions of CSA progressively declined after the first 50 pages. 24 publications were selected based on their relevance to the research objectives, an additional 6 were included by reviewing the references cited in these studies. During this initial stage, empirical case studies on the implementation of CSA were excluded in order to focus on conceptual and policy-oriented literature.

Subsequently, the same search query was repeated with the results restricted to systematic review articles. The purpose of this search was to identify comprehensive reviews and syntheses of the existing body of knowledge on CSA. These results were likewise presented to the researchers by Google Scholar's algorithm by relevance and screened according to relevance to conceptualization of CSA, historical evolution, policy, Europe related CSA research. Additionally, bibliometric analyses were identified to map the existing body of CSA research. A search using the terms *"climate-smart agriculture"* and *"bibliometric analysis"* was conducted. Together the systematic reviews and the bibliometric search resulted in another 10 relevant articles.

Finally, a third search strategy was employed to map empirical CSA research within Europe. To identify empirical evidence, an additional search was conducted using the query *allintitle: "climate-smart agriculture" "case study"*, ensuring that climate smart agriculture was explicitly identified as the primary focus of the publication. Furthermore, this search strategy was repeated for each individual European country, including the United Kingdom, by combining *allintitle: "climate-smart agriculture"* with the name of each country. These additional searches aimed to identify country-specific case studies that might not have been retrieved through the broader European search. Another 7 studies were retrieved.

To limit the amount of literature for this exploratory study, only studies explicitly addressing climate smart agriculture were included and only English-language A1 publications were included; book chapters and grey literature were excluded. The only exceptions were the book chapter by Lipper and

Zilberman (2018) and the FAO (2013; 2021) publications on CSA which were included because they are considered seminal contributions to the historical development of the CSA concept. The search strategy was applied iteratively, with search terms being refined where necessary and additional relevant references identified through the references of selected publications being considered for inclusion. The final selection of the publications was performed by the researcher and was based on the title, abstract, and the full text when necessary. A publication was considered relevant by the researcher if it addressed one or more of the following aspects:

- the conceptualization and definitions of CSA;
- the historical evolution of the CSA concept;
- bibliometric analyses of CSA research;
- systematic reviews of the CSA concept;
- the integration of CSA into European or national policies;
- the implementation and development of CSA within Europe;
- scientific research on CSA in a European context.

Studies focusing exclusively on case studies conducted outside Europe were excluded from the review. In total, 30 publications were included that covered the conceptualization of CSA, the historical evolution of CSA, policy related issues or applied CSA research in EU context (mostly on the adoption issue). Additionally, 10 systematic literature reviews and bibliometric analyses on CSA were included. And finally, 7 European empirical case studies were identified and consulted.

2.1.1. Limitations

This exploratory literature review has several limitations that should be considered when interpreting the findings. First, the search was conducted exclusively through Google Scholar. Although Google Scholar provides broad coverage of academic publications, its search algorithm is proprietary and not fully transparent. Consequently, search results may vary depending on factors such as indexing updates, location, user search history, and the timing of the search, limiting the reproducibility of the search strategy compared with systematic literature reviews conducted in databases with transparent and replicable search procedures. Relevant publications may therefore have been overlooked, particularly those appearing beyond the first 50 pages of search results. To mitigate this limitation, the review did not rely solely on Google Scholar's relevance ranking. The reference lists of selected publications were manually screened to identify additional relevant studies that may not have been captured in the initial search. Nevertheless, because the review was not conducted according to a systematic review protocol, such as PRISMA, the body of literature included cannot be considered exhaustive. The findings should therefore be interpreted as exploratory rather than comprehensive.

Secondly, the search strategy deliberately required the explicit use of the term ‘climate smart agriculture’. This criterion ensured that the reviewed literature directly engaged with the CSA concept, but it also excluded studies describing similar practices under alternative concepts such as agroecology, sustainable intensification, regenerative agriculture, conservation agriculture, or climate adaptation in agriculture. Consequently, the review may underestimate the extent to which CSA-related principles are embedded within European agricultural research without being labelled as CSA.

Furthermore, almost exclusively English-language peer-reviewed (A1) publications were included. This exclusion of publications in other languages and most grey literature may have limited the representation of national research, policy reports, and practical experiences, particularly given the diversity of European agricultural research systems.

2.2. Surveys

2.2.1. Survey design and distribution

To gain insight into current CSA research across Europe, two online surveys were conducted among ERSs. The surveys were designed to collect information on current research activities, priorities, and perceptions regarding CSA. The first survey (S1) consisted of 26 questions and was designed using Microsoft forms. The survey questions first inquired into general information on the research institutes. Consequently, they went into the ongoing climate related agricultural research of the research stations, followed by questions on transdisciplinarity, systems thinking and reflexivity. Finally, the survey also served as an invitation to future events and activities that will be organized within CSR context. The S1 distribution was coordinated through multiple partner organizations to utilize direct national relations between CSR ERSs and their network to increase the likeliness of a response. This action also aimed to incentivize the ERSs to join the CSR network for knowledge exchange events such as online masterclasses and (intern)ational events. However, tracking this network distribution proved too difficult for establishing a reliable response rate.

The second survey (S2) followed a similar questionnaire design. This survey targeted PioneERS and InnovatERS participating in the CSR project and focused on research and innovation design in climate-smart related research projects. S2 followed a similar questionnaire design as S1 but went into more detail about CSA topics, research and innovation design and methodologies, transdisciplinarity, systems thinking and reflexivity. It also inquired about the perceptions of researchers on the RPG. Finally, it also aimed to get insight into their interests for further capacity building events organized by WP2 in CSR. S2 was designed using Limesurvey and was sent directly to its respondents (the 29 participating ERSs; 10 Pioneers and 19 InnovatERS) of CSR. The response rate was 100% percent. It is noted however that one ERS did not complete the survey in its entirety, leaving the last 10 questions unanswered.

2.2.2. Survey sample

S1 generated 69 valid responses from agricultural research organizations across Europe. The geographical distribution of responses was uneven, with most responses originating from France (n = 26) and Romania (n = 19). The remaining responses were distributed across several other European countries, although in considerably smaller numbers: Belgium (n = 3), Croatia (n = 1), Cyprus (n = 2), Hungary (n = 1), Ireland (n = 6), Lithuania (n = 1), Netherlands (n = 3), Norway (n = 1), Portugal (n = 1), Scotland (n = 2), Spain (n = 2), United Kingdom (n = 1).

The participating infrastructures can be broadly classified into five dominant categories. Of the 69 survey responses, the majority represented livestock research farms, arable crop research stations and horticultural research stations. A smaller proportion represented integrated crop-livestock systems and controlled-environment or laboratory-based research infrastructures. The different types of research centers and their respective share of the total respondents is listed below.

1. Arable and crop research stations (+- 29,6% of the sample)**:** typical research activities include crop variety testing and breeding, tillage and soil management, precision agriculture and digital farming, irrigation and climate adaptation research and some long-term cropping system experiments.
2. Horticultural and perennial crop stations (+-15,3% of the sample): research topics include orchard management, greenhouse production, precision irrigation, fertigation and germplasm conservation.
3. Integrated crop-livestock experimental research stations (+-16,3% of the sample)**:** research topics include whole-farm system design, mixed crop-livestock interactions, agroecological and organic transition pathways, and biodiversity management.
4. Livestock research farms (dairy, beef, sheep, goats, pigs, poultry) (+-31,6% of the sample): research topics include grazing system research, feed efficiency studies, methane emissions monitoring, automated milking systems and animal health and welfare research.
5. Controlled-environment, laboratory and technology-focused research stations (+-7,1% of the sample)**:** research topics include plant response to climate change, soil and ecosystem functioning, plant-microbe interactions, plant breeding, biodiversity research, and technology validation.

The ERSs that participated in the S1 are mainly research institutes with a strong reliance on public funding across the surveyed research units. Of the 69 respondents, 56 (81%) reported being funded mainly through public sources, while only 3 respondents (4%) indicated that their activities are funded mainly through private sources. A further 10 respondents (14%) reported a roughly equal balance between public and private funding. In terms of the origin of this funding, 33 out of the 69 respondents (47.8%) identified national funding as their primary source of support, making it the most common funding model. A further 29 respondents (42.0%) reported relying on a balanced mix of local, national, and European funding, indicating strong integration into regional, national, and international funding frameworks. Only 6 respondents (8.7%) reported depending mainly on local or regional funding, while just one respondent (1.4%) selected another funding source.

S2 targeted all the 29 ERSs participating in the CSR project distributed across 24 countries, with Spain being the most represented country (n = 3), followed by Belgium, France and the United Kingdom (n = 2). The remaining countries are represented by one research station each, illustrating a broad geographical coverage across Northern, Western, Southern and Eastern Europe, as well as participation from New Zealand. The participating infrastructures cover a diverse range of research domains. Livestock research farms form the largest category (approximately 11 stations), focusing on dairy, beef, sheep and pig production systems. Arable and crop research stations represent the second largest group (approximately 8 stations), conducting research on crop production, soil management and climate-smart cropping systems. Around 5 stations operate integrated crop-livestock systems, while another 5 specialize in controlled-environment experimentation or technology and precision agriculture.

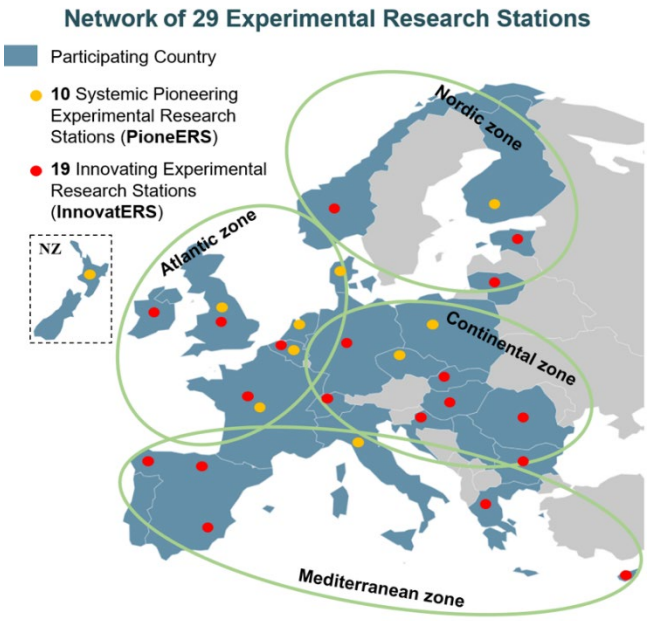


Figure 2. Visual representation of the experimental research stations participating in CSR.

The sample of 29 research stations is dominated by public-sector research infrastructures and is funded predominantly by public funding sources. Nearly half of the stations (n = 14) are operated by public research organizations, while more than a quarter (n = 8) are affiliated with universities. And, of the 29 participating research stations, 24 reported that their research is funded mainly through public funding. Hybrid organizations, combining characteristics of public, academic, and/or private actors, account for 5 stations of the sample. Only a small proportion of participating research stations are privately operated (n = 2). Financially speaking only 5 stations indicated a roughly equal balance between public and private funding. None of the respondents identified private funding as their primary source of support.

2.2.3. Data analysis

Survey data were analyzed using Microsoft Excel. Given the exploratory nature of the surveys and the relatively small sample sizes, the analysis focused primarily on descriptive statistics, including frequencies, percentages, and simple cross-tabulations where appropriate. The objective was to identify general trends and patterns in the responses rather than to conduct inferential statistical analyses or establish causal relationships. The qualitative data were analysed independently by the researcher. During the analysis process, Microsoft Copilot (Enterprise) was used as a supporting tool. As this version operates within a secure institutional environment and does not use user-provided data to train AI models, the confidentiality of the research data was maintained. Copilot was used solely to assist in identifying patterns, organising and structuring textual data, and supporting the analytical process. All coding, analytical decisions, interpretations, and conclusions were made independently by the researcher. The prompt used for categorizing the qualitative data of the survey questions was the following: *"I have developed a various categories (x, y, z...n) for analyzing qualitative survey responses. The categories were developed by me and must not be changed. I want you to act as a critical second reader of my categorization, give feedback and categorize all the answers accordingly."*

2.2.4. Limitations

Several limitations should be considered when interpreting the survey findings. First, because the surveys were distributed through the CSR consortium partners rather than through a systematic sampling strategy, the sample cannot be considered representative of agricultural research organizations across Europe. The uneven geographical distribution of responses—particularly the strong representation of France and Romania in the first survey—may have influenced the observed patterns. Additionally, the relatively limited number of responses means that the survey results should be interpreted as exploratory rather than representative. The surveys are therefore used to identify broad trends and complement the findings from the literature review and the document analysis, rather than to provide statistically generalizable conclusions.

Second, because the total number of organizations that received the survey is unknown, no response rate could be calculated, making it impossible to assess potential non-response bias.

3. Exploratory literature review of climate smart agriculture and research in Europe

This literature review first traces the emergence and conceptual development of CSA, examining its underlying principles, the range of practices associated with the concept, as well as the key criticisms and remaining knowledge gaps identified in the literature. It then provides an overview of the current state of CSA research, highlighting major research trends and developments. Finally, the review focuses on the European context, examining how CSA has been interpreted and operationalised within European agricultural research and policy. Particular attention is given to the practices most commonly associated with CSA in Europe, the emphasis on the adoption of climate-smart practices, and the business strategies and value creation mechanisms that support the transition towards more climate-resilient agricultural systems.

3.1. Climate smart agriculture: Global history and conceptualization

3.1.1. The emergence of climate smart agriculture

CSA is a conceptual framework and management approach introduced by the Food and Agriculture Organization (FAO) in 2009 to address the interlinked challenges of food security and climate change (Lipper & Zilberman, 2018). It is defined by three main objectives, often referred to as the "triple-win" pillars: sustainably increasing agricultural productivity and incomes, building resilience and adapting to climate change, and reducing or removing greenhouse gas (GHG) emissions where possible. Rather than constituting a new agricultural system or a fixed set of farming practices, CSA is intended as an integrated approach for identifying management strategies that are appropriate to specific contexts (Lipper et al., 2014). The concept was innovative at the time because it articulated a relationship between agriculture and climate change that recognized the need for both mitigation and adaptation strategies, while emphasizing the potential synergies between these objectives (Neufeldt et al., 2013).

CSA drew attention to the relationship between agriculture and climate change by emphasizing that agriculture both requires adaptation to climate change because it is highly vulnerable to its impacts and contributes significantly to greenhouse gas emissions (Lipper et al., 2014). By linking agriculture, food security, and climate change within international policy discourse the FAO sought to mobilize new sources of climate finance for sustainable agricultural development under the umbrella of CSA (Lipper & Zilberman, 2018). This development was not coincidental. Around the same time, the IPCC Fourth Assessment Report (Smith et al., 2007) demonstrated that agriculture possessed substantial technical and economic potential to mitigate climate change, particularly through soil carbon

sequestration, improved cropland management, and improved livestock management. This scientific evidence provided an important rationale for linking agriculture to mitigation finance, including carbon markets, by presenting agriculture as part of the solution to climate change rather than solely as one of its victims (Lipper & Zilberman, 2018; Chandra et al., 2018).

Following the emergence of the CSA discourse in 2009 and the first global conference held in The Hague in 2010, the concept quickly gained prominence within the agricultural development community. Numerous development projects around the world were subsequently labelled as climate smart agriculture initiatives. However, the broad formulation of CSA's three pillars provided limited guidance for practical implementation, leading to considerable ambiguity and critique civil society organizations (Taylor, 2018).

3.1.2. Key features of the CSA concept: efficiency and resilience

From its inception, CSA has sought to integrate its three objectives by recognizing trade-offs while maximizing synergies through policy, institutions, and financing mechanisms (Chandra et al., 2018; Lipper & Zilberman, 2018). As mentioned, initially little methodological guidance was provided on how these three objectives should be prioritized or balanced in practice (Chandra et al., 2018). To address this gap, the FAO published the Climate-Smart Agriculture Sourcebook in 2013 (FAO, 2013), which aimed to clarify the concept. In this sourcebook, two principals were emphasized as central to the CSA framework. The first is increasing resource-use efficiency, and the second is enhancing the resilience of agricultural systems and livelihoods. Particularly the former closely connects the CSA discourse to sustainable intensification (SI), another influential concept in agricultural development (Lipper & Zilberman, 2018; (Campbell et al., 2014). Resource-use efficiency is central to both SI and CSA because reducing inputs while maintaining or increasing productivity can improve farmers' net incomes, thereby creating a potential synergy between productivity and climate change mitigation (Lipper & Zilberman, 2018). More broadly, CSA emerged from the sustainable intensification discourse, and the two concepts therefore share a common narrative centered on responding to interconnected global challenges – including population growth, food insecurity, and climate change – that encouraged policymakers, multilateral organizations, and researchers to seek more efficient ways of increasing agricultural productivity (Chandra et al., 2018).

The second cornerstone of the CSA framework is enhancing the resilience of food and agricultural systems, although this concept remains remarkably vague (Lipper et al., 2014). The FAO defines resilience as the capacity of systems, communities, households, or individuals to prevent, mitigate, cope with, recover from, and adapt to shocks and long-term environmental change while sustaining their essential functions over time (FAO, 2013). According to the FAO, resilience and efficiency are complementary objectives that should be pursued simultaneously:

> *"Being efficient without being resilient will not be helpful over the long term, given that shocks will occur more often due to climate change. Being resilient without being efficient or without allowing for an increase in production, will pose problems for ensuring food security over the long term and for supporting livelihoods." (FAO, 2013, p. 22)*

Although resilience constitutes a central pillar of CSA, it remains difficult to define, measure, monitor, and evaluate, and is therefore often overlooked in practice (Bazin et al., 2026). Consequently, many researchers and policymakers have interpreted CSA primarily as a collection of technological innovations, including digital agriculture, precision agriculture, and improved crop varieties, placing greater emphasis on productivity and mitigation because these objectives are more readily quantified (Bazin et al., 2026).

CSA Pillar 1: Sustainably increasing agricultural productivity and incomes		
1.A	**Increasing agricultural productivity** Any improvements in the productivity or efficiency of food production systems; expressed as food production per unit area or per unit of a specific input.	Productivity
1.B	**Increasing food producers' incomes** Any improvements in incomes or profitability at household, farm or product level; expressed as household income, net revenue per unit area, internal rate of return, etc.,	Income
1.C	**Social and environmental sustainability**[5] Based on the aim of CSA Pillar 1 to achieve increases in productivity and incomes 'sustainably'. While economic sustainability is represented in Objectives 1.A and 1.B, this objective captures relevant aspects of social and environmental sustainability, e.g. food security, social equality, biodiversity and ecosystem services.	Soc./Env. sustainability

CSA Pillar 2: Adapting and building resilience to climate change		
2.A	**Improving climate risk mitigation strategies for food producers' livelihoods** Any improvements in livelihood resilience to climate impacts derived from mitigation strategies such as diversification or microinsurance; expressed as income stability, change in unsustainable coping strategies, etc.	Livelihood resilience
2.B	**Adapting food production systems to current and expected future climate change** Any technical or agronomic adaptation measures that aim to reduce exposure and sensitivity to physical impacts of climate change, as well as to exploit opportunities offered by changing climate conditions, e.g. use of improved varieties, adoption of irrigation, change of crop or livestock species or construction of dykes; expressed as yield stability, area under irrigation, etc..	Production system adaptation
2.C	**Increasing the resilience of agro-ecosystems** Any improvements in the resilience of food production systems to climate impacts derived from the enhancement of ecosystem functions and services, e.g. species diversification, increasing structural diversity and natural habitats or improving soil health; expressed as yield stability, damage from climate-related disasters, etc.	Agro-ecosystem resilience

CSA Pillar 3: Reducing and/or removing greenhouse gas emissions, where possible		
3.A	**Increasing carbon stocks in soils and biomass** Any measures to conserve or enhance terrestrial or marine carbon sinks at field, farm, landscape or seascape level; expressed as carbon stock per unit area, area reforested, area of carbon-rich ecosystems conserved, etc.	Carbon stocks
3.B	**Reducing emission intensities of agricultural products** Any improvements in GHG emission per unit of product or unit area at product, field, farm, landscape or national level; expressed as emissions of individual GHGs per unit or emissions of carbon dioxide equivalent (CO_2eq), i.e. global warming potential (GWP) per unit.	Emissions
3.C	**Replacing fossil fuels with renewable energies** Volume of renewable energy production, as far as related to agriculture. This includes, for example, renewables that are integrated in agricultural systems (e.g. solar-powered irrigation), or bioenergy and/or bioenergy feedstock that are derived from agriculture. It may also concern the production of renewable energy outside the agriculture sectors, where agriculture competes for the same resources (e.g. hydropower versus irrigated agriculture); expressed as energy production at river basin level, energy content of bioenergy feedstock, biomass yield, etc.	Renewables

Figure 3. Schematic representation of CSA pillars by FAO (FAO, 2021, p.6).

The conceptual development of CSA has continued beyond its initial formulation. International organizations, including the FAO, the World Bank, the Global Alliance for Climate-Smart Agriculture (GACSA), and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), have further refined the framework in response to both practical experience and academic criticism. One important development has been an increased emphasis on ecosystem services following criticism that the original CSA framework did not sufficiently account for broader environmental processes (Akamani, 2021). Likewise, debates concerning the appropriate scale at which CSA should be implemented have contributed to the evolution of the concept (Prestele & Verburg, 2020; Scherr et al., 2012). More broadly, these criticisms have led several scholars to

propose alternative frameworks that seek to make CSA more inclusive and holistic in promoting food system resilience and sustainability, including ‘Climate-Wise Food Systems’ (Taylor, 2018), ‘Vulnerable-Smart Agriculture’ (Azadi et al., 2021), ‘Climate-Smart Landscapes’ (Scherr et al., 2012), and ‘Climate-Resilient Agriculture’ (Hellin et al., 2023).

Despite this initial conceptual ambiguity, and the persistence of multiple interpretations, CSA has evolved over the past decade into a widely recognized framework for agricultural development. Its principles have been incorporated into numerous national and international policy frameworks, including the environmental policy frameworks of many African countries, the European Union's Common Agricultural Policy, the United States Department of Agriculture's Partnerships for Climate-Smart Commodities, China's Agriculture Green Development Initiative, and India's National Mission on Sustainable Agriculture (Torquebiau et al., 2018).

3.1.3. Climate smart agricultural practices

Rather than prescribing a single set of agricultural practices, CSA provides a framework for identifying context-specific management strategies that balance productivity, adaptation, and mitigation objectives across different spatial and institutional scales (Lipper et al., 2014; Prestele & Verburg, 2019; Scherr et al., 2012). Nevertheless, the CSA literature consistently identifies a number of practices that are commonly considered climate-smart. The following sections briefly discuss the principal groups of practices identified in the global CSA literature (Lipper et al., 2014; Steenwerth et al., 2014; Bouri et al., 2023; Gemtou et al., 2024; Kabato et al., 2025; Lee et al., 2024; Martinho & Guiné, 2021; Waheed et al., 2026). These broadly encompass agroecological and cropping practices, soil and nutrient management, water management, livestock management, digital and smart farming technologies, and institutional and policy-based interventions.

Agroecological and cropping practices seek to enhance ecosystem functioning while increasing the diversity and resilience of farming systems, possibly contributing to all the three CSA pillars. These practices include intercropping and crop diversification, which improve soil health while diversifying farmers' sources of income. Agroforestry, through the integration of trees into agricultural landscapes, contributes to carbon sequestration, improves soil fertility, creates favorable microclimates and provides additional products such as timber, fuelwood, and fruit (Kabato et al., 2025). The adoption of improved crop varieties, including drought-tolerant, heat-tolerant, and early-maturing cultivars, enables farmers to adapt to changing climatic conditions. Widening the crop rotation can help improve nutrient cycling, increase soil organic matter and reduces pest and disease pressures, thereby contributing to the resilience and sustainability of cropping systems (Lipper et al., 2014; Steenwerth et al., 2014).

A second group of practices concerns soil and nutrient management, reflecting the recognition that healthy soils are fundamental to both agricultural productivity and climate mitigation. Conservation agriculture, characterized by minimum or no tillage, permanent soil cover, and diversified crop rotations, aims to reduce soil erosion, conserve soil moisture, and increase soil organic carbon. Precision nutrient management, including the "4R" principles – applying the right fertilizer source, at the right rate, at the right time, and in the right place – improves nutrient-use efficiency while reducing greenhouse gas emissions. Similarly, enhanced-efficiency fertilizers, including slow-release fertilizers and nitrification or urease inhibitors, reduce nitrous oxide emissions. Soil amendments such as biochar, compost, and vermicompost further improve soil structure, restore degraded soils, and enhance long-term carbon storage (Lipper et al., 2014; Paustian et al., 2016; Steenwerth et al., 2014; Waheed et al., 2026).

Water management practices have become increasingly important as agriculture faces more variable rainfall patterns and increasing water scarcity. These practices include efficient irrigation technologies, such as drip irrigation, micro-sprinklers, and variable-rate irrigation systems, which optimize water use according to crop requirements. Water harvesting and storage measures, including rainwater harvesting and wetland restoration, increase water availability during dry periods while contributing to groundwater recharge. More recent developments include digital water monitoring, using soil moisture sensors and Internet of Things (IoT) technologies to support real-time irrigation management (Lipper et al., 2014; Steenwerth et al., 2014; Erekalo et al., 2024).

Within livestock management, CSA seeks to improve livestock productivity while reducing greenhouse gas emissions per unit of production. This includes improved feed and grazing management through optimized grazing intensity, high-quality forage species, and feed additives that reduce methane emissions. Precision livestock farming employs sensors and automated feeding technologies to monitor individual animals, thereby improving resource-use efficiency and animal welfare. In addition, measures that improve animal health and resilience, including vaccination programmes and adapted housing systems, enable livestock to better cope with heat stress and changing disease patterns (Steenwerth et al., 2014).

Recent developments within CSA have increasingly emphasized the role of digital and smart farming technologies. Precision agriculture technologies, including drones, GPS-guided machinery, and proximal sensors, enable the more precise application of fertilizers, pesticides, and irrigation, thereby improving resource-use efficiency. At the same time, artificial intelligence and machine learning are increasingly applied to crop yield prediction, pest detection, fruit ripeness assessment, and other decision-support applications, enabling farmers to make more informed management decisions (Mmbando, 2025; Gemtou et al., 2024; Lee et al., 2024; Martinho & Guiné, 2021).

Finally, the literature demonstrates that CSA extends beyond field-level management by incorporating institutional and policy-based interventions that create enabling conditions for the adoption of climate smart practices. Climate information services, delivered through digital platforms or mobile applications, provide farmers with weather forecasts, pest alerts, and sowing recommendations to support climate risk management. Weather index-based insurance offers financial protection against climate shocks through payouts triggered by weather conditions rather than individual damage assessments. Certification schemes and circular bioeconomy initiatives, such as the production of biofuels from agricultural waste, further create economic incentives that encourage the adoption of climate smart practices in the wider value-chain while contributing to renewable energy production and nutrient recycling (Steenwerth et al., 2014; Zhao et al., 2023).

Taken together, these examples illustrate that there is no single practice that can be considered inherently climate-smart. Rather, practices become climate smart depending on how they contribute to the three CSA objectives within a particular social, environmental, and institutional context (Lipper et al., 2014). Consequently, the practices associated with CSA are highly diverse, ranging from agroecological approaches and resource management to digital technologies and policy instruments. This diversity reflects the conceptual flexibility of CSA, which enables context-specific implementation while simultaneously creating ambiguity regarding which practices can legitimately be considered climate smart (Lipper et al., 2014; Chandra et al., 2018; Pathak & Magliocca, 2026).

3.1.4. Critiques of CSA

Although CSA has become firmly embedded in agricultural policy and research, it has also attracted substantial criticism within the scientific literature and among civil society organizations. As mentioned

above there is the risk of CSA rebranding unsustainable practices such as biofuel plantations or crop varieties that require high fertilizer inputs as 'climate-smart' (Torquebiau et al., 2018; Tomar & Singh, 2025). Another recurring critique concerns the largely apolitical framing of the concept. Several scholars argue that CSA primarily emphasizes technical and production-oriented solutions while paying insufficient attention to the broader social, political, and institutional contexts that shape agricultural systems (Taylor, 2018). In particular, critics contend that CSA overlooks persistent inequalities in access to land, resources, and decision-making, as well as the diverse livelihoods, priorities, and aspirations of farmers (Pathak & Magliocca et al., 2026). Similarly, many CSA assessment frameworks adopt a predominantly biophysical perspective, focusing on productivity, and greenhouse gas emissions while neglecting important social dimensions, including gender relations, labor dynamics, and the cultural integrity of rural communities (van Wijk et al., 2020). More critical perspectives, such as those advanced by civil society organization La Via Campesina, argue that CSA risks reinforcing existing corporate-led agricultural models by promoting technological solutions without addressing underlying questions of power, food sovereignty, and the political economy of agricultural production (Taylor, 2018).

A second area of debate concerns the mitigation dimension of CSA and its implications for climate justice. Although mitigation constitutes one of CSA's three central objectives, scholars have questioned whether its implementation disproportionately shifts responsibility for reducing greenhouse gas emissions onto smallholder farmers in developing countries (Lipper & Zilberman, 2018; Steenwerth et al., 2014). In particular, concerns have been raised regarding the promotion of carbon sequestration and carbon offset mechanisms, which may provide limited benefits to farmers while effectively transferring part of the mitigation burden from industrialized countries to those least responsible for climate change. Consequently, critics argue that adaptation and food security objectives risk becoming subordinated to broader global mitigation agendas (Torquebiau et al., 2018).

Finally, the literature highlights the absence of a clear and universally accepted framework for assessing what constitutes "climate-smartness." Although CSA is founded on the three objectives of productivity, adaptation, and mitigation, these objectives are operationalized differently across policies and research projects. As a result, the criteria used to evaluate climate-smartness frequently remain implicit, making it difficult to compare interventions or assess their effectiveness (Taylor, 2018). This conceptual ambiguity is reflected in empirical research, where inconsistent definitions and measurement approaches limit the comparability of findings across geographical and socioeconomic contexts (Lee et al., 2024). A related challenge concerns the spatial and contextual dimensions of CSA implementation. Large-scale assessments often estimate the benefits of climate smart practices using aggregated data, potentially overstating their effectiveness across diverse farming environments (Prestele & Verburg, 2020). Researchers therefore caution against assuming that practices found to be successful at regional or global scales will necessarily produce similar outcomes at the farm level (Bazin et al., 2026). Instead, the effectiveness of climate smart practices depends on local biophysical conditions, farming systems, institutional arrangements, and social networks. Failure to account for these contextual factors may not only reduce the effectiveness of interventions but may, in some cases, even increase farmers' vulnerability to climate change.

3.2. Climate smart research: evolution and persisting knowledge gaps

3.2.1. Evolution of CSA reserach

Since its introduction by the Food and Agriculture Organization (FAO) in 2009–2010, CSA has developed into a rapidly expanding and highly interdisciplinary field of research. Bibliometric studies consistently demonstrate a substantial increase in scientific output over the past decade, reflecting growing international concern about the interconnected challenges of climate change, food security, and sustainable agricultural development (Okolie et al., 2023; Li et al., 2022; Manyike et al., 2025; Zaidi et al., 2024). Between 2012 and 2023, annual publications increased from only a handful of studies to more than 260 publications per year, illustrating the rapid institutionalization of CSA as both a scientific field of research and a global policy framework (Zaidi et al., 2024).

This expansion has been strongly supported by international organizations and funding bodies. According to Zaidi et al. (2024), CGIAR is the largest funder of CSA research, followed by USAID, the European Commission, IFAD, and the Australian Centre for International Agricultural Research. Likewise, Li et al. (2022) show that four of the five most influential authors in the field are affiliated with international organizations rather than universities, including the FAO, the IPCC, and the World Bank. At the same time, scholars and institutions from developing countries remain comparatively underrepresented among the leading contributors to CSA research. Together, these findings suggest that international organizations have played a decisive role in shaping the development of the CSA research agenda (Li et al., 2022). Geographically, the United States is the most productive country in terms of scientific output, followed by Kenya and India (Zaidi et al., 2024).

As the field has expanded, CSA research has also become increasingly interdisciplinary, spanning environmental sciences, agricultural sciences, development studies, business and economics, and plant sciences (Li et al., 2022). The evolution of the literature further reflects a gradual shift in research priorities. According to Li et al. (2022), studies published between 2010 and 2012 primarily focused on defining and conceptualizing the CSA framework. Between 2013 and 2015, research increasingly explored the relationships between food security, adaptation, mitigation, and agricultural development. Since 2016, however, attention has shifted towards implementation, with growing emphasis on technology adoption, policy interventions, household-level impacts, soil health, carbon management, and productivity improvements. More recently, emerging technologies—including digital agriculture, precision farming, artificial intelligence, Internet of Things (IoT) applications, drones, and smart farming systems—have become prominent themes within the CSA literature (Lee et al., 2024; Manyike et al., 2025).

3.2.2. Characteristics of CSA reseach

Despite the rapid growth of the field, many of the conceptual ambiguities surrounding CSA remain evident within the scientific literature. In the academic literature there is still no universally accepted understanding of what constitutes as CSA or which practices should be considered climate smart (Chandra et al., 2018; Pathak & Magliocca, 2026). CSA has been variously described as a framework, strategy, development approach, collection of practices, or technological innovation. Furthermore, several authors argue that many practices currently labelled as climate-smart—including agroforestry, conservation agriculture, soil and water conservation, and grazing management—predate the emergence of CSA, suggesting that the concept often functions as an umbrella term for existing sustainable agricultural practices (Chandra et al., 2018).

This conceptual ambiguity is also evident in how CSA is studied in the scientific literature. Pathak and Magliocca (2026) found that only four of the thirty-two reviews they analyzed explicitly examined how the three CSA objectives interact with one another. Most studies instead assumed that CSA practices can simultaneously increase productivity, strengthen climate resilience, and reduce greenhouse gas emissions, treating CSA as a straightforward "triple-win" approach. As a result, relatively little

attention was given to the context in which practices are implemented, the trade-offs that may arise between objectives, or the challenges of achieving multiple goals at the same time.

The literature reveals clear geographical differences in the focus of CSA research. Studies on the Global South have predominantly concentrated on rural and traditional farming systems, with productivity remaining the most extensively researched dimension of CSA (Chandra et al., 2018; Pathak & Magliocca, 2026). This emphasis reflects the historical priorities of major international organizations, including the FAO, the World Bank, and CGIAR, which have focused on improving agricultural productivity and food security in developing countries (Pathak and Magliocca, 2026). In contrast, CSA research in the Global North is more strongly associated with climate risk management (Chandra et al., 2018), a difference attributed to the greater institutional and scientific capacities of these countries to develop long-term climate strategies (Chandra et al., 2018). Consequently, mitigation receives greater attention than adaptation, reflecting current European policy priorities (Totin et al., 2018; Zhao et al., 2023), although adaptation has become an increasingly prominent research theme in recent years (Chandra et al., 2018). These geographical differences are also reflected in the practices being studied, with European research placing greater emphasis on advanced technological innovations such as precision agriculture, drones, sensors and the Internet of Things (IoT) applications (Pathak & Magliocca, 2026; Zhao et al., 2023).

3.2.3. Persisting knowledge gaps

Despite the rapid expansion of CSA research, several knowledge gaps emerge consistently across recent reviews and bibliometric studies. First, there remains limited understanding of the barriers that influence the scaling-up of CSA interventions across different contexts (Zaidi et al., 2024). For example, Adamides et al. (2020) identifiy a lack of scientific knowledge and practical implementation tools for CSA in Cypriot livestock systems, illustrating how research and infrastructure gaps can limit adoption. Second, although CSA research has become increasingly implementation-oriented, it continues to exhibit a predominantly technological, production-oriented, and biophysical focus. Most studies examine the adoption of climate smart technologies, management practices, and their effects on agricultural productivity, while comparatively little attention is paid to broader social dimensions such as farmer participation, governance, social equity, gender relations, market institutions, livelihood aspirations, and decision-making processes (Chandra et al., 2018; Martinez-Baron et al., 2018; Pathak & Magliocca, 2026; Manyike et al., 2025). Consequently, although CSA originated as a largely top-down policy discourse, farmer-centred perspectives remain underrepresented within the literature. Comparatively few studies investigate how farmers themselves understand CSA, how they participate in shaping research agendas, or how their goals, decision-making processes, and livelihood aspirations influence the development and implementation of climate smart innovations (Chandra et al., 2018; Pathak & Magliocca, 2026; Steenwerth et al., 2014).

A third and more fundamental knowledge gap concerns the systemic character of CSA interventions. Although CSA promotes integrated adaptation and mitigation strategies that seek to create synergies while minimizing trade-offs, relatively little is known about how combinations of practices interact within specific social, ecological, spatial, temporal, and institutional contexts (Chandra et al., 2018; Erekalo et al., 2024). Research suggests that the effectiveness of CSA depends not on individual practices, but on identifying appropriate combinations of interventions suited to local conditions (Sala et al., 2016). Nevertheless, most empirical studies continue to evaluate individual technologies and practices in relation to one or more of the three CSA objectives, providing only limited insight into the interactions and trade-offs between different interventions (Pathak & Magliocca, 2026).

Closely related to this challenge is the absence of standardized approaches for assessing "climate-smartness." Researchers continue to call for common evaluation frameworks capable of assessing the effectiveness of CSA interventions, balancing trade-offs between productivity, adaptation, and mitigation, and comparing environmental and sustainability outcomes across different contexts (Li et al., 2022).

Consequently, recent reviews increasingly advocate participatory and systems-based approaches that move beyond the diffusion of individual technologies towards collaborative forms of knowledge production involving farmers, researchers, extension services, policymakers, and other stakeholders (Pathak & Magliocca, 2026; Steenwerth et al., 2014).

3.3. Climate smart agricultural research and innovation in Europe

Geographically, CSA research within Europe is unevenly distributed, with most studies originating from Central, Northern, and Southern European countries, while Eastern European farming systems remain comparatively underrepresented in the scientific literature (Gemtou et al., 2024; Erekalo et al., 2024). A similar geographical pattern emerges from the analysis of CSA projects funded under the Seventh Framework Programme (FP7), Horizon 2020 (H2020), and the Competitiveness and Innovation Programme (CIP). Fusco et al. (2020) found that the distribution of EU-funded CSA projects largely mirrors the geographical distribution of scientific publications, suggesting that research capacity and funding opportunities are concentrated in the same regions. At the same time, CSA has gained considerable momentum across Europe over the past decade. Gemtou et al. (2024) show in figure 6 how publications on CSA were limited between 2012 and 2016 but increased steadily from 2017 onward, peaking in recent years. Nearly half (49%) of the reviewed studies were published between 2020 and 2022, highlighting growing research interest in this field; although publication numbers declined slightly to 15 studies in 2023, and up until March 2024, four studies had been published. Likewise, Fusco et al., (2020) observed a substantial rise in EU-funded CSA projects between 2009 and 2019, with project activity reaching its peak between 2016 and 2018. Together, these findings indicate both a rapid expansion of CSA research and persistent geographical disparities in where research activities and funding are concentrated.

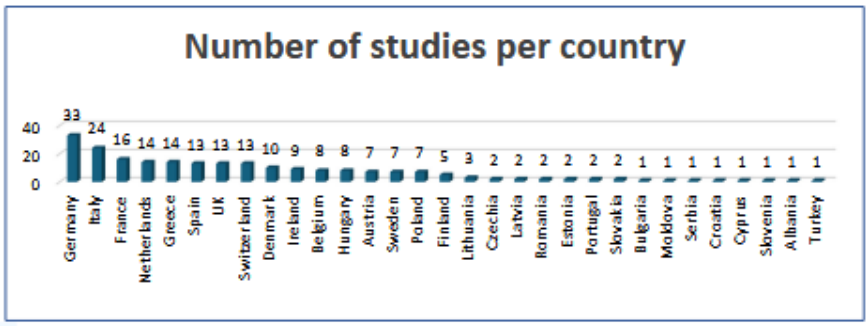


Figure 4. Number of farm-level studies on CSA published per country between 2012 - 2024 (Gemtou et al., 2024).

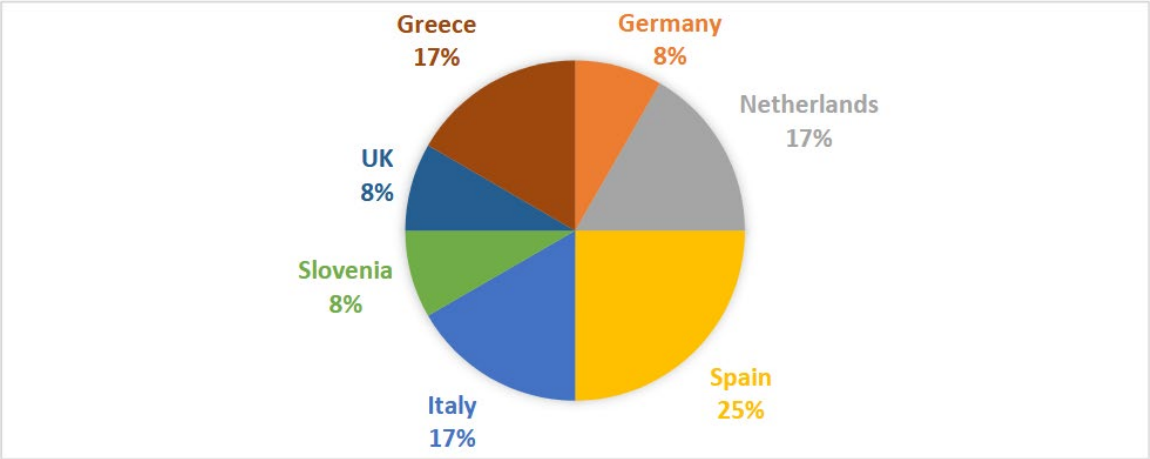


Figure 5. Countries involved as coordinators of the EU projects (Fusco et al 2020).

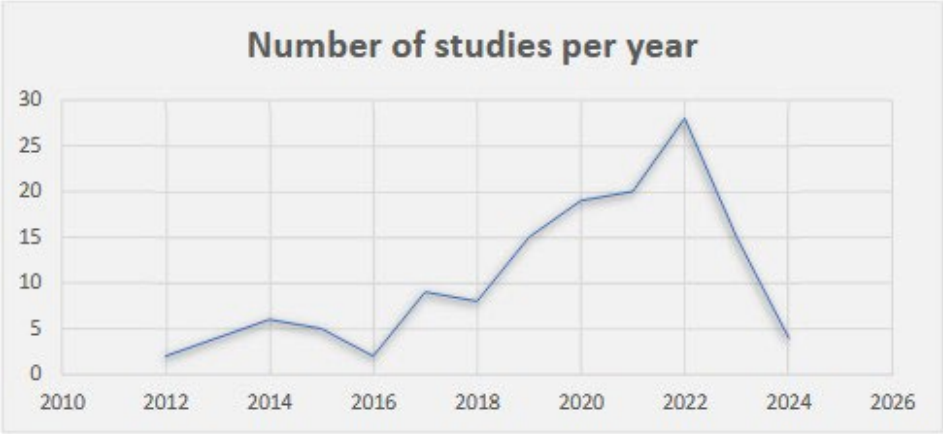


Figure 6. Number of farm-level CSA studies published in the EU per year (Gemtou et al., 2024).

Although the global literature on CSA has predominantly focused on Africa, Asia, and Latin America, the concept has become increasingly embedded within the European Union's broader sustainability agenda (Tomar & Singh, 2025). CSA is not addressing food security as its primary objective, but it has largely evolved around the challenge of maintaining agricultural productivity while reducing greenhouse gas (GHG) emissions and strengthening resilience to climate change. This interpretation closely aligns with the objectives of the European Green Deal, the Farm to Fork Strategy, the EU Biodiversity Strategy for 2030, and the Common Agricultural Policy (CAP) 2023–2027, all of which seek to reduce the environmental footprint of agriculture through lower chemical inputs, biodiversity conservation, increased organic farming, and the achievement of climate neutrality by 2050.

In contrast to the Global South, where CSA research has primarily focused on enhancing agricultural resilience and food security, European CSA research is generally oriented towards climate mitigation, resource-use efficiency, and climate risk management within already highly productive agricultural systems (Gemtou et al., 2024; Chandra et al., 2018). Within this context, technological innovation such as precision agriculture, digital decision-support systems and other smart framing technologies are in the EU frequently presented as a key mechanism for delivering climate-smart outcomes (Erekalo et al., 2024; Gemtou et al., 2025; Fusco et al., 2020; Isakhanyan et al., 2024). Not

surprisingly, most funded climate smart agricultural projects in Europe focused on the development of digital and precision agriculture technologies, including robotics, sensors, remote sensing, big data analytics, cloud computing, digital decision-support systems, and smart irrigation (Fusco et al., 2020).

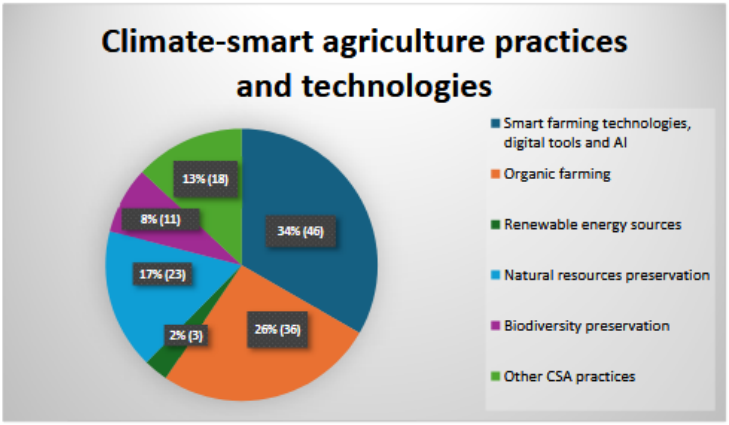


Figure 7. Climate smart agricultural practices and technologies (Gemtou et al., 2024).

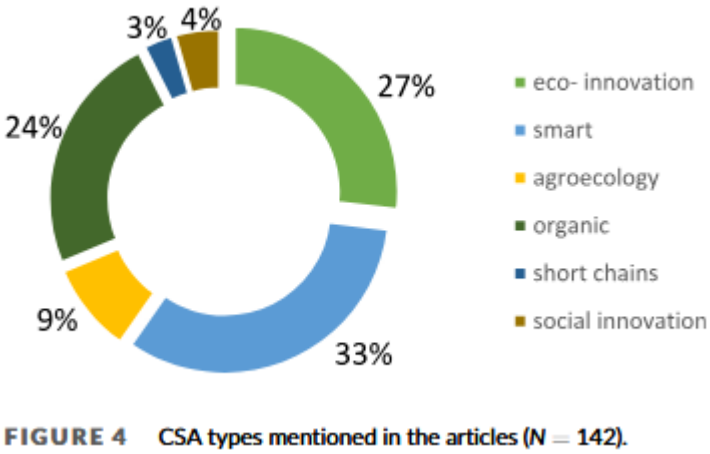


FIGURE 4 **CSA types mentioned in the articles (*N* = 142).**

Figure 8. CSA types mentioned in the articles (Isakhanyan et al., 2024).

This technological orientation is reflected across numerous national case studies. In France, satellite data and remote sensing are integrated with agricultural models to support precision farming and resource-efficient decision-making under climate uncertainty (Long et al., 2015). In the Netherlands, energy-efficient LED horticultural lighting has improved both productivity and resilience by reducing energy consumption and heat loads, while in Cyprus agricultural robots have been introduced to optimize pesticide application and reduce chemical inputs (Long et al., 2015). Beyond digital technologies, Switzerland illustrates how circular agricultural systems contribute to CSA through the conversion of agricultural waste into renewable energy and recycled fertilizers, thereby reducing emissions and closing nutrient cycles (Long et al., 2015). Together, these examples demonstrate that European CSA extends beyond precision technologies alone, encompassing a broader range of technological and circular innovations aimed at improving resource efficiency and environmental performance.

However, a systematic review on identifying CSA practices in Europe by Erekalo et al. (2024) also demonstrates that European CSA extends beyond digitalization alone, encompassing agroecological practices such as crop diversification, cover cropping, and legume integration. The review identified 74 climate smart practices, with approximately 70% of the literature focusing on crop production, while the remainder addressed livestock systems and integrated farming. Frequently studied crop-based practices in Europe include crop rotation, cover cropping, conservation tillage, crop diversification, integrated pest management, precision nutrient and irrigation management, and biofertilizer application. Livestock research primarily examines manure management, precision livestock technologies, forage improvement, feed additives, and grazing management, whereas integrated farming studies focus on organic farming, mixed farming, and diversified production systems. Across these sectors, practices are commonly evaluated in terms of their contribution to productivity, resilience, greenhouse gas mitigation, biodiversity, water-use efficiency, energy-use efficiency, and animal welfare (Erekalo et al., 2024).

Although the meta-analysis by Erekalo et al. (2024) highlights a wide variety of climate smart practices and technologies, several approaches consistently emerge as particularly promising in the literature. In crop production, legume-based cover crops, crop rotation, intercropping, crop diversification, and conservation tillage are associated with improvements in soil health, carbon sequestration, biodiversity, resilience, and reductions in fertilizer use and greenhouse gas emissions while maintaining agricultural productivity (Erekalo et al., 2024; see also Drosou et al. (2026) for a case study in Lithuania). Within livestock systems, improved grazing management, forage production, legume-based feed additives, precision livestock technologies, and manure management practices—including composting, slurry acidification, and biogas production—are identified as effective strategies for improving productivity while reducing methane emissions and generating renewable energy (Erekalo et al., 2024). For the use of smart technologies, especially technologies targeting fertilization, crop protection and irrigation, have a promising potential contribution to achieve the contextualized CSA objectives, according to Erekalo et al. (2024). Finally, studies on integrated farming systems suggest that organic farming, mixed farming, and diversified production systems can strengthen biodiversity, soil health, resilience, and environmental sustainability, although these benefits may involve trade-offs with agricultural productivity (Erekalo et al., 2024).

3.3.1. Adoption of climate smart agriculture

Despite more than a decade of policy development and research, the adoption of CSA across Europe remains relatively limited and insufficiently understood (Long et al., 2015; Pagliacci et al., 2020; Zaidi et al., 2024). Recent research increasingly moves beyond the technical performance of climate smart practices to examine the wider economic, institutional, technological, and behavioral factors that shape farmers' adoption decisions.

Economic barriers are consistently identified as one of the strongest determinants of adoption (Fusco et al., 2024; Gemtou et al., 2024; Vărzaru et al., 2024). Although many climate smart practices generate long-term environmental and economic benefits, their implementation often requires substantial upfront investments, maintenance costs, and uncertain financial returns, particularly for technology-intensive innovations (Long et al., 2015). Drosou et al. (2026) demonstrate in a Lithuanian case study that although some CSA practices are economically competitive such as intercropping, others such as no-tillage remain financially viable only when supported by targeted eco-scheme payments, underscoring the role of public incentives in facilitating climate smart transitions. Limited access to capital and credit further constrains adoption, while financial incentives, improved market opportunities, premium prices, and participation in agricultural cooperatives can help reduce

investment risks and increase farmers' willingness to adopt CSA (Gemtou et al., 2024; Long et al., 2016; Vărzaru, 2024).

Beyond farm-level economics, the literature increasingly emphasizes the importance of institutional and policy conditions. Adoption depends not only on individual farmers but also on broader interactions within food systems involving advisory services, processors, markets, cooperatives, consumers, and policymakers (Gemtou et al., 2024). Weak market demand, fragmented value chains, insufficient infrastructure, and inflexible policy instruments can all constrain climate smart transitions. Consequently, several authors advocate more targeted policy approaches that reflect the diversity of European farming systems rather than uniform support schemes (Biró et al., 2021; Gemtou et al., 2026). Well-designed financial support remains essential, but excessive administrative complexity may discourage rather than stimulate adoption, particularly among innovative farmers seeking to implement new technologies and business strategies (Long et al., 2019).

Knowledge exchange represents another recurring theme within literature. Access to advisory services, extension programmes, farmer training, demonstrations, and peer-to-peer learning consistently enhances farmers' willingness to adopt CSA practices (Fusco et al., 2020; Gemtou et al., 2024; Long et al., 2015; Vărzaru et al., 2024). At the same time, limited technical guidance, uneven access to information, and weak connections between actors in agricultural value chains continue to restrict the diffusion of knowledge across Europe. Consequently, researchers stress the importance of strengthening advisory systems and collaborative learning networks to support climate smart transitions (Gemtou et al., 2024).

Although technological innovation plays a central role within European CSA, technological advancement alone does not guarantee adoption. The perceived characteristics and personal character also play an important role. Farmers are more likely to adopt climate smart technologies when they perceive them as useful, compatible and economically viable with existing farming systems, and sufficiently tested under practical farming conditions (Gemtou et al., 2024; Lee et al., 2024; Long et al., 2015). A case study from the Veneto region in Italy shows that these factors are as important as initial economic support (Pagliacci et al., 2020). They show that although financial incentives facilitate the initial adoption of CSA practices, their long-term continuation is primarily driven by farmers' innovativeness, risk attitudes, and social learning, highlighting the importance of advisory services and peer-to-peer knowledge exchange alongside public support. This has become all the more relevant with the emergence of digital agriculture, including precision farming, artificial intelligence, and Internet of Things (IoT) technologies, where concerns regarding complexity, costs, data ownership, and uncertain economic returns continue to limit uptake (Gemtou et al., 2024).

Finally, behavioral factors further influence adoption. Resistance to changing established farming practices, skepticism towards new technologies and climate-related terminology, and limited entrepreneurial attitudes may all discourage innovation (Fusco et al., 2020; Long et al., 2015; Vărzaru et al., 2024). Collectively, these findings suggest that successful CSA transitions require more than technological innovation alone, instead depending on interactions between economic incentives, institutional support, knowledge exchange, and farmers' motivations and decision-making processes (Gemtou et al., 2024).

3.3.2. Business model transitions

Rather than viewing CSA solely as a set of technical innovations of which farmers are the passive recipients, the literature in Europe increasingly conceptualizes climate smart transitions as changes in farm business models and value-chain relationships. These business model changes determine how

environmental, social, and economic value is created, delivered, and captured, leading to a higher uptake of CSA by farmers that are willing to change the course of their farm business (Galgo. et al., 2026; Isakhanyan et al., 2024; Long et al., 2017, 2019).

Most studies suggest that climate smart transitions currently result primarily in incremental rather than transformative business model innovation. Farmers generally integrate CSA by improving resource-use efficiency within existing production systems, whereas more transformative approaches – such as participation in carbon markets, payments for ecosystem services, or on-farm biogas production – remain comparatively rare because of high investment costs, institutional complexity, and uncertain revenue streams (Galgo et al., 2025).

However, Isakhanyan et al. (2024) finds that exactly these transformative business models that incentivize collaboration across the agricultural value chain are more likely to be successful. They identify resource pooling, innovation networks, and collaborative governance arrangements as key strategies that distribute investments, risks, and knowledge across multiple actors.

Such mechanisms could help address the misalignment between the costs and benefits of CSA identified by Long et al. (2019), whereby farmers bear most of the costs associated with adopting CSA practices, while a substantial share of the economic benefits accrues to downstream actors such as processors and retailers. For example, Nazzaro et al., (2022) shows how in Italy the *La Guardiense* wine cooperative successfully operationalized a transformative business model by combining collaborative governance, resource pooling, and knowledge sharing, thereby reducing investment risks and creating economic incentives for farmers to adopt climate smart innovations. These studies suggest that multi-actor collaboration involving farmers, cooperatives, processors, advisors, and other stakeholders is essential for enabling successful business model transformation (Isakhanyan et al., 2024; Long et al., 2019).

The literature further identifies value capture as one of the principal challenges for wider CSA diffusion. Although climate smart practices often improve environmental performance and operational efficiency, farmers frequently struggle to translate these benefits into sufficient economic returns (Galgo et al., 2025; Isakhanyan et al., 2024). Consequently, researchers increasingly emphasize mechanisms that enable farmers to capture the value created through CSA, including certification schemes, sustainability labels, price premiums, public support mechanisms, and targeted eco-schemes. For example, Comincioli et al., (2025) show in their Spanish case study that although climate smart technologies such as soil moisture sensors and photovoltaic irrigation systems can be economically viable, their adoption remains highly dependent on public financial support to offset substantial upfront investment costs (Comincioli et al., 2025). While Cominicioli's case study shows the need for subsidies, Dimitrova (2021) provides consumer-side evidence for monetizations as the study finds that more than half of the surveyed Bulgarian consumers are willing to make financial sacrifices – specifically paying a premium – to obtain products with a recognized CSA brand (Dimitrova, 2021).

Nevertheless, unequal value distribution across agri-food chains remains a persistent barrier, with farmers typically bearing the costs of adopting climate smart innovations while downstream actors capture a substantial share of the economic benefits (Long et al., 2015). Collectively, these findings suggest that successful climate smart transitions require not only farm-level innovation but also supportive market arrangements, infrastructure, and institutional conditions that allow farmers to be fairly rewarded for the value they generate (Gemtou et al., 2024).

3.4. Preliminary conclusions

Overall, the literature demonstrates that CSA has since 2011 evolved from a global policy concept into an increasingly institutionalized framework for agricultural development and innovation. Although originally conceived as an integrated approach to simultaneously enhance productivity, strengthen resilience, and reduce greenhouse gas emissions, its operationalization remains highly context-dependent and conceptually flexible. This flexibility has facilitated the widespread uptake of CSA across policy and research but has also contributed to persistent ambiguity regarding what constitutes climate-smartness, how trade-offs between objectives should be managed, and how the effectiveness of interventions should be evaluated.

Within Europe, CSA has been shaped by the region's highly productive agricultural systems and broader sustainability agenda. Consequently, research has predominantly emphasized productivity through technological innovation, digitalization and resource-use efficiency, as well as climate mitigation.

Despite the rapid expansion of CSA research, important knowledge gaps remain. Existing studies continue to focus primarily on individual technologies and practices, while comparatively little attention has been devoted to understanding how combinations of interventions function within specific social, ecological, and institutional contexts. Similarly, farmer-centered perspectives remain underrepresented, and there is still no widely accepted framework for assessing climate-smartness across diverse agricultural systems. These gaps point towards the need for more participatory, systems-oriented research that examines how climate smart innovations are developed, implemented, and embedded within broader agricultural innovation systems. The survey results will elaborate more on the extent to which transdisciplinarity, and system-oriented research design are integrated already in Europe and which barriers they face.

4. Ongoing climate smart research at experimental research stations across Europe

The following section first examines the thematic areas of CSA research pursued by the participating ERSs. It then explores how these research stations design and conduct research and innovation activities, with particular attention to the extent to which transdisciplinarity, systems thinking, and reflexivity are integrated into their research and innovation processes.

4.1. Ongoing climate smart research: a thematic exploration

4.1.1. Different thematic areas within climate smart agriculture

CSA encompasses a broad range of practices and interventions aimed at addressing the interconnected challenges of agricultural productivity, climate change adaptation, climate change mitigation, and environmental sustainability (FAO 2013). As agricultural systems vary considerably across regions, production sectors, pedoclimatic conditions and the climate challenge at hand, climate smart agricultural research is inherently diverse and covers many different topics.

To better understand current climate smart research priorities within ERSs, respondents were asked to identify the five most important thematic areas addressed within their research activities. The thematic areas used in the survey were aligned with those previously developed by the CSR project's sister initiatives, CSA and CFD (Climate Farm Demo, 2023). The thematic areas are the following: additives for reducing enteric methane emissions; agroforestry and relation to landscape; manure storage and spreading; soil health and biodiversity; grassland management: forage production; biogas production; crops management; water management; energy management; rewarding mechanisms; herd management.

Figure 9 illustrates the frequency with which ERSs selected each CSA area among their five most-studied areas. The y-axis represents the number of selections, while the x-axis displays the different CSA areas. The results reveal a relatively high degree of convergence in research priorities across the surveyed ERSs. In both surveys, soil health and biodiversity and crop management emerged as the most frequently selected thematic areas, counted together they both have been selected 71 times. These thematic areas clearly occupy a central position within current climate smart research activities and appear to constitute core pillars of ongoing research efforts. Beyond these dominant areas, the findings demonstrate a broad distribution of research activities across multiple thematic areas. This diversity illustrates the multidimensional nature of climate smart agricultural research and highlights the wide range of challenges addressed by ERSs throughout Europe. Research topics related to the

thematic areas water management (S1+S2 n =58), forage production (S1+S2 n =42) and grassland management (S1+S2 n = 40) also scored highly in both surveys compared to other topics.

In contrast, certain themes received considerably less attention across the surveyed institutions. In particular, biogas production (S1+S2 n = 10) and rewarding mechanisms, (e.g. financial, policy based and market-based incentive schemes) (S1+S2 n = 8) were among the least frequently selected topics. This suggests that current research efforts are still more strongly concentrated on biophysical and agronomic dimensions of CSA while the economic and institutional context in which the farms are embedded might remain underexplored.

The open-ended responses filled in the box of 'other' areas (S1 + S2 n = 17) elaborate further on the variety of research areas studied. Some entries are closely related to the existing thematic areas. For example, answers such as 'crops cover below trees' and 'Nature Based Solution' relate to agroforestry and relation to landscape. Other entries represent distinct dimensions which are not included in the 12 thematic areas that the projects use to group different climate smart agricultural topics. These were plastic pollution, pollination ecosystem services, food value chains, and physical workload.

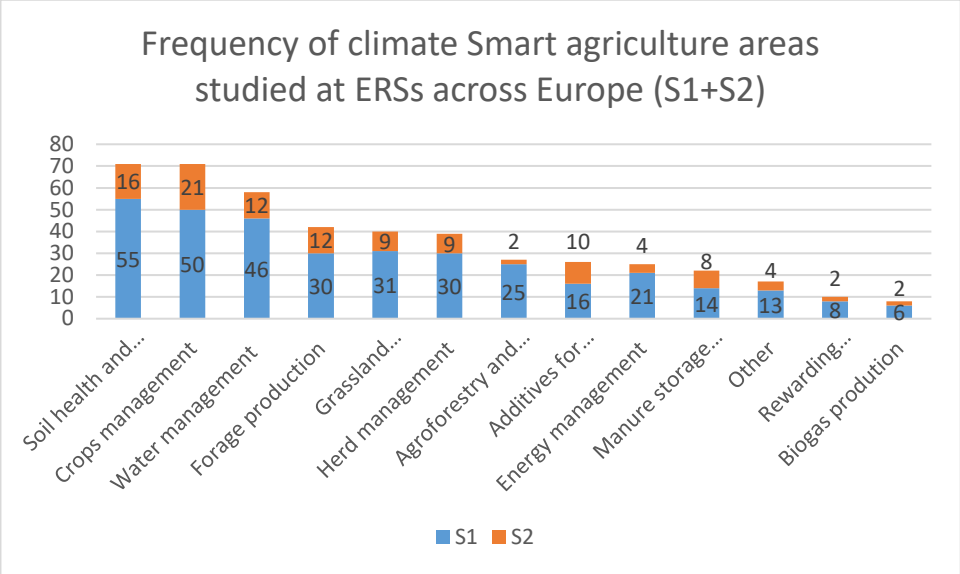


Figure 9. Frequency of CSA areas studied by ERSs across Europe (S1 +S2)

Taken together, the results indicate that climate smart agricultural research within European ERSs covers a wide spectrum of thematic areas. However, it is also clear that within this variety of topics studied there are certain topics dominating the current research agendas – mostly crops management, soil health, water management and forage production – whereas the socio-economic and context remains seem to receive less attention.

Geographical differences

The distribution of thematic categories across geographical zones reveals several notable patterns. Rather than being randomly distributed, thematic priorities appear to reflect differences in agricultural systems, environmental conditions, and regional challenges throughout Europe.

To explore these patterns, countries were grouped into the different regions: Northern Europe (Denmark, Finland, Ireland, the United Kingdom, Scotland, and Norway), Western Europe (Belgium, the Netherlands, and France), Southern Europe (Spain, Cyprus, Portugal, Italy, and Greece), and Eastern Europe (Romania, Hungary, Croatia, Lithuania, Bulgaria, Czechia, Poland, Estonia, and Slovakia). Eastern Europe and Western Europe represent the largest respondent groups, accounting for 31 (32%) and 38 (39%) of the 97 survey responses, respectively (see figure 10). The following figure (figure 11) shows percentages which indicate the relative distribution of research areas within each cluster. They were calculated by dividing the number of responses for each thematic area by the total number of topic responses within that cluster. Consequently, the percentages sum to 100% for each cluster.

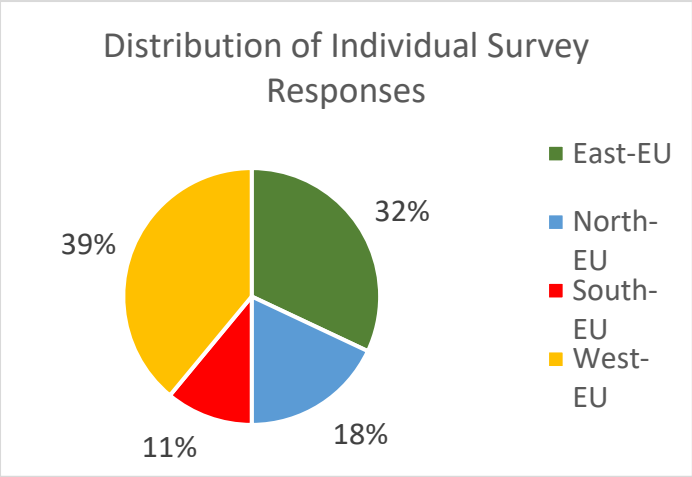


Figure 10. Distribution of individual survey responses per region.

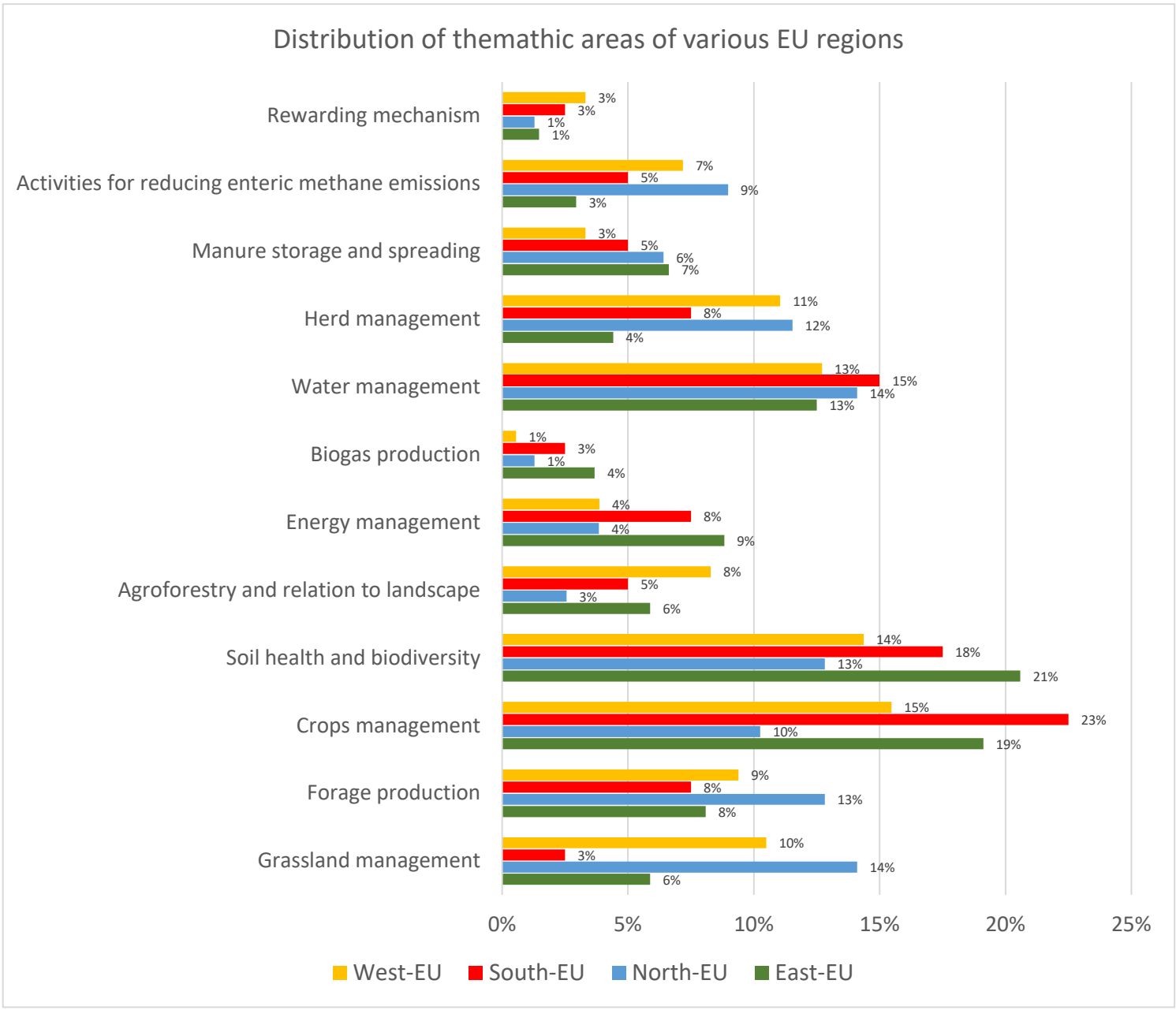


Figure 11. Distribution of thematic areas of various EU regions.

Grouping countries by region allowed for a comparative analysis of the popularity of the different thematic areas, holding in mind the uneven distribution of survey respondents across the various regions. Western Europe demonstrates a relatively balanced distribution of interests across the thematic areas. The greatest interest is observed in crops management, followed by soil health and biodiversity and water management. In addition, Western Europe shows relatively strong interest in several livestock-related topics, particularly herd management, grassland management, and forage production.

A similar but more pronounced pattern emerges in Southern Europe. Interest is strongly concentrated on crops management, soil health and biodiversity, and water management. Notably, water management receives the highest level of interest among all regions, likely reflecting the importance of water scarcity and drought-related challenges in Southern European agricultural systems. Compared with Western and Northern Europe, interest in livestock-related topics is considerably lower. Themes such as herd management, forage production, and manure storage and spreading receive less attention, indicating a stronger focus on crop production and resource management.

Eastern Europe exhibits a somewhat different profile. Similar to the other regions, soil health and biodiversity emerges as one of the most important themes. In fact, Eastern Europe records the highest level of interest in this topic among all regions. Crops management and water management also attract substantial attention, highlighting the importance of maintaining agricultural productivity while addressing environmental challenges. Interest in livestock-related themes is generally moderate. While topics such as manure storage and spreading, forage production, and energy management receive some attention, they are less prominent than land and crop-related subjects.

Northern Europe displays a thematic profile that differs from Southern Europe and is more oriented toward livestock production systems. Compared with the other regions, there is greater interest in livestock-related topics, including activities for reducing enteric methane emissions, manure storage and spreading, herd management, forage production, and grassland management. This emphasis likely reflects the importance of dairy and grazing-based livestock systems within Northern European agriculture. At the same time, crop management and soil health remain relevant themes, although they are relatively less dominant than in Southern and Eastern Europe.

Overall, all regions place considerable emphasis on crops management, soil health and biodiversity, and water management, highlighting these as common priorities across Europe. However, clear regional differences emerge. Southern Europe is particularly focused on crop and water-related challenges, Eastern Europe prioritizes soil health and biodiversity, while Northern and Western Europe show stronger interest in livestock-related topics, reflecting the structure of their agricultural systems.

4.1.2. Different pillars within climate smart agriculture

To complement the analysis of thematic research priorities, respondents were asked to assess the extent to which the core pillars of CSA research framework - mitigation, adaptation, productivity and ecosystem services - are integrated into research activities at their ERSs. Specifically, respondents had to evaluate the degree from one to ten (with ‘1’ meaning to a very small extent; ‘10’ meaning to a very large extent) to which their research considers (i) agricultural productivity, (ii) climate change mitigation, (iii) climate change adaptation (iv) ecosystem services. Ecosystem services refer to the ecological functions and benefits that ecosystems, including agricultural ecosystems, provide to the society. Within the CSR framework, these include soil formation and nutrient cycling, water retention and regulation, carbon storage and sequestration, biodiversity conservation, and protection against climate-related risks such as droughts and floods (Ziv et al., 2026). Ecosystem services are viewed as both a foundation for climate-resilient and productive farming systems and as outcomes that can be strengthened through climate-smart agricultural practices (Akamani, 2021).

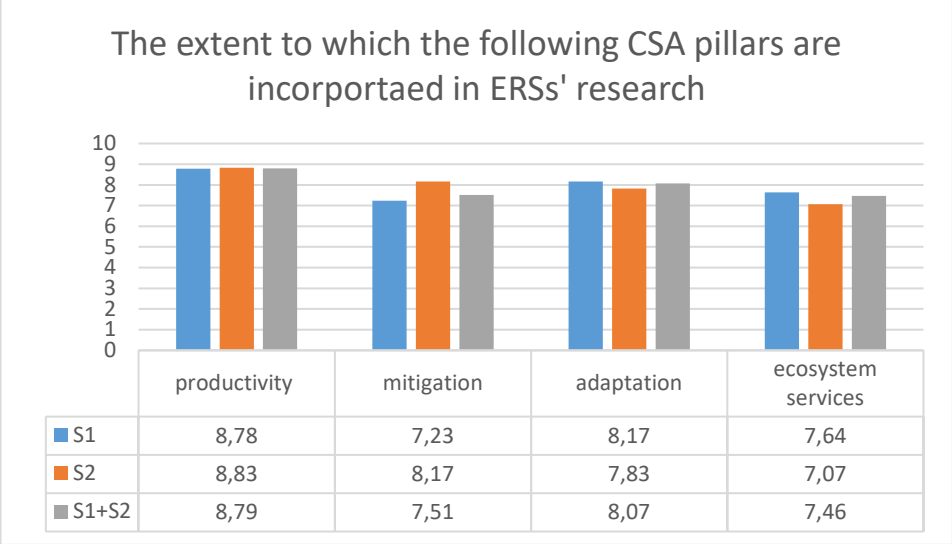
The results indicate that researchers estimate a generally high level of integration across all these four dimensions, with average scores exceeding seven on a ten-point scale in both surveys. Agricultural productivity received the highest ratings in both surveys, with scores of 8.78 in S1 (ERSs outside of CSR) and 8.83 in S2 (ERSs within CSR).

Adaptation also received consistently high ratings across both surveys. Respondents reported average scores of 8.17 in S1 (ERSs outside of CSR) and 7.83 in S2 (ERSs within CSR), resulting in a combined average of 8.07.

Mitigation was likewise strongly represented. While S1 respondents (ERSs outside of CSR) reported an average score of 7.23, the corresponding value in S2 (ERSs within CSR) reached 8.17.

The boxplots (figure 13) give more insight into the variability of the answers. Productivity emerges again as the most strongly emphasized pillar, with the highest median score and a concentration of responses at the upper end of the scale. Adaptation is also consistently considered, reflecting broad agreement on its importance. In contrast, mitigation exhibits greater variability among respondents, suggesting differences between research stations in the degree to which mitigation objectives are incorporated into research programs. Overall, the findings suggest that productivity and adaptation are more uniformly integrated across research stations, whereas mitigation remains a comparatively less consistent focus.

Respondents also had to evaluate the degree from one to ten (with ‘1’ meaning to a very small extent; ‘10’ meaning to a very large extent) to which their research considers the role of the wider ecosystem. Respondents indicated relatively high scores for the extent to which ecosystem services are researched, with average values of 7.64 in S1 (ERSs outside of CSR) and 7.07 in S2 (ERSs within CSR). Although this dimension received the lowest overall rating compared to the three CSA pillars, the combined score of 7.47 nevertheless indicates that environmental considerations are to some level incorporated within current research activities of the surveyed ERSs. The corresponding boxplot (figure 15) similarly indicates that ecosystem services are generally well integrated into the research activities of the surveyed research stations, with a median score of approximately 8. Most responses are concentrated between 6 and 9, suggesting a relatively high level of consideration. Nevertheless, the distribution reveals moderate variability among respondents, indicating differences in the extent of integration across research stations. The presence of a single low outlier suggests that while ecosystem services are widely recognized, a small number of stations devote comparatively little attention to this area. Overall, the findings point to a substantial, though not yet uniform, incorporation of ecosystem services within research programmes



	productivity	mitigation	adaptation	ecosystem services
S1	8,78	7,23	8,17	7,64
S2	8,83	8,17	7,83	7,07
S1+S2	8,79	7,51	8,07	7,46

Figure 12. The extent to which the following CSA pillars are incorporated in ERSs' research.

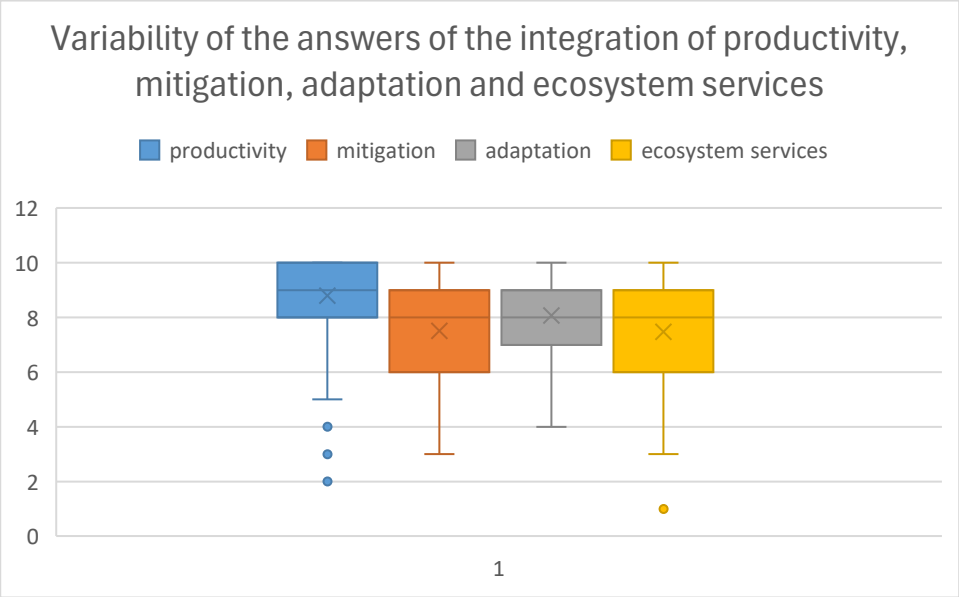


Figure 13. Variability of the answers of the integration of productivity, mitigation, adaptation and ecosystem services.

Additionally, respondents were inquired about other environmental aspects that are explored within the ERSs by asking '*Are there any other environmental aspects that are addressed by the experimental research at your ERS?'* The qualitative responses to this question highlight a broad spectrum of environmental aspects and sustainability-oriented practices researched at the ERSs. The most prominent theme relates to soil, nutrient and resource management. Respondents frequently referred to nutrient use efficiency, nutrient cycling, and the reduction of nutrient losses, with particular emphasis on reducing nitrogen and ammonia emissions. Phosphorus management was also mentioned, although less frequently. Soil health and soil conservation emerged as important research areas, including research on soil fertility, carbon sequestration, erosion prevention, and the sustainable management of soil resources.

Water management and water quality constituted another major research area. Respondents highlighted efficient water use, irrigation management, water-use efficiency, and the reduction of nutrient leaching and other forms of water pollution. Several responses linked water management directly to climate resilience and the sustainable use of natural resources.

Biodiversity and ecosystem conservation also featured prominently in the responses. Research activities include the conservation of plant genetic resources and varieties, the protection of field-scale and landscape-scale biodiversity, and the enhancement of beneficial insects, pollinators, hedgerows, and field margins. Agroecological approaches, agroforestry systems, and organic production methods were frequently mentioned as strategies to strengthen biodiversity while supporting sustainable agricultural production.

Further research concerns the reduction of chemical inputs and the development of more sustainable production systems. Respondents referred to integrated pest management, reduced pesticide use, precision fertilization, precision irrigation, and other management practices aimed at maintaining productivity while reducing environmental impacts. The use of precision agriculture technologies and digital monitoring systems was often highlighted as a means of improving resource efficiency and supporting evidence-based decision-making.

For the respondents the environmental research at the ERSs also extended to efficient energy use, emissions reduction, and circular resource management. Several respondents mentioned renewable energy technologies, particularly agrivoltaics, photovoltaic systems, and biomethane production. Others referred to circular bioeconomy approaches, including the valorization of agricultural by-products, the reuse of biomass streams, and the promotion of more locally integrated production systems to reduce resource dependency and transport-related impacts.

Theme / Cluster	Examples mentioned	Frequency
Soil health, soil conservation, soil fertility, sustainable fertilisation & nutrient cycling	Soil health, soil fertility, soil conservation, soil compaction, erosion control, polluted soil remediation, carbon sequestration. N-P-K balance, manure management, nutrient circularity.	**15**
Biodiversity & ecosystem conservation	Biodiversity, conservation of varieties/genetic resources, pollinators, beneficial insects, landscape features, hedgerows	**10**
Water quality & water management	Water quality, N leaching, irrigation efficiency, water-use efficiency, smart irrigation, plant water consumption	**9**
Input reduction, resource-use efficiency, reduction of pesticides & chemical inputs	Nitrogen efficiency, nutrient-use efficiency, fertilizer optimisation, precision agriculture, low-input systems, resource efficiency. Integrated pest management, reduction of synthetic pesticides, low chemical inputs	**9**
Reduction of emissions & air quality	Ammonia emissions, greenhouse gases, carbon footprint, air quality	**7**
Renewable energy & agrivoltaics	Agrivoltaics, photovoltaic systems, biogas/biomethane production, renewable energy integration	**5**
Circular economy & biomass valorisation	By-products reuse, circular bioeconomy, pruning residues, grape pomace	**3**
Agroforestry & landscape management	Agroforestry systems, landscape-scale approaches, hedgerows	**3**
Food security & protein self-sufficiency	Food-feed competition, food security, local feed production	**3**
Animal welfare & livestock environment	Animal welfare, antibiotics reduction, livestock housing conditions	**2**

Table 1. Frequency of the responses on environmental topics studied by ERSs.

4.2. Ongoing climate smart research: research and innovation design

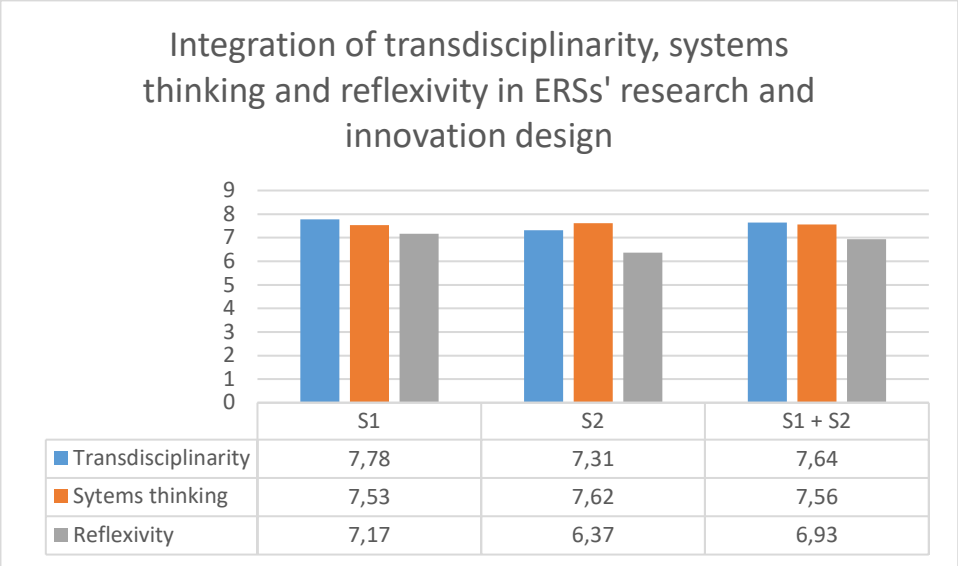
To gain more insight into the research and innovation design the extent was researched to which transdisciplinarity, systems thinking and reflexivity – the core concepts of CSR's conceptual framework– are integrated into climate smart research design of the ERSs. Transdisciplinarity in the CSR framework refers to a collaborative research approach in which academic and non-academic actors jointly co-create knowledge to address complex real-world challenges (Lang et al., 2012). Within the CSR project and as defined in the survey transdisciplinarity involves the active participation of farmers, advisors and other stakeholders throughout the research process, with the objective of generating action-oriented and practice-relevant knowledge for CSA (Ziv et al., 2026). Systems thinking, within the CSR framework and surveys, is defined as an approach that seeks to understand the complexity of a whole agricultural system emphasizing the interactions between system components and recognizing that there is no single solution but that simultaneous change is needed at multiple levels. Rather than evaluating individual practices in isolation, systemically designed research considers agronomic, economic, social, and governance dimensions simultaneously to support the transition towards CSA (Ziv et al., 2026). Finally, reflexivity is defined as the continuous process of critically examining and questioning one's own assumptions, values, positionality, methods, and potential impacts in order to understand how they shape the production of knowledge and influence outcomes (Finlay, 1998). It involves both personal self-awareness and methodological scrutiny and extends beyond reflection itself to include actions and changes made in response to these insights.

First respondents were asked to give a score from one to ten, (with '1' meaning to a very small extent; '10' meaning to a very large extent), answering the question '*To what extent does the research at your ERS take into account the following topics?*' The results presented in figure 14 combine responses from both S1 and S2, thereby offering an overview of the methodological orientation of ERSs both within and beyond CSR network. The remainder of this section examines these findings for each topic – transdisciplinarity, systems thinking and reflexivity – in greater detail.

Overall, the quantitative findings indicate that the ERSs assess the extent to which they incorporate transdisciplinarity, systems thinking to a similar amount; all estimated this to be between 7-8 out of 10. For reflexivity they indicated a little less incorporation; the number lowers, falling between 6 and 7 out of 10. The numbers stay quite steady over the two samples, suggesting consistency in the wider network of ERSs in Europe.

Systems thinking and transdisciplinarity show the strongest and most consistent levels of integration, with median scores of approximately 8 and relatively limited variability among respondents (figure 15). In both cases, the interquartile ranges are relatively narrow, indicating broad agreement among respondents that these approaches are well embedded within their organizations. Although a small number of lower scores are visible as outliers, the majority of responses cluster in the higher scoring range (7-9), suggesting that systems-oriented and transdisciplinary ways of working are widely adopted. Reflexivity also receives generally positive ratings, with a median score of around 7 (figure 15). However, responses are more dispersed, as reflected by the wider interquartile range and the

larger overall spread of scores. Ratings range from very low to very high values, indicating substantial differences in how reflexive practices are understood and implemented across organizations. This greater variability suggests that reflexivity is less consistently integrated than systems thinking and transdisciplinarity.



	S1	S2	S1 + S2
Transdisciplinarity	7,78	7,31	7,64
Sytems thinking	7,53	7,62	7,56
Reflexivity	7,17	6,37	6,93

Figure 14. Integration of transdisciplinarity, systems thinking and reflexivity in ERSs' research and innovation design.

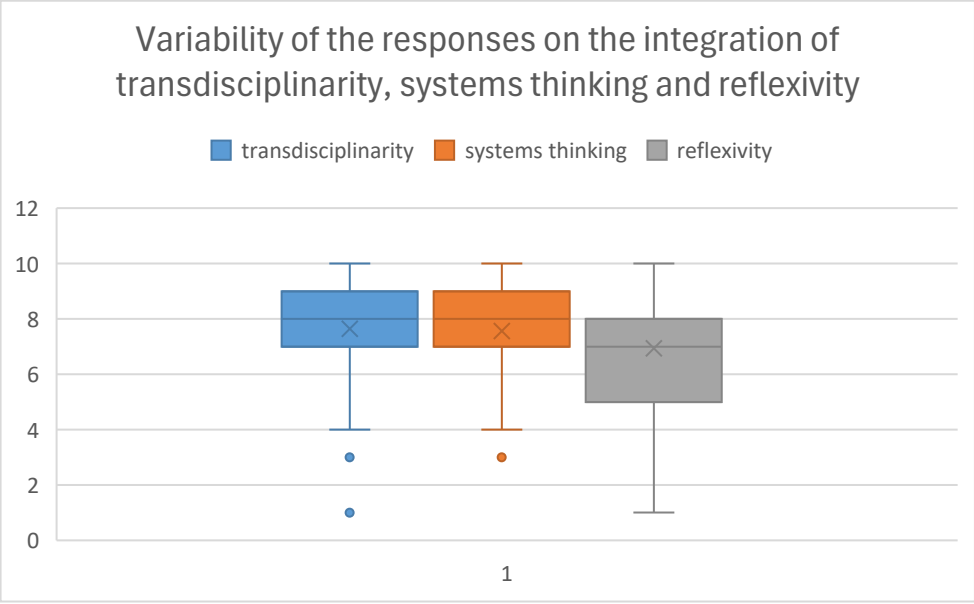


Figure 15. Variability of the responses on the integration of transdisciplinarity, systems thinking and reflexivity.

4.2.1. Transdisciplinarity in research and innovation design

Respondents within and beyond CSR rated their level of transdisciplinary engagement at an average of 7.6 out of 10. The qualitative data presented here first responds to the question: '*Can you briefly elaborate on your indicated answer from 1–10?*' Through this question, a deeper understanding of respondents' numerical interpretation of transdisciplinarity was gained.

First, it is important to note that there is considerable ambiguity in how transdisciplinarity is understood and interpreted by respondents, even if we provided the definition as provided within the conceptual framework of CSR. Some participants rated their research as highly transdisciplinary because they actively involve farmers and other stakeholders in workshops, field days, and dissemination activities. In several cases, participants also appeared to conflate transdisciplinarity with interdisciplinarity, despite the survey defining it as the involvement of non-academic stakeholders in the research process. For example, one respondent awarded a score of 10 and explained that transdisciplinarity meant that "*in order to be able to define a strategy and an integrated approach for sustainable production the links and connection between several disciplines are taken into account*." This reflects collaboration across academic disciplines rather than between researchers and societal actors. In other instances, respondents seemed to associate transdisciplinarity with applied or systems-oriented research. For example, one participant scored their institution 8/10, arguing that their research is conducted under conditions that are transferable to real agricultural production settings. Together, these responses highlight that researchers draw on different reference points when evaluating transdisciplinarity, making direct comparison of scores more difficult and suggesting that the concept is not uniformly understood across institutions.

About 22,5% of respondents reported high level of transdisciplinarity (scores between 7 and 8). They generally describe transdisciplinarity as an important and well-developed component of their research activities, characterized by close collaboration with farmers, advisors, industry partners, and other stakeholders. Research is typically highly applied and conducted in real-world settings through on-farm trials, demonstration farms, Living Labs, and participatory experiments, ensuring that projects address practical challenges faced by the agricultural sector. Knowledge exchange is a central feature, with many institutions acting as intermediaries between research and practice through workshops, field days, advisory networks, and stakeholder committees.

Another 22,5% of the respondents gave scores between 1 and 6. In these ERS, research remained predominantly discipline-based and researcher-led, with transdisciplinary collaboration occurring mainly in specific projects rather than as a standard practice. While farmers, advisors, industry representatives, and other stakeholders are mentioned to be engaged through consultations, advisory structures, field days, dissemination activities, and project feedback, their involvement is often limited to implementation and validation rather than co-design of research. Examples of knowledge co-creation are mentioned, particularly in European, externally funded, or multi-actor projects, but systematic integration of non-academic stakeholders throughout the research process remains relatively uncommon.

In contrast, high-scoring ERSs (9-10 out of 10, which amounted to 27,6% of the two samples) describe transdisciplinarity as a core element of their research approach rather than a project-specific activity. Research is typically co-designed and implemented with farmers, advisors, industry representatives, policymakers, and other societal actors. Stakeholders are often involved throughout the research process, including setting priorities, defining research questions, testing innovations, evaluating results, and disseminating findings. Several institutions report that transdisciplinary collaboration is embedded in their organizational structures, long-term strategies, and funding models, with the aim of producing practical solutions to agricultural, environmental, and societal challenges. Overall, these responses reflect a strong emphasis on knowledge co-creation and ensure that research is both scientifically robust and directly relevant to end users.

For the respondents it appears that the primary objective of transdisciplinary research is to increase the relevance, applicability, and impact of research outcomes by closely aligning them with the needs and realities of end users. Respondents emphasized that stakeholder involvement helps ensure that

research addresses practical challenges and incorporates not only technical but also economic and social dimensions of innovation. Several respondents also noted that involving farmers throughout the research process increases their trust in the results, thereby facilitating the adoption and implementation of research outcomes in practice.

Finally, it is also worth mentioning that many research stations are involved in transdisciplinary research activities precisely because they are part of EU funded multi-actor partnership projects. This indicates that the EU's embedding of this form of transdisciplinarity in research is helping the ERSs to engage in participatory research. However, it seems to be that at some ERSs only or mostly EU funded projects engage with transdisciplinarity whereas other research remains quite disciplinary driven due to institutional constraints. Transdisciplinary research design is not consistently applied throughout most ERSs. Someone answered for example:

> "*I indicated 8 because, in my experience, transdisciplinary approaches are already partially integrated into our research through collaboration with farmers, advisors, and other practitioners, especially in applied and EU-funded projects. These interactions improve relevance and uptake of results, but they are not yet systematic across all projects or stages of the research process. Stronger incentives, long-term partnerships, and clearer mechanisms for co-creation would be needed to reach a higher level of transdisciplinarity."*

Other reasons for lower participatory involvement were private sources of funding, limited time for collaborative efforts and varying attitudes towards collaboration of researchers. An example demonstrating the latter is this respondent who answered that they didn't see the added value of stakeholders in research, saying: "*Experimental designs are often complex and input from non-academic partners often fails to add value to the process (…)".*

Transdisciplinarity in more detail within CSR

In order to gain deeper insight into the dept and quality of transdisciplinary work ERSs within CSR (survey 2) were asked a series of questions on elaborating on the integration of transdisciplinarity in research design. This improved the understanding of which stakeholders participate when in the research process, and the barriers experienced to stakeholder engagement.

The origin of research ideas is an important first indicator of who is setting the research agenda and how collaborative this process is. Figure 16 presents the main sources from which research ideas emerge. Scientific or academic interests constitute the most frequently cited source (n = 28), indicating that research agendas are primarily driven by scientific interest from within academic contexts. Collaboration with farmers or advisors also represents an important source of ideas (n = 22), followed by previous research projects (n = 20), calls for funding (n = 19), and policy priorities (n

= 18). Private sector needs (n = 17) and broader societal or environmental challenges (n = 16) were somewhat less frequently mentioned, but still relatively present.

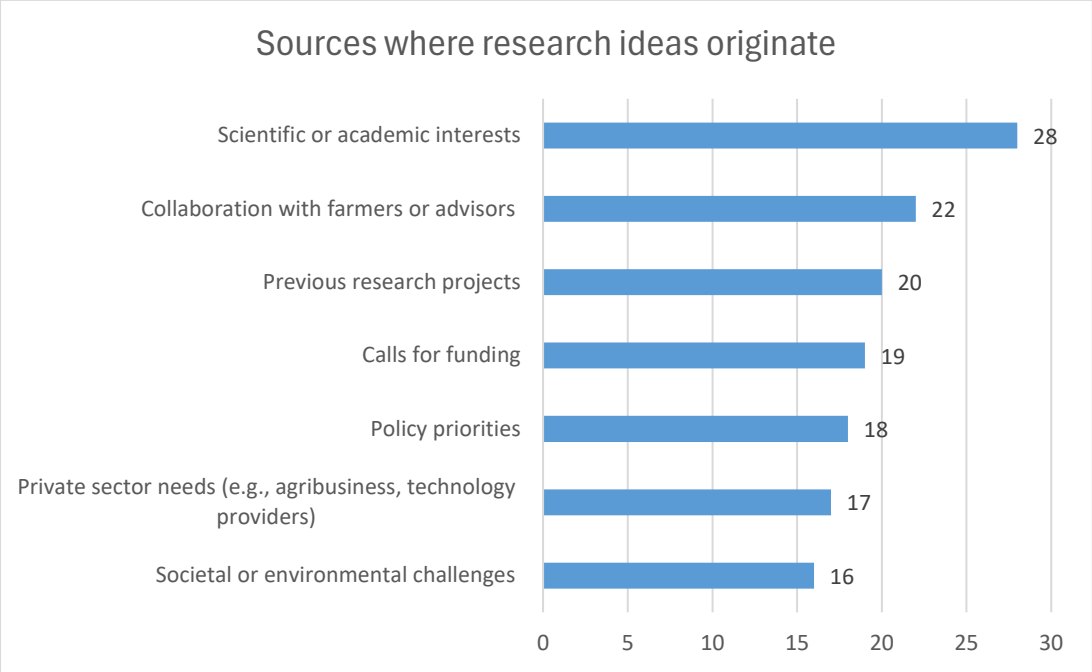


Figure 16. Sources where research ideas originate.

In it shows what types of actors are involved overall in the research activities at the ERSs. As expected researchers from institutions or universities dominate participation (n = 27), followed by private sector companies (n = 19) and farmer organizations (n = 18). To a lesser extent it is indicated that agricultural advisors (n = 14), individual farmers (n = 13), and policy makers (n = 12), collaborate in these projects. NGOs and civil society organizations (n = 6) are involved to an even lesser extent. Notably, no respondents reported the absence of collaboration.

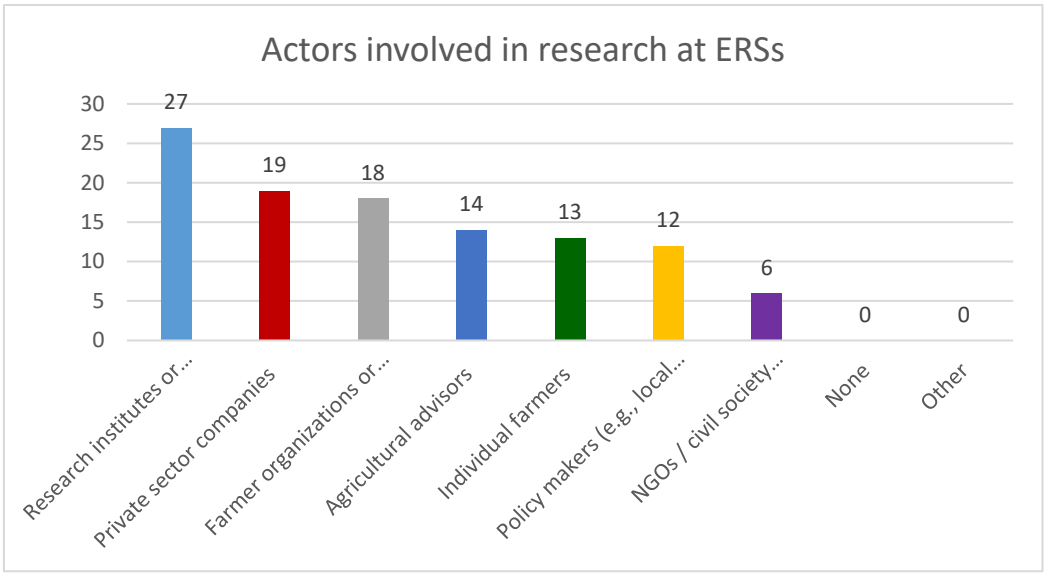


Figure 17. Actors involved in research at ERSs.

All in all, these results suggest that although research agenda setting remains strongly science-driven, but a wide diversity in other factors also influences research topics. In reality various factors, such as policy priorities, private sector and farmers input, will probably have an impact on the topics that are researched, but it can be assumed that researchers' own interests play a very important and probably decisive role. Similarly to the qualitative data discussed above, private sector companies, farmers organization, agricultural advisors and individual farmers come forth as the most engaged actors apart from the research institutes themselves. Civil society and NGOs on the other hand are way less present in these relationships.

Involvement of actors per research stage

Per research stage – identifying research needs, research design, data collection and data interpretation – the type of involved actor was asked. Figure 18 shows that researchers from respondents' own institutions play the dominant role in identifying research needs (n = 28). Researchers from other institutions (n = 18), farmer organizations (n = 16), policy makers (n = 16), agricultural advisors (n = 15), and private sector partners (n = 12) also contribute. Individual farmers (n = 9) and NGOs or civil society organizations (n = 5) are less frequently involved. However, this is clearly the stage where most collaboration with the most diverse pool of actors is situated.

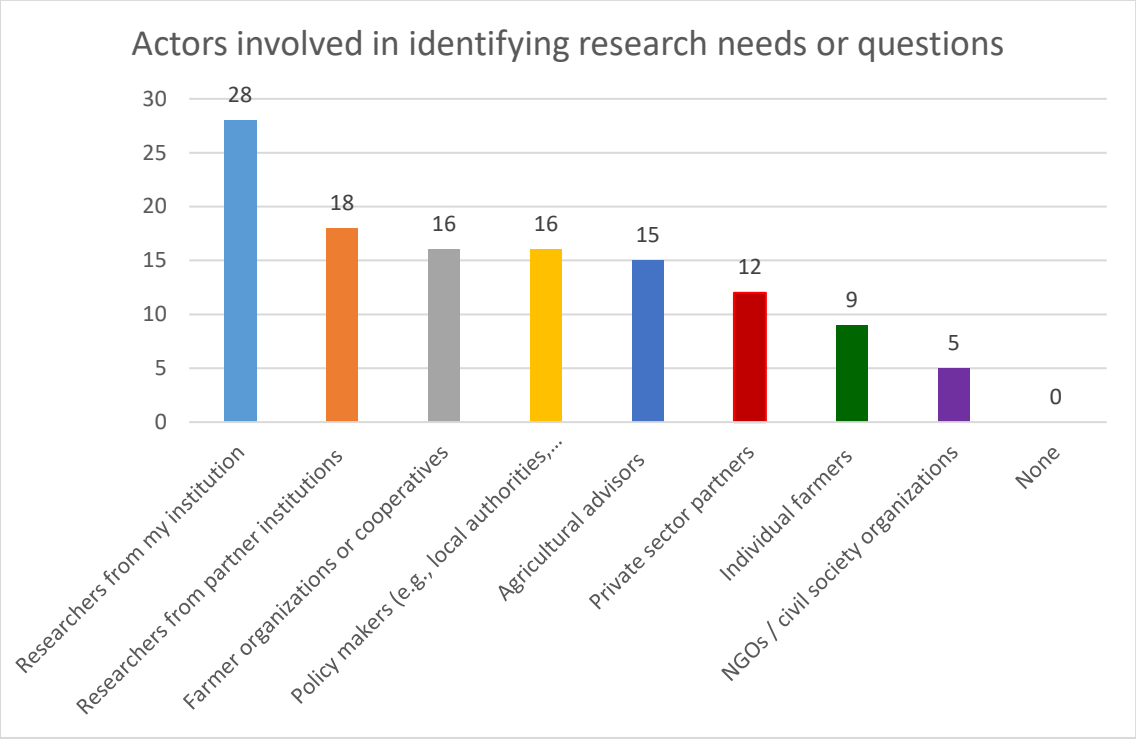


Figure 18. Actors involved in identifying research needs or questions.

Involvement of partners outside of their own organizations drops significantly when we look at the next stage of designing the research. Researchers from partner institutions (n = 20) play the most important role apart from the researcher from the institution itself. Private sector actors (n = 9) and agricultural advisors (n = 7) are reported still somewhat present in the research at this stage. Individual farmers (n = 4), farmer organizations or cooperatives (n = 4), policy makers (n = 3), and NGOs or civil society organizations (n = 1) play very seldom a role in this stage.

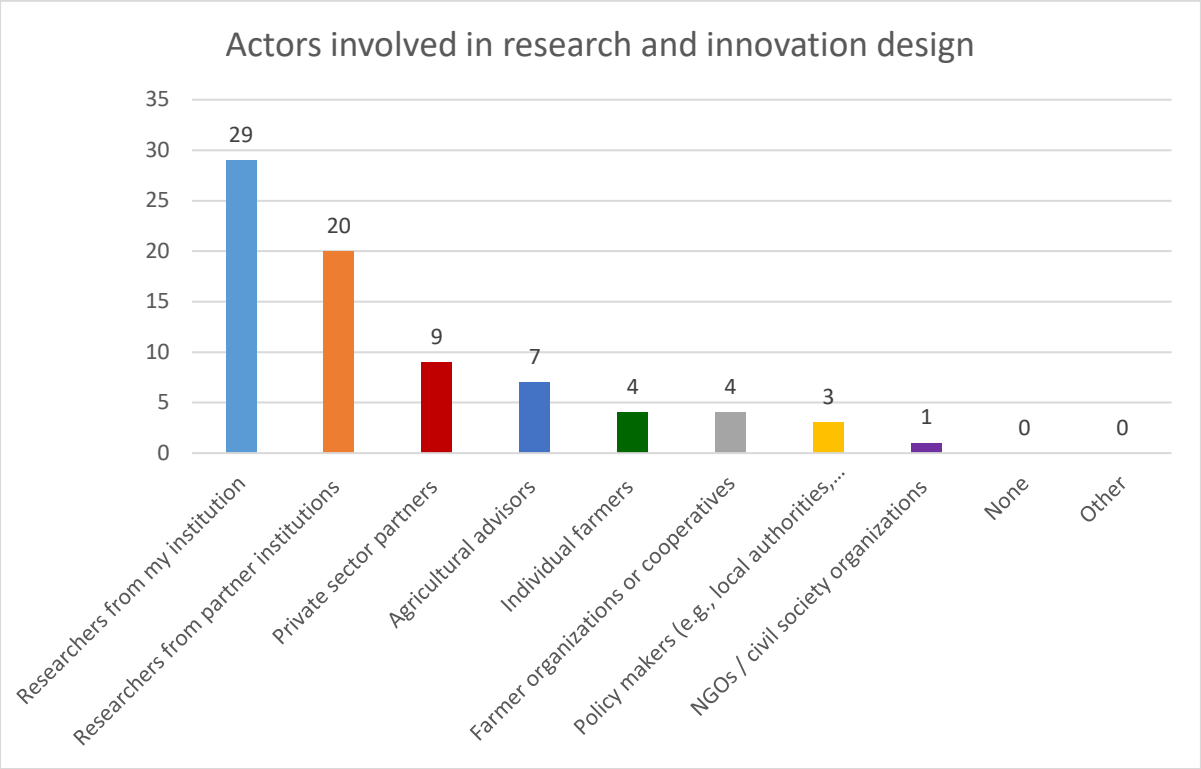


Figure 19. Actors involved in research and innovation design.

This pattern is continued throughout the next phases of research. Data collection relies mainly on researchers from respondents' institutions (n = 29) and researchers from partner institutions (n = 16). Agricultural advisors and private partners contribute to some degree, but less substantially than before. In contrast, individual farmers (n = 8) seem to be more involved here than in some of the other stages. Indicating that they are not rarely involved in partnerships where they provide the data. This could relate to ERSs conducting research at actual farms, as was mentioned in the qualitative data discussed above. Farmer organizations (n = 3), policy makers (n = 1) and NGOs and civil society organizations are largely absent.

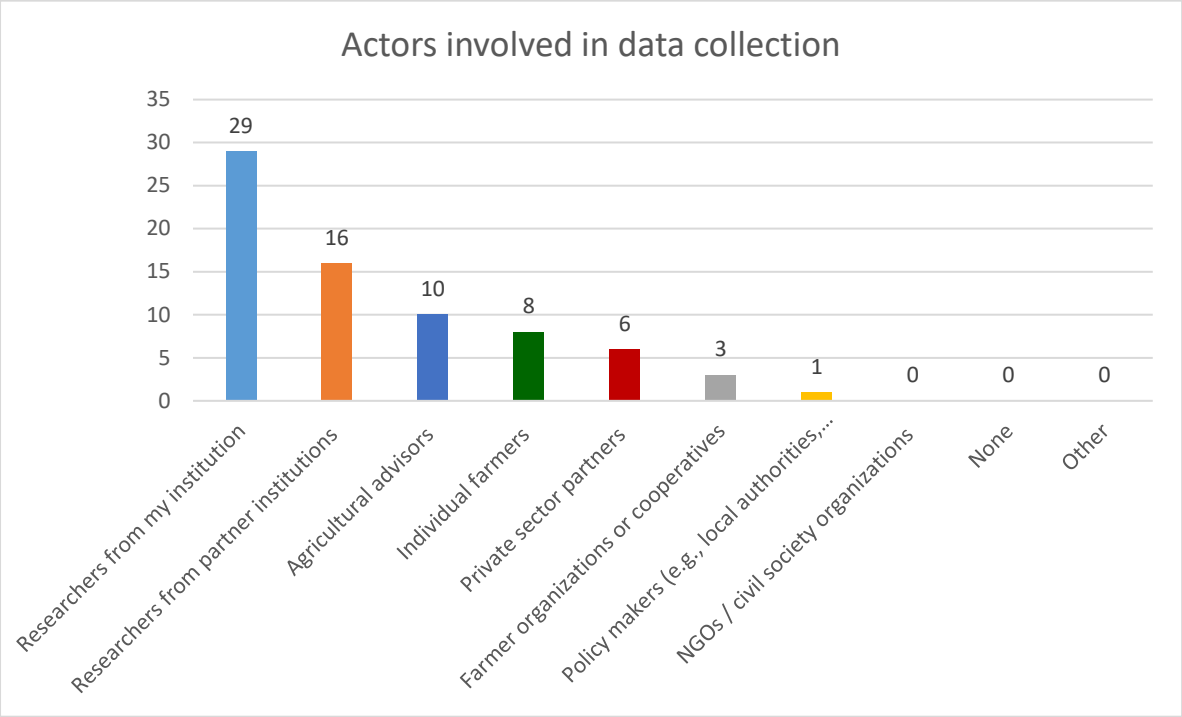


Figure 20. Actors involved in data collection.

Figure 21 reveals that data analysis and interpretation are overwhelmingly performed by researchers from respondents' institutions (n = 29) and partner institutions (n = 19). Agricultural advisors (n = 3), and private sector partners (n = 2) play only marginal roles, while individual farmers, NGOs, and policy makers are effectively absent.

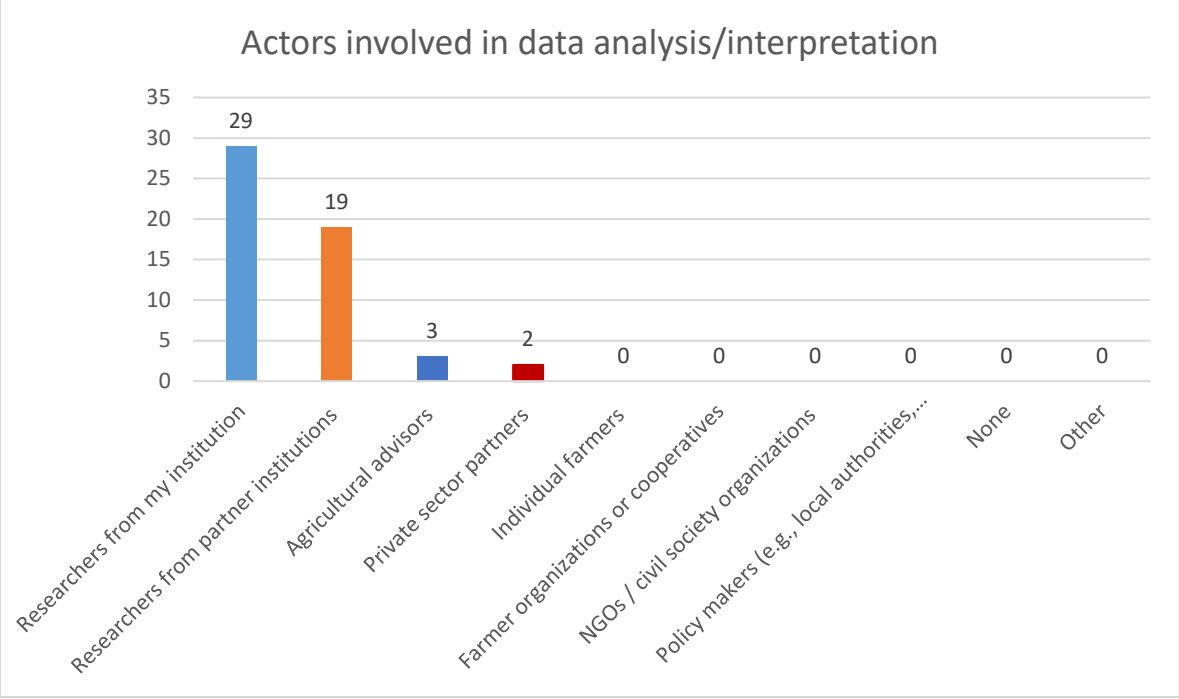


Figure 21. Actors involved in data analysis/interpretation.

Barriers and support to overcome challenges in transdisciplinary work

Next respondents were asked about the main barriers that ERSs experience when trying to collaborate with external stakeholders. The most frequently reported barriers are limited time availability (22%), lack of funding for collaborative activities (20%), and differences in expectations, priorities, or goals (17%). These barriers are followed by communicative barriers and 'administrative and institutional' constraints accounting for respectively 9% and 8%. Difficulties reaching external actors, physical distance, and limited stakeholder interest all made up 6% of the answers and lack of trust (4%), and lack of clear contact person (2%) were less frequently identified.

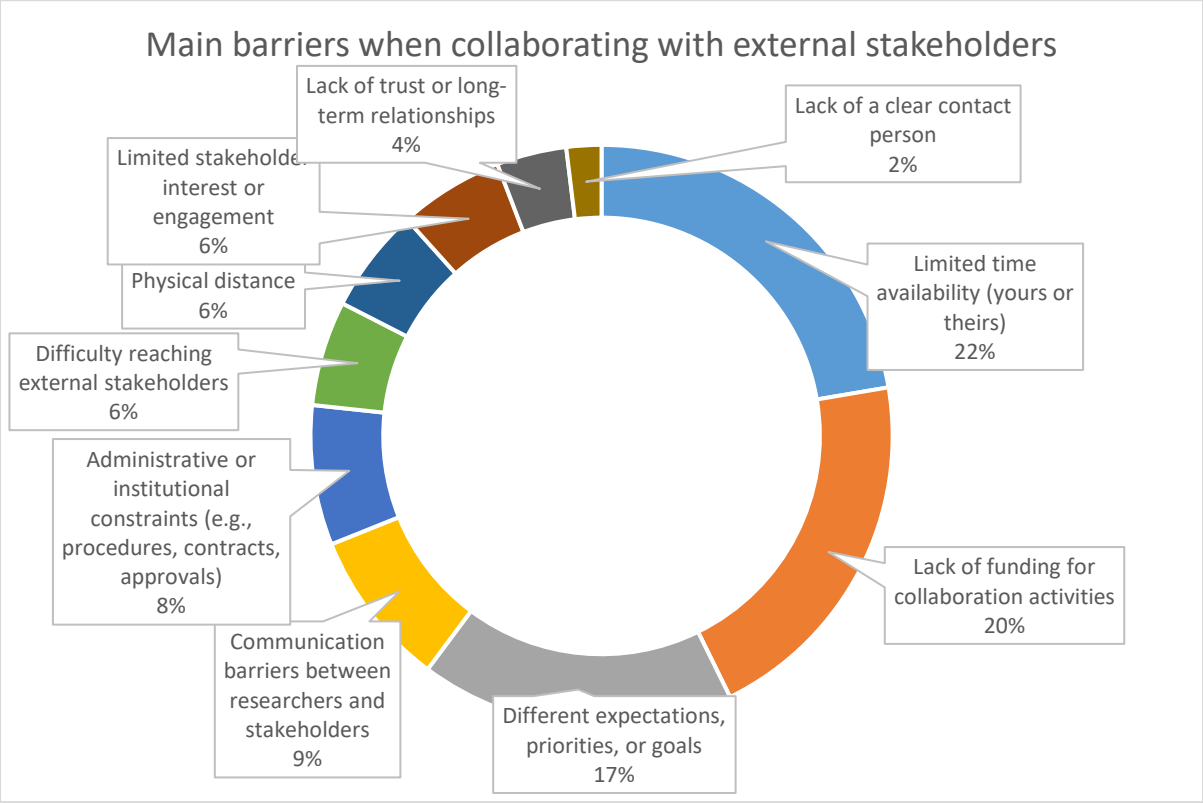


Figure 22. Main barriers when collaborating with external stakeholders.

Subsequently researchers were asked to formulate their main barrier when it comes to collaborating with external stakeholders. The qualitative responses align strongly with previous graph. First and foremost funding and specifically financial support specifically for collaborative activities is needed. 20 out of 29 made a remark about financial support. Participants emphasize not only the quantity of funding, but also its design and flexibility. Several respondents stress the importance of:

- Dedicated budgets for co-creation and dissemination activities.
- Financial compensation for farmers and advisors participating in research.
- Long-term funding arrangements.
- Resources for training, communication, and network building.

Secondly, time emerges as the second most prominent issue. Participants emphasize that both researchers and practitioners have limited time available for stakeholder engagement. Specifically, time is mentioned in context of the lack of time to organize regular co-creation activities, the limited time for building a network and maintaining these relationships and the limited time to disseminate

and communicate results. It seems like collaboration has become an expectation for many research funding calls, which requires extra work, but the capacity of the staff hasn't increased, which minimizes the quality and thus the impact of the collaboration.

Thirdly, another highly mentioned concern is institutional and administrative support and incentives for collaboration. Even though collaboration is expected nowadays in many research projects, collaborative activities are not yet totally facilitated by the academic and institutional context. This relates for example, back to specific mechanisms to fund stakeholders and incentivize them to join workshops covering for accommodation, travel costs, …etc. Researchers also indicate the need for organizations to support structures that recognize transdisciplinary work, give access to co-creative materials and offer training on facilitating methods.

This point touches upon a fourth barrier mentioned by the respondents, namely the fact that training is needed for researchers to collaborate with external stakeholders. It seems that researchers aren't always comfortable with facilitating such activities, even though this might feel expected nowadays. Someone for example answered: *" I think that not every researcher has the same experience or willingness to collaborate with practitioners, and I don't think that's necessary. So, training of these 'collaboration experts' would be my main demand, together with institutional support to determine and validate these collaboration experts in the institution."* Other specific training related needs included:

- Overall expertise for working with non-academic actors.
- Communication skills, video communication and dissemination.
- Designing practical tools and methodologies.
- Speaking the local language.

The translation of research into practice was a fifth barrier often mentioned. Some respondents emphasize the challenge of producing and making research relevant and accessible to practitioners. Issues raised include:

- Inability to do on-farm testing
- Inability to identify research usefulness for farmers
- Translating scientific findings into practical applications.

Finally, there is also the issue of the lack of relationships with external stakeholders. Some mentioned the inability to find farmers who are interested in collaborating or maintaining existing relationships. Access to experienced intermediaries seems necessary.

The responses suggest that improving collaboration with practitioners requires moving beyond individual and project-level interventions and addressing broader systemic conditions. However, individual barriers such as the lack of skills for communicating results or maintaining valuable networks will need to be addressed equally. The findings point toward a dire need for dedicated and long-term funding, institutional recognition of transdisciplinary work, capacity building, and stronger networks. Together, these elements form the enabling environment necessary for more sustained and meaningful research-practice interactions. This indicates that the challenge lies less in motivating researchers to collaborate and more in creating organizational and funding structures that make such collaboration feasible and rewarding.

4.2.2. A systems approach in research and innovation design

As with transdisciplinarity, respondents were asked to quantify the integration for systems thinking in their research design. Additionally, they were also asked to elaborate on their rating on ten to gain a

deeper understanding of how respondents interpret a systems approach and to better assess what their numerical score of 7.5 out of 10 actually represents.

Respondents scoring 7-8/10 (46% of the two samples combined) generally describe systems thinking as an important and regularly applied element of their research, although not yet fully integrated across all activities. Research is typically conducted from a holistic perspective that considers interactions between agronomic, environmental, economic, and, in some cases, social factors. Many respondents highlighted whole-farm or farming-system approaches, long-term experiments, and integrated assessments that evaluate trade-offs between productivity, profitability, resource use, animal welfare, biodiversity, climate adaptation, and environmental impacts. One example of a typical response focusing on systemic approaches by integrating trade-offs says: *"I would say it is moderately integrated as we consider interactions between practices, yields, soil carbon, nutrient losses and farm economics, and we aim to assess trade-offs rather than single indicators."*

A recurring theme is the use of multidisciplinary collaboration and stakeholder engagement to address complex agricultural challenges. Researchers frequently collaborate with advisors, farmers, industry actors, policymakers, and experts from different scientific disciplines to develop and evaluate solutions at system level. Several institutions also reported dedicated system experiments, Living Labs, or long-standing traditions in systems research.

At the same time, respondents acknowledged important limitations. Systems thinking is often applied more strongly in some projects or departments than in others, and broader social, policy, governance, and value-chain dimensions are not always incorporated. Practical constraints, including time, funding, expertise, and data availability, can limit the extent to which a systems perspective is achieved. Overall, this group reflects a substantial commitment to systems thinking, but one that remains unevenly implemented and often project-dependent.

The lower-scoring responses (1-6/10 amounting to 22% of the two samples) indicate that systems thinking is only partially integrated into research and is often limited to agronomic and environmental aspects. While respondents commonly consider interactions between factors such as crop production, soil health, climate impacts, and farm economics, broader socio-economic, policy, and value-chain dimensions are often missing.

Many respondents acknowledged the importance of a more holistic approach but pointed to barriers such as limited interdisciplinary collaboration, insufficient institutional support, lack of resources or time, and data constraints. For example one respondent mentions: "*However, full system-level modelling and inclusion of wider value-chain and policy dimensions is still limited by data availability and resources, so most studies remain focused on specific cultivars."* As a result, research tends to focus on specific components of agricultural systems rather than fully addressing their wider interconnections and trade-offs. Several also noted that systems thinking is considered in some projects, but not yet applied consistently across all research activities.

The highest-scoring respondents (9-10/10 amounting to 32% of the two samples) describe systems thinking as a fundamental principle that is embedded in their research strategies, experimental platforms, and organizational structures. A key characteristic of this group is the use of system-level experiments and integrated assessments. Respondents frequently refer to long-term system trials, whole-farm approaches, Life Cycle Assessment (LCA), multi-criteria evaluation frameworks, and research platforms specifically designed to test combinations of innovations under real-world conditions. Topics such as soil health, biodiversity, water quality, greenhouse gas emissions, productivity, profitability, climate adaptation, and resource efficiency are often assessed simultaneously. Compared with the lower-scoring groups, these respondents more frequently

integrate environmental, economic, technological, and socio-economic perspectives into a single analytical framework. Stakeholder involvement, technology transfer, and practical applicability are often part of this approach, although the main emphasis is on understanding and managing the complexity of agricultural systems as a whole.

A systemic approach in more detail within CSR

This section examines how the systemic dimension is integrated into research and innovation design among ERSs within CSR. We asked the ERSs within CSR (n = 29) about the types of interactions they address in their research. Specifically, we distinguished between interactions across scales (e.g. crop, plot, farm, landscape, and value chain), across domains (agronomic, social, economic, and environmental), and among different climate-smart practices. In addition, respondents were asked to identify the trade-offs they explore in their work. This was followed by questions on perceived barriers and the tools used to support system analysis.

Consideration of interactions across scale dimensions, domains and agricultural practices

Firstly the following questions was asked; '*Does your research take into account interactions (synergies and trade-offs) of impact at several scale dimensions (crop/animal – plot – farm- landscape – region – value chain?'* Almost one third (31%) of the ERSs within CSR indicated that their research explicitly considers the interactions across several scale dimensions. The majority (55%) percent considers these kinds of interactions to a certain degree, while 14 percent indicates they do not take this into account in their research design.

When asked to explain briefly the methodological approach for understanding the interactions of impact on serval scale dimensions it becomes clear that most often this happens through the integration of experimental studies with modelling approaches. Modelling mostly happens to the farm level, but also at the regional and national level to determine the impact at larger scales. Another approach mentioned was the use of LCA and another ERS explained that through "*models and national scale data (e.g. remote sensing, national surveys) the results from xxxx can be out-scaled to the 1843km2 of lowland xxxx grazing farming."* Research also happens at different scales, without modelling approach for example one ERS mentions that they conduct research at pot, mesocosm, lysimeter, plot, field, farm and catchment scale. One answer mentioned they collaborate with farmers to carry out research on farm level. And one indicated a barrier for doing research at different scales is the lack of data, for example for value chain and landscape scales.

Secondly, the interaction between different domains were inquired by asking; *'Does your research take into account interactions (synergies and trade-offs) at several domains (agronomic, economic, social and environmental)?* These types of interactions were most studied by the ERSs. A substantial majority of respondents (62%) reported that their research accounts for interactions, synergies, and trade-offs between agronomic, economic, environmental, and social domains. Another 31% indicated that this is done only to some extent, while 7% reported no consideration of these interactions.

Similar to the interactions at different scales, respondents were asked to clarify how they methodologically integrate the interactions and impacts of different domains, such as the agronomic, economic, social and environmental dimensions. The qualitative responses suggest that multidimensional assessments are well embedded in climate smart research, especially regarding the agronomic, economic and environmental dimensions. Economic and environmental dimensions appear to be routinely integrated, whereas social impacts are less consistently addressed. According to some respondents, the economic dimension is taken into account to consider the anticipated implementation for farmers, for example through cost-benefit analyses. The environmental dimension

is mostly assessed using nutrient and soil indicators. This popularity on soil and nutrient cycles reflects the same results from discussed under 4.1.3. when researchers were asked what other environmental aspects were considered in their research. Some respondents specified this further by indicating that they focus on soil health and water management. The social dimension was mentioned less frequently, mostly by gathering feedback from practitioners. Other methodologies mentioned include LCA, whole-farm assessment tools, scenario analysis and multi-criteria evaluations. Several respondents also highlighted data limitations and constraints imposed by the research boundaries (field, farm or region), which hinder comprehensive assessments across all sustainability dimensions.

Thirdly, it was asked '*Does your research adopt a systems approach to CSA by taking into account interactions (synergies and trade-offs) between several agricultural practices?'* Approximately 38% indicated that such interactions are explicitly assessed, while 52% stated that they are considered only to some extent. Ten percent reported that they do not address these interactions.

The researchers indicated in the qualitative section of this question that they see the need to implement multiple practices at once in their research design because of the complexity of the agricultural system. For example, one respondent stated: "*Agricultural systems are inherently highly complex, and numerous sensitivity tests / trials are required to obtain fundamental information on how each parameter interacts with the system*." However, fewer responses explained how this is done in practice. Researchers described that they focus on combined agricultural practices such as crop–livestock systems, where they try to improve the overall system performance of the farm. Other combinations mentioned include soil conservation practices with precision agriculture, and cover crops with reduced tillage and optimized fertilization. How this research is conducted remains unclear in many of the answers. LCA and modelling are mentioned as methodologies by many. Another ERS explains that they compare different farms with different farming practices.

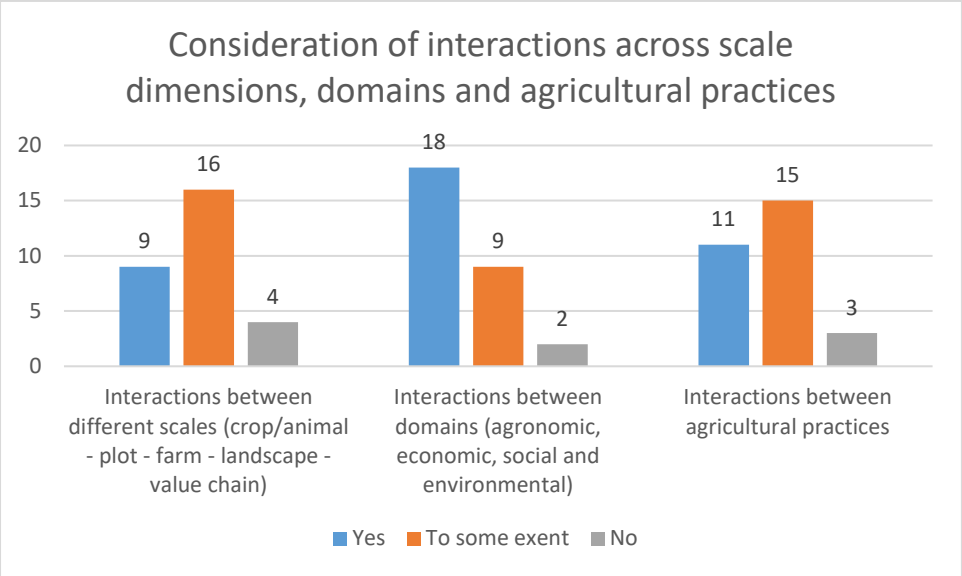


Figure 23. Consideration of interactions across scale dimensions, domains and agricultural practices.

Consideration of trade-offs

When asked what kinds of trade-offs the ERSs explored, economic viability versus environmental performance and productivity versus mitigation where most popular. One ERSs specified that they were specifically looking into economic viability versus soil health and economic viability versus

biodiversity. These trade-offs as well as the other interactions we discussed highlight the same trend seen before in the topical analysis. Namely that the agronomic, the environmental and economical dimensions of CSA are most popular in research design. The social dimensions are less considered in these systemic research designs.

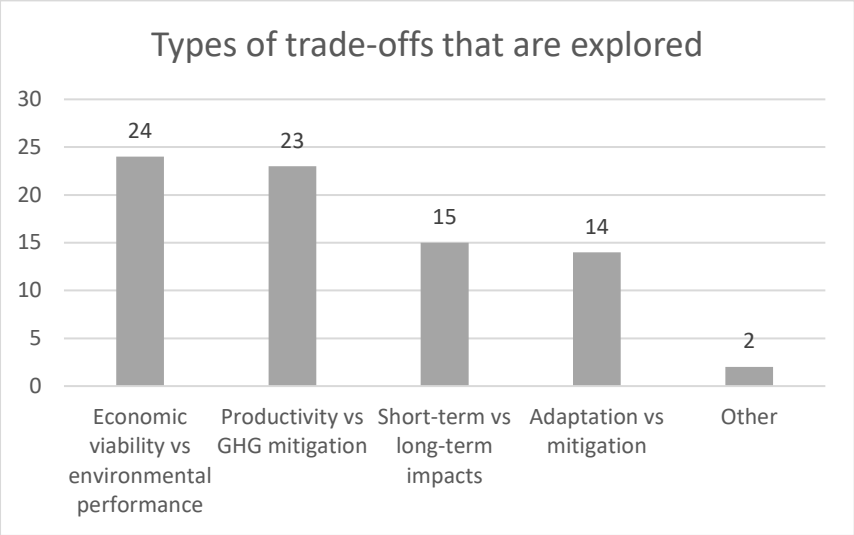


Figure 24. Types of trade-offs that are explored.

Barriers to integrating systems thinking

Although the data shows that systems thinking is actively adopted in research design, respondents still reported several barriers to its implementation. The responses to these questions were relatively equally distributed among the possible answers. The most frequently mentioned challenge was lack of time to explore or apply systems thinking approaches (13). This was followed by three equally often indicated barriers: lack of data, difficulty in collaborating with other disciplines and insufficient intuitional support (11). Almost equally often indicated were the lack of knowledge or training in system thinking approaches and the lack of suitable methods, tools or frameworks (10).

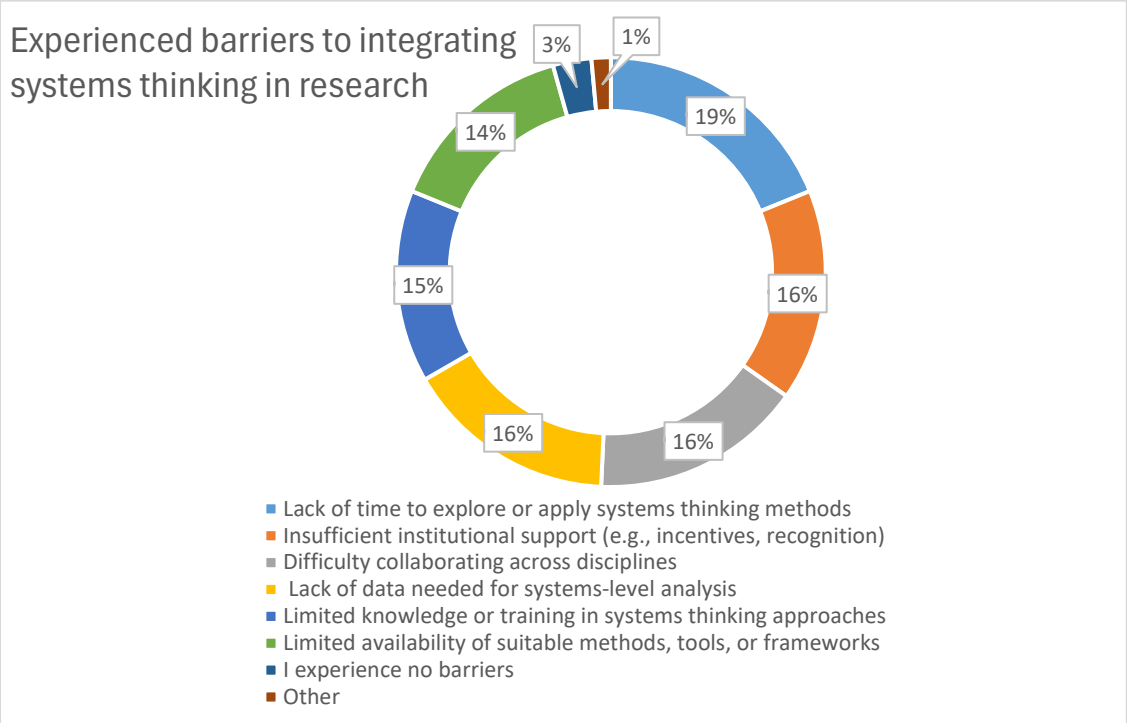


Figure 25. Experienced barriers to integrating systems thinking in research.

Familiarity with system thinking tools

To be able to analyze system dynamics, certain tools are typically used to map out the actors that influence each other. Respondents displayed rather lower levels of familiarity with different system mapping tools with one third up to half of the ERSs not being familiar with the tools. Participation tools for stakeholder engagement were the most known tool among the ERSs. 22 of the ERSs were familiar to some degree with these kinds of tools. The second most known type of system mapping tools are stock and flow diagrams with up to 21 researchers of the ERSs being familiar at some level. Thirdly there are the mind maps (19/29). The least known tool are the causal loop diagrams with just more than half of the respondents who indicated they had no familiarity with these kinds of mapping tools. Overall, the system mapping tools we proposed weren't very known among the ERSs.

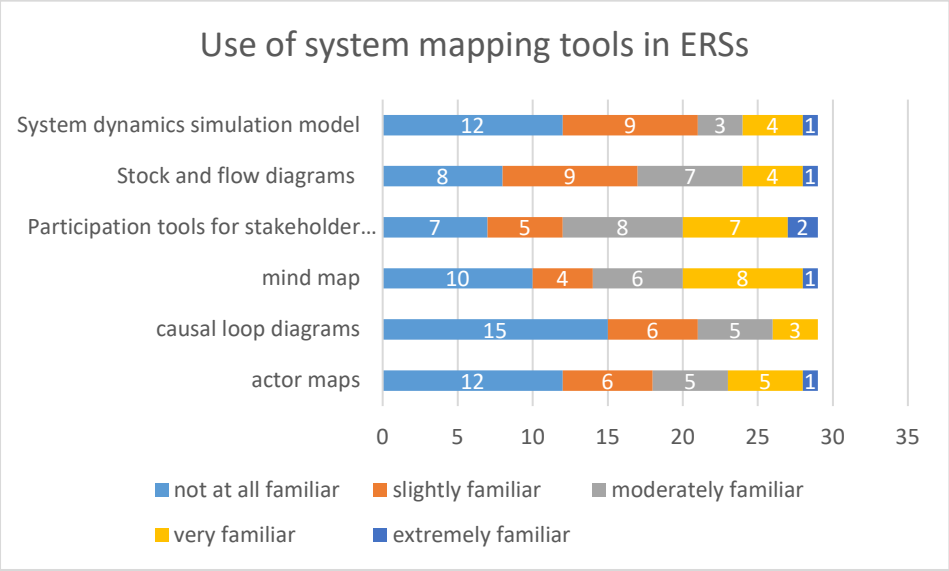


Figure 26. Use of system mapping tools in ERSs.

The tools mentioned by the respondents as 'other' show that what they understand as system thinking tools are rather 'system aware' tools that are and can be applied to analyze different dimensions on a system farm level. They can be grouped into three main categories: LCA approaches, whole-farm simulation and biophysical models, and trade-off analysis as a form of systems thinking. The most prominent category consists of whole-farm simulation and biophysical models. Examples include Farmax, Overseer, DairyNZ Whole Farm Modelling, CAP'2ER, DIAPASON, BIOTEX, CLIM'ALEA DIAG, as well as process-oriented biogeochemical modelling approaches. They typically focus on elements such as nutrient flows (nitrogen and phosphorus), greenhouse gas emissions (methane and ammonia), production outputs, and in some cases biodiversity or climate risk. A third category that emerges is trade-off analysis, which reflects an underlying systems thinking approach rather than a specific set of tools. Examples include references to the identification of trade-offs such as ammonia versus methane emissions or nitrogen versus methane, as well as farm-level partial cost–benefit analysis.

4.2.3. Reflexivity in research and innovation design

Lastly, as with two previous sections on transdisciplinarity and systems thinking, respondents were asked to elaborate on the reflexive practices they integrate in their research by asking the same question. In doing so a deeper understanding of respondents' numerical interpretation of reflexivity was obtained.

Respondents scoring 7-8/10 (amounting to 42,9% of the two samples) generally describe reflexivity as an ongoing and iterative process of reflection, adaptation, and learning throughout the research cycle. Reflexivity is often embedded in applied research through the continuous evaluation of research methods, experimental results, and practical impacts, with adjustments being made based on field observations, stakeholder feedback, and emerging challenges. A recurring theme is the importance of engagement with farmers, advisors, industry partners, steering committees, and scientific collaborators in reviewing research approaches and identifying opportunities for improvement. Many respondents highlighted feedback loops, participatory approaches, monitoring systems, field diaries, and periodic evaluation moments as mechanisms that support learning and

adaptation. Several ERSs also emphasized that being closely connected to farming practice helps ensure that research remains relevant to real-world challenges and societal needs.

At the same time, reflexivity is often described as being informal rather than guided by explicit frameworks or methodologies. While critical reflection and adaptation are common, formal processes for assessing assumptions, researcher positionality, ethical implications, societal impacts, or long-term consequences are less consistently applied. Some respondents also noted that reflexive practices vary across projects and research groups and can be constrained by time, resources, or institutional structures.

The high-scoring respondents (9-10/10, amounting to 21,4% of the two samples view reflexivity as a core principle underpinning responsible and impactful research. It is characterized by critical self-assessment, stakeholder engagement, evidence-based adaptation, and a strong focus on ensuring that research remains relevant, effective, and aligned with sustainability goals. Here, a prominent theme is the consideration of the broader implications of research, including environmental sustainability, economic viability, societal needs, and practical applicability for farmers. One response exemplifying this stated:

> *"Feedback from farmers, advisors, companies and research partners is incorporated throughout the research process, allowing the adjustment of methodologies and priorities when necessary. This iterative process helps ensure that research outcomes remain relevant, practical and aligned with societal and environmental goals."*

In contrast, the lower-scoring responses (1-6/10 amounting to 35,5%) suggest that reflexivity is generally limited, informal, or not clearly understood within research activities. Several respondents indicated that they do not have specific methods, structures, or institutional processes for integrating reflexivity into their work, while others were unfamiliar with the concept itself.

Where reflection does occur, it is typically confined to internal discussions within research teams, focusing on experimental design, methodological challenges, interpretation of results, and project planning. Some respondents reported incorporating feedback from collaborators, advisory boards, or stakeholders, but this is often done on an ad hoc basis rather than through systematic reflexive practices.

Several barriers to reflexivity are described. The most frequently mentioned barrier is the lack of formalized reflexive structures or methodologies. Multiple respondents state that reflexivity is not systematically integrated, remains informal, or depends on individual researchers or specific projects. Time constraints are another recurring barrier, with one respondent explicitly stating that there is rarely sufficient time for reflexive engagement: "*It is not that we don't engage in reflexivity, it is primarily the problem that we rarely have the time, which of course is no excuse!"* Institutional constraints are also mentioned as limiting the full application of reflexivity. Several responses further indicate that the level of reflexivity depends on project duration, with longer-term projects providing more opportunities for reflection and adaptation than shorter studies.

Reflexivity in more detail within CSR

Reflexive practices such as feedback moments appear to be widely embedded in long term research projects (projects longer than 3 years). Two-thirds of respondents (66%) indicated that they regularly organize feedback moments, while 21% do so occasionally and 10% only rarely. Only 3% reported never organizing such interactions. This pattern demonstrates a strong commitment to iterative learning and stakeholder engagement within the participating organizations.

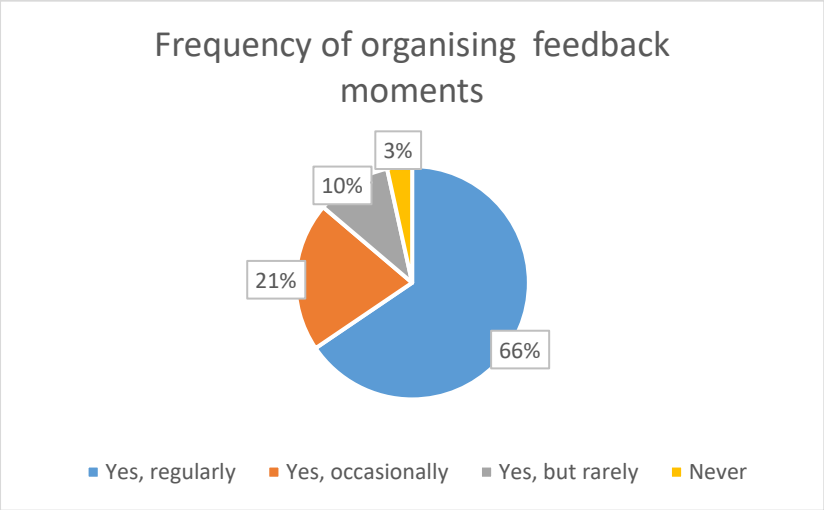


Figure 27. Frequency of organising feedback moments.

The amount of feedback moment doesn't say much yet about the quality of these moments. Various mechanisms are employed to facilitate reflection and feedback. We asked what was most applied in research activities of the ERSs. Stakeholder workshops, advisory board meetings and farm visits emerged as the most relied on feedback- moment activities. As they imply real life contact moments, they are qualitative and as such these results are quite positive. Surveys or interviews are less frequently used. Online meetings, email exchanges and written reports appeared as least used forms of interaction to gain feedback. When asked what other forms of feedback organized by the ERSs, peer-to-peer learning was mentioned a couple of times, for example some ERSs organize individual meetings with farmers. And finally, educational activities for farmers are also organized by some ERSs.

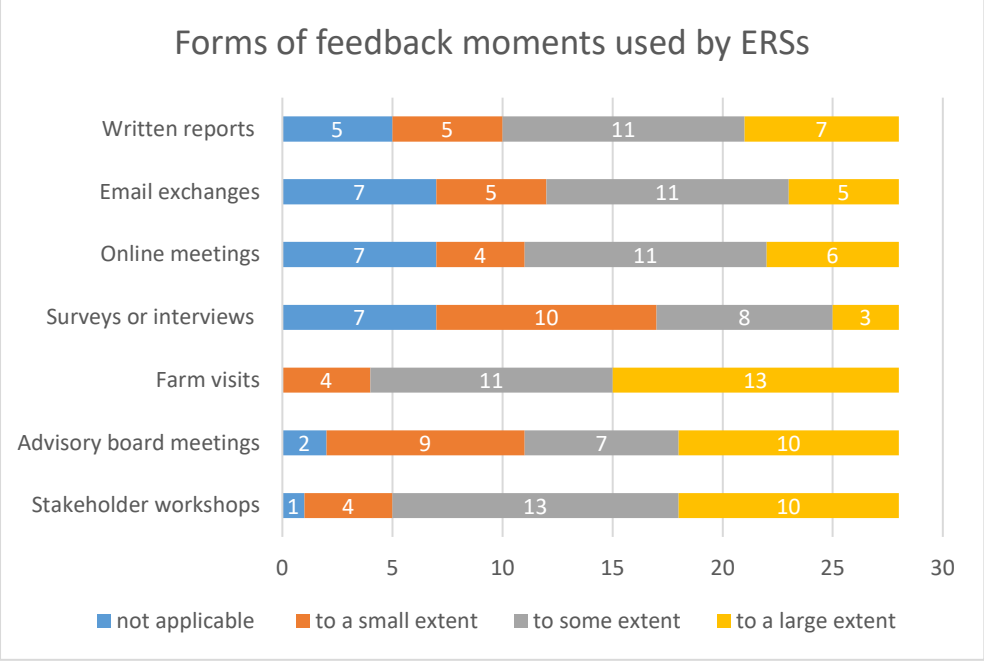


Figure 28. Forms of feedback moments used by ERSs.

5. Knowledge in networks

The following part examines barriers and opportunities for improving knowledge flows in networks. It focuses first on the RPG, then on konwledge transfer practices and lastly on ERSs in their AKIS networks.

5.1. The research practice gap

This section based on the results from S2 examines researchers' perspectives on the RPG. The RPG refers to the persistent challenge of translating research and innovation into practical implementation, due to a range of theoretical, methodological, personal, and practical barriers (Siebrecht, 2020). Conversely, farmers' tacit and experiential knowledge is often not adequately communicated to researchers, which can result in research outcomes that are difficult to apply in practice or insufficiently aligned with farmers' needs. Therefore, various dimensions of research design (transdisciplinary methods, systemic design and reflexivity) as well as targeted communication and sustainable networks play a central role in bridging this gap.

Providing researchers with a definition of the RPG similar to the one above, they were asked '*to what extent do you recognize this gap between research outcomes and their implementation in real-world farming situations?*' The researchers from the ERSs within CSR clearly indicated that they recognize a RPG with almost half of the researchers (48%) reported largely recognizing the gap, while an additional 34**%** recognized it to some extent. Only 14% indicated recognizing the gap to a small extent, and 3**%** were unsure. Notably, no respondents reported that they did not experience a RPG.

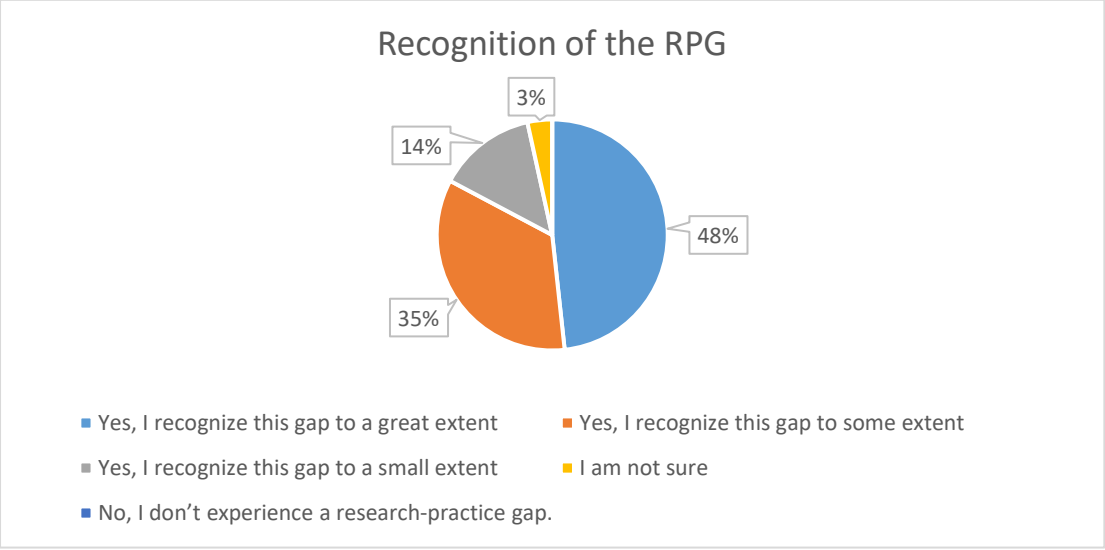


Figure 29. Recognition of the RPG

These findings demonstrate a strong consensus among researchers that a disconnect exists between research outputs and their practical implementation within agriculture. The absence of respondents denying the existence of the gap suggests that it is perceived as a systemic issue rather than an isolated problem.

Next, researchers were asked to indicate what they thought were the most important factors contributing to the RPG. Out of these results the following figure 30 was made. The most signaled reason was the fact that ‘the impact of research and innovation is not clear enough for farmers.’ The fact that researchers believe this to be the most important barrier underlies the importance of stronger collaborative and co-creative work. It points towards a fundamental misunderstanding in the activities of researchers and farmers’ needs. The second most indicated factor researchers believe to sustain the RPG is the fact that there are too little economic incentives for farmers to engage with new technologies. This strongly aligns with what the literature review also reveals about adoption of climate smart agricultural practices.

On a third position are two seemingly interrelated barriers: ‘institutions prioritize academic output over non-academic results’, and ‘insufficient time and funding are attributed to dissemination activities and adoption support’. Related and almost as popular was the idea that a ‘too heavy workload is limiting the time that is available for outreach or dissemination.’

Additionally, on this third position on the chart researchers believe that ‘innovation remains disconnected from the complex farming environment’ which underlies the importance of good systemically designed research that tries to take wider environmental interactions into account.

The following table goes into more detail on the frequency of the answers. The two ‘other’ responses submitted mentioned that there is a difference between the experimental situation and the actual farming situation and that there are various barriers across the supply chain.

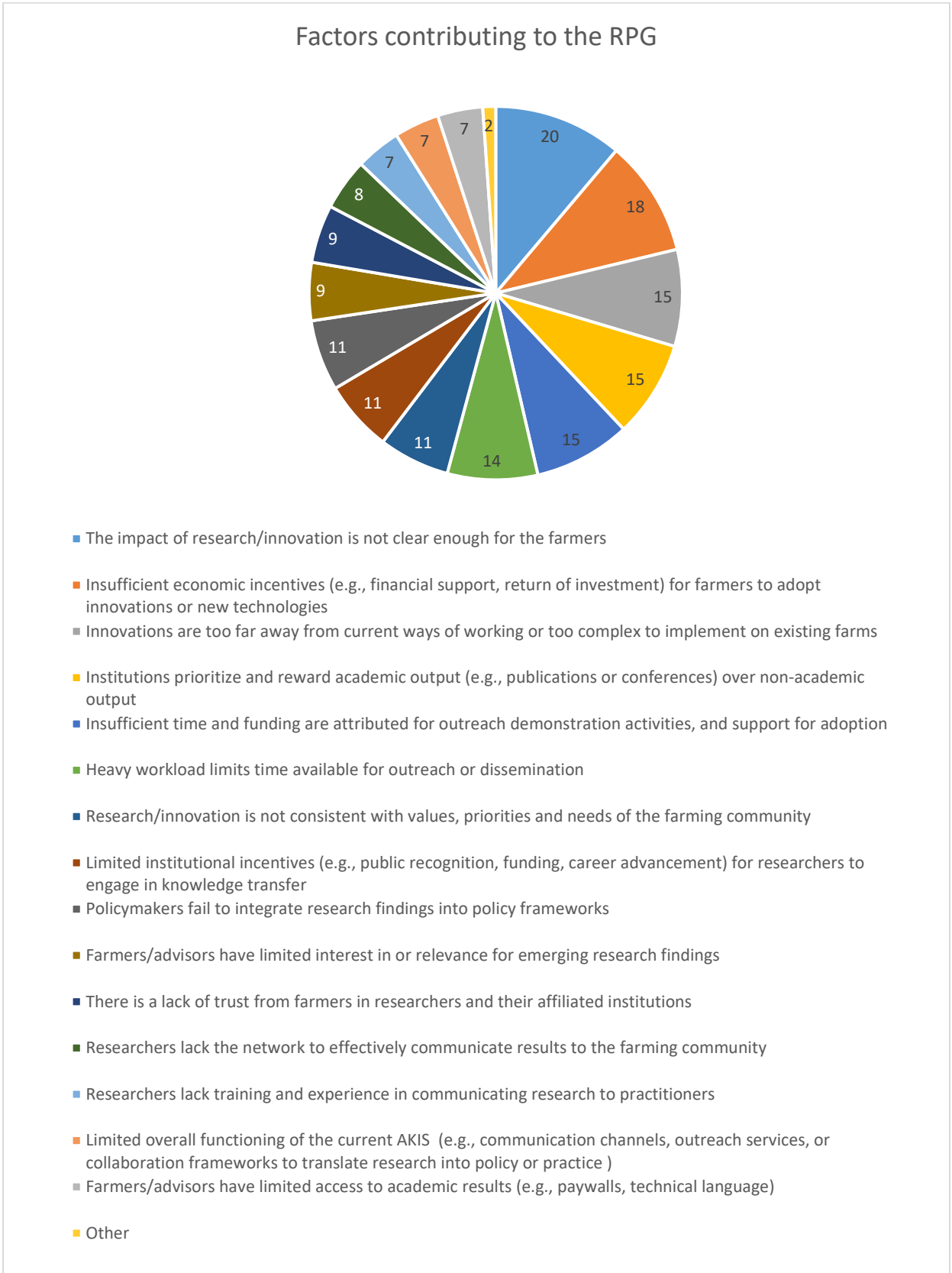


Figure 30. Factors contributing to the RPG

Additionally, researchers were asked what they believe is the single most significant barrier to the RPG. Overall, the qualitative results overlap with the quantitative responses. Qualitative data reveals that for the researchers the main barriers to implementing research results are concentrated around four major themes: ‘economic constraints’, ‘communication and knowledge transfer’, ‘the gap between research and practice’ and ‘time and capacity limitations’.

‘Economic and financial barriers’ dominate the responses. Many researchers indicated that farmers are unlikely to adopt innovations unless there is a clear financial benefit or external support. Respondents repeatedly referred to the high costs of implementing new technologies, limited farm cash flow, uncertain returns on investment, and the financial risks associated with changing farming practices. Several noted that innovations and emerging technologies are particularly inaccessible for small and medium-sized farms without public funding or subsidies. Others emphasized that mitigation strategies, especially those targeting greenhouse gas emissions, often lack an immediate economic return, making adoption unattractive.

A second prominent theme concerns ‘communication and knowledge transfer’. Several respondents argued that research findings are not communicated effectively to farmers and other stakeholders. Researchers noted a lack of incentives and funding for dissemination activities, insufficient time for knowledge exchange, and limited training in communicating scientific findings to practitioners. Communication barriers across the larger agricultural supply chain were also described as further limiting the transfer of knowledge into practice.

The responses also highlight a significant mismatch between ‘research and practical farming conditions’. Several researchers stated that experimental conditions often differ substantially from the realities of farming. Others argue that research priorities, particularly in environmental research, are often disconnected from farmers' day-to-day concerns, values, and priorities. Farmers were described as needing locally validated results and practical evidence before they are willing to modify existing management practices.

Another recurring barrier relates to ‘time and workload’. Both researchers and farmers were perceived to have limited time available for implementation activities. Respondents mentioned heavy farmer workloads, insufficient labor capacity, and limited opportunities for exchange between researchers and practitioners. Researchers similarly referred to limited time for dissemination and outreach, reducing opportunities for effective knowledge transfer.

Some other less mentioned responses identified institutional and behavioral barriers as well. Some researchers mentioned skepticism among farmers regarding the effectiveness of new practices, limited trust in institutions, and concerns about policy initiatives such as the Green Deal. Administrative burdens on farms were also viewed as discouraging the adoption of new practices. In addition, some respondents argued that governments place insufficient emphasis on supporting the practical implementation of innovations through policy and incentive structures.

Actors bridging the RPG

When asked which actors play the most important role in bridging this gap respondents identified farmers organizations and agricultural advisors as the most influential actors. To lesser extent they viewed policy makers, research institutes and farmers themselves as important contributors. They

recognized agri-food sector private companies and NGO's play, as playing comparatively smaller roles. In the category of others, researchers, funding bodies and the farming media were mentioned.

These findings indicate that respondents view knowledge exchange as a collaborative process involving multiple stakeholders such as advisors and farmers representatives rather than the sole responsibility of researchers. The prominent role assigned to advisors and farmers organizations reflects their position as intermediaries who translate scientific knowledge into practical recommendations effectively bridging the RPG. Policy makers, more so than researchers themselves, are also regarded as responsible actors in facilitating this process. Finally, researchers are recognizing farmers, although less than themselves as an active actor in bridging the RPG.

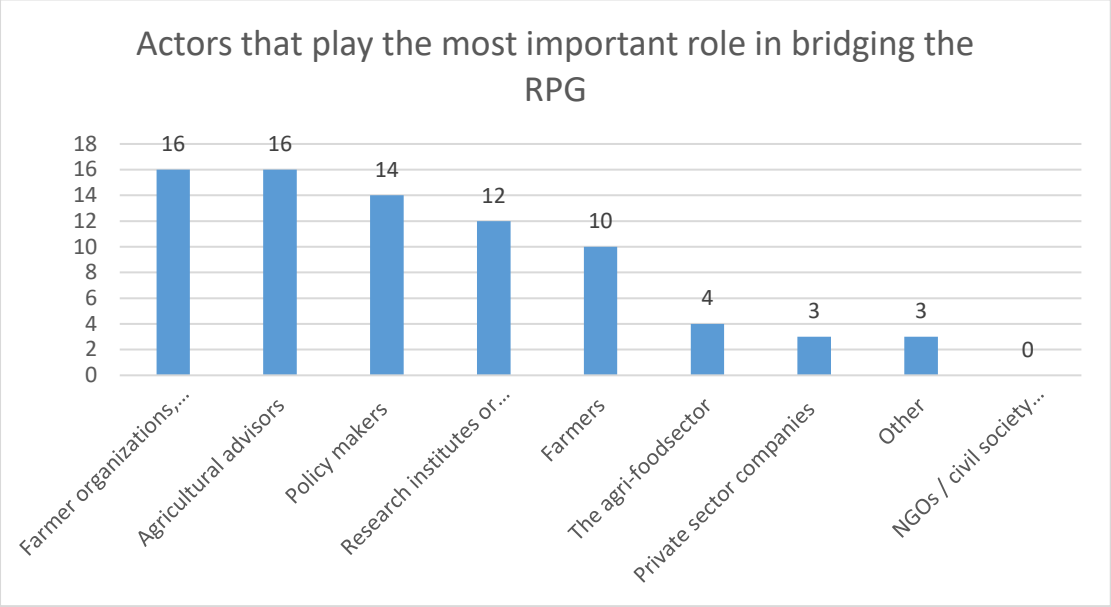


Figure 31. Actors that play the most important role in bridging the RPG.

Lastly, we presented various statements related to the RPG to which researchers could answer to which extent they agree. Figure 32 presents these results. Overall, the responses indicate strong support for researcher responsibility and collaboration with practitioners, while highlighting concerns regarding institutional support and funding mechanisms.

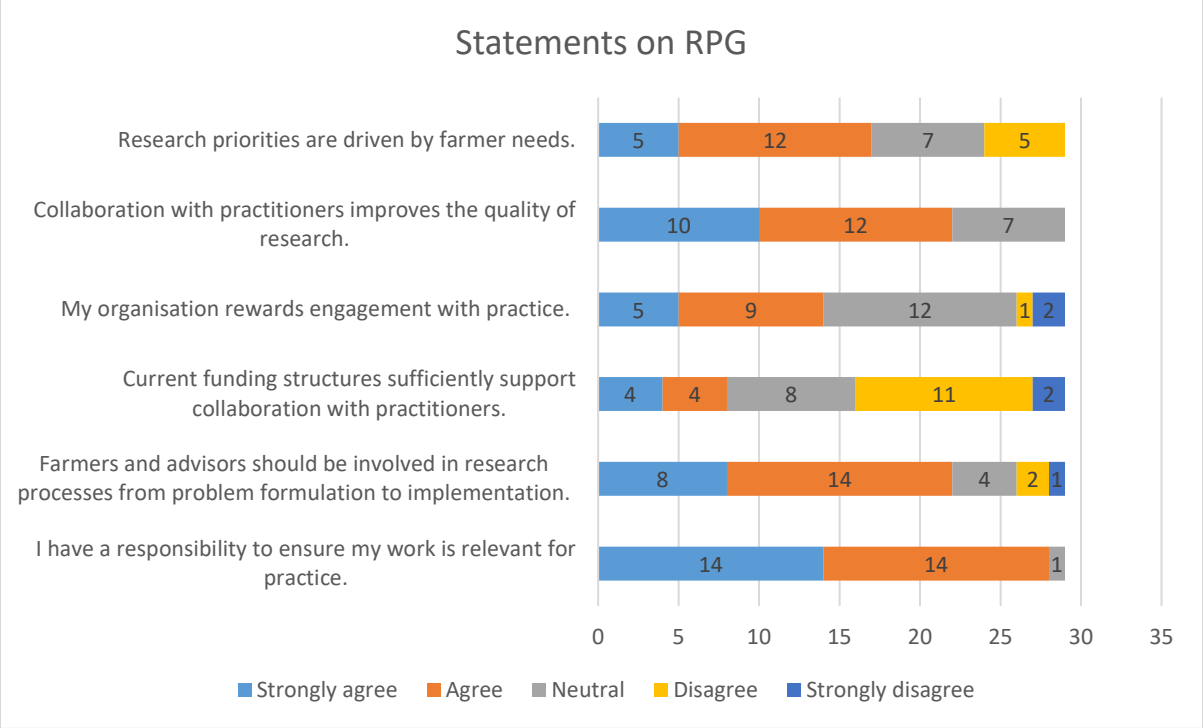


Figure 32. Statements on RPG.

The strongest consensus was observed for the statement "I have a responsibility to ensure my work is relevant for practice." Fourteen respondents (48.3%) strongly agreed and a further fourteen (48.3%) agreed, while only one respondent (3.4%) remained neutral. No respondents disagreed with this statement. This demonstrates an almost unanimous recognition among researchers that ensuring practical relevance forms part of their professional responsibility.

High levels of agreement were also observed for the statement "Collaboration with practitioners improves the quality of research." Ten respondents (34.5%) strongly agreed and twelve (41.4%) agreed, while seven respondents (24.1%) remained neutral. Importantly, no respondents expressed disagreement with this statement, indicating widespread recognition that practitioner engagement contributes positively to research quality.

The agreement of the two above-mentioned statements seems to translate into a strong support for involving practitioners and advisors throughout the total research process. For the statement "Farmers and advisors should be involved in research processes from problem formulation to implementation," eight respondents (27.6%) strongly agreed and fourteen (48.3%) agreed. Four respondents (13.8%) selected a neutral response, while only two respondents (6.9%) disagreed and one respondent (3.4%) strongly disagreed. Overall, over three-quarters of respondents supported participatory approaches overall all stages of research while still 10.3% believe that end users should not be involved in some stages of the research process

More mixed responses emerged regarding institutional recognition of engagement activities. For the statement "My organization rewards engagement with practice," only five respondents (17.2%) strongly agreed and nine (31.0%) agreed. Twelve respondents (41.4%) selected a neutral response, while one respondent (3.4%) disagreed and two respondents (6.9%) strongly disagreed. Although almost half of respondents perceived some organizational support, the high proportion of neutral

responses might suggest uncertainty or inconsistency in how engagement activities are recognized across institutions.

The statement "Current funding structures sufficiently support collaboration with practitioners" received the least favorable responses. Only four respondents (13.8%) strongly agreed and four (13.8%) agreed. Eight respondents (27.6%) remained neutral, while eleven respondents (37.9%) disagreed and two respondents (6.9%) strongly disagreed. Nearly 45% of respondents expressed dissatisfaction with current funding arrangements, making this the statement with the highest level of disagreement and confirming what has been reported earlier as well on the main barriers for transdisciplinary work.

Finally, responses to the statement "Research priorities are driven by farmer needs" demonstrated considerable variation. Five respondents (17.2%) strongly agreed and twelve (41.4%) agreed, suggesting that most respondents believed farmer needs influence research priorities to some extent. However, seven respondents (24.1%) remained neutral, while five respondents (17.2%) disagreed. No respondents strongly disagreed. Compared with other statements, this item displayed the greatest variation between agreement, neutrality and disagreement, indicating differing perceptions regarding the extent to which research agendas genuinely reflect farmers' priorities.

Overall, the responses show that researchers believe that the implementation of agricultural research is less constrained by the scientific quality of the research itself than by factors surrounding it such as economic feasibility, weak communication between researchers and practitioners, and insufficient institutional support for translating research into practice. The findings also indicate that the principal challenge in addressing the RPG may not lie in researchers' attitudes, but rather in the institutional environment in which research is conducted. Generally, researchers appear willing to collaborate with practitioners and recognize the value of engagement yet perceive organizational recognition and funding support as insufficient to fully realize these ambitions. Strengthening incentive structures, embedding better support in terms of time and funding for collaborative activities, and rewarding impact-oriented research may therefore be critical steps in narrowing the RPG.

5.2. Knowledge transfer practices

The second focus of this section is to explore the knowledge transfer practices employed by ERSs. Specifically, it investigates how researchers communicate scientific knowledge and engage with farmers and other stakeholders to support the transition towards CSA. The large majority of ERSs (83%) indicated that they felt like they had the necessary skills to communicate with non-academic stakeholders. They were asked to which audiences they usually communicate and how they usually go about this.

Figure 33 shows that researchers most frequently disseminate their findings to other researchers, agricultural advisors, farmer organizations, individual farmers and policy makers. Communication towards the general public and NGOs and civil society organizations is substantially lower, whereas private sector partners are somewhere in the middle. By asking the follow up question with whom else they communicate many responses mentioned students as being another important audience to the institute’s research results.

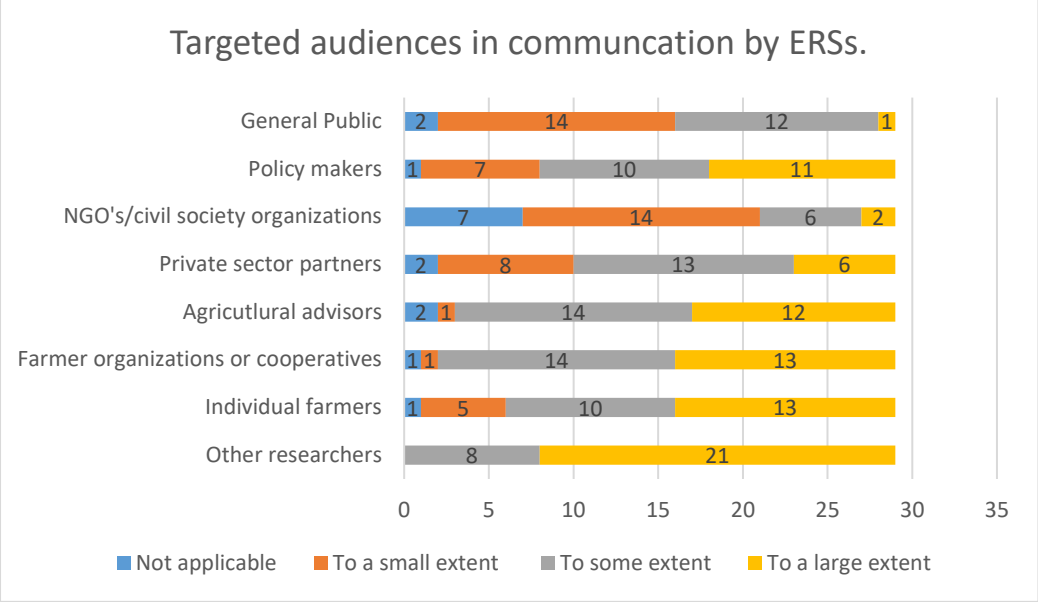


Figure 33. Targeted audiences in communication by ERSs.

Next, the method used by ERSs to disseminate the results was inquired. Many respondents reported using a variety of dissemination methods, with 'farmer events, on-field demonstrations, field days', 'academic journal articles, 'scientific conferences', and 'scientific reports/ project deliverables' among the most frequently used approaches. These are followed by 'non-academic materials (such as farm magazines, websites, technical guides, social media and newsletters)' and 'workshops or training sessions'. Finally, to a lesser extent results are disseminated through 'farmer networks', 'videos', 'policy advisory reports' and lastly 'advisory or extension services'.

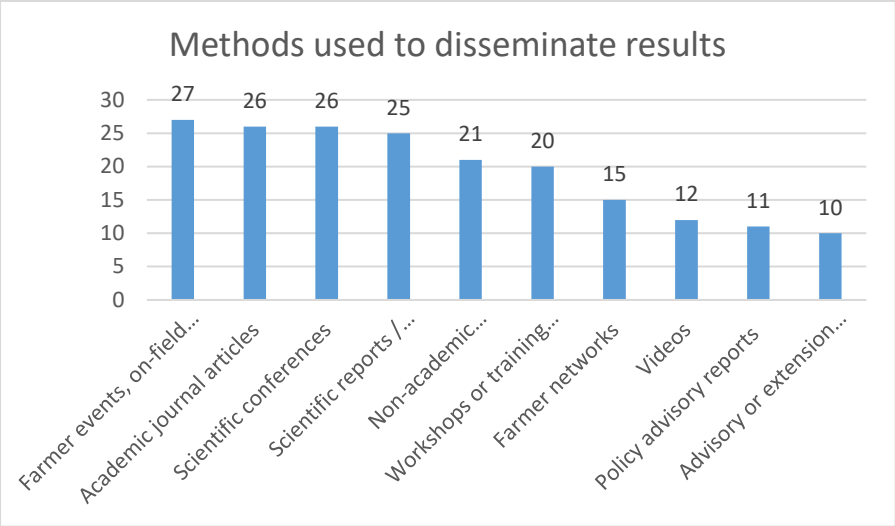


Figure 34. Methods used to disseminate results.

Lastly, it was asked what type of support would be helpful. Almost ¼ of the ERSs (17%) indicated they felt that they didn't possess the necessary skills to communicate with non-academic stakeholders.

Respondents focused in their answers on the need for guidance and training in science communication. Suggestions included providing written tips for good general communication, support in translating scientific results into practical messages for farmers and advisors, training in applied science communication, and assistance in preparing simple advisory materials. One respondent also highlighted the need for methods to engage practitioners in research activities to improve knowledge transfer. Another explained that although considerable effort is already devoted to communicating research findings to different stakeholder groups, additional support is needed to evaluate the effectiveness of these communication efforts.

5.3. ERSs within national AKISs

Technological innovation emerges from the interactions of different actors within a system of innovation. Hence, the way ERSs are entangled within their national AKISs can make a significant difference to the dissemination, and eventually uptake of scientific evidence. For this reason it is interesting to understand the role the ERSs have with their AKISs.

In the following part respondents were asked to indicate the type of interaction that their ERSs maintain with different actors within the national AKIS. Interactions were distinguished according to five levels: informing, understood as providing information to stakeholders; consulting, meaning to gather feedback from stakeholders to help make decisions; collaborating, understood as partnering with stakeholders to co-create solutions; and finally understood as joint decision making so that stakeholders are equal partners and co-ownership emerges.

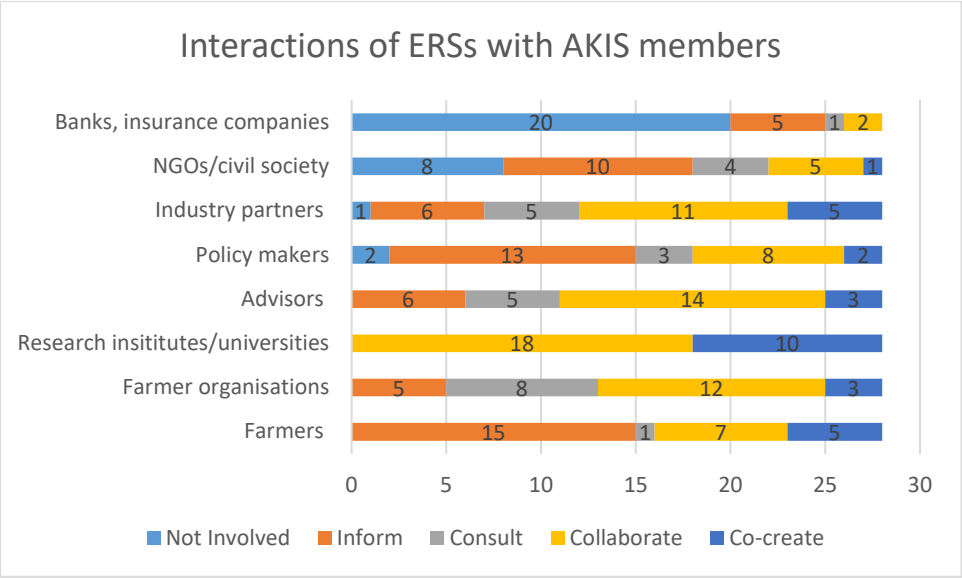


Figure 35. Interactions of ERSs with AKIS members.

As expected, interactions with other research institutes and universities are characterized by the highest levels of collaboration and co-creation. All the responses indicated either collaboration or co-creation. At the opposite end of the spectrum, NGOs and civil society organizations as well as banks

and insurance companies appear to be only marginally involved, suggesting that these actors occupy a peripheral position within the ERSs network. Policy makers are mostly informed.

Industry partners are considerably integrated into activities at ERSs. Five respondents reported consultation. Additionally, eleven respondents reported collaboration and five reported co-creation, amounting to 57% percent of 'active' collaboration with industry actors, while only one respondent indicated no involvement.

No ERSs indicated that advisors, farmer organizations or farmers are not involved. It becomes clear that ERSs collaborate and co-create more easily with advisors (60,7%) and farmers organizations (53,6%) than with farmers (42,8%).

Additionally, the survey gathered information on the role ERSs take up in their AKISs and the activities they perform. Both figures (36 and 37) tell the same story: ERSs seem to be mainly involved in knowledge production and sharing through demonstration of technologies or practices or education activities. In contrast they are significantly less involved in providing advice or knowledge brokering (i.e. connecting the knowledge producers with knowledge users).

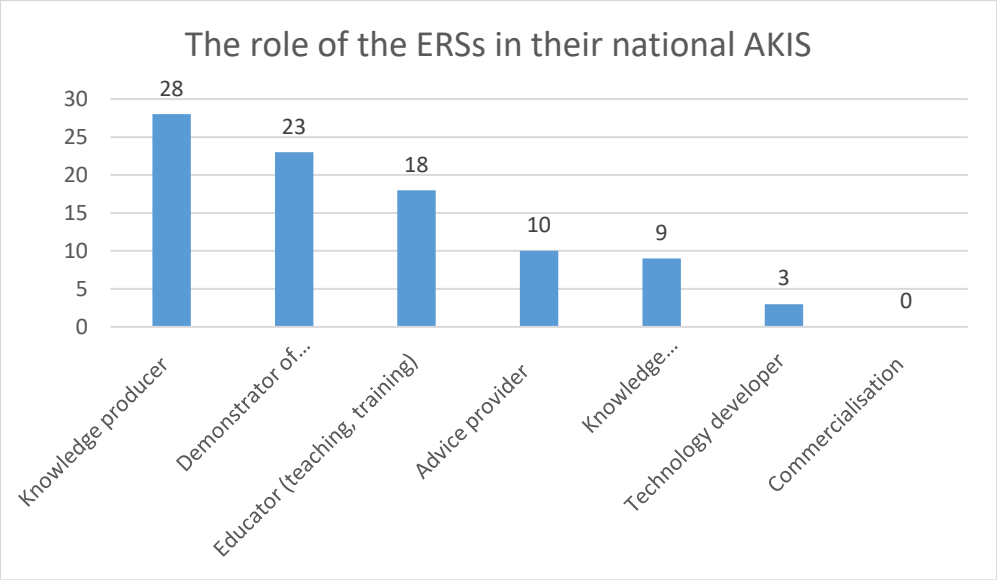


Figure 36. The role of the ERSs in their national AKIS.

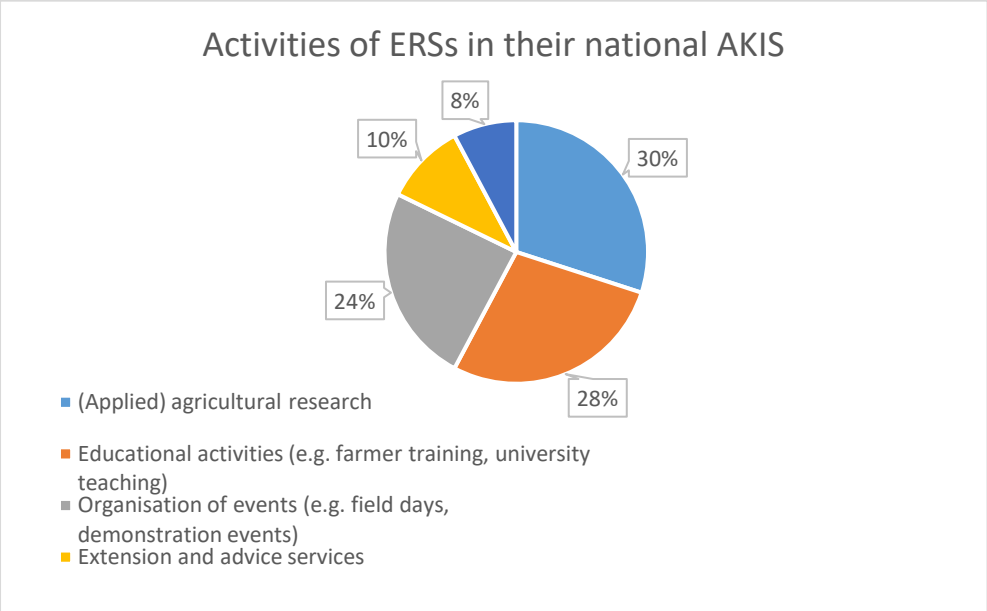


Figure 37. Activities of ERSs in their national AKIS.

These findings reveal a hierarchy in the relationships maintained by ERSs with actors in the AKIS. The highest degree of interaction and shared ownership is observed with other research institutions, indicating that the strongest collaborative networks remain firmly rooted within academia. Outside the research community, collaboration is concentrated mostly around farmer organizations, advisors, and industry partners. In contrast, NGOs, civil society organizations, and financial institutions occupy a much more peripheral position in relation to the ERSs. The central role of ERSs is primarily knowledge production, and secondly education. They are significantly less occupied with advisory activities. From previous findings (see figure 31) it seems they rather recognize advisors as a more important actor in the AKIS to play an intermediary role between themselves and farmers to bridge the RPG.

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6. Capacity building needs within the ERS network

The following and final section of this report reflects on the capacities that the ERSs indicate they have aquired as well as have shown throughout this report. It starts at examining a survey question where they indicated their own capacities. Then it goes to reflect on the overall findings of this report in regards to the capacities to conduct good climate smart research. Finally it completes this report by learning about the ERSs' wishes of learning new skills and capacties in the future.

6.1. Self assesment of climate smart research capacities

Figure 38 illustrates how the ERSs assess their own capacities across several dimensions: engaging in multi-actor collaboration, demonstrating reflexivity, adopting a systems approach, integrating environmental aspects into research, and conducting research on mitigation and adaptation. The results indicate that ESRs generally perceive themselves as having well-developed capacities across all assessed areas. In every category, most of the responses fall within the "strong" and "very strong" ratings, suggesting a high level of confidence in their ability to conduct climate smart research. However, as discussed previously, these self-assessments should be interpreted with caution, as they are strongly influenced by respondents' individual understandings of what constitutes "good" practice and by their personal standards of evaluation.

The areas with the comparatively lowest ratings are the capacity to research climate adaptation and to research the role of ecosystems, where a greater number of respondents reported neutral or weak capacities. For ecosystem services seven respondents rated their capacity as neutral, four as weak, and one as very weak, marking a clear distinction from the responses for the other dimensions. This finding is consistent with responses to another survey question within the CRS project, which asked ERSs to what extent they integrate productivity, mitigation, adaptation, and ecosystem services into their research. Ecosystem services received the lowest average rating (7.0/10), compared with productivity (8.8/10), mitigation (8.2/10), and adaptation (7.8/10), indicating that this aspect is consistently perceived as less well integrated into research practices.

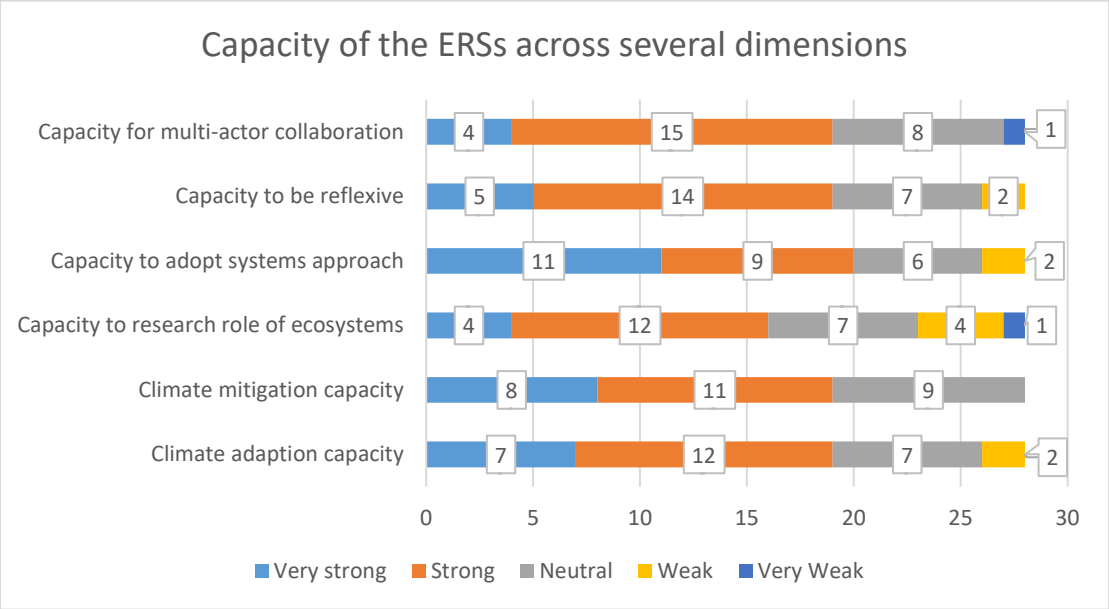


Figure 38. Capacity of the ERSs across several dimensions.

6.2. ERSs' interests in building capacity

The strongest interest was expressed in peer-to-peer exchange on ongoing research conducted at other ERSs, followed by learning on the design and implementation of field trials and on identifying trade-offs and synergies within CSA. These findings suggest that researchers place considerable value on exchanging practical experiences and learning from the approaches adopted by their peers.

A second group of priorities concerns research methodologies and research design. Respondents expressed interest in developing systems thinking skills, facilitating participatory workshops and field activities, building and maintaining stakeholder networks, engaging with farmers, advisors and practitioners, and integrating reflexivity throughout the research process. By contrast, communication strategies for non-academic audiences received comparatively less interest. While this may indicate that researchers perceive communication as a lower priority than methodological development, qualitative responses throughout the survey suggest that science communication nevertheless remains an important area requiring further support.

Other capacity-building priorities were also identified in the survey. Earlier sections highlighted comparatively weaker integration of ecosystem services within research activities, suggesting that future capacity-building initiatives could include approaches for incorporating ecosystem service perspectives more systematically into research design. Similarly, respondents reported lower levels of stakeholder involvement during the implementation of research, particularly regarding on-farm experimentation and monitoring. Strengthening methodological approaches for participatory field trials and collaborative data analysis could therefore represent another valuable area for future training. Qualitative responses further highlighted several areas where researchers would benefit from additional capacity building to strengthen research–practice interactions. A recurring theme concerned science communication, with respondents indicating a need for support in translating scientific findings into clear and practical messages for farmers, advisors, and other non-academic audiences through accessible communication materials and diverse dissemination formats.

Researchers also identified challenges in engaging external stakeholders throughout the research process, including facilitating collaboration, applying participatory methodologies, and translating research findings into practical applications. Finally, respondents reported difficulties in establishing and maintaining long-term relationships with practitioners, particularly in identifying interested farmers, sustaining collaborations, and accessing experienced intermediaries. Together, these findings point to a need for capacity building in science communication, stakeholder engagement, knowledge translation, and partnership development to strengthen the uptake and practical relevance of climate-smart agricultural research.

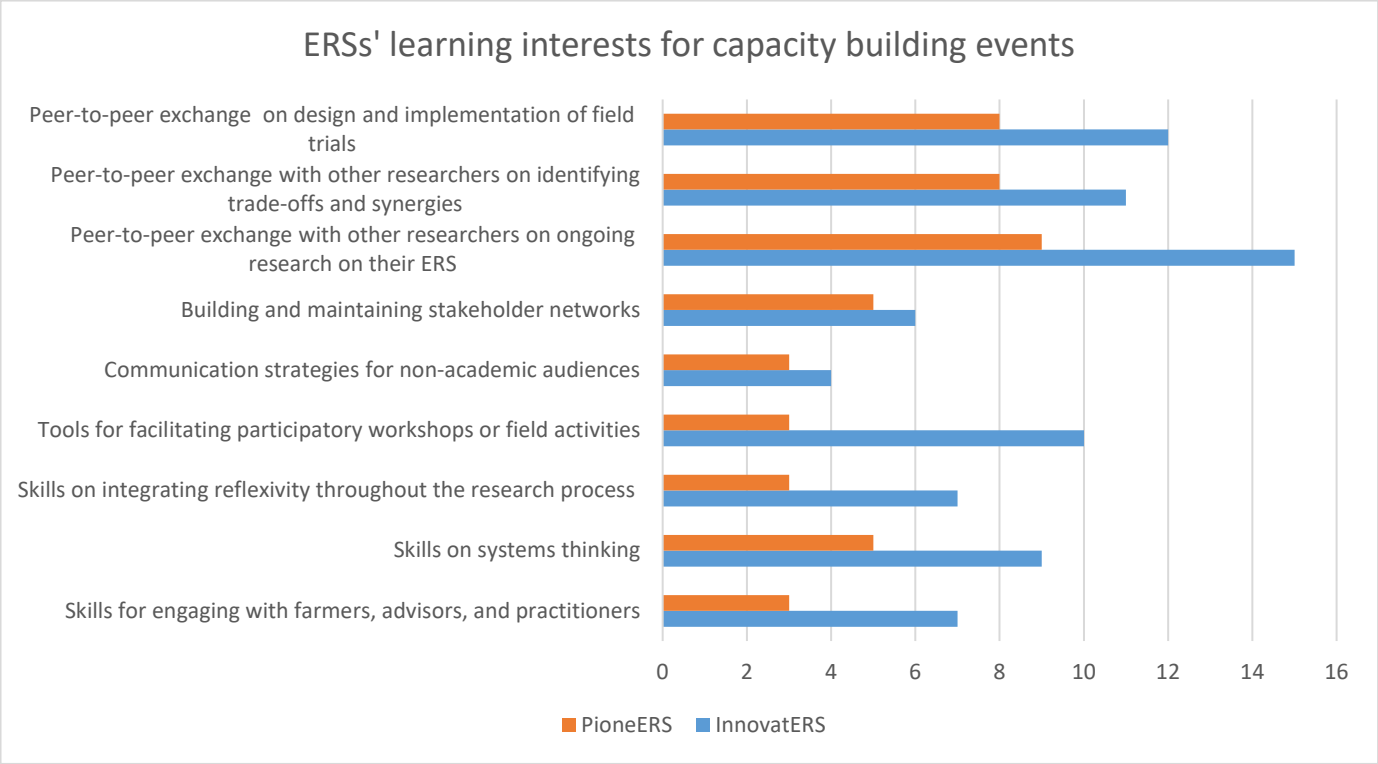


Figure 39. ERSs' interests for capacity building.

7. Discussion

7.1. Interpreting the findings in light of the study design

This report combined an exploratory literature review with two surveys among ERSs to provide a state-of-play analysis of CSA research in Europe. The findings offer valuable insights into current research priorities, research and innovation design practices, perceptions of the RPG, and capacity-building needs among participating ERSs. However, the findings should be interpreted in light of several methodological and sampling considerations that influence both the scope and generalizability of the results.

Most importantly, the survey findings do not constitute a representative picture of all agricultural research organizations in Europe. Both surveys relied on purposive network-based sampling. Survey 1 was distributed through project partners and existing networks, while Survey 2 targeted the 29 ERSs participating in the Climate Smart Research project. Consequently, respondents are more likely to be organizations already engaged in climate-related agricultural research and interested in collaboration, innovation, and European research networks. This may partially explain the generally high self-assessments regarding transdisciplinarity, systems thinking, reflexivity, and stakeholder engagement. The results should therefore be understood as representing the participating and responding ERSs rather than European agricultural research infrastructures as a whole.

Furthermore, the geographical distribution of Survey 1 responses was highly uneven. France and Romania together account for approximately two-thirds of responses, meaning that some findings may primarily reflect the characteristics of the French and Romanian CSA research rather than broader European patterns. This limitation is particularly relevant for the results presented in Section 4.1.1. which examined the thematic areas across geographical regions and 5.3, which examined the role of ERSs within national AKISs. Caution should be applied when interpreting regional differences in thematic research priorities, as several regions are represented by relatively small numbers of respondents and individual countries often dominate regional clusters. Similarly, the observed patterns of collaboration, knowledge exchange, and stakeholder interaction are likely influenced by the institutional contexts that are most strongly represented in the sample.

7.2. The implications of self-reported data

A second important consideration concerns the use of self-assessment data. Many findings in this report are based on respondents evaluating the extent to which concepts such as transdisciplinarity, systems thinking, reflexivity, climate adaptation, mitigation, and ecosystem services are incorporated into their research. Self-assessment provides valuable insight into researchers' perceptions and intentions but does not necessarily reflect actual research practices. Respondents may interpret concepts differently, apply different standards when scoring their organizations, or provide socially desirable answers that align with current policy and scientific expectations.

This challenge became particularly visible in the qualitative responses concerning transdisciplinarity, systems thinking and reflexivity. Although definitions were provided in the surveys, several responses suggest that concepts such as transdisciplinarity, interdisciplinarity, stakeholder engagement, and systems thinking are not always clearly distinguished. Similarly, respondents often associated reflexivity with stakeholder feedback and adaptive learning without necessarily referring to the more critical examination of assumptions, positionality, or knowledge production processes that is commonly emphasized in methodological literature. As a result, the reported scores should not be interpreted as objective measurements of climate-smart research quality but rather as indicators of how these concepts are currently understood and valued within participating organizations.

Interestingly, this itself constitutes an important finding. The variability in interpretation suggests that although concepts such as systems thinking, reflexivity, and transdisciplinarity are increasingly present in agricultural research discourse, they have not yet been institutionalized in a uniform manner across European research environments. This reinforces the need for capacity building and conceptual clarification within the CSR network.

7.3. Scope and boundaries of the literature review

The literature review was intentionally exploratory rather than systematic. Its objective was to map key developments, trends, and knowledge gaps within CSA research rather than provide an exhaustive synthesis of the literature. While this approach was appropriate for a state-of-play analysis, it inevitably influences the findings. By requiring the explicit use of the term "climate-smart agriculture", the review excluded research conducted under related concepts such as agroecology, regenerative agriculture, conservation agriculture, climate-resilient agriculture, and sustainable intensification. Given the conceptual overlap between these approaches, the review likely captures only part of the broader European research landscape addressing climate-related agricultural challenges.

7.4. Implications for the conclusions of this report

The conclusions of this report should therefore be interpreted as indicative rather than representative of European CSA research as a whole. The findings provide a valuable snapshot of perceptions, priorities, and practices among a large group of climate-engaged research stations and a geographically diverse network of ERSs. However, they cannot be used to claim that all European agricultural research organizations follow similar approaches or face identical opportunities and challenges.

Nevertheless, the consistency between the literature review and the survey findings strengthens confidence in several overarching conclusions. Both sources point towards the need for more integrated research designs that combine multiple CSA objectives, better account for interactions and trade-offs across agricultural systems, involve stakeholders throughout the research process, and generate knowledge that is both scientifically robust and practically relevant. Future research could build on this study by employing more systematic sampling approaches, collecting objective indicators

of research design practices, and examining differences between countries, AKIS configurations, and types of research infrastructures in greater detail.

8. Conclusion

CSA has become firmly embedded within European agricultural research over the past decade, with a rapidly expanding body of research addressing the challenges of climate mitigation, adaptation and agricultural productivity. Within the European context, CSA research has predominantly focused on productivity and mitigation, often through technological innovation, digitalization and resource-use efficiency. At the same time, the literature increasingly emphasizes that achieving meaningful transitions towards CSA requires moving beyond isolated technological solutions towards more integrated, systems-oriented and participatory approaches that recognize the complexity and context-dependency of agricultural systems. This implies a need not only to broaden the thematic scope of CSA research, but also to reconsider how research itself is designed and conducted.

The findings from the surveys indicate that European ERSs already possess substantial capacities to contribute to such a transition. Research activities cover all twelve CSA thematic areas identified within the CSR and CFD projects, and the three core pillars of CSA—productivity, adaptation and mitigation— as well as ecosystem services are widely embedded within existing research portfolios. However, the distribution of research activities also points to persistent imbalances. Technical, agronomic and environmental dimensions of CSA are considerably more strongly represented than socio-economic and institutional dimensions, including rewarding mechanisms and other factors influencing agricultural transitions. Similarly, ecosystem services appear to be less systematically integrated than productivity, adaptation and mitigation. These findings suggest that, although ERSs demonstrate broad scientific capacity, further strengthening the social, economic and systemic dimensions of CSA research could contribute to a more comprehensive understanding of agricultural transitions.

The findings concerning research design provide a similarly nuanced picture. Many ERSs demonstrate both the capacity and commitment to engage in transdisciplinary, systems-oriented and reflexive research. However, these approaches are not yet consistently embedded throughout the research cycle. Stakeholder engagement is most commonly concentrated around the identification of research needs, validation and, to a lesser extent, on-farm experimentation, while more substantive forms of co-ownership and shared decision-making remain less common. Systems approaches are frequently used to integrate environmental, agronomic and economic dimensions, but social dimensions such as labor, management and other practical considerations receive comparatively less attention. Reflexive practices are likewise present, particularly through feedback from academic and non-academic actors, but are often informal, project-specific and interpreted differently across researchers. Combined, these findings indicate that the challenge is not necessarily a lack of awareness of these approaches, but rather their systematic and meaningful integration across the research process.

The implementation of more integrated research designs is further constrained by practical and institutional conditions. Respondents identified the substantial time and resources required for systems-oriented and participatory research, limitations in data availability, difficulties in interdisciplinary collaboration, fragmented stakeholder engagement and a lack of appropriate capacities as important challenges. At the institutional level, research environments continue to place considerable emphasis on scientific excellence and conventional research outputs. This can limit the incentives for investing in activities whose benefits are less readily captured through established academic reward structures. The findings therefore suggest that strengthening research design

cannot be achieved solely through developing individual researchers' skills. It also requires institutional conditions that provide the time, resources, incentives and organizational support necessary to sustain more collaborative, systemic and reflexive forms of research.

These findings are particularly relevant considering the persistent RPG identified throughout the report. Although ERSs conduct extensive research on CSA and increasingly engage with stakeholders, the production of scientifically robust knowledge does not automatically translate into knowledge that is accessible, relevant and applicable to agricultural practice. Respondents highlighted challenges related to science communication, the translation of scientific findings into practical information, and the connections between researchers, advisors, farmers and other actors. This illustrates that the RPG cannot be addressed through communication and dissemination alone. Rather, the relevance and applicability of knowledge need to be considered from the outset of the research process, through research questions, design, stakeholder involvement, experimentation, interpretation and communication.

Overall, the literature review and survey findings point towards a common conclusion: advancing CSA in Europe depends as much on transforming research and innovation processes as on developing new technological solutions. Future CSA research would benefit from research designs that; (1) integrate multiple CSA objectives: (2) explicitly consider interactions and trade-offs across agricultural systems; (3) involve relevant actors throughout the research cycle; and (4) produce knowledge that is meaningful and applicable beyond the research environment. Such a transformation requires a combination of individual capacities and enabling institutional conditions. It also requires stronger and more sustained connections between research, advisory services, farmers, policymakers and other societal actors.

The conclusions presented in this report should be interpreted in light of the study's methodological limitations. The findings primarily reflect the perspectives of participating ERSs and are influenced by the composition of the survey sample, particularly the strong representation of some countries and the self-reported nature of several indicators. The results therefore provide an informative snapshot of current practices and perceptions among climate-engaged research organizations rather than a statistically representative overview of all agricultural research infrastructures in Europe. Nevertheless, the convergence between the literature review and survey findings increases confidence in the broader trends identified throughout this report

For the Climate Smart Research project, these findings provide a clear direction for future capacity-building and network activities. Strengthening ERSs' capacities should extend beyond technical expertise to include transdisciplinary and participatory methodologies, systems thinking, reflexive research practices and effective science communication. At the same time, capacity building should be accompanied by opportunities for longer-term collaboration and institutional support that enables these skills to be meaningfully incorporated into research practice. Strengthening these capacities and conditions across the European network of ERSs can contribute to research that is not only scientifically robust, but also more relevant, applicable and capable of supporting the wider transition towards CSA.

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Annex

Survey 1

Section 1 – Informed Consent

1. I have read and understood the information in the information form. It provided me with sufficient information on the objectives of the project and the survey. I understand that I can be removed from the contact list for receiving invitations at any moment.

Options:

- Yes
- No

2. I confirm that I have given the project partners permission to collect the data, and further analyse and use it, as detailed in the information form. I understand that I have the right to access my information, and adjust if and where necessary.

Options:

- Yes
- No

Section 2 – General Information

3. Name of your research institute

Answer: Free text

4. Name of the department and/or unit involved

Answer: Free text

5. Name of the experimental research station (ERS) involved

Answer: Free text

6. Country of your research institute

Answer: Free text

7. Contact person

Answer: Free text

8. Email of contact person

Answer: Free text

9. Give a brief description of the research conducted by your department and/or unit/ERS. Describe in short the mission of your research station or department/unit, the agricultural sector/agricultural approach targeted (organic farming, regenerative farming, precision farming, etc.), etc. No longer than 100 words.

Answer: Free text

10. Describe in short the research infrastructure for experimentation (production system, agricultural area, infrastructure for livestock) of your research department and/or unit. No longer than 100 words.

Answer: Free text

Section 3 – Climate Related Objectives of Ongoing Agricultural Research

11. To what extent does the experimental research on your research department and/or unit take into account agricultural productivity?

Options: 0–10

12. To what extent does the research focus on climate change mitigation (e.g. greenhouse gas emission reductions, carbon sequestration) in your research department and/or unit?

Options: 0–10

13. To what extent does the research focus on climate change adaptation (e.g. resilience, risk reduction, adaptation strategies) in your research department and/or unit?

Options: 0–10

14. To what extent does the research focus on provision of ecosystem services (e.g. water regulation, biodiversity, soil quality, ...) in your research department and/or unit?

Options: 0–10

15. Are there any other environmental aspects that are addressed by the experimental research on your research department and/or unit?

Answer: Free text

16. In the Climate Smart Research project, we work around main thematic areas. You can find the definition of the thematic areas in the added links. What are the five most important thematic areas within your field or work? (indicate 5 options)

Select 5 options from:

- Grassland management
- Forage production
- Crops management
- Soil health and biodiversity
- Agroforestry and relation to landscape
- Energy management
- Biogas production
- Water management
- Herd management
- Manure storage and spreading
- Activities for reducing enteric methane emissions
- Rewarding mechanism
- Other

Section 4 – Transdisciplinarity, Systems Thinking & Reflexivity

Scale: 0–10

- 0 = Not at all
- 10 = Fully integrated

17. Transdisciplinarity is defined as the co-creation of knowledge and action together with stakeholders across academic and non-academic stakeholders (e.g. farmers, advisors), addressing societal challenges with the aim to reach maximal social benefit. To what extent is transdisciplinarity integrated in the research design of your research?

Options: 0–10

18. Please explain.

Answer: Free text

19. Systems thinking is about understanding the complexity of a whole system, defined as recognising that there is no single solution and instead simultaneous change is needed at multiple levels (agronomic, socio-economic, scientific, etc.) in the transformation to climate neutral and resilient agriculture in Europe. To what extent is systems thinking integrated in the research design of your research?

Options: 0–10

20. Please explain.

Answer: Free text

21. Reflexivity is defined as critically examining your own assumptions, values, and positionality (doing the right things), as well as methods and impacts (doing things right). It is not just the act of reflecting itself, but the actions and change resulting from such reflection. To what extent is reflexivity integrated in the research design of your research?

Options: 0–10

22. Please explain.

Answer: Free text

Section 5 – Local, National and European Embedding

23. To what extent is the research on your research department/unit funded by public versus private sources?

Options:

- Mainly public funding
- Mainly private funding
- Roughly equal public and private funding
- Not applicable/unknown

24. Which level of funding is the primary source of your research funding?

Options:

- Primarily local/regional
- Primarily national
- Primarily European
- A balanced mix of local, national, and European funding
- Other

25. How would you assess the strength of your research department/unit networks at the following level?

Rating scale:

- Very weak
- Weak
- Moderate
- Strong

Levels assessed:

- Local/regional
- National
- European

Section 6 – Activities of the Network of European Research Stations

26. I want to receive an invitation for:

Options:

- Online masterclasses on the topic of effective climate smart research and innovation design
- EU brokerage event connecting researchers, advisors and demonstration farmers across Europe
- National events, connecting farmers, advisors and researchers within the local AKIS (Agricultural Knowledge and Innovation System) to exchange knowledge on climate smart farming practices
- In depth survey in spring 2026 to develop tailored capacity building activities on effective research and innovation design
- Joint newsletter of the sister projects Climate Smart Research (CSR), Climate Smart Advisors (CSA) and Climate Farm Demo (CFD

Survey 2

Section A – Survey Introduction

A1. I have read and understood the information in the information form...

Options:

- Yes
- No

A2. I confirm that I have given the project partners permission...

Options:

- Yes
- No

Section B – General Information

B1. Name

Answer: Free text

B2. Email

Answer: Free text

B3. Name of your research institute

Answer: Free text

B4. Name of the department and/or unit involved

Answer: Free text

B5. Name of the experimental research station (ERS) involved

Answer: Free text

B6. Country of your research institute

Answer: Country selection

Section C – Ongoing Climate Research at ERS

C1. What type of organisation describes your ERS best?

Options:

- Public
- University-affiliated

- Private
- Hybrid
- Other

C2. At your ERS, what share (%) of staff is formally involved in:

Answer: Percentage for each category

- Research
- Technical support
- Advice
- Other

C3. Please specify "other"

Answer: Free text

C4. How would you describe your ERS's strongest contribution within the CSR project?

Options:

- Long-term systems research
- Tool testing and validation
- Practice innovation and demonstration
- Method development
- Capacity building
- Networking facilitation
- Other

C5. At what stage are your current climate-related activities within CSR project?

Options:

- Planning phase
- Early implementation
- Ongoing activities
- Long-term established research

C6. Five most important thematic areas within your ERS (select max. 5)

Options:

- Grassland management

- Forage production
- Crops management
- Soil health and biodiversity
- Agroforestry and relation to landscape
- Energy management
- Biogas production
- Water management
- Herd management
- Manure storage and spreading
- Activities for reducing enteric methane emissions
- Rewarding mechanism
- Other

C7. To what extent does research at your ERS take into account:

Scale: 1 (very small extent) to 10 (very large extent)

Topics:

- Agricultural productivity
- Climate change mitigation
- Climate change adaptation
- Provision of ecosystem services

C8. Are there any other environmental aspects addressed by the experimental research at your ERS?

Options:

- Yes
- No

C9. Please specify the environmental aspects

Answer: Free text

C10. Does your ERS have experience in using climate tools?

Options:

- Yes
- No

C11. Which categories of tools have been used?

Options:

- Farm-level GHG calculator/model
- Agricultural life cycle assessment tool
- Decision support system
- Adaptation planning or resilience services
- Other

C12-C16. Please list the specific climate tools tested at your ERS (up to 5 tools)

For each tool:

- Tool name
- Developer/source
- Where used
- How applied

C17. What is the main purpose of using these tools?

Options for each tool:

- Estimating or monitoring GHG emissions
- Evaluating carbon sequestration potential
- Support farm-level decision making process
- Other

C18. What is your level of experience with these tools?

Options for each tool:

- Exploratory/pilot use
- Regular operational use
- Involved in tool development

C19. Did you encounter limitations in the current climate tool(s)?

Options:

- Yes
- No

C20. Please specify the limitations

Answer: Free text

C21. Do you have specific research questions related to the use of farm-level climate tools?

Options:

- Yes
- No

C22. Please specify the research question

Answer: Free text

C23. Which additional tools would you like to implement in the future?

Answer: Free text

C24. In relation to climate tools, what are your main needs?

Options:

- Better understanding of tool methodologies
- Choosing the right tool for my ERS
- Learning from other ERS experiences
- Technical support
- Staff training or capacity building
- Other

Section D – InnovatERS: Climate Practices & Emerging Solutions

D1. Are you an InnovatER?

Options:

- Yes
- No

D2. Interested in contributing to:

Options:

- Climate tools
- Emerging practices
- Both

D3. What improvements would help make tool testing results more informative?

Answer: Free text

D4. Which barriers would you face in contributing to tool comparison?

Options:

- Limited farm-level activity data
- Lack of resources
- Licensing/restrictions
- Uncertainty about reliability
- None
- Other

D5. Field of expertise for validation of emerging practices?

Answer: Free text

D6. Which thematic areas best describe mitigation/adaptation work? (max. 3)

Options:

- Soil carbon management
- Crop system diversification
- Livestock emission reduction
- Nutrient management
- Water management
- Agroforestry
- Digital monitoring
- Other

D7. Please indicate any sub-themes occurring within adaptation/mitigation activities

Answer: Free text

Section E – Research Process and Design

E1. Where do your research ideas commonly originate?

Options:

- Scientific or academic interests
- Previous research projects
- Policy priorities

- Collaboration with farmers or advisors
- Private sector needs
- Calls for funding
- Societal or environmental challenges
- Other

E2. Extent of public versus private funding

Options:

- Mainly public funding
- Mainly private funding
- Roughly equal
- Not applicable/unknown
- Other

E3. Main funding source

Options:

- Primarily local/regional
- Primarily national
- Primarily European
- Other

E4. Please specify other

Answer: Free text

E5. Which actors are typically involved in research?

Options:

- Research institutes or universities
- Individual farmers
- Farmer organizations/cooperatives
- Agricultural advisors
- Private sector companies
- NGOs/civil society organizations
- Policy makers

- None
- Other

E6. Who identifies research needs/questions?

Same options as E5

E7. Who designs the research?

Same options as E5

E8. Who is involved in data collection?

Same options as E5

E9. Who is involved in data analysis/interpretation?

Same options as E5

Section F – Research-Practice Gap

F1. Extent to which you recognize the research-practice gap

Options:

- Yes, to a great extent
- Yes, to some extent
- Yes, to a small extent
- I am not sure
- No, I don't experience a research-practice gap

F2. Would you add or change anything in the definition?

Options:

- Yes
- No

F3. Please specify

Answer: Free text

F4. Which factors contribute to the research-practice gap?

Options (15 + Other):

- Research not consistent with farming needs

- Impact not clear enough
- Innovations too complex
- Limited institutional incentives
- Heavy workload
- Lack of communication skills
- Lack of networks
- Institutions prioritize academic output
- Insufficient outreach funding
- Limited AKIS functioning
- Limited access to academic results
- Limited farmer/advisor interest
- Lack of farmer trust
- Insufficient economic incentives
- Policy-makers fail to integrate research findings
- Other

F5. Most significant barrier?

Answer: Free text

F6. Which actors are most important in bridging the gap?

Options:

- Farmers
- Farmer organizations
- Research institutes/universities
- Agricultural advisors
- Policy makers
- Private sector companies
- NGOs
- Agri-food sector
- Other

F7. Agreement with statements

Scale:

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

Statements:

- I have a responsibility to ensure my work is relevant for practice.
- Farmers and advisors should be involved from problem formulation to implementation.
- Current funding structures support collaboration.
- My organisation rewards engagement with practice.
- Collaboration improves research quality.
- Research priorities are driven by farmer needs.

Section G – Transdisciplinarity, Systems Thinking and Reflexivity

G1. To what extent is transdisciplinarity integrated?

Scale: 1-10

G2. Elaborate

Answer: Free text

G3. Main collaboration challenges?

Options:

- Limited time
- Difficulty reaching stakeholders
- Communication barriers
- Different expectations
- Lack of funding
- Administrative constraints
- Physical distance
- Lack of trust

- Limited stakeholder interest
- Lack of a clear contact person
- Other

G4. What would support better collaboration?

Answer: Free text

G5. To what extent is systems thinking integrated?

Scale: 1-10

G6. Elaborate

Answer: Free text

G7. Main barriers to systems thinking?

Options:

- Limited knowledge/training
- Lack of time
- Lack of suitable tools
- Insufficient institutional support
- Difficulty collaborating across disciplines
- Lack of data
- No barriers
- Other

G8. Does research consider interactions across scale dimensions?

Options:

- Yes
- To some extent
- No

G9. Explain methodology

Answer: Free text

G10. Does research consider interactions across domains?

Options:

- Yes

- To some extent
- No

G11. Explain methodology

Answer: Free text

G12. Does research adopt a systems approach considering interactions between practices?

Options:

- Yes
- To some extent
- No

G13. Explain methodology

Answer: Free text

G14. Which trade-offs are explored?

Options:

- Productivity vs GHG mitigation
- Adaptation vs mitigation
- Economic viability vs environmental performance
- Short-term vs long-term impacts
- None of the above
- Other

G15. Familiarity with systems-thinking tools

Scale:

- Not at all familiar
- Slightly familiar
- Moderately familiar
- Very familiar
- Extremely familiar

Tools:

- Actor maps
- Causal loop diagrams

- Mind map participation tools
- Stock and flow diagrams
- System dynamics simulation model

G16. Other tools?

Answer: Free text

G17. To what extent is reflexivity integrated?

Scale: 1-10

G18. Elaborate

Answer: Free text

G19. During projects >3 years, do you organize feedback moments?

Options:

- Yes, regularly
- Yes, occasionally
- Yes, but rarely
- Never

G20. Forms of feedback

Scale:

- Not applicable
- To a small extent
- To some extent
- To a large extent

Formats:

- Stakeholder workshops
- Advisory board meetings
- Farm visits
- Surveys/interviews
- Online meetings
- Email exchanges
- Written reports

G21. Other feedback approaches?

Answer: Free text

G22. Audiences targeted when sharing results

Scale:

- Not applicable
- To a small extent
- To some extent
- To a large extent

Audiences:

- Researchers
- Individual farmers
- Farmer organizations
- Advisors
- Private sector partners
- NGOs
- Policy makers
- General public

G23. Other audiences?

Answer: Free text

G24. Dissemination methods

Options:

- Academic journal articles
- Scientific conferences
- Policy advisory reports
- Advisory/extension services
- Scientific reports/project deliverables
- Farmer networks
- Farmer events/field days
- Workshops/training sessions

- Videos
- Non-academic materials
- Other

G25. Do you have the skills to support knowledge transfer?

Options:

- Yes
- No
- I'm not sure

G26. What support or training would be helpful?

Answer: Free text

Section H – AKIS, FFC Repository and Capacity Building

H1. What is the role of your ERS in your national AKIS?

Options:

- Knowledge producer
- Knowledge broker/intermediary
- Demonstrator
- Advice provider
- Educator
- Technology developer
- Commercialisation
- Other

H2. Which activities does your ERS carry out?

Options:

- Applied agricultural research
- Educational activities
- Policy development/policy advocacy
- Extension and advice services
- Organisation of events

- Other

H3. Interaction with AKIS actors

Scale:

- Inform
- Consult
- Collaborate
- Co-create
- Not involved

Actors:

- Farmers
- Farmer organisations
- Research institutes/universities
- Advisors
- Policy makers
- Industry partners
- NGOs/civil society
- Banks/insurance companies

H4. Most useful information about other ERSs on the FFC platform

Options:

- Research themes
- Climate mitigation/adaptation measures tested
- Expertise and skills
- Tools used
- Facilities/capacities
- ERS context details
- Collaboration interests
- Other

H5. Which type of ERS would be most beneficial to connect with?

Options:

- Similar farming system
- Similar climatic zone
- Same research theme
- Same tool users
- Complementary expertise
- Other

H6. Most valuable contribution your ERS can make to the repository

Answer: Free text

H7. Rate the current capacity of your ERS

Scale:

- Very weak
- Weak
- Neutral
- Strong
- Very strong

Topics:

- Climate adaptation research
- Climate mitigation research
- Role of ecosystems in CSA
- Multi-actor collaboration
- Systems approach
- Reflexivity throughout research

H8. What knowledge or experience could your ERS share?

Options:

- Practical insights from long-term research
- Methodological experience
- Lessons learned
- Training or field visits
- Other

H9. What would be most valuable during capacity-building visits?

Options:

- Skills for engaging farmers/advisors
- Systems thinking skills
- Reflexivity skills
- Participatory workshop tools
- Communication strategies
- Building stakeholder networks
- Peer-to-peer exchange on ongoing research
- Peer-to-peer exchange on trade-offs and synergies
- Peer-to-peer exchange on field trial design and implementation
- Other

H10. Is there anything else you would like to share before submitting the survey?

Answer: Free text.

climate smart research

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