BEATLES
BEHAVIOURAL CHANGE TOWARDS
Climate-Smart Agriculture

CO-CREATING BEHAVIOURAL CHANGE TOWARDS CLIMATE-SMART FOOD SYSTEMS

D1.1 Integrated framework of decision-making factors

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Executive Summary

The deliverable D1.1 Integrated framework of decision-making factors aims to provide a mapping and analysis of the full range of decision-making factors that affect agri-food systems transition to climate-smart agriculture (CSA). For this purpose, five systematic reviews have been conducted to map the: i) CSA practices and technologies used by farmers, ii) decision-making factors affecting farmers' behavioural shifts to CSA, iii) business strategies affecting transition to CSA, iv) decision-making factors affecting consumers' purchase of products that have been produced in environmentally-friendly ways at farm level, v) current policy and regulatory framework affecting the transition to CSA. Two surveys, one targeting farmers and one for consumers, have been designed and employed in 6 Use Cases (UCs) (Germany, Denmark, Netherlands, Spain, Lithuania, Slovenia), to evaluate the effect of individual, systemic and policy factors in the adoption of CSA practices and the purchase of environmentally friendly products respectively. Finally, a set of interviews with industry stakeholders (including food processors, manufacturers, retailers, distribution, transportation, logistics and marketing companies) have been conducted using stakeholders from the UCs to understand their role in the transition to CSA, the practices they are using that promote the adoption of CSA as well as the factors that affect their decisions to support the uptake of CSA at the farm level. The output of these tasks will provide an integrative framework of the CSA landscape with special emphasis on the individual, systemic and policy factors that affect agri-food stakeholders' transition to the CSA which will form the basis for the work to be conducted in WP2, WP3, WP4 and WP5.

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List of Terms and Definitions

Abbreviation	Definition
AES	Agri-Environmental Schemes
AECM	Agri-Environment-Climate Measure (2014-2020)
AEM	Agri-Environmental Measures (for 2021-2027)
ANC	Areas With Natural Constrains
CAP	Common Agricultural Policy
CBD	Convention for Biological Diversity
CH_4	Methane
CO_2	Carbon dioxide
CSA	Climate Smart Agriculture
DEA	Data Envelopment Analysis
EC	European Commission
EEA	European Environmental Agency
FADN	Farm Accountancy Data Network
FAO	Food Agricultural Organization
GHG	Greenhouse gas
HNVF	High Nature Value Farmland
IPM	Integrated Pest Management
IWM	Integrated Weed Management
LULUCF	Land Use, Land Use Change and Forestry
LEADER	Liaison Entre Actions de Développement de l'Économie Rurale
LFA	Less Favoured Areas
NH_3	Ammonia
N_2O	Nitrous oxide
OFS	Organic Farming System
PRSIMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RDP	Rural Development Programmes
SDGs	Sustainable Development Goals
SMART	Specific, Measurable, Assignable, Realistic and Time-related
SOC	Soil Organic Carbon
UAA	Utilised Agricultural Area
UAV	Unmanned Aerial Vehicles
UC	Use Case
UGV	Unmanned Ground Vehicles
UN	United Nations
UNFCC	United Nations' Framework Convention on Climate Change
WP	Work Package

Table 1: Terms and Definitions

1. Introduction

Through its Farm-to-Fork Strategy and Biodiversity Strategy, the EU Green Deal aims to reduce the overall use of chemical pesticides by 50%; nutrient losses by at least 50%; use of fertilisers by at least 20%; antimicrobials use for farmed animals by 50%; and achieve at least 25% of agricultural land under organic farming by 2030. Climate-smart agriculture (CSA) is promoted as a solution to the interconnected problems of productivity, resilience, and climate change and has significant potential towards the fulfilment of the EU's ambitious goals. CSA is a new approach aiming to increase agricultural productivity in a way that doesn't hurt the environment, makes farms more resilient, and helps mitigate climate change. However, diffusion and adoption rates of CSA in Europe still remain low. Hence, behavioural shifts are needed to foster the adoption of CSA. BEATLES adopts a food systems approach where the agri-food value chain is viewed as a system of interlinked components where interactions lead to systemic innovations. In this sense, farmers' behaviour is not examined in isolation but as embedded in a system composed of interactions between various agri-food stakeholders which create trade-offs, feedback loops and synergies that influence farmers' behaviour. Transitions to CSA are long-term, complex and multi-dimensional processes that require changes at individual, technological, socio-cultural, organisational, institutional, economic and political levels. Therefore, increasing our understanding of barriers and drivers to adoption from a food system perspective is required.

The deliverable D1.1 aims to investigate the "lock-ins" and levers that hinder or motivate farmers to adopt CSA practices or technologies. By adopting a food system approach, the behavioural shifts of farmers will be examined in the context of the behaviour and interactions with other agri-food value chain stakeholders (e.g., industry stakeholders and consumers) to account for a value-chain wide behavioural change to CSA. The activities undertaken in the deliverable will first systematically review existing research and literature on the full range of individual, systemic and policy factors affecting transitions to CSA in Europe. Subsequently, the deliverable will provide empirical evidence for the specific factors that have an influence in behavioural change based on surveys and interviews. More specifically, the following tasks have been designed and realised:

- 5 systematic reviews that map the: i) CSA practices and technologies used by farmers, ii) decision-making factors affecting farmers' behavioural shifts to CSA, iii) business strategies affecting transition to CSA, iv) decision-making factors affecting consumers' purchase of environmentally-friendly products, v) current policy and regulatory framework affecting the transition to CSA.
- A survey targeting farmers in the 6 UCs to identify the individual, systemic and policy factors that affect the adoption of CSA practices and technologies.
- A survey targeting consumers in the 6 UCs to evaluate the effect of individual, systemic and policy factors in the purchase of environmentally-friendly products.
- A set of interviews with industry stakeholders (including food processors, manufacturers, retailers, distribution, transportation, logistics and marketing companies) from the UCs to understand their role in the transition to CSA, the practices they are using that promote the adoption of CSA as well as the factors that affect their decisions to support the uptake of CSA at the farm level.

The deliverable first outlines the methodology and findings from the five systematic reviews. Subsequently, it reports the methodology and findings from the farmer and consumer surveys and finally discusses findings from the interviews with industry stakeholders. Some general conclusions about the integrated framework of decision-making factors are provided at the end of the deliverable.

2. Systematic Mapping of CSA practices and technologies

2.1 Introduction

The global food system is currently confronting with several interconnected challenges related to environmental sustainability (e.g., climate change, biodiversity loss, air and water pollution, and food waste), social sustainability (e.g., food security and safety, fair value distribution), and economic viability (e.g., jobs and income) (Calicioglu et al., 2019; Takács-György and Takács, 2022). Furthermore, the world's population could reach 8.5 billion in 2030 and 9.7 billion in 2050 (UN, 2022). Therefore, agriculture must transform itself if it is to feed a growing global population while at the same time mitigating the interlinked challenges (FAO, 2021). Under a business-as-usual scenario, climate change will make this effort more difficult due to adverse impacts on agriculture as well as agriculture's substantial role in contributing to climate change (Lalit et al., 2022). To address the interconnected challenges, appropriate and long-term mitigation strategies are found to be necessary; one such strategy is climate-smart agriculture (CSA) (Selbonne et al., 2022; Khalil and Osborne, 2022; Francesco et al., 2020; Adesipo et al., 2020; Kakamoukas et al., 2021). FAO introduced CSA as an integrated approach to developing agricultural strategies to address the interrelated challenges of economic viability, food security, and mitigating climate change, with the objective of increasing agricultural productivity in a sustainable way, enhancing climate change resilience and reducing greenhouse gas (GHG) emissions (Matteoli et al., 2020). Climate-smart agriculture (CSA) is not a completely new production method, but the term is used to capture existing or new agricultural practices including smart farming technologies that can contribute to reaching its objectives (Selbonne et al., 2022; Naujokiene et al., 2022; Kakamoukas et al., 2021; Adamides et al., 2020; Adesipo et al., 2020).

The CSA pillars stated by FAO have the main goal of development and food security with synergies and trade-offs between the pillars that are context- and location-specific and it is not possible to achieve all outcomes simultaneously (Jagustovi et al., 2021; Matteoli et al., 2021). European agriculture is characterized by its smart farming, which aims to transform traditional farming practices through the application of smart farming technologies (Moysiadis et al., 2021). CSA practices may differ based on location and context and it is not possible to generalize it for one another (Thornton et al., 2018; Jagustović et al., 2021). The European Union (EU) through its Green Deal has established several initiatives, including the farm-to-fork, biodiversity and the Common Agricultural Policy (CAP), to pave the way for more sustainable, resilient, and competitive agricultural systems (Pe'er et al., 2020; Smędzik-Ambroży et al., 2019). EU also included eco-schemes in its new CAP (2023–2027) that mainly focus on climate-friendly practices and animal welfare that should be included as eco-schemes within its member states (Runge et al., 2022; Pilvere et al., 2022). On the other hand, through its Farm-to-Fork Strategy and Biodiversity Strategy, the EU Green Deal aims to reduce the overall use of chemical pesticides by 50%; nutrient losses by at least 50%; use of fertilisers by at least 20%; antimicrobials use for farmed animals by 50%; and achieve at least 25% of agricultural land under organic farming by 2030 (Tataridas et al., 2022).The new CAP (2023-2027) also seeks to reduce the degradation of the environment and loss of biodiversity on European farmland (Morales et al., 2023). Accordingly, on top of the FAO-directed CSA outcomes, this study attempts to evaluate the identified farming practices and technologies in terms of their support for improvement in biodiversity, animal welfare, water use, and energy efficiency through their direct and indirect links. More specifically, this systematic mapping focuses on answering the research questions: what are the current existing CSA practices and SFTs in Europe? How do the existing CSA practices and technologies contribute to CSA outcomes in Europe?

2.2 Methods

2.2.1 Document sources and search strategy

This study followed an updated stepwise process of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology (Page et al. 2021) with the aim of identifying current climate-smart agricultural practices and farming technologies in Europe. Accordingly, formulation of the research question, protocol development, literature search, data extraction, quality assessment, data analysis and interpretation were done. It begins with a search using basic keywords for specifics about terms like ("climate-smart agriculture" OR "climate-smart farming" OR "climate-smart cultivation" OR "climate-smart arable farming" OR "climate-smart food system" OR "climate-smart feeding" OR "climate-smart livestock farming" OR "climate resilient farming" OR "climate-smart irrigation" OR "smart farming technologies") and ("Increase sustainability" OR "Increase productivity" OR "Increase income " OR "Reduce contribution to climate change " OR " Ensure food security" OR " Meet nutritional needs" OR " Strengthen resilience to climate change" OR "Improves biodiversity " OR "Improve animal welfare" OR "Optimize energy use" OR "Optimize water use"). The keywords for basic searching were selected based on discussions with participants of the BEATLES project. The main keywords that included variations of the key concepts in the research question and matched the scope of our research question were proposed based on the search algorithm from the database for basic searching (Appendix Table SM1).

Based on the research question, this systematic mapping involves identifying relevant research documents, selecting documents, extracting, and mapping the data, and summarising and reporting the results. The search was conducted by using Scopus (access via Elsevier) and Web of Science Core Collection (access via Web of Science) databases. To make it more focused and to retrieve the latest literature, the research team at the BEATLES project has discussed and decided to use filters such as year (2017-2022) since the focus this mapping is on current and existing CSA practices and technologies, publication stage (final), subject area ("AGRI", "ENVI", "SOCI", "ENGI", "COMP", "ENER", "BUSI", "ECON", "EART", "DECI", "MULT", "VETE", "PSYC") and language (English).

Accordingly, by using the specified filters, search results from the two databases were combined, and duplicates were removed using the excel remove duplicate function. After removing duplicates, papers were selected based on their title, abstract, and full text based on the following inclusion criteria:

1. Studies that concentrated on agricultural practices and technologies that are relevant for two or more CSA outcomes (sustainable productivity, resilience and GHG mitigation), as well as the biodiversity, animal welfare, water and energy use improvement) (Appendix Table SM3),
2. Studies that are focused on European countries,
3. Studies that focused on primary production (crop and livestock production),
4. Journal-published research (not in books and books chapters)

2.2.2 Screening process

1105 documents from SCOPUS and 564 documents from Web of Science were extracted and exported in CSV and Excel format, respectively, based on pre-specified filters such as year of publication, publication stage, subject area, and language. To eliminate duplicates, the documents from the two databases were merged using a CSV file. As a result, 228 duplicate records were excluded from a total of 1669 papers. The screening of duplicates removed records took place in two phases. First, the screening was done based on their title and abstract with respect to the inclusion criteria in the above section. As a result, from the 1441 papers considered, a total of 1064 documents that did not emphasise CSA outcomes and were conducted in non-European countries were excluded based on abstract and title evaluation. The titles and abstract screening were carried out by the first and second authors to reduce the possibility of mistakenly include inappropriate records and unintentionally excluding suitable records.

It could be difficult to obtain complete information to decide on the inclusion criteria and finalize the screening based on the title and abstract. As suggested by the PRISMA protocol, a full-text review could be done for selecting the final documents to be included (Page et al., 2021). Thus, using the prescribed inclusion criteria, the second screening was performed with the 377 documents selected by reading the full text. Even though all 377 papers were considered in the second stage of screening, eleven records were eliminated because the University of Copenhagen library database could not extract their full texts. Thus, the remaining 366 full-text documents were assessed for eligibility based on the inclusion criteria the above section.

The full texts of the selected papers were independently reviewed by the first two authors, with discrepancies cross-checked and fixed through discussion. Full papers were critically reviewed at this stage to determine whether their contents aligned with CSA outcomes following the prescribed indicators of CSA outcomes in Appendix Table SM3. Accordingly, 256 documents were excluded, and the remaining 110 documents were selected for the final systematic mapping process. The entire process from database and document identification to final screening was summarised in the PRISMA flow diagram in Figure 1 using Shiny app (Haddaway et al. 2022) for producing PRISMA 2020-compliant flow diagrams.

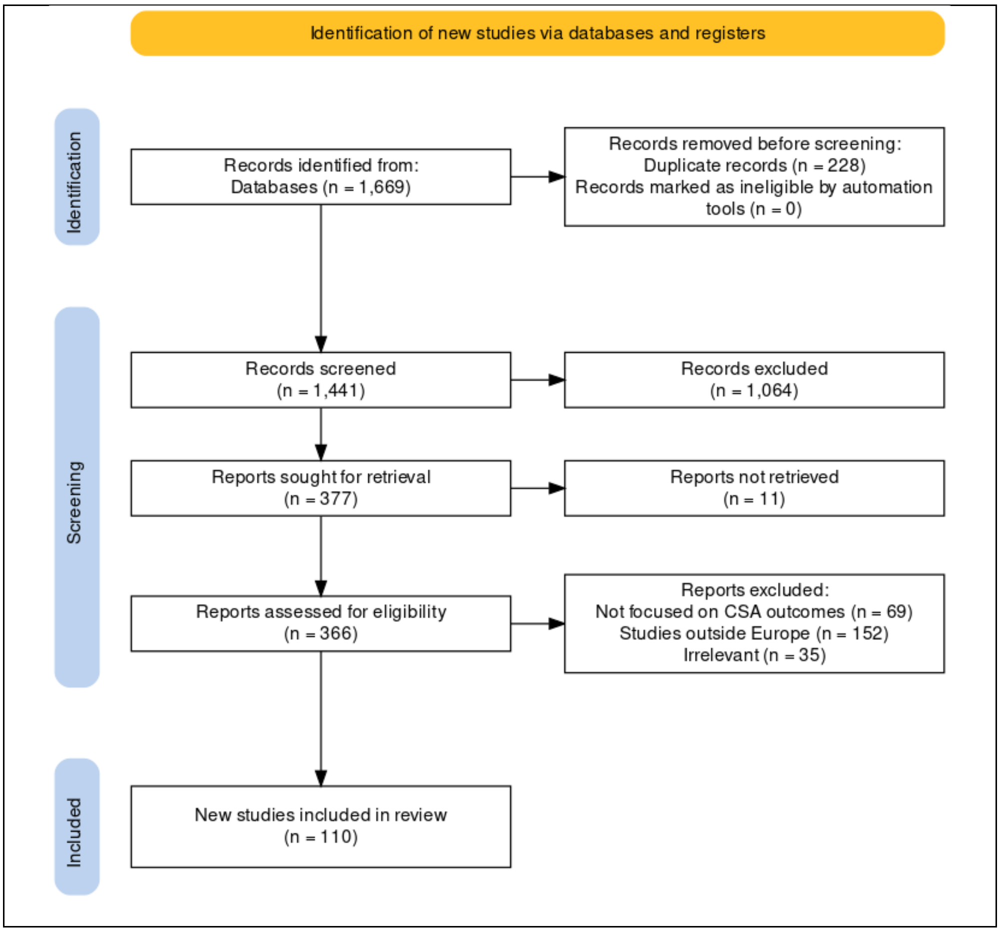

Figure 1: PRISMA flow diagram to illustrate the steps involved in the CSA systematic review

2.2.3 Data extraction and analysis

The relevant information was taken from the articles in accordance with the objectives of our systematic review. This was done by manually extracting the data after reviewing the full text of the articles and recording it in a designated spreadsheet. The accuracy of the extraction process was verified independently by the authors, and any discrepancies were resolved by discussion. Firstly, the categorization was done on CSA practises and SFTs. Secondly, based on farming types, we classified the papers into crop and livestock CSA practises by including practises that are applied for both livestock and crops as an additional category. Thirdly, the categorization of identified CSA practices and technologies with their potentiality towards to CSA outcomes following the indicators (Appendix Table SM3). To increase reliability and reduce the risk of bias, we used an iterative process whereby open discussions were made with a team of researchers on the identification process and proposed categorization (see Appendix Table SM2).

2.3 Results

2.3.1 Categorization of final selected studies

This systemic mapping aims to identify currently available CSA practices and technologies ultimately, how they are related to achieving key CSA outcomes. A total of 110 study papers were analyzed for this systemic mapping. Figure 2 illustrates the number of publications per year that focus on CSA practices and technologies applied in Europe. We observed that the number of publications increased significantly, for instance for first stage, the combined studies that are extracted from Scopus and web of science based on our search string show increasing trend from 126 in 2017 to 341 in 2021 and while from 4 in 2017 to a peak of 32 in 2021 for final selection. While the recent emphasis on CSA and the development of smart farming technologies is likely to have contributed to this increase in publications.

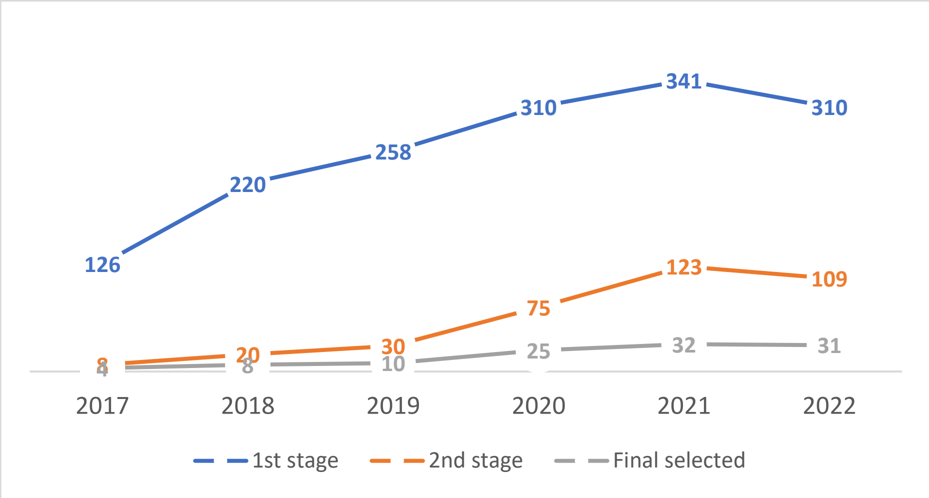

Figure 2: Distribution of final selected papers by years of publication type

We also categorized the final selected papers based on the keywords used and our review focus, which is on CSA practices and technologies in primary agricultural production. Accordingly, we categorized primary agricultural production as the main farming types like arable crops, open-field vegetables, orchards, vineyards, and animal husbandry other than pig (Figure 3). From the distribution of studies regarding farming type focus (Figure 3), about 71% of the final selected studies for this mapping focused on crop production and the remaining 29% of papers focused on the livestock sector.

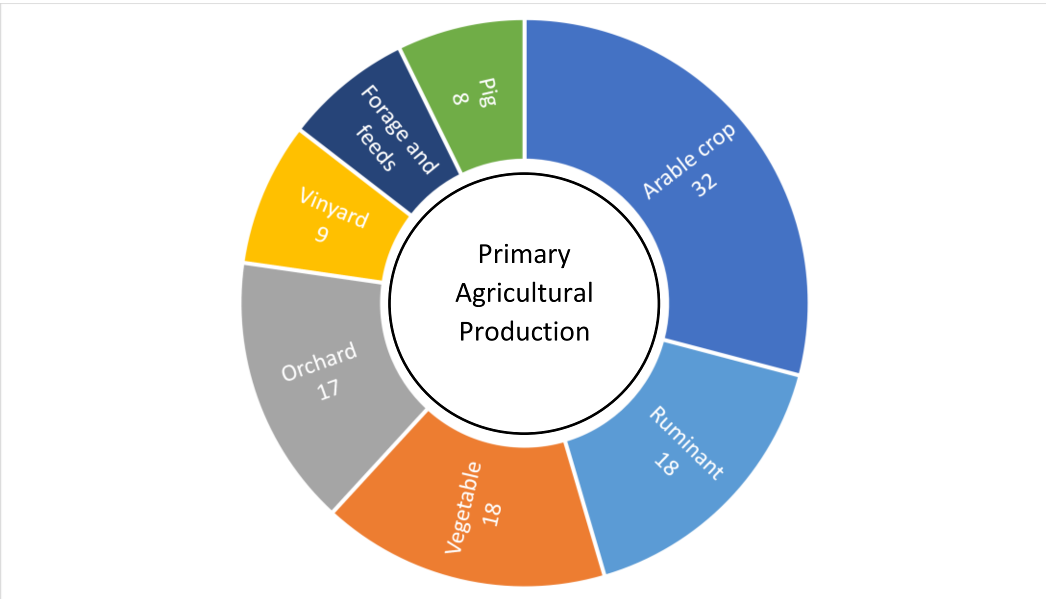

Figure 3: Categorization of studies by farming type focus (N=110)

2.3.2 Categorization of CSA practices and technologies.

Before categorization, based on this systematic mapping we have defined CSA with respect to farming practices and technologies identified. FAO (2017) described CSA as "a form of agricultural practices that sustainably boost agricultural productivity and income, enhance adaptation and resilience to climate change, and where possible reduces or removes greenhouse gases." Reducing the amount of GHG from agriculture and increasing the productivity of agriculture in a sustainable way not only needs the application of crop and livestock management practices but also the use of smart farming technologies (SFTs) (Dineva et al., 2022; Garske et al., 2021; Moysiadis et al., 2021; Lieder and Schröter-Schlaack, 2021; Adamides, 2020; Balafoutis et al., 2020). SFTs are referring to the use of digital technologies in crop farming (precision farming) and animal husbandry (precision livestock farming) to make agriculture more efficient by optimizing inputs (Boursianis et al., 2022; Dineva et al., 2022; Dayioğlu and Türker, 2021) and improve productivity (sometimes maintaining of production rate) and quality of a product (Dayioğlu and Türker, 2021, Moysiadis et al. 2021; Lieder and Schröter-Schlaack, 2021; Balafoutis et al., 2020). Because CSA is context-specific, what is climate-smart in one location may not be climate-smart in another location (Thornton et al., 2018). As a result of analysis based on site-specific lead to different CSA practices and technologies for different countries (Torquebiau et al., 2018).

The need for freshwater in Europe's agricultural sector is increasing, requiring efficient utilization (Maria et al 2020). EU's green deal targets ambitious sustainability goals for 2030 and focuses on the reduction of biodiversity loss and enhancing animal welfare as climate-friendly approaches (Runge et al., 2022). As a result, in addition to the three pillars of CSA identified by FAO, this systematic mapping included water and energy use efficiency, biodiversity, and improving animal welfare as outcomes of CSA (Bregaglio et al., 2022; Cooledge et al., 2022; Routis et al., 2022; Peddi et al., 2022; Dubois et al., 2021). Accordingly, we defined CSA as the application of farming practices, whether they are crop, livestock, or integrated and smart farming technologies, with the aim of sustainable productivity and income improvement, building resilience and adaption, reducing GHG emissions, improving water and energy use efficiency, and enhancing biodiversity and animal welfare.

Regarding categorization of the final selected studies, it is evident from Figure 4 that majority of the included studies focus on crop CSA practices that account for more than 71%. This indicates that there is a limited number of published studies on livestock CSA practices. Smart irrigation is the most pointed out crop-based CSA practice in this review, accounting for 13% of the studies. Other mostly discussed CSA practices by the included studies are organic farming (8%), smart fertilization (8%), integrated pest management (IPM) and integrated weed management (IWM) (7%), alternative fertilizers (organic fertilizer, biofertilizers and organic amendments (composition of organic moieties derived from biomass and/or living beings e.g compost, biochar)) (6%), smart chemical application (6%) and conservation tillage (5%). With regard livestock-based CSA practices, manure management (11%), feed improvement (5%), pasture grazing (4%) and integrated husbandry (2%) were mostly pointed out as shown in Figure 4. Some of the selected studies have also focused on both livestock and crops; for instance, the issue of breed improvement has been discussed from both perspectives. The CSA practices and technologies from the systematic mapping are classified in the following subsections based on our keyword search boundary, which is the primary production (crops and livestock). As a result, CSA from the identified papers is classified as crop-based, such as soil management practices and smart crop protection, as well as smart irrigation and smart farming technologies. While livestock-based CSA practices include manure management, husbandry improvement, feed improvement, and pasture grazing. Finally, in the context of sustainable production and climate change mitigation, the CSA that are commonly applied as integrated crop-livestock management are presented.

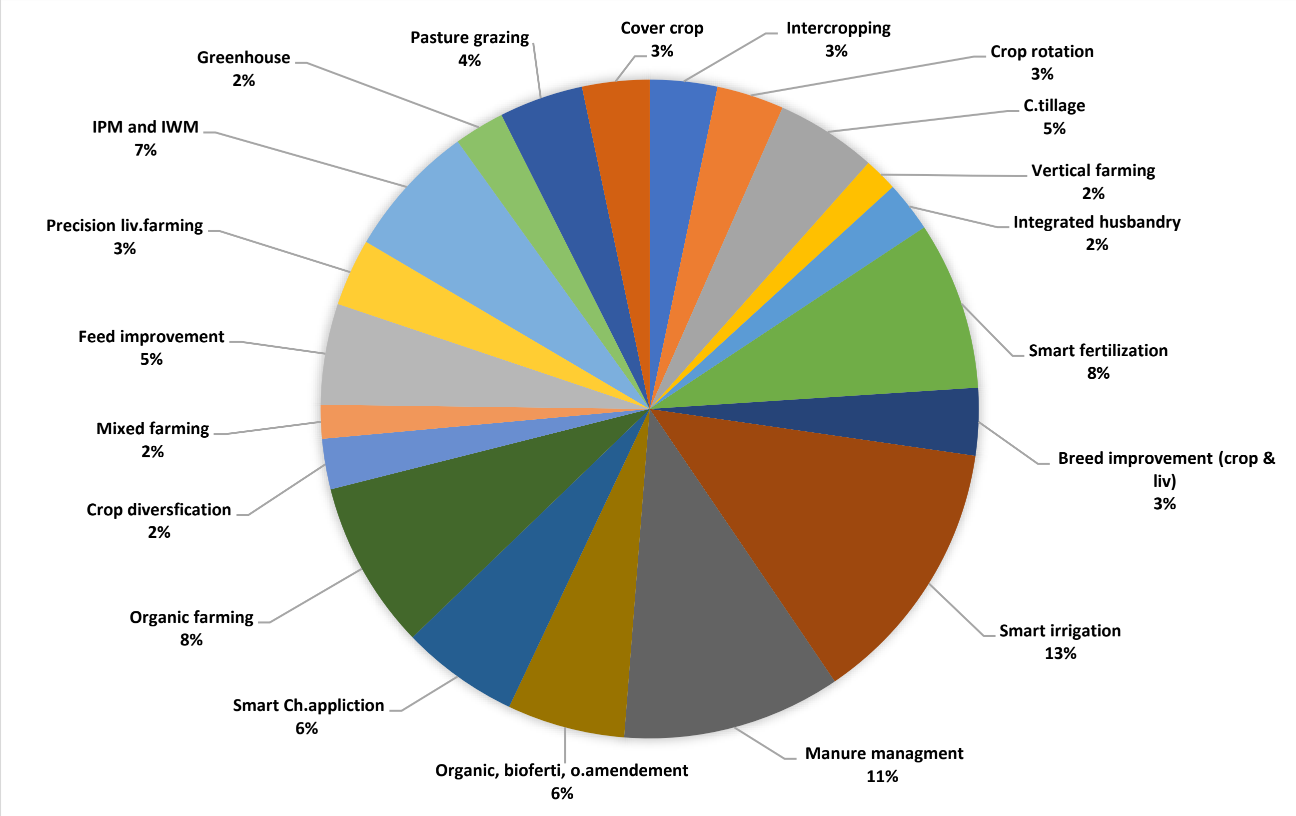

Figure 4: Categorization of final included studies by individual CSA practices (N=110)

Based on our keyword search boundary, which is primary production (crops and livestock) and CSA outcomes contribution, the CSA practices and technologies from the systematic mapping (Figure 4) are further categorized into the broader category namely climate-smart soil management practices, climate-smart crop protection, climate-smart irrigation management, livestock-based CSA practices, and CSA practices for both crop and livestock production. The detail of each broad category was presented in following subsections.

2.3.2.1. Climate-smart soil management practices

In its climate targets, the European Union (EU) places emphasis on sustainable soil management since European soils are currently a net source of greenhouse gas emissions (EEA, 2023). Among crop-based practices, sustainable soil management is given priority since soils can both sequester carbon from the atmosphere or emit greenhouse gas emissions (Francaviglia et al., 2023). Around 17% of the papers reviewed focused on climate-smart soil management practices, which aim to reduce GHG emissions from agricultural soils while also improving resilience and crop productivity. Even though different management practices and technologies are applied for sustainable soil management in Europe, agroecological practices are getting greater attention to reduce the negative effects of agriculture in a sustainable manner (Korchagin et al., 2022; Revoyron et al., 2022; Peltonen-Sainio et al., 2022; Bregaglio et al., 2020; Cooper et al., 2020 and Lutz et al., 2019). Furthermore, these management practices are listed as climate-friendly agricultural practices in the new CAP (2023-2027) eco-schemes because they contribute significantly to the transition to a sustainable food system (Runge et al., 2022). Smart farming technologies for nutrient management planning and precision crop farming to optimize fertilisers by accounting for field spatial and temporal variability are also potentially relevant for short and long-term soil health improvement (Adamides, 2020; Rehman et al., 2022; Fabiani et al., 2020; Boursianis et al., 2020; Dayiolu and Türker, 2022). Accordingly, we classified CSA practices for soil improvement as agroecological farming practices and climate-smart fertilization.

1.3.2.1.1. Agroecology-based CSA practices for soil improvement

Cover crops, intercropping, crop rotation, diversification and conservation tillage are primarily identified practices that have the potential to reduce agricultural GHG emissions by capturing CO2 in the soil for a long time (Deguine et al. 2023; Peltonen-Sainio et al. 2022; Rivière et al. 2022; Bregaglio et al. 2022; Cooledge et al. 2022; Jindo et al. 2021; Verschuuren, 2018; Gallardo-López et al. 2018). Conservation tillage is agroecological practices that increase not only soil organic carbon (SOC), but also the amount of water that percolates into the soil, organic matter retention in the soil, and nutrient cycling, all of which improve soil health and environmental sustainability without compromising crop productivity (Francesco et al. 2020; Bregaglio et al. 2022; Cooledge et al. 2022; Cooper et al. 2020; Lutz et al. 2019). Increasing SOC while reducing GHG emissions and water footprint are effective measures to enhance crop productivity with minimum environmental impact (Cooper et al. 2020). No-tillage farming boosts soil and litter C supplies and increases productivity by 1.5-3.5% (Lutz et al. 2019). But studies by Cooper et al. (2020) and Cooledge et al. (2022) found that in lowland intensive arable settings, conservation tillage alone is inefficient at enhancing the short-term environmental sustainability of farming methods. In this regard, aspects of cover crops, crop rotations, and precision farming methods must be included to improve yield and reduce adverse environmental effects (Cooper et al. 2020; Francesco et al. 2020). De Pinto et al. (2020), for example, demonstrated how integrated soil fertility management, which includes no-tillage, alternate wetting and drying, and nitrogen use efficiency, can increase production under future unfavourable climatic conditions by improving soil fertility and lowering GHG emissions.

Crop rotation and cover crops are also pointed out agroecological CSA practices for soil health improvement (Peltonen-Sainio et al., 2022; Rivière et al., 2022; Tribouillois et al., 2018; Billen et al., 2018; Peltonen-Sainio et al., 2022; Lieder et al., 2021; Korchagin et al., 2022; Assirelli and Liberati, 2022; and Jindo et al., 2022). A contemporary problem for the agriculture sector is to increase soil organic carbon (SOC) while reducing GHG emissions and sustaining crop productivity (Dinesh et al., (2022). The application of optimized crop rotations increases soil carbon and reduces GHG emissions without sacrificing yields (Jindo et al. 2022., Lieder et al., 2021, Korchagin et al., 2022). A study by Cooledge et al. (2022) found that reintroducing leys into arable rotation increases ecosystem service delivery in agriculture through increasing carbon sequestration, symbiotic nitrogen fixation, water infiltration, and biodiversity in soil fauna and microbial communities. Bringing legumes into rotations also helps to capture more nitrogen, reducing the need to use mineral N fertilizer, and this can also bring more protein self-sufficiency in feed production (Cooper et al., 2020; Billen et al. 2018; Schumacher et al., 2018). The incorporation of cover crops into crop rotation as green manure increases the soil's organic carbon content (SOC) without compromising crop output (Cusworth et al., 2021). Cover and catch crops are considered a viable option to mitigate greenhouse gas emissions through soil carbon sequestration (building up the soil organic carbon content) and reducing emissions from fertilizer production (Peltonen-Sainio et al. 2022; Rivière et al. 2022; Vogeler et al. 2023). Vogeler et al. (2023) showed that use of catch crops could reduce N leaching by 21-64% and Veronika et al. (2023) also found that growing cover crops like winter-persistent legumes as a promising tool for increasing subsequent crop yields through nitrogen input and nutrient cycling.

Intercropping and crop diversification are also agroecological practices that are discussed in the reviewed literature (Antoine et al., 2021; Erik et al., 2020; Revoyron et al., 2022; Rivière et al., 2022). The studies by Cusworth et al. (2021) and Jensen et al. (2020) pointed out that intercropping systems require less nitrogen fertilizer and often require fewer weed control measures than grain legumes cropped alone, which will facilitate low-input agricultural practices for sustainability. While crop diversification improves soil structure due to a diversity of root systems (Erik et al., 2020; Revoyron et al., 2022). This optimizes nutrient cycling, reduces leaching, increases infiltration, and boosts soil organic matter, which is important for healthy crop production (Revoyron et al., 2022; Cusworth et al., 2022). It also increases biodiversity, benefits pollinators, improves pest management and weed control, and reduces the need for chemical fertilizers or herbicides (Revoyron et al., 2022; Tataridas et al., 2022; Peltonen-Sainio et al., 2022, Erik et al., 2020).

2.3.2.1.2. Climate-smart fertilization for sustainable soil improvement

Excessive use nutrients for crop production from commercially produced fertilizers, can be a major source of air, soil, and water pollution, as well as have negative effects on human health, soils, biodiversity, and climate (Grzebisz et al 2022; Gavrilescu, 2021; Agrimonti et al. 2021, Sefeedpari et al. 2020). Due to the adverse environmental effect of mineral fertilizers, the European Commission by its Green Deal aims to reduce fertilizer use by at least 20% by 2030, while ensuring no deterioration in soil fertility. To this end, organic fertilizers, bio-fertilizers, organic amendments, and soil microbiomes are alternative climate-smart inputs for soil nutrient improvement and sustainable plant growth (Agrimonti et al. 2021, Brenzinger et al. 2021). Organic fertilizers are plant- or animal-based products used to provide essential nutrients to crops such as compost, manure, and bone meal, providing essential nutrients to plants while also improving soil structure and fertility (Agrimonti et al., 2021; Billen et al., 2018; Micha et al., 2020). The reviewed literature pointed out that biofertilizer is a crucial input for improving soil fertility and plant growth (Tur-Cardona et al. 2018, Agrimonti et al. 2021).

Organic amendments like compost and biochar and microbiomes are used as an alternative climate smart input to substitute synthetic fertilizers for soil nutrient improvement. For instance, studies by Luigi et al. (2022), Brenzinger et al. (2021) and Delitte et al. (2022) pointed out that the use of organic amendments can improve soil physical and chemical properties such as soil pH, drainage, and nutrient content. It also encourages a shift in the diversity and abundance of key microbial groups and has the potential to not only lower GHG emissions by modifying the microbial community's abundance and composition but also favour crop growth-promoting microorganisms (Brenzinger et al., 2021). The soil microbiome is a diverse community of microorganisms that live in the soil and play important roles in nutrient cycling and soil health and fertility (Delitte et al., 2022). Microbes can also bring out the hidden strengths of plants, making them more resistant to disease and increasing their yield by offsetting the use of agrochemicals (Agrimonti et al., 2021).

The application of smart farming technologies (SFTs) for agricultural production is useful in soil nutrient management plans by reducing input use based on a specific field's spatial and temporal variability (Routis et al., 2022; Agrimonti et al., 2021; Adamides, 2020; Fabiani et al., 2020). For instance, variable rate of application (VRA) based on precision mapping and adjusting the application rate of inputs based on the variation in soil and crop conditions allows farmers to precisely control the amount of fertilizer to the farm field based on the specific area demand (Dayioğlu and Türker, 2021; Fabiani et al., 2020; Balofoutis et al., 2017; Balofoutis et al., 2020). The use of smart agricultural technologies helps on-farm management by improving productivity and increasing the efficiency of grassland soil nutrient management. A study by Higgins et al. (2019) found that controlled traffic farming and variable-rate fertilizer application has potential economic and environmental benefits for monitoring soil properties and grass yields. Based on the systematic review, the use of smart or precision farming technologies has directly or indirectly supported soil nutrient management.

2.3.2.2. Climate-smart crop protection

The EU Green Deal aims to reduce the use and risk of chemical pesticides by 50% by 2030 to achieve sustainable production with minimum environmental effects (EC, 2022). To meet this goal, the use of sustainable and environmentally friendly techniques to reduce the adverse effects of agrochemicals and protect crops from pests, diseases, and weeds should be given priority (Candel et al., 2023; Silva et al., 2022; Tataridas et al., 2022; Jindo et al., 2021; Heeb et al. 2019). As agreed during the UN Biodiversity Summit (COP15) and the Kunming-Montreal Global Biodiversity Framework, reducing the risks of pesticide use is a key leverage point for addressing the biodiversity crisis (Candel et al., 2023). To be climate smart, it requires a variety of strategies to protect crops from pests and diseases while minimising negative environmental and human health impacts (Schumacher et al., 2018; Heeb et al. 2019, Deguine et al 2021). Integrated pest management (IPM), integrated weed management, biological pest control, prohibiting the use of pesticides in sensitive areas, and use of smart farming technologies are recommended practices for climate-smart crop protection (Assirelli and Liberati., 2022; Tataridas et al., 2022; Deguine et al 2021, Jindo et al., 2021; Shankar et al., 2020; Filho et al., 2020; Mestre et al., 2020). Application of these practices not only reduces pest-induced crop losses but also boosts ecosystem services, reduces GHG emissions, and improves the resilience of agriculture in a changing climate (Heeb et al. 2020). The EU by its green deal promoted Integrated Pest Management (IPM) practices as environmentally friendly pest control measures to reduce chemical pesticide use (EC, 2022). From this systematic mapping, we found that the application of IPM could increase crop production, soil organic matter, reduce emissions of GHG that come from pesticide use, and reduce biodiversity loss as compared to conventional chemical pesticide use (Jindo et al., 2021; Filho et al., 2020; Mestre et al., 2018; Heeb et al., 2019).

Integrated weed management (IWM) has the potential to reduce the use of agrochemicals in agricultural production by combining agroecological farming practices, such as intercropping, with support from smart farming technologies (Tataridas et al., 2022; Allmendinger et al., 2022; Jindo et al. 2021, Adamides, 2020 and Libran-Embid et al. 2020, Schumacher et al., 2018). The use of precision technologies such as decision support system (DSS) as part of integrated pest management may aid in the identification of disease and pest attacks with the anticipated date of exceeding control thresholds and the application of fungicides or pesticides (Deguine et al., 2021; Tataridas et al., 2022; Jindo et al., 2021). Furthermore, the use of disease and pest-resistant crop varieties, as well as the use of a greenhouse, were suggested as climate-smart crop protection practices (Peltonen-Sainio et al. 2022; Cesco et al. 2022; Gruda et al. 2021; Jennings et al. 2020; Gruda et al. 2019; Billen et al. 2018).

SFT monitors crop health and early breakouts and creates better predictions based on present and past conditions to reduce agricultural diseases and pest infestations (Cecchetti and Ruscelli, 2022; Wolfert and Isakhanyan, 2022; Balafoutis et al., 2020; Filho et al., 2020). For instance, a study by Boursianis et al. (2022) pointed out that the use of IoT with SFT improves crop yield and quality, reduces costs, and mitigates the ecological footprint of traditional farming by monitoring crops even at the per-plant level. While the study by Wolfert and Isakhanyan (2022) pointed out that the use of IoT solutions within field management zones reduces herbicide use by about 33%, increases yield by 6% and reduces nitrogen use by about 30%. Another study by Shankar et al. (2020) pointed out that the use of artificial intelligence-driven spray timing, variable rate application maps, and product recommendation has resulted in a 30% reduction in fungicide usage on field-trial cereal crops and a 72% reduction in tank leftovers, reducing environmental pollution. Drones outfitted with remote sensing equipment (sensors) could be used as decision-making tools, as early detection and response to suboptimal abiotic conditions could help to prevent large pest outbreaks by mapping and image visualisation of large-scale arable farms (Routis et al., 2022; Dayioğlu and Türker, 2021; Filho et al., 2020). It is also used for crop scouting to identify pests and diseases in crops, helping farmers take action to prevent crop damage (Ahmad et al., 2020; Pascuzzi et al., 2018; Rehman et al., 2022). Farm robotics is another SFT that is increasingly being applied in crop protection and that can navigate through fields and remove weeds without the use of chemicals (Tataridas et al., 2022; Assirelli and Liberati, 2022; Saiz-Rubio et al., 2021). IoT-based smart traceability and farm management systems for fertilization increase agricultural production, improves soil biodiversity while decreasing fertiliser use, pesticide use, weed pressure, pesticide residue, disease, and pest pressure (Routis et al., 2022; Alexandris et al., 2021; Martn et al., 2021; Filho et al., 2020). Application of smart farming technologies like UAVs, UGVs and variable rate sprayers could allow a timely and balanced distribution of agrochemicals that have the potential effect on microorganisms that support soil improvements (Lieder & Schröter-Schlaack 2022; Moysiadis et al, 2021).

The use of greenhouses for crop production based on sustainable energy sources such as biogas, photovoltaics, and geothermal energy, as proposed by Gruda et al. (2021), Gruda et al. (2019), and Cecchetti and Ruscelli (2022), serves as a strategy for transforming and reorienting agricultural development in response to the new realities of climate change. For example, Gruda et al. (2021) demonstrate that using sem and closed greenhouses results in an 80% reduction in chemical plant protection. According to Tomar (2021), employing an integrated photovoltaic greenhouse (PV-GH) also resulted in a decrease in the quantity of agrochemicals and irrigation water needed. A study by Wolfert and Isakhanyan (2022) also highlighted that the use of chain-integrated greenhouses can reduce pesticide application by 20.8%. Vertical farming also has the potential to solve widespread crop diseases, which decrease productivity, and the harmful effects of pesticides and insecticides by applying precision technologies (Preininger, Hafner, 2021).

2.3.2.3. Climate smart irrigation management

Through irrigation, agriculture is one of the sectors that use the most water. It makes crops more productive but also threatens the conservation of water resources. Because of this, the problem of not having enough water requires careful thought about the trade-off between increasing agricultural productivity and letting water resources deteriorate (Gobin et al 2017). The quantity of irrigation water utilised in agriculture is determined by the types of crops and cropping technique, soil characteristics, and irrigation method (Roma et al 2022, Gobin et al 2017). In this regard, climate-smart agricultural practices and technologies can provide opportunities for enhanced water management (Fotia et al. 2021; Neupane and Geo, 2019). Smart irrigation is one of the pointed-out crop-based CSA practices for optimising the amount of water and nutrients required, based on variables such as weather, soil moisture, and plant growth on the field (Routis et al., 2022; Peddi et al., 2022; Dubois et al., 2021; Alexandris et al., 2021; Sishodia et al., 2020; Filintas et al., 2022; Martín et al., 2021; Visconti et al., 2020).

Using smart irrigation with IoT technologies can also help to determine more precisely its actual location and its status and lower the cost of input (Matilla et al., 2020; Campana et al., 2018). Water management through the application of SFTs like variable-rate irrigation (VRI) increases crops' water use efficiency (WUE) (Balafoutis et al. 2017). For instance, a study by Neupane and Guo (2019) pointed out that the application of VRI across different crops and weather regimes in the world concluded that VRI could save 10–15% of water. Martín et al. (2021) used SFT for stacking evapotranspiration from the soil to predict and manage irrigation water. Smart irrigation using a decision support system (DSS) could reduce water and energy use (Fotia et al., 2021; Suciu et al., 2019). Smart irrigation technologies help reduce the risk of salinization of soils by using sensors and other technology to monitor soil moisture levels and by adjusting the amount of water applied based on those levels (Routis et al., 2022; Dubois et al., 2021; Alexandris et al., 2021; Fotia et al., 2021; Peddi et al., 2022; Thomopoulos et al., 2021; Massa et al., 2020). Among SFTs, an unmanned aerial vehicle (UAV) equipped with advanced sensors, cameras, and other technologies allows farmers to efficiently collect data on crop growth, soil moisture, and other important factors to make more informed decisions about crop management and irrigation (Boursianis et al., 2022; Filho et al., 2020). Taking advantage of the development of UAVs, Alexandris et al. (2021) did research in Greece on integrating a UAV called GreenWaterDrone (GWD). They found that the ground meteorological station (GMMS), the onboard aerial micrometeorological system (AMMS), and the portable IRT radiometers can all be used to measure canopy temperatures.

2.3.2.4. Livestock-based CSA practices

In the agricultural sector, livestock production is a leading contributor to GHG like methane (CH_4) and nitrous oxide (N_2O) and ammonia emissions (Overmeyer *et al.,* 2023; Beyers et al. 2022; Creissen et al., 2022; Frolova e*t al.* 2020). This is mainly caused by fermentation in the digestive systems of ruminants, feed production and manure decomposition (Sefeedpari *et al.,* 2020; Chun *et al.,* 2022; Overmeyer *et al.,* 2023). On contrary, the livestock sector also contributes to the EU GHG emissions reduction efforts by its grassland restoration that have effect soil carbon stocks, manure management like recycling and bio digestion and crop-livestock integration (Julia et al., 2021, Emmerling et al., 2020). Due to demands for a lower environmental impact, more animal welfare, and less intensive production, livestock farmers in the EU are facing challenges today to balance stable production (Molnár, 2022). CSA practices are essential for raising the sustainability and effectiveness of animal production while reducing GHG emissions (FAO, 2019). Based on their contribution to the reduction in GHG emission reduction, support to productivity and animal welfare and water and energy use efficiency, currently available livestock-based CSA are identified from the reviewed studies. Accordingly, we categorized livestock-based CSA practices and technologies as manure management, improved animal husbandry and improved feed management including fodder production, pasture grazing, precision livestock farming.

About 11% of the final selected studies (Figure 4) showed that manure management is the most important CSA practice for reducing GHG emissions from livestock (Naujokiene et al. 2022; Izmaylov et al. 2022; Julia et al., 2021; Romaniuk et al. 2021; Frolova et al. 2020; Emmerling et al, 2020; Micha et al. 2020; Sefeedpari et al. 2020; Thumba et al. 2020; Pexas et al. 2020; Saez et al. 2017; Saez et al. 2017; Saez et al. 2017). Animal housing modifications that increased ventilation efficiency and improved barn insulation through their combination of non-renewable resources were the most cost-effective options to manage the effect of manure and improve animal welfare (Pexas et al. 2020). Composting of the solid part of manure by utilizing a passive windrow system and aeration of the liquid phase is also an effective method for reducing greenhouse gas emissions on farms (Saez et al. 2017). Acidification of slurry and manure is also another identified manure management practice that reduces GHG emissions from manure (Beyers et al., 2022; Emmerling et al, 2020). Acidification of slurry with sulphuric acid in the barn or at the time of application is an effective way that can reduce ammonia losses and reduce methane emissions (Overmeyer et al., 2023; Chun et al., 2022; Emmerling et al., 2020 and Niccolucci et al., 2021). For instance, studies by Overmeyer et al. (2023), Chun et al. (2022) and Emmerling et al. (2020) pointed out that acidification of manure reduced emissions of NH_3 by up to 69%, CH_4 up to 67% and N_2O up to 21%. Application of precision technologies at feeding, livestock housing, manure storage, and application to soils as a climate-smart holistic management system reduced environmental impact from animal husbandry (Naujokiene et al., 2022). Manure management also provides environmental and economic benefits for agricultural-rural structures to effectively manage animal manure by producing electricity, heat and organic fertilizer (Cooledge et al. 2022; Sefeedpari et al. 2020). Integrating renewable energy production like biogas with manure management increases energy efficiency and at the same time reduces emissions from the livestock sector (Romaniuk et al., 2021).

Feed management, the primary methane mitigation strategy, requires improvements in forage quality, feed additives, grassland management, and fodder production (Cooledge etal.2022, Rivero et al. 2021, Ouatahar et al. 2021, Rønningen et al. 2021, Higgins et al., 2019; Hocquette et al. 2018, Cortignani et al. 2021, Cusworth et al. 2021, Mu et al. 2017) is another livestock-based CSA practices mentioned to lower emissions and enhance animal health and productivity. In this regard, land allocation for green feed production, including grass and legumes, is indicated as a strategy to reduce the current climate change effect (Cortignani et al., 2021; Cusworth et al., 2021; Rivero et al., 2021). Feeding legumes, which have been suggested as the future of green livestock, has huge potential on top of feeding livestock to reduce emissions from fertiliser use and improve soil fertility (Cusworth et al., 2021; Cooledge et al., 2022). For instance, locally produced high-protein legume-based feed reduced GHG emissions by 15-42% when compared to imported soy products of the same nutritional value (Cusworth et al., 2021). Reintroducing multispecies leys and livestock grazing in arable rotations is another livestock feed management option that improves ecosystem services, soil structure, soil carbon and nitrogen cycling, and reduces livestock GHG emissions (Cooledge et al., 2022; Krieger et al., 2017). For instance, a study by Matthew et al. (2022) found that using grass-based ley arable rotations can increase SOC stocks by 3-16 tonnes per hectare. Feed additives are another identified feed management practice to be considered as CSA practices in the livestock sector. Improving feed quality by incorporating organic ingredients like organic barley, oats, and legumes improves diet while lowering CH4 emissions (Niccolucci et al., 2021; Cooledge et al., 2022). In addition, reducing concentrate use by replacing feed quality with green protein sources such as clover, alfalfa, and grasses also lowers CH4 emissions (Naujokiene et al., 2022; Ouatahar et al., 2021; Cortignani et al., 2021). According to Ouatahar et al. (2021), feed additives could reduce enteric CH4 emissions by 12-20% and GHG emissions by 10-30% from manure.

Pasture-based grazing is another considered climate-smart livestock practice in Europe that can store carbon in the soil and reduce ammonia emissions from livestock, improving soil health and animal welfare (Collas et al., 2019; Rivero et al., 2021; Roningen et al., 2021). Despite the fact that grazing animals emit methane, a potent greenhouse gas, pasture-based systems have the potential to reduce methane emissions when compared to intensive indoor systems that rely on grain-based feed (Rivero et al., 2021). This is because pasture-based systems typically use more diverse forage sources, which can reduce methane emissions from enteric fermentation (Thompson and Rowntree, 2020). Grazing animals can convert grasses and other plant material into high-quality protein, and their manure can be used as organic fertilizer for crop production (Collas et al 2019; Micha et al. 2020). Additionally, well-managed grazing systems can improve soil health, reduce erosion, and increase biodiversity (Rivero et al., 2021). Overall, the integration of pasture-based grazing systems into agriculture can provide multiple benefits for both farmers and the environment (Krone et al., 2018; Rønningen et al., 2021).

As livestock sector's largest source of GHG emissions, it requires extensive management with smart farming technologies and strategies that do not impede animal welfare (Naujokiene et al., 2022; Chun et al., 2022; Ouatahar et al., 2021; Emmerling et al., 2020). Application of precision technologies at feeding, livestock housing, manure storage, and application to soils as a climate-smart holistic management system ensures both comfortable working conditions and improves productivity while reducing emissions (Naujokiene et al., 2022; Gabriel and Gandorfer, 2022; Romaniuk et al., 2021; Cortignani et al., 2021; Frolova et al., 2020). Naujokiene et al. (2022) pointed out that modernization of cow housing with technologies and ventilation systems, or box barns with shallow boxes and manure handling technology, can improve the welfare of the animal and reduce emissions. Smart farming technology enables an advanced decision-support system by providing farmers with real-time data for analysis on livestock management, resulting in more efficient and sustainable farming practices (Dayiolu and Türker, 2021). Precision technologies for fodder production and livestock monitoring can optimize input used for fodder production and allow farmers to follow the animals' conditions and farm environmental status (Dineva et al., 2022; Thumba et al., 2020). For instance, drones equipped with sensors and cameras are also currently used for monitoring animal movement, providing valuable information about their health and well-being (Moysiadis et al., 2021; Thumba et al., 2020; Libran-Embid et al., 2020).

2.3.2.5. CSA practices for both crop and livestock production

The reviewed literature revealed that some CSA practices were used with animals and crops and that these practices were also interconnected with one another (Kakamoukas et al., 2021; Bayram et al., 2023). Thus, in the context of sustainable production and climate change mitigation, the CSA that are commonly applied in both livestock and crop sectors, like organic and mixed farming, as well as integrated crop-livestock management and energy efficiency, are presented.

Organic farming, mixed farming, and diversification are the identified CSA practices by this SM. The Farm to Fork (F2F) Strategy of the European Commission sets ambitious targets to transform the whole food system towards greater sustainability. In this regard, for implementing the F2F strategy, the EU plans to meet the goal of having 25% of its land organically farmed by 2030 (Moschitz et al., 2021). In this review, we considered organic farming as CSA practices as it focuses production of crops and livestock using methods that priorities environmental sustainability, biodiversity, and the health of the ecosystem even though there is a productivity trade-off (Creissen et al., 2022; Holka et al., 2022; Agrimonti et al., 2021). It also encourages other CSA practices to be applied as part of it, including a low-input agroecosystem in which crop and livestock productivity are reliant on the use of green manure, biological pathogen control, and permanent pasture (Agrimonti et al., 2021; Holka et al., 2022; Tiziano, 2018). Mostly it relies on agroecological practices like conservation tillage, intercropping, crop rotation, the use of cover crops, pasture grazing, and agroforestry systems, which can help sequester carbon in the soil and reduce greenhouse gas emissions (Peltonen-Sainio et al., 2022; Schumacher et al., 2018; Billen et al., 2018). By combining tillage techniques with the growing of catch crops and leguminous plants, for example, organic agriculture can help cut down on carbon emissions and make the land more resilient (Holka et al., 2022). It also relies on the use of organic fertilizers and bio-fertilizers that promote biodiversity (Tur-Cardona et al., 2018; Agrimonti et al., 2021) and integrated crop protection mechanisms to control pests and diseases (Assirelli and Liberati, 2022). Organic farming also encourages animals' welfare by providing them access to pasture grazing (Blanco-Penedo et al., 2018). Since organic farming is based on the principle of no chemicals for plant protection, it encourages agroecological practices that increase agro-biodiversity in agricultural fields (Schumacher et al., 2018).

Even though organic farming has positive environmental and health effects, there is also debate about the impact of organic systems on productivity and cost of production when compared to conventional systems. Agrimonti et al. (2021) state that a drop in yield between 5 and 34% is expected, depending on the crops, agroecological context, and practices compared to their conventional counterparts. Nevertheless, the gap may be lower for the best organic practices, even it would be higher for legume-based crop rotation and under severe drought conditions due to the better ability of organically managed soil to store water (Wilbois and Schmidt, 2019). With regards to production costs, it would be significantly higher with organic farming (Tiziano, 2018). Organic farming, on the other hand, may result in higher soil organic carbon content compared to non-organic systems as well as significant reductions in GHG emissions that come from the use of chemical fertilisers and agrochemicals (Holka et al., 2022). Organic livestock farming that is based on pasture and green feed encourages carbon footprint reduction while also improving soil health and biodiversity by using natural resources (Blanco-Penedo et al., 2018). Furthermore, it promotes the identification of effective health management measures at the farm level for reducing production diseases without antibiotic use (Creissen et al., 2022; Krieger et al., 2017). To summarise, organic farming achieves at least two CSA targets by promoting environmentally friendly farming practices for long-term production and animal welfare while lowering greenhouse gas emissions. Participating in organic farming, unlike other CSA practices, allows for the simultaneous implementation of other CSA practices.

Diversified and mixed farming are also considered climate-smart agricultural practices because they promote a more sustainable and resilient agricultural system (Antoine et al., 2022; Kakamoukas et al., 2021; Revoyron et al., 2022; Garca-Cornejo et al., 2022). Diversified farming can enhance soil health, reduce the need for chemical inputs, and increase crop and animal diversity (Garca-Cornejo et al., 20220). Mixed farming also improves the efficiency of nutrient cycling and reduces the need for inputs such as fertiliser and pesticides (Antoine et al., 2021; Kakamoukas et al., 2021). This practice also contributes to the farm's resilience to climate change, as the farm can produce a variety of products, reducing the risk of crop failure (Kakamoukas et al., 2021; Antoine et al., 2022). Overall, diversified and mixed farming can help improve agricultural systems' resilience to the effects of climate change, reduce the need for inputs, and improve biodiversity.

Integrated crop-livestock systems with mutually supportive and mutually dependent to rebalance the economic and environmental trade-offs in both systems (Antonius et al. 2021). For instance, using the manure from animals as organic fertilizer for crops, will encourage the sustainability of agriculture (Bayram et al. 2023; Cooledge et al., 2022; Higgins et al., 2019; Romaniuk et al., 2021; Rønningen et al., 2021; Krieger et al., 2017). The implementation of integrated crop-livestock systems will also improve climate resilience. A study by Rivero et al. (2021) show that improved livestock integration into arable systems through novel rotations including grazed grass leys could increase arable system resilience in terms of soil quality, nutrient utilization, and combating weeds, pests, and diseases, thereby increasing biodiversity. It also offers producers with a wider range of mitigation and adaptation options to climate change (Bayram et al., 2023).

Energy efficiency is becoming increasingly crucial in reducing GHG emissions (López-Morales et al., 2021; Fotia et al., 2021; Gruda et al., 2019). Accordingly, we identified practices from the reviewed studies that enhance energy use efficiency and reduce the environmental impact of agriculture. For instance, irrigation wells using an IoT-based platform save close to 10% of energy (López-Morales et al., 2021). Integrating automation solutions in precision agriculture that reduce energy will not only reduce GHG emissions but also increase the uptake of technology by farmers (Suciu et al., 2019). A study by Fotia et al. (2021) also confirmed that smart irrigation practices using a decision support system (DSS) could reduce water and energy use by 42.1% compared to conventional practices. Another important strategy for increasing energy efficiency in agriculture is the use of renewable energy sources. A study by Gruda et al. (2019) pointed out that the use of renewable energy sources such as biogas, photovoltaics, and geothermal energy reduces the impact of climate change adaptation for protected cultivation in a greenhouse. Implementing these strategies contributes to efforts to create a more sustainable and resilient agricultural sector, as well as to mitigate the effects of climate change (Fotia et al., 2021; López-Morales et al., 2021; Gruda et al., 2019). Furthermore, DSS can be used to optimise the use of resources such as water and energy, as well as predict crop yields, allowing farmers to better plan for market demands (Fotia et al., 2021).

2.3.3 Potential contributions of identified practices on CSA outcomes

Based on a review of the selected literature, CSA encourages farmers to use more environmentally friendly practices like cover cropping, crop rotations, intercropping, conservation tillage, and pasture grazing (Rivière et al. 2022; Revoyron et al. 2022; Collas et al. 2019; Erik et al. 2020), climate-smart inputs (organic fertilizers, compost, organic amendments, microbiomes, biochar) (Delitte et al 2022, Brenzinger et al. 2021, Agrimonti et al. 2021; Romaniuk et al 2021; Micha et al 2020; Tur-Cardona et al. 2018) and SFTs for optimization of chemical fertilizers and agrochemicals for healthier soils and improved water quality and reduced biodiversity impact (Moysiadis et al 2021; Boursianis et al 2022; Rehman et al 2022; Cesco et al. 2021, Balafoutis et al 2020). Furthermore, CSA focuses on feed and manure management for improved livestock production and animal welfare by encouraging green feeding with adequate space, ventilation, and access to pasture (Cooledge et al., 2022; Naujokiene et al., 2022; Ouatahar et al., 2021; Niccolucci et al., 2021). CSA also promotes biodiversity through conservation agriculture (minimizing soil disturbance, maintaining soil cover, and diversifying crop rotations), agroforestry that integrates trees into agricultural landscapes, rotational grazing and organic farming, and the restoration of degraded land (Revoyron et al. 2022; Peltonen-Sainio et al. 2022; Cooledge et al. 2022; Tataridas et al. 2022; Schumacher et al. 2018; Mestre et al. 2018; Revoyron et al. 2018). Irrigation water use efficiency is also another focus of CSA that could be achieved by the use of smart farming technologies, reducing evapotranspiration, and keeping soil moisture (Cooledge et al., 2022; Routis et al., 2022; Filintas et al., 2022; Martín et al., 2021; Fotia et al., 2021; Suciu et al., 2019; Visconti et al., 2020). Finally, CSA promotes the integration of renewable energy with sustainable agriculture to minimise emissions from the sector (Bas et al., 2022; López-Morales et al., 2021; Fotia et al., 2021; Suciu et al., 2019; Gruda et al., 2019).

As a result, we categorized the final selected studies into 7 groups by their potential CSA outcome contribution (Figure 5). On top of the three main CSA outcomes that FAO described, improving the efficiency of water and energy use, enhancing animal welfare and biodiversity conservation were included in reviewed studies as additional potential outcomes. Accordingly, majority of the identified CSA practices and SFTs from the selected studies focus on mitigating greenhouse gas emissions from the agriculture sector and ensuring sustainable productivity in this sector (Fig. 5).

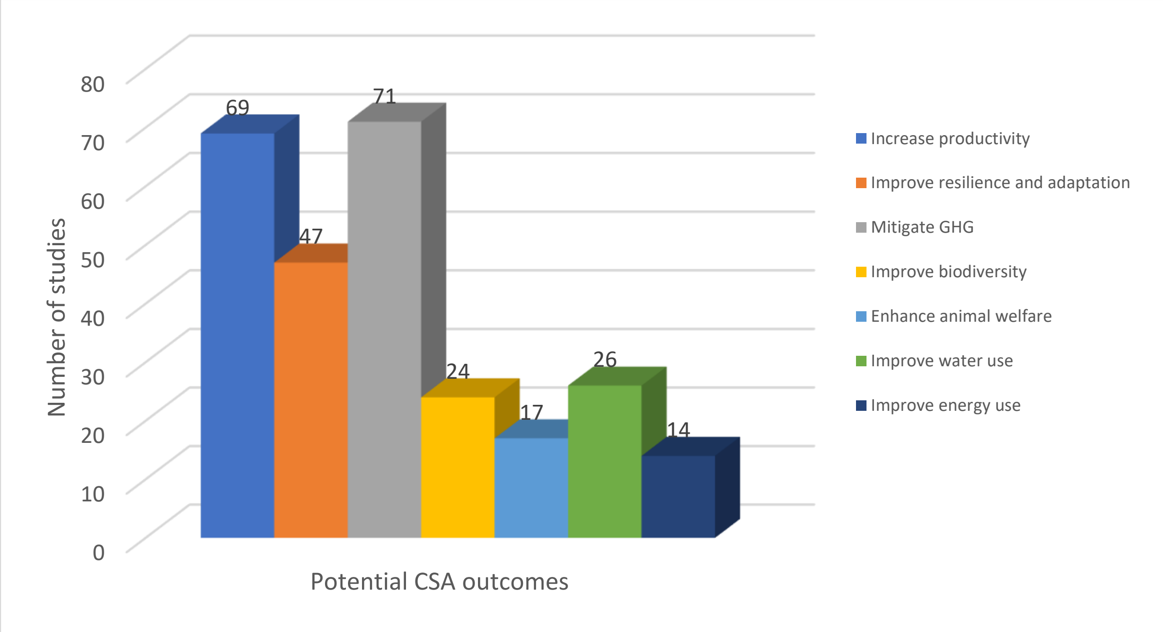

Figure 5: Categorization of papers by farming type

Based on this systematic mapping, water and energy use efficiency, and improvement biodiversity and animal welfare have been used as additional potential outcomes of CSA (Dabkienė et al., 2022; Takacs-Gyorgy & Takacs, 2022, Kakamoukas et al., 2021; López-Morales et al., 2021; Mestre et al., 2018; Romaniuk et al., 2021; Naujokiene et al., 2022; Neupane and Guo, 2019; Collas et al., 2019). Accordingly, on top of the three main CSA pillars identified by FAO—increasing productivity in sustainability, improving resilience and adaptation, and reducing GHG emissions from agriculture—we extended it by including efficiency in water and energy use and improvements in biodiversity and animal welfare to evaluate whether the selected agricultural practices and technologies is CSA or not. Table 2 summarizes the quantitative contributions from the identified CSA practices and technologies from the reviewed articles on CSA outcomes namely increased productivity, increased adaptation and resilience, reduced GHG emissions, improvement in biodiversity, improvement in animal welfare, reduced water use, and increased energy efficiency. In the table, we also included some CSA practices and technologies where the selected papers show the impact direction, whether it increases or decreases, on the outcomes of CSA. By following the prescribed indicators for each CSA outcome (Appendix table SM3), we summarized the identified CSA practices and technologies with their potential contribution towards CSA outcomes (Table 2).

Identified CSA (practices or SFTs)	Productivity (Yield/cost-benefit)	Building resilience and adaptation	Mitigation potentials (Reduction or removal of GHG)	Others (improvement in biodiversity, animal welfare, water and energy)	Reference
Agroecological-based farming practices					
Cover and Catch cropping	Enhance crop yield or keeping crop yields not dropped	Reduce the risk of soil degradation. Reduce fertilizer utilization.	Reduce N leaching by 21–64% Increase SOC stocks by 10 $t{\cdot}ha^{-1}$ 4.5% to 9% of annual GHG emissions	Enhance biodiversity. Reduce groundwater contamination by N leaching	Matthew et al 2022, Vogeler et al 2023, Rivière et al 2022, Tribouillois et al. 2018, Seitz et al. 2022,
No-till/minimal tillage	1.8-13.5% increase in yield (with highest in arable crop)	Increasing soil moisture Increase SOC by 21- 25%	Increase 3.5-8.3 % soil carbon, Reduced N_2O emissions.	Reduce soil evaporation by 10−15 %, Improve soil biodiversity	Bregaglio et al 2022, Lutz et al 2019, Cooper, et al. 2020
Intercropping	Enhance crop productivity	Improves soil fertility	Reduce emissions from chemical fertilizer utilization	Increase soil microbial biodiversity	Cesco et al 2021, Cusworth et al 2021, Jensen et al. 2020,
Crop rotation	Improves crop productivity,	Increase by 6- 9% SOC, Enhance efficient nutrient cycling	Reduce GHG emissions through carbon sequestration	Improve the conservation of biodiversity	Lieder et al. 2021, Korchagin et al. 2022, Cooledge et al. 2022, Billen et al. 2018
Integrated soil fertility management	Increase production.		Reduce GHG emissions from N fertilizer use	Reduce biodiversity Loss	De Pinto et al 2020
Climate smart fertilization					
Variable rate of N application	Reduce up to 10 % total cost, Increase productivity	8–19 % reduction in N fertilizer,	1-9.4% reduction in GHG emission from N leaching	Reduce indirect energy inputs up to 12.3%	Jovarauskas et al 2021, Fabiani et al 2020, Balafoutis et al 2020,
Organic fertilizers	Increase crop yield.	Increase soil fertility	Reduce GHG by offsetting the use of chemical fertilizer.	Improves biodiversity.	Agrimonti et al. 2021, Micha et al 2020,
Biofertilizer	Increasing productivity.	Improve soil organic matter, increase nutrient availability	Reducing greenhouse gas emissions by Reducing chemical fertilizer		Tur-Cardona et al. 2018 Agrimonti et al, 2021
Organic amendments (Biochar, compost)		Improve soil's physical and chemical properties, favour crop growth-promoting microorganisms	Reduce greenhouse gas (GHG) emissions	Improves microbial abundance and composition. Increase water retention	Libutti et al, 2020, Brenzinger et al. 2021, Luigi et al. 2022, Delitte et al. 2022
Bio-waste compost	Increase productivity	Build soil-improving material	Increase SOC concentration 1.2- 1.4%		Luigi et al, 2022
Climate smart Irrigation					
Smart irrigation	Increase in yield up to 17% Reduce cost by up to 23%	Improves resilience		Reduce the use of irrigation water by up to 22%	López-Morales et al 2021, Adamides et al, 2020, Neupane and Guo, 2019
DSS-based irrigation management	Increase by 22.6% for 1 ha of cultivated land		5.3-10.4% per 1 ha of the total environmental impact of irrigation	Reduce water and energy use up to 42.1%	Fotia et al 2021
Smart fertigation	Enhance productivity		Reduce emissions from fertilizers use	Increase water use efficiency	Visconti et al 2020

Climate smart crop protection					
Variable rate spraying	Reduce the cost of production	Reduce residues on products. Reduce 30% fungicides on average. Reduce 14 -70% herbicides,	Reduce emissions from agro-chemicals use	Reduce the effect of chemicals on soil microorganisms	Moysiadis et al 2021, Agrimonti et al. 2021, Lieder & Schröter-Schlaack, 2021
Integrated pest management	Increase crop production	Increase soil organic matter	Reduce emission of GHG from pesticides	Reduce biodiversity loss as compared to conventional	Jindo et al, 2021, Filho et al 2020, Mestre et al. 2018, Heeb et al. 2019.
Integrated weed management	Improves yield	Increase soil health	Reduce emissions from herbicides use	Lower chemical effect on biodiversity	Tataridas et al, 2022
Biological pest control		Improves soil nutrient	Reduce emissions that come from agrochemical use	Increase biodiversity	Heeb et al. 2019, Mestre et al. 2018
Precision chemical weed management	Increased labour efficiency by 11 %		Contribute to reducing GHG emissions from herbicide use		Allmendinger et al, 2022, Wolfert and Isakhanyan, 2022, Rehman et al, 2022
Precision mechanical weeding		Increase soil health	Reduce herbicide use that in turn reduces GHG emissions		Assirelli and Liberati, 2022
IoT-based field management zoning	6% increase in yield		33% reduction in herbicide use		Wolfert and Isakhanyan, 2022, Rehman et al 2022
Smart greenhouse production	Improve yield and quality of crops	Reduce nutrient loss and protect plants from extreme weather conditions	Up to 5.3 % reduction in pesticide use	Reduce water use by 25%	Thomopoulos et al, 2021, Gruda et al, 2019, Martos et al 2021.
Improved disease resistance varieties	Results in higher productivity,	Increase resistance to climate change,	Reduce agrochemicals utilization		Jindo et al, 2021, Agrimonti et al, 2021, Cesco et al, 2021
Vertical farming		Increase resilience	Reduce the carbon footprint by minimizing agrochemical utilization	Reduces amount of water and energy required	Preininger & Hafner, 2021
Improved livestock feed management					
High-protein legume-based feed	Reduce of import expenses		Reduce GHG emissions by 15-42% relative to imported soy products		Cusworth et al, 2021
Feed additives	Reduce the cost-reducing concentrate feed	Replacing with concentrate with green proteins sources	Reduce 12–20% enteric CH_4. Reduce 10–30% GHG from manure		Ouatahar et al, 2021 Bayram et al, 2023
Feeding legumes (future of green livestock)	Reducing concentrate feed by replacing green proteins	Symbiotically fixed nitrogen, Improve soil fertility	Reduce emissions by displacing the use of inorganic N fertilizer		Cusworth et al 2021 Cooledge etal.2022
Grass ley arable rotations		Increase SOC stocks by 3 to 16 $t{\cdot}ha^{-1}$	Increase carbon sequestration	Improve soil biodiversity	Matthew et al 2022
Pasture management		Improves soil fertility	Sequester carbon in the soil	Improves animal welfare and water retention	Rivero et al., 2021, Micha et al 2020, Collas et al 2019

Manure management					
Holistic management (feed and manure)	Improves livestock productivity		4.6 -19.7% emission reduced from animal production	Improves animal welfare	Naujokiene et al 2022
Acidification of slurry			Reduced emissions of NH_3 by up to 69%, CH_4 by up to 67%, N_2O up to 21%	Reduce effect on soil biodiversity	Overmeyer et al. 2023, Chun et al. 2022, Emmerling et al. 2020
Anaerobic digestion (AD) technology			GHG emissions from manure management can be reduced by 1.13%	Improve energy efficiency	Ersoy and Ugurlu, 2020
Manure composting		Improves soil fertility	Reduced N_2O and CH_4 emissions	Improves soil biodiversity	Necpalova et al. 2018, Julia et al 2021
Manure separation		Reduce nutrient loss by 9-13.9%	Reduce NH_3 emissions from manure		Izmaylov et al. 2022, Julia et al 2021
Improved animal husbandry					
Housing with a ventilation system			Reduce emissions	Improves animal welfare	Pexas et al. 2020, Ruckli et al. 2022 Naujokiene et al. 2022
Smart technologies for milking	Increase production. Improves product quality			Animal-friendly	Bianchi et al. 2022, Gabriel & Gandorfer. 2022, Micha et al. 2020
Health management	Improves productivity.	Improves diseases resistance at the farm level	Reduce the use of antibiotics.	Improves animal welfare	Krieger et al. 2017
Others (CSA applied both in crop and livestock)					
Organic farming (crop and livestock)	0-34% yield decreases, 7–13% higher labour costs	Increase soil organic matter and Improves resilience.	Increase carbon sequestration by 7% and higher. Reduce emissions from agriculture	Improves biodiversity and animal welfare	Tiziano 2018, Billen et al 2018, Holka et al 2022, Verburg et al. 2022, Creissen et al, 2022
Mixed farming	Improves productivity	Improves soil health and efficiency of nutrient cycling, reduces the risk of failure	Reduces the need for inputs such as fertilizer and pesticides that in turn reduce emissions,	Improves crop and animal diversity	Antoine et al., 2021; Kakamoukas et al, 2021, Garca-Cornejo et al, 20220

Table 2: Potential outcomes of identified CSA

2.4 Conclusions

The main aim of this systematic mapping is to identify and categorize the current existing CSA practices and technologies and their potential contribution towards CSA outcomes. We used Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) as a methodological framework, and we examined 110 studies that has been published within 2017-2023 as our focus was on current existing CSA practices and technologies. We identified various CSA practices and technologies categorized the based on their farming typologies and their potential contribution towards CSA outcomes. Agroecological farming practices like crop rotation, intercropping and cover cropping focusing on legume crops are the the identified farming practices to increase carbon sequestration, symbiotic nitrogen fixation, water infiltration, and biodiversity in soil fauna and microbial communities. Climate-smart fertilization category includes the use of smart farming technologies like variable rate of application that could enhance crop productivity, water and energy use efficiency. While organic and biofertilizers, soil microbiomes, and organic amendments are which are alternatives to synthetic fertilizers to promote soil health and sustainable plant growth are identified CSA under climate smart fertilization category. Integrated pest and weed management, disease-resistant crop varieties, mechanical weeding, and biological control to reduce crop diseases and pest infestations are identified climate-smart crop protection practices. Climate smart irrigation based on decision support system and IoT technologies are the identified CSA practice for optimising the amount of water and energy required.

Grassland restoration for pasture grazing, acidification of slurry and manure, composting, green feeding, housing with ventilation, feed additives, and livestock precision farming are identified livestock-based CSA practices. Feed additives and green feed production, including grass and legumes, feeding legumes, reintroducing multispecies leys, and livestock grazing in arable rotations are identified as CSA practices for livestock feed and pasture management to enhances both animal welfare and productivity while reducing emissions. Organic farming is identified as CSA practices as it gives priority to environmental sustainability, biodiversity, and animal welfare while minimising GHG emissions during the production process. While mixed farming, diversification are are identified CSA practices as they integrate crop-livestock systems to enhance agricultural sustainability on a mutually beneficial basis. We examined that in most of the identified CSA practices, smart farming technologies play a great role in terms of their support for sustainable production by optimising inputs that ultimately have a negative impact on climate change. We evaluated the potential contribution towards CSA outcomes for identified agricultural practices and technologies. We found that there are synergies and trade-offs in fulfilling CSA outcomes and, in some cases, a positive indirect mutual relationship in the long run. Many of these practices can help to achieve the CSA's more than two outcomes but not all at the same time. Therefore, focusing should be given for those identified CSA practices and technologies that contribute more towards CSA outcomes. Particularly, the adoption of feed management practices and forage varieties, pasture management, green feeding, and legume-based feed additives is suggested to reduce GHG emissions from the livestock sector, as feed management has the potential to reduce enteric fermentation. Finally, we would like to emphasise the significant role that smart farming technologies could play in implementing climate-smart agriculture under the climate change challenge. Thus, increased focus should be given to the adoption of smart farming technologies by integrating them within other identified CSA practices in transforming European agriculture towards sustainability.

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3. Systematic review of the farmer decision making factors

3.1 Introduction

This systematic review aims to identify the determinants of farmers' adoption of Climate-Smart Agriculture (CSA) practices and technologies in Europe. The review examines 117 studies that have been published during the decade 2012-2022. The review follows a systematic methodology that involves searching electronic databases for relevant studies, screening the studies based on inclusion criteria, and extracting data from the selected studies. The data is then analysed and synthesized using a narrative synthesis approach. Factors are categorised into socio-demographic, psychological factors, farm characteristics, geographical, technology-related, systemic and policy factors. The review demonstrates that adoption of CSA is significantly affected by factors such as age, perceived behavioural control, motives, farm size, perceived costs and benefits, extension and advisory services, collective decision-making, participatory approaches to adoption, legal framework, and governmental financial support. The review emphasizes the importance of implementing targeted interventions that address the specific factors that have the greatest impact on the adoption of CSA practices and technologies.

3.2 Methods

3.2.1 Study selection

The scope of this systematic review is to identify empirical studies on factors impacting on farmers' conversion to CSA practices. This systematic review was conducted in November 2022 using Web of Science and Scopus databases based on a combination of keywords and their synonyms to locate studies published from 2012 to 2022, written in English. In order to limit the number of results, Scopus was filtered by publication stage ("final") and document type ("Articles" and "Conference Paper") while Web of Science was filtered by document type ("Articles", "Early Access", and "Proceedings Paper"). The search keywords were related to producers (farmer* OR producer*), influencing factors (factor* OR driver* OR barrier* OR determinant* OR percept* OR motivat* OR attitud*) behaviour (decision* OR behaviour* OR behavior* OR switch* OR adopt* OR uptake OR behavio*change OR transition* OR conversion OR implement* OR "willingness to pay") and CSA practices or technologies ("sustainable agriculture" OR "sustainable farming" OR "organic farming" OR "organic agriculture" OR "climate-smart agriculture" OR "climate-smart farming" OR "precision farming" OR "precision agriculture" OR "smart farming technolog*" OR "smart farming" OR "smart agriculture"). The search resulted in a total of 2248 papers eligible for screening.

3.2.2 Screening process

Although the aim of this study was to provide a broad overview of articles which focus on decision-making factors in farmers adoption of CSA practices and technologies, those studies which did not fulfil inclusion criteria were excluded. In particular, the studies had to meet the following characteristics: (1) were conducted at a farm level, meaning that the surveyed population had to be farmers, and any change in behaviour had to come from primary production; (2) analysed primary data to assess the impact of factors on the adoption of CSA practices and technologies; (3) examined the adoption of CSA practices as the dependent variable; (4) were carried out in Europe and (5) examined a farm practice or technology related to CSA.

Figure 6 depicts the search and screening procedure for the articles. Initially, 2248 articles were obtained through database searches, 971 from the Web of Science database and 1277 from Scopus. After removing duplicates, 1577 articles remained. In the first screening process, only titles and abstracts were evaluated, and 1333 articles were excluded due to not conforming to the inclusion criteria. The remaining 224 articles were then carefully examined by reading the full text and were assessed for inclusion. At this stage, 107 references were rejected for various reasons, as specified in Figure 1. This resulted in 117 articles being included in the analysis [1–117].

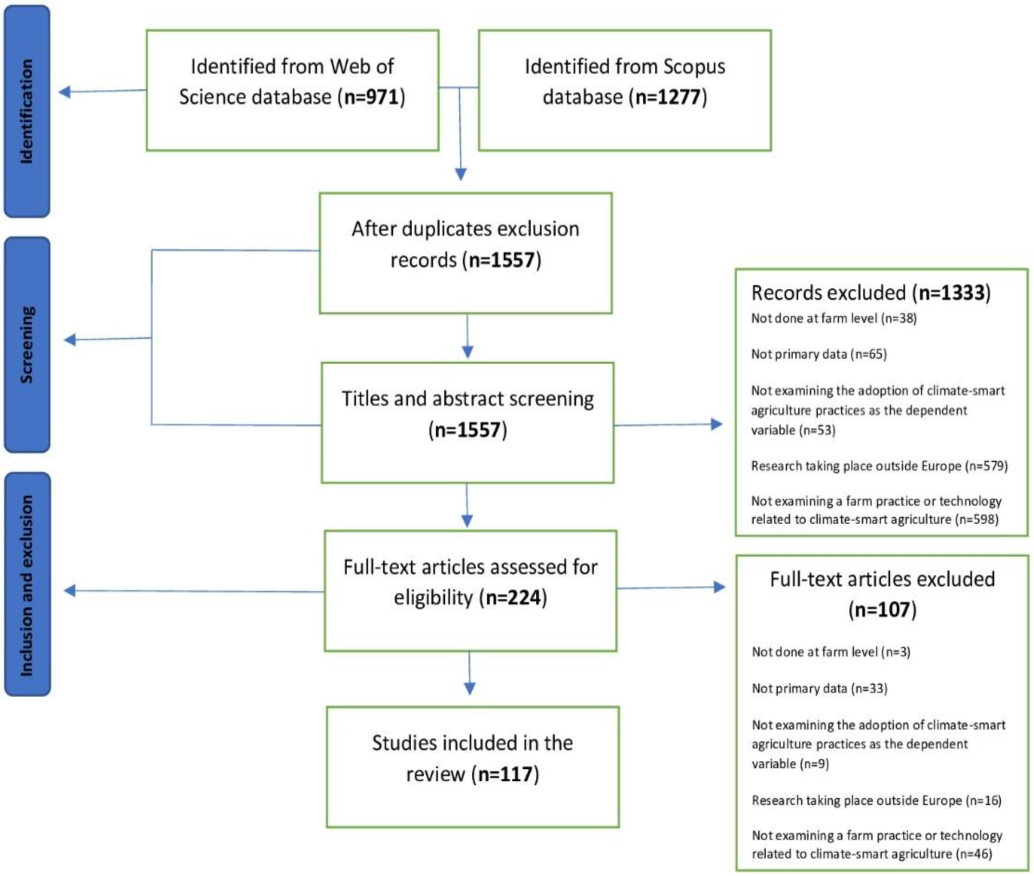

Figure 6: PRISMA flow diagram for farmers adoption systematic review

3.2.3 Data extraction and analysis

The relevant information was taken from the articles in accordance with the objectives of our systematic review. This was done by manually extracting the data after reviewing the full text of the articles and recording it in a designated spreadsheet. The accuracy of the extraction process was verified independently by the authors, and any discrepancies were resolved by discussion. To synthesize the findings from multiple sources, we counted the number of times a variable had a positive, negative, or non-significant effect on farmers' adoption of CSA practices across the studies.

We recorded the background information for the 117 studies selected, which included the year of publication, authors, country of research, type of research used (quantitative, qualitative, or mixed), and the CSA practices, technologies, and farming systems examined. To conduct an in-depth analysis of the articles, we looked at the full text, focusing on the results section and any statistical analysis tables. We categorized the factors affecting farmers' decision to adopt CSA practices into six main categories and smaller subcategories, based on previous research. These categories included sociodemographic, psychological, farm characteristics, geographical, characteristics of the practice/technology, systemic, and policy factors. For descriptive purposes, we also classified CSA practices into six categories, which included smart farming technologies, digital tools and AI, organic farming, renewable energy sources, natural resources preservation, biodiversity preservation, animal welfare, and other CSA practices. To categorize the CSA practices, two authors conducted content analysis independently, and any discrepancies were resolved through discussion.

3.3 Results

3.3.1 Study characteristics

As shown in Figure 7, the studies in the systematic review span from 2012 to 2022, with the majority (84%) published in the last six years. This literature review also revealed a substantial increase in the number of articles published in the last three years, accounting for more than half (57%) of the total articles extracted.

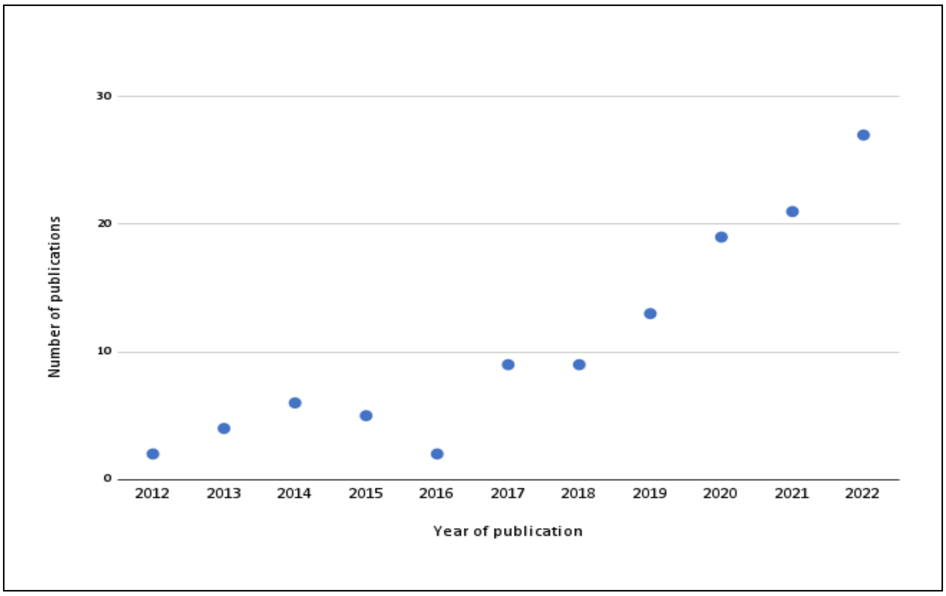

Figure 7: Number of publications published per year

This systematic review included studies from 37 European countries, displayed in Figure 8, with the highest concentration of studies being conducted in Germany (28), Italy (20), France (14), Greece (13), the Netherlands (13), Denmark (10), UK (10), Spain (10) and Switzerland (10).

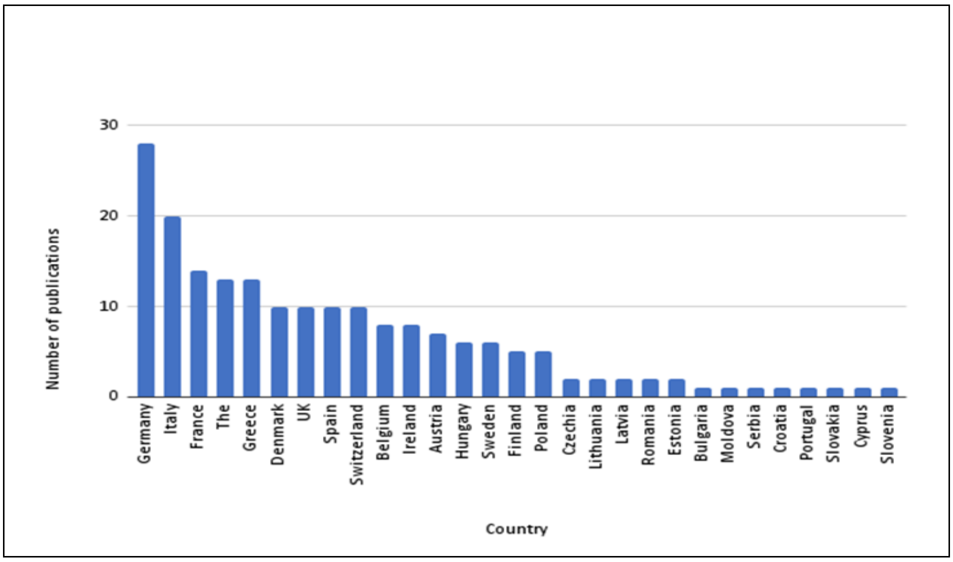

Figure 8: Number of publications published per country.

With regards to the categorization of CSA technologies and practices (Figure 9), most of the studies (36 of 117) focus on the group namely “smart farming technologies, digital tools and artificial intelligence" and the group of "organic farming" (32), followed by the group which involves all studies that did not look at a specific CSA practice (30).

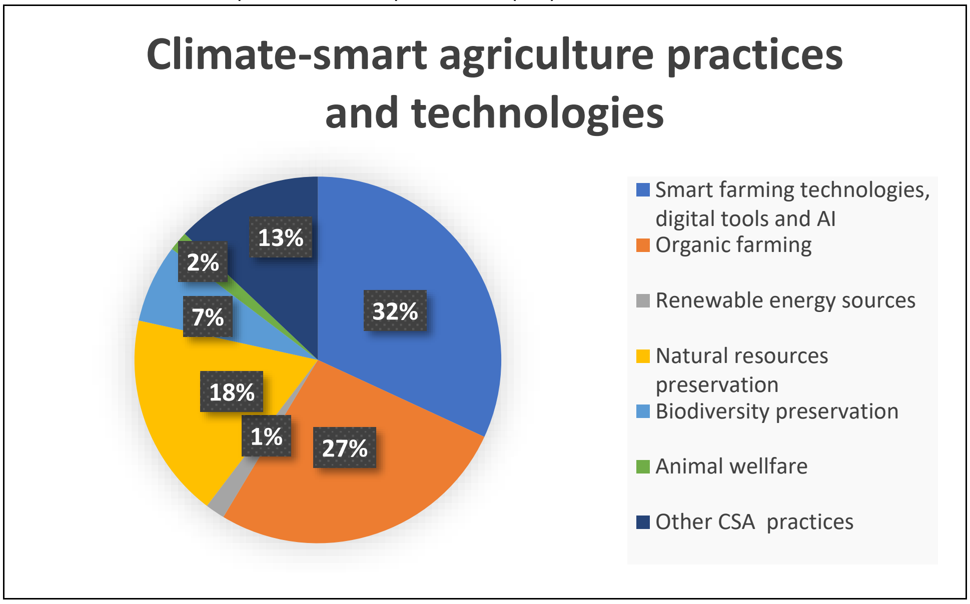

Figure 9: CSA practices studied in the articles

3.3.2 Determinants of farmer adoption of CSA practices and technologies

In summary, our review of 117 articles reveals a variety of factors that influence decision-making by primary producers when it comes to CSA practices and technologies in agriculture. For each subsection below, tables are provided to summarise the significant determinants. The decision-making factors have been broadly categorised into socio-demographics, psychological factors, farm characteristics, geographical, characteristics of the practice/technology, systemic, and policy factors based on categorisation used in previous studies [118–120].

3.3.2.1. Socio-demographic factors

Socio-demographic factors encompass the individual characteristics (e.g., age, gender, and level of education) and household characteristics (e.g., household size and income) of the farmers. The effect of farmers' age on adoption of CSA practices was assessed demonstrating an inverse relationship. Compared to older farmers, young farmers are more likely to adopt CSA practices because they are usually more interested in new practices and technologies and it is easier for them to learn to use and also to search for suitable solutions to fit their production systems [121]. In reference to education level, the effect of education on adoption was assessed to be mainly positive, that is, higher levels of education are associated with an increased likelihood of utilizing CSA. Research indicated that those with higher educational attainment possess the appropriate skills and knowledge needed to appreciate the potential benefits of CSA, as well as the capacity to experiment with different solutions [40,102]. On the other side, gender was found to have a statistically insignificant influence on adoption. It is plausible that this outcome is due to elimination of socio-cultural inequalities in access to information, knowledge, markets, and services, inequalities which perpetuated gender disparities [35,122]. As for farming experience, the majority of cases displayed a positive correlation with the adoption of CSA. Consistent with the literature, experienced farmers were found to be more likely to adopt CSA practices than those with less experience. This may be due to the fact that more experienced farmers have greater awareness of the potential benefits of these practices and are better able to evaluate the suitability of their farm. In addition, experienced farmers may be in a better financial position to invest in CSA practices and may possess the necessary knowledge and skills to efficiently implement them [121].

Regarding household characteristics and their impact on adoption of CSA agricultural practices and technologies, most of the studies have found that higher income status can be positively correlated with the adoption of CSA, which is consistent with the theories found in the literature, particularly if such innovation has a significant input cost and a long a payback for the business [119,123]. Farmers with higher on-farm and off-farm income have the financial resources to invest in new practices and technologies that are sometimes costly and risky to invest and require time and effort commitments [63,124]. Subsequently, full-time farmers tend to be more likely to adopt CSA practices than part-time farmers, as it is viewed as an essential requirement for the successful implementation of CSA [54]. Finally, household size was infrequently considered as potential variable in our review, and when taken into account, was typically not found to have a significant influence on adoption, which is similar to other related reviews [119,125].

The result in Table 3 presents a summary of the aggregated effects of socio-demographic factors on the adoption of CSA technologies and practices, based on the literature we have included in our review. The table includes five columns: name of each factor, positive effects, negative effects, insignificant effects, and % significant. The positive effects column indicates the number of articles that have identified each factor as a driver of CSA adoption, while the negative effects column shows the number of articles that have identified each factor as a barrier to adoption. The insignificant effects column lists the number of articles that have found no significant relationship between the factor and CSA adoption. Finally, the «% significant» column presents the proportion of articles that have found a significant effect (either positive or negative) for each factor, relative to the total number of articles that have investigated that factor.

Socio-Demographics	Positive effect	Negative effect	Insignificant	% Significant
Age	3	26	11	72
Education level	19	0	15	55.9
Gender (male)	2	3	8	38.5
Farming experience	3	1	0	100
On-farm income	4	1	3	62.5
Off-farm income	5	0	3	62.5
Full-time farmers	4	1	1	83.3
Household size	1	0	2	33.3

Table 3: Socio-demographics affecting adoption of CSA

3.3.2.2. Psychological factors

Psychological factors include cognitive, affective, and dispositional factors that may influence farmers' adoption of CSA. The review of the articles provides considerable evidence on cognitive factors such that farmer awareness related to environmental challenges, climate change, benefits of CSA practices, current regulatory framework for sustainable agriculture, plays a significant role in promoting the adoption. Farmers who are aware are in a better position to assess the challenges facing agriculture and the benefits of the transition to CSA practices and technologies. Knowledge is revealed to have a positive correlation with adoption, which suggests that knowledge can help motivate farmers to act and make changes [12,38–40]. Moreover, regarding technology skills, the results of the reviewed papers indicate that as technology-related skills increase, farmers have greater capacity to adopt new technologies since they are better equipped to make decisions and implement CSA [41,42]. Respectively, perceived behavioural control from the perspective of whether farmers feel they have the control, confidence, and skills to adopt a practice, has been investigated several times, with most studies finding a significant positive correlation with the adoption of CSA [25,54].

Equally importantly, the effects of motives have been studied in several papers. Motives can involve economic, environmental, social, and moral considerations, as well as family traditions, cultural heritage preservation, and social embeddedness. The distinct characteristics of each of these motives are found to impact the adoption process differently [23,37,48,49]. When it comes to attitudes and beliefs, most of the studies have shown that favourable attitudes towards CSA methods, have been linked to an augmented readiness for adoption. Moreover, beliefs regarding the environmental and economic efficacy of these practices and technologies have been shown to shape the adoption of CSA [12,44,52,53]. Finally, regarding subjective norms, the majority of the papers indicate a significant positive influence on adoption, since farmers are attuned to social expectations and will act in accordance with them if they believe that this will earn societal approval [47,55].

With regards to dispositional factors, risk aversion and resistance to change have both been recognized as obstacles to the adoption of CSA practices and technologies. Risk aversion refers to a reluctance to take on risks, while resistance to change refers to an unwillingness to abandon traditional practices [15,43–45]. Trust also plays a crucial role in adoption, since farmers will not accept CSA practices and technologies if they cannot trust the sources promoting them [16,46,47]. Finally, the relation between innovativeness and the adoption of CSA practices and technologies is in general positive. More innovative farmers are more likely to adopt CSA in their attempt to find new ways to increase production and efficiency while lowering the environmental impacts of their farming activities [23,41,50,51]. In addition, environmental consciousness and having a sense of responsibility for future generations are found to be key motivations to adopt CSA practices and technologies. These farmers are conscious of the impact of their agricultural activities on the environment, animal welfare, public health and food security on the one side and they feel a sense of moral obligation to protect and act on behalf of future generations on the other side [36,37]. Table 4 below presents the sum of papers that found a significant positive, significant negative and insignificant effect for each psychological factor, as well as the percentage of the total number of papers that found a significant effect.

Psychological factors	Positive effect	Negative effect	Insignificant	% Significant
Awareness	15	0	2	88.2
Knowledge	14	0	1	93.3
Farmer skills	7	0	3	70
Perceived behavioural control	22	0	1	95.7
Motives	17	7	0	100
Attitudes	17	1	4	81.8
Trust	3	0	0	100
Subjective norms	9	1	1	90.9
Risk aversion	8	0	0	100
Resistance to change	5	0	0	100
Innovativeness	8	1	2	81.8
Environmental consciousness	12	0	0	100
Responsibility for future generations	2	0	0	100

Table 4: Psychological factors affecting adoption of CSA

3.3.2.3. Farm characteristics

Farm size has shown a statistically significant positive relationship with adoption of CSA in most papers. Specifically, larger acreage is associated with higher likelihood to adopt CSA. Farmers with larger farms are able to spread the cost of high fixed costs across their farms, meaning that their cost per unit decreases. This is also applicable to larger cultivable land area, which is associated with increased adoption rates [43,119]. Even more, farms with increased profitability and yield have greater resource capacity and are more likely to invest in CSA, especially when they believe that the practice or technology offers gains in their farm profitability and yield [33,35,44].

Farm ownership is a significant factor that influences farmers' engagement in CSA practices. Tenants who lack land ownership are less likely to adopt CSA practices due to the insecurity associated with tenancy, their risk-averse nature, and reduced financial capacity [43,73,110]. In addition, their decisions are often limited by their landlords' will. On the other hand, the existence of a successor to the farm or a guarantee of long-term continuity can increase the likelihood of a farmer adopting CSA practices and technologies. This is because farmers who have a successor or long-term guarantee are more likely to invest in CSA practices, knowing that their investments will yield long-term benefits [33].

Findings of the systematic review further indicate that the type of farming systems (crop, livestock, mixed) create different adoption rates of CSA practices depending on the benefits that the practice or technology offers for different farming systems [5,33,44,86]. With regard to labour availability, studies have revealed that there is not a strong correlation with the adoption of CSA. While the increased supply of labour is diminishing the risk of investing in new methods or technologies that require significant labour input, it is not found to be a key consideration for the final decision [10,49,78,96]. Similarly, the availability of shared machinery has been studied in a few articles of the review which predicted no impact on farmers' adoption of CSA practices [43,44]. The table 5 presented below provides the sum of papers that found a significant positive, significant negative and insignificant effect for each farm characteristic, as well as the percentage of the total number of papers that found a significant effect.

Farm characteristics	Positive effect	Negative effect	Insignificant	% Significant
Farm size	18	6	6	80
Size of arable land	8	1	1	90
Farm outputs (yield, profitability)	5	2	1	87.5
Farm ownership	5	3	2	80
Farm successor	4	0	2	66.7
Labour availability	5	1	8	42.9
Shared machinery	0	0	2	0

Table 5: Farm characteristics affecting adoption of CSA

3.3.2.4. Geographical factors

The location of the farm plays a significant role in the decision-making process. Different farm locations lead to different adoption rates, due to regional differences such as if the farm is located in a favorable or protected area, differences in infrastructure according to location, remoteness from or proximity to major roads and the natural, historical, social, economic and political differences that lead to varying adoption rates between countries [1,29,50].

The presence of living organisms, such as weeds, pests, and microorganisms that cause crop diseases, known as biotic factors, are often taken into account in the decision to adopt CSA. [54,100]. Practices such as crop diversification and the use of crop resistant varieties are considered to increase the resilience of the farms against biotic stresses while other practices like organic farming increase their exposure to these risks [60,63]. Finally, abiotic factors, such as temperatures, precipitation, drought and extreme weather events did not significantly affect adoption of CSA in contrast with soil quality where farmers were more receptive to change to CSA to reverse the effects of poor soil quality [35,37,78,91]. The Table 6 provides the sum of papers that found a significant positive, significant negative and insignificant effect for each geographical factor, as well as the percentage of the total number of papers that found a significant effect.

Geographical factors	Positive effect	Negative effect	Insignificant	% Significant
Weeds	0	3	1	75
Pests	1	0	1	50
Crop diseases	1	0	0	100
Soil quality	0	5	1	83.3
Temperature	0	0	1	0
Precipitation	1	0	2	100
Drought	0	0	1	0
Extreme weather conditions	1	0	3	25

Table 6: Geographical factors affecting adoption of CSA

3.3.2.5. Technology-related factors

Farmers' perceptions of CSA practices and technologies are a key determinant of the decision to adopt or not. Firstly, characteristics associated with perceived usefulness, ease of use and compatibility drive adoption. Perceived usefulness is defined in terms of the capacity of the technology or practice to enhance productivity, reduce workload, and simplify farm operations [104,106,109]. Perceived ease of use is a measure of the farmers' beliefs about the ease of using a practice or technology (user-friendliness) [7,113]. Finally, with regards to perceived compatibility, the studies have investigated the compatibility between the new technology or practice and the current farm practices, as well as the compatibility between the new technology or practice and the individual's current situation, including their social and economic circumstances, goals, and values [45,85,115].

As regards to perceived costs, including investment costs, training requirements, increased workload, and long payback periods, these have been found to be negatively associated with adoption rates [13,19,23,45,47,66]. Perceived benefits, such as economic gains, environmental benefits, and improved societal outcomes, such as food safety, quality, and higher yields have been identified as significant drivers of adoption [16,25,36,78,92,111].

Studies on the perceived trustworthiness of technologies have identified unresolved issues surrounding data ownership, privacy protection, and information technology security, which could pose obstacles to the adoption of CSA technologies [7,25]. Similarly, the perceived absence of solid evidence on the positive impact of a technology is negatively associated with the adoption of CSA. To invest in new practices and technologies, potential adopters require assurances of their beneficial impact. Therefore, in instances where the benefits of CSA practices and technologies were uncertain, there was a lower probability of adoption among farmers [19,41].

Finally, the role of certification schemes has been studied in a few articles. The findings indicate that farmers view certification in a positive light as providing a guarantee for product quality, subsidies, higher selling prices and indirect publicity incentivizing them to adopt CSA practices. However, some farmers also pointed out the high bureaucratic burden, control, and time needed for certification schemes [6,13,59]. Table 7 provides the sum of papers that found a significant positive, significant negative and insignificant effect for each technology-related factor, as well as the percentage of the total number of papers that found a significant effect.

Characteristics of practice/technology	Positive effect	Negative effect	Insignificant	% Significant
Perceived usefulness	17	0	1	94.4
Perceived ease of use	13	0	3	81.3
Perceived compatibility	11	0	0	100
Perceived costs	37	0	0	100
Perceived benefits	43	0	3	93.5
Perceived trustworthiness	6	0	0	100
Perceived lack of verified impact	0	8	1	88.9
Availability of certification	4	0	0	100

Table 7: Characteristics of the practice/technology affecting adoption of CSA

3.3.2.6. Systemic factors

This systematic review has identified various systemic factors that can influence the adoption of CSA technologies and practices by farmers. As is evident, systemic factors are being relatively under-studied and hence, understanding of the influence of these factors is imperative. The adoption of CSA practices is influenced by social norms, with practices that are socially acceptable and supported within the community being more likely to be adopted by farmers. The values and norms of the society regarding environmental protection, animal welfare, and public health determine what is socially approved and thus provide a signal of community support and peer pressure, indicating that cultural and societal beliefs can either facilitate or hinder adoption [28,58]. Farmers are more likely to adopt CSA practices if they can learn from their peers who have already adopted such practices. This is known as social learning, which involves first-hand observation of other farmers who have successfully implemented CSA practices in their own farms, leading to increased trust in the new practices and ultimately encouraging adoption. Similarly, the social networks that farmers belong to can also influence their decision-making process. Farmers are more likely to adopt CSA practices if they have social connections with like-minded individuals who value CSA, as they are more likely to mimic the practices of their peers [8,15,56,57].

In addition, access to information is a significant positive factor as it gives the chance to better understand how farmers can benefit from the implementation of CSA. With regard to the extension and advisory services, they are found to play a major role in promoting the adoption of CSA practices and technologies among farmers. In particular, ongoing training services and technical support can provide farmers with necessary knowledge, skills, and confidence, providing guidance on appropriate management practices and helping overcome barriers to adoption. Most studies highlight the importance of tailored advisory services that take into account individual farm characteristics and farmer needs [9,19,23,36,90]. Furthermore, effective marketing and communication campaigns have shown a positive correlation with adoption in most studies, emphasizing the importance of raising awareness and encouraging adoption through effective communication [53,55]. On the other hand, a lack of research, education, and knowledge provided by universities and governments has been negatively correlated with adoption, highlighting the need for accessible and relevant information and education to support adoption [13,87].

The availability of a suitably qualified workforce is an enabling factor for adoption. The reason is that the adoption of CSA practices and technologies often requires highly skilled workforce with expertise in various fields, such as agriculture, engineering and computer science [66]. With regard to the lack of infrastructure, such as lack of high-speed internet, inadequate roads, transportation, and communication systems, this can hinder the adoption of CSA practices and technologies, as it makes it more challenging [35,37,87,104].

Studies have further highlighted the significance of convenient and effective market channels and the availability of financial resources in promoting the adoption of CSA. According to research findings, farmers are more likely to adopt CSA practices if they have easy access to markets, as well as alternative channels to sell their produce directly to consumers, such as direct marketing. The proximity between farmers and consumers provided by direct marketing fosters a closer relationship between them, which increases the profitability of CSA practices, ultimately encouraging their adoption. Additionally, short supply chains were observed as promoters of CSA adoption as they allow farmers to reduce reliance on intermediaries and gain more control over pricing [13,17]. Finally, access to credit can help farmers invest in CSA technologies, as it increases their financial and investment possibilities [28], while low market demand, can inhibit the adoption of CSA practices and technologies [6,89].

Our systematic review further suggests that collective decisions and participatory approaches involving different actors of the value chain encourage farmers to share their experiences and knowledge and actively engage in the learning process which can increase their engagement in the implementation of CSA practices and technologies [2,3,13,79]. Finally, membership in a cooperative is found to enable the adoption of CSA practices and technologies since cooperatives provide farmers with technical support, access to information and market opportunities [13,110]. The table 8 below presents the sum of papers that found significant positive, significant negative and insignificant effect for each systemic factor, as well as the percentage of the total number of papers that found a significant effect.

Systemic factors	Positive effect	Negative effect	Insignificant	% Significant
Social norms	5	4	2	81.8
Social learning	11	0	2	84.6
Social networks	6	0	4	60
Information sources	13	1	3	82.4
Extension and advisory services	35	0	2	94.6
Marketing and communication campaigns	9	0	1	90
Lack of research, education, and knowledge	0	7	0	100
Access to market	7	0	0	100
Direct marketing	5	0	0	100
Short supply chains	3	0	0	100
Access to credit	4	0	0	100
Market demand	11	0	0	100
Lack of infrastructure	13	0	0	100
Collective decisions and participatory approach	23	0	0	100
Membership in a cooperative	6	0	4	60

Table 8: Systemic factors affecting adoption of CSA

3.3.2.7. Policy factors

The papers included in this systematic review indicate that the adoption of CSA practices and technologies is impacted by several policy-related factors, which can either incentivize or disincentivize the adoption of such practices. For example, supportive legal and political environment enables the adoption, while inconsistent and overly strict regulations and policies that limit flexibility and do not support CSA practices were found to be a barrier to the implementation of CSA [18,45,56,69,101].

Similarly, studies investigating the effect of government financial support on the uptake of CSA have revealed a statistically significant positive association. Financial support, including subsidies, tax reductions, and schemes, can compensate for income loss and investment risks. Nonetheless, farmers have identified a number of constraints in the provision of such assistance, including insufficient compensation for costs, complex and bureaucratic procedures, and heavy penalties for mistakes [30,59,65,75]. Finally, bureaucratic regulations, such as those involved in subsidies and certifications, are a hindrance to farmers due to the resources involved in terms of time, efforts, skills, and knowledge required to complete the paperwork. This emphasizes the negative impact of bureaucracy on the uptake of CSA practices [13,17,46]. The table presented below (Table 9) provides the sum of papers that found a significant positive, significant negative and insignificant effect for each policy-related factor included in this systematic review, as well as the percentage of the total number of papers that found a significant effect. A broader policy and regulatory framework analysis is discussed in Chapter 6 of this document and aims to provide a comprehensive overview of the policy factors that can influence the uptake of CSA practices.

Policy factors	Positive effect	Negative effect	Insignificant	% Significant
Legal framework	14	10	0	100
Financial support	29	0	2	93.5
Bureaucracy	0	8	0	100

Table 9: Policy factors affecting adoption of CSA

3.4 Conclusions

The adoption of CSA practices and technologies is crucial in ensuring sustainable agricultural practices that mitigate the effects of climate change. Thus, understanding the behavioural factors that influence the adoption of such practices is essential in promoting their uptake among farmers. In this systematic review, we examined the literature on the determinants of the adoption of CSA practices and technologies.

The review found that of the many factors influencing farmers' adoption, there are certain determinants which are particularly significant and were analysed most frequently. Firstly, age was found in the majority of the articles to be a critical factor, with younger farmers being more likely to adopt CSA practices than their older counterparts. This suggests the need for targeted interventions for older farmers to encourage the adoption of CSA practices [121]. In addition, perceived behavioural control was also found to be a significant factor, with farmers who feel they have control over the adoption process being more likely to adopt CSA practices. This underscores the importance of educating farmers to enable them to make informed decisions about the adoption of CSA practices [25,54]. Moreover, motives such as economic returns, modernization and improvement of farming activities, environmental and animal welfare and social embeddedness were found to influence the adoption of CSA practices. This highlights the need for interventions that align with the diverse motives of farmers. For instance, a combination of voluntary and mandatory approaches can be used, with voluntary schemes targeting those farmers who are more environmentally conscious and willing to take risks, while mandatory schemes are used to address those who are more reluctant to make changes [23,37,48,49]. Furthermore, farm size was found to have a significant influence on the adoption of CSA practices, with smallholder farmers being less likely to adopt. This emphasizes the need for interventions that specifically target smallholder farmers [43,119]. Likewise, the perceived costs and benefits of adopting CSA practices and technologies were also found to be significant factors. This suggests the need for interventions that increase awareness of the benefits of CSA practices which can be achieved through media and marketing campaigns [16,25,36,78,92,111]. Also, extension and advisory services were found to be crucial in promoting the adoption of CSA practices, highlighting the importance of investing in extension services and providing farmers with access to relevant information and expertise [9,19,23,36,90]. Similarly, collective decisions and a participatory approach to adoption were also found to be significant factors. This suggests that interventions that engage farmers in the decision-making process, where their voice is heard and where they are given the opportunity to interact with other value chain stakeholders are more likely to be successful [2,3,13,79]. Finally, a supportive legal framework and financial support were found in most of the studies to be essential in promoting the adoption of CSA practices and technologies, which points to the need for policymakers to create an enabling environment that promotes the uptake of CSA practices by farmers [18,45,56,69,101].

In conclusion, this review provides invaluable insights into the factors that influence the adoption of CSA practices and technologies. Effective policies and interventions that consider these factors are likely to be more successful in promoting the adoption of CSA practices and technologies by farmers.

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4. Systematic review of the business strategies for CSA

4.1 Introduction

This systematic review aims to explore the existing knowledge in the academic literature on innovative business strategies for CSA and how the actors capitalize from collaboration with innovating business models. We used the grounded theory to rigorously review the literature. The review examines 142 studies that have been published within the year 2000-2022. The review follows a systematic methodology that involves searching electronic databases for relevant studies, screening the studies based on inclusion criteria, and extracting case studies and conceptual frameworks from the selected studies. The articles are then analysed and synthesized using a content analysis approach. Factors are categorised into types of CSA practice and technology, business strategies, and fairness factors. The review demonstrates that CSA adoption requires multi-actor collaboration networks that comprise strategic activities of the actors and depend on the strategic decisions the actors make to invest in innovations for sustainability. Farmers often need engaged stakeholders to combine their resources and align their strategic goals to trigger systemic changes and eventually contribute to the transition towards climate smart actions in agrifood. When taking a multi-stakeholder approach, however, fairness of value propositions become part of the individual business models, as well as of the entire network. This review emphasizes the importance of inter-organisational networks and multi-stakeholder collaboration platforms that considers value creation and capture at individual actor level, as well as at network level that have the greatest impact on the adoption of CSA practices and technologies.

4.2 Methods

4.2.1 Study selection

The scope of this systematic review is to identify empirical case studies on different aspects of innovative business models for CSA and how the actors capitalize from collaboration with innovating business models. This systematic review was conducted in November 2022 using Web of Science and Scopus databases. With a use of search query, we combined keywords and their synonyms to locate studies published up to 2022. the search query was as follows: *(TS=(("business*" or "industry" or "agro-food industr*" or "agri-food industr*" or "private sector*" or "firm*" or "enterprise*" or "corporat*" or "intermediar*" or "processor*" or "retailer*" or "smes" or "organi?ation" or "venture" or "conglomerate" or "cooperativ*" or "food system*" or "supply chain*" or "manufactur**" or "service provider*" or "supermarket*") and ("decision mak* factor*" or "driver" or "lock-ins" or "lever" or "enabl*" or "barrier" or "element" or "motivat*" or "determinant" or "behavi* factor*" or "pressure*" or "trigger*") and ("behav* chang*" or "transition*" or "adopt" or "adapt*" or "innovat*" or "uptake" or "shift" or "transform*" or "move" or "scal*" or "switch") and ("sustainable agricult*" or "sustainable farm*" or "organic farm*" or "organic agricult*" or "climate smart agricult*" or "climate smart farm*" or "precision farm*" or "precision agricult*" or "smart farm*" or "smart agricult*" or "smart farming technolog*" or "digital agricult*" and (title-abs-key (fair*))).*

In order to limit the large number of results, we limited the selection into (1) Language: English, (2) Publication stage: final paper, (3) Discipline: for the limitation in disciplines, we selected the following categories in Web of Science *=("environmental sciences" or "agriculture multidisciplinary" or "green sustainable science technology" or "environmental studies" or "agronomy" or "food science technology" or "geography" or "computer science information systems" or "engineering environmental" or "plant sciences" or "economics" or "engineering electrical electronic" or "agricultural economics policy" or "ecology" or "regional urban planning" or "sociology" or "management" or "multidisciplinary sciences" or "veterinary sciences" or "computer science artificial intelligence" or "computer science theory methods" or "engineering chemical" or "geosciences multidisciplinary" or "operations research management science" or "computer science hardware architecture" or "soil science" or "automation control systems" or "energy fuels" or "education educational research" or "anthropology" or "urban studies" or "business" or "history philosophy of science" or "public environmental occupational health" or "nutrition dietetics" or "agriculture dairy animal science" or "computer science interdisciplinary applications" or "development studies" or "agricultural engineering" or "biodiversity conservation" or "biology" or "horticulture" or "political science" or "public administration" or "social sciences interdisciplinary" or "water resources" or "business finance" or "communication" or "engineering* *multidisciplinary" or "ethics" or "social issues" or "psychology multidisciplinary" or "psychology experimental" or "logic" or "information science library science" or "forestry" or "fisheries" or "education scientific disciplines" or "engineering civil"))*, and in Scopus we selected = *(subjarea , "agri", "envi", "soci", "engi", "comp", "ener", "busi", "econ", "eart", "deci", "mult", "vete", "psyc").*

The search resulted in 391 references in Web of Science and 999 in Scopus. After combining the results of these two databases, and removing the duplicates, a total of 1103 papers went through the first round screening.

4.2.2 First round screening

In order to screen the articles and find the ones most relevant to our research objective, we have used the following inclusion criteria: (1) business aspects are discussed in a case study setting; (2) examined the adoption of CSA practices as the dependent variable; (3) were carried out in Europe; and (4) examined strategic choices related to CSA adoption and successful application. Accordingly, we have excluded articles that: (1) focused other sectors, e.g., tourism, (2) descriptive without empirical evidence, e.g., perspective or discussion papers, and (3) failed to discuss causal relations between business aspects and CSA practices and technologies. Figure 10 depicts the search and screening procedure for the articles. Initially, 1390 articles were obtained from the two databases, specifically, 391 from the Web of Science database and 999 from Scopus. After removing

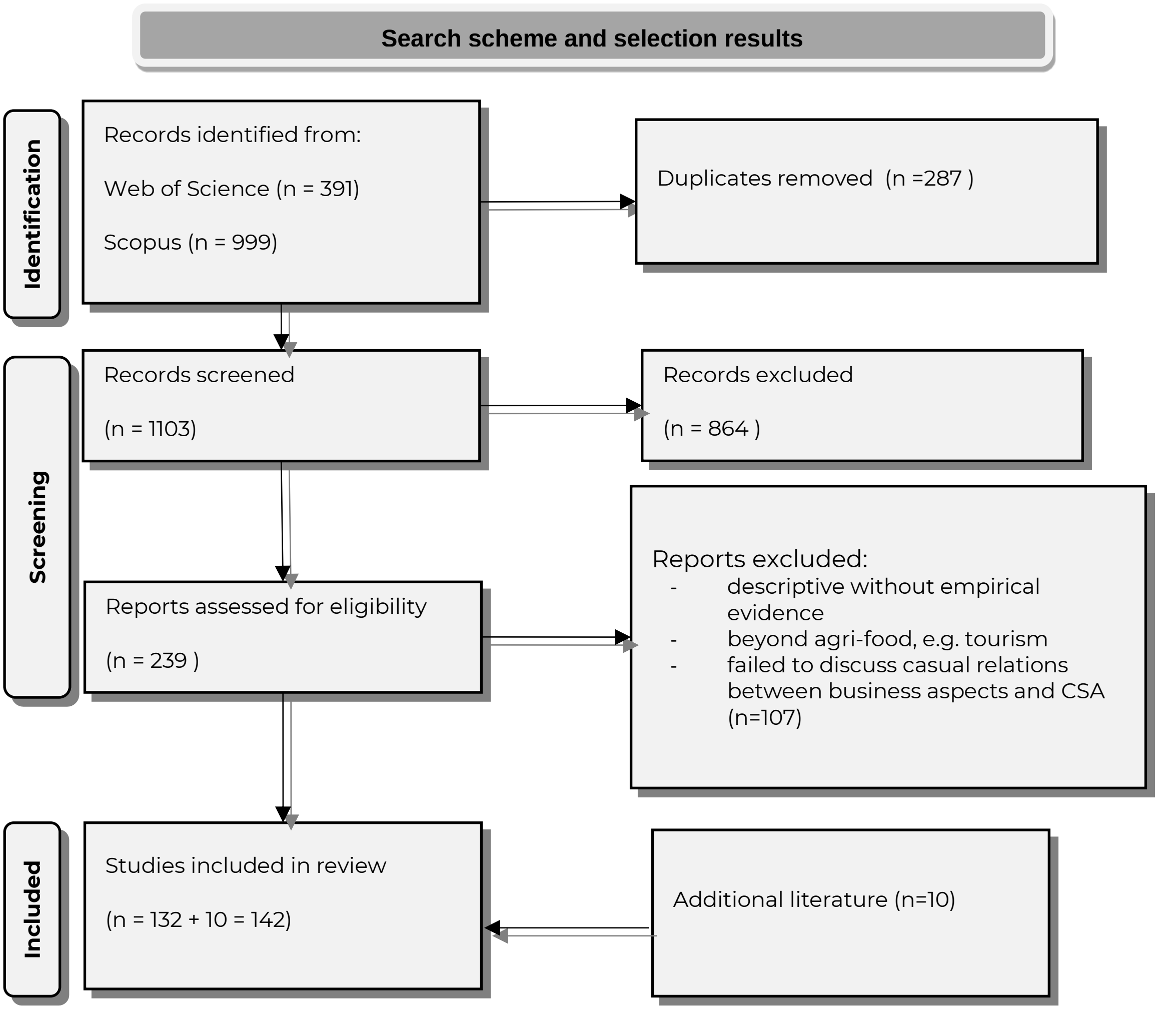

Figure 10: PRISMA flow diagram to illustrate the steps involved in the systematic review

duplicates, 1103 articles remained. In the first screening process, only abstracts were evaluated, and 864 articles were excluded due to not conforming to the inclusion criteria. The remaining 239 articles were then carefully examined by reading the full text and assessed for inclusion. At this stage, 107 references were rejected for various reasons, as specified in Figure 10. This resulted in 132 articles being included in the analysis [1–117]. However, we added yet another 10 articles by using the citations from the current articles, which made the total number of references 142.

4.2.3 Data extraction and analysis

The researchers have further read and detailed analysed the full text of the articles to extract the final set for content analysis. Articles were analysed to find relevant information for the objectives of our systematic review. This was done by manually extracting the data after reviewing the full text of the articles and recording it in a designated spreadsheet. The accuracy of the extraction process was verified independently by three authors, and any discrepancies were resolved by discussion. To synthesize the findings from multiple sources, we created a conceptual framework to show the link between business strategies and adoption of CSA practices across the studies.

We recorded the background information for the 132 studies selected, which included the year of publication, authors, country of research, CSA practices and technologies, and decision-making factors, business strategies, barriers and levers from business strategy perspective and fairness aspects. To conduct an in-depth analysis of the articles, we looked at the full text, focusing on the results section and conclusion and analysis. Based on the detailed reading we have not considered articles that failed to discuss any CSA practice or technology and provide empirical evidences, despite the fact that the paper was positioned in that domain. For example, papers that discussed digital technologies and possible applications, but focused on engineering instead of sustainability impact. Another example is papers that discussed food fraud or improving farm advisory services. Also, the papers that failed to discuss business aspects have been extracted from the content analysis. Such detailed screening resulted in yet another exclusion of 66 article, leaving us with 76 articles for content analysis. We classified CSA practices into six categories:

1. Smart farming
2. Eco-innovation
3. Organic agri-food
4. Agroecology
5. Social Innovations
6. Short chains

We used three CSA strategies as guideline: mitigation, adoption and resilience. Two authors conducted content analysis independently, and any discrepancies were resolved through discussion.

4.3 Results

4.3.1 Study characteristics

As shown in Figure 11, the studies in the literature review span from 2000 to 2022. What is not shown in Figure 11 is that between 1977 and 2000, only 30 articles have been published. Between 2000 and 2022, we observe an increasing line of frequencies reaching the top of 191 articles in 2021. Majority of articles, about 66% are published since 2017, and 98% since 2010. This literature review also revealed a substantial increase in the number of articles published since 2020. Note that the decrease in 2022 is due to the fact that the search has been conducted in November 2022, and accordingly the articles of November and December not included. We expect literature body growth on the topic for coming years as well.

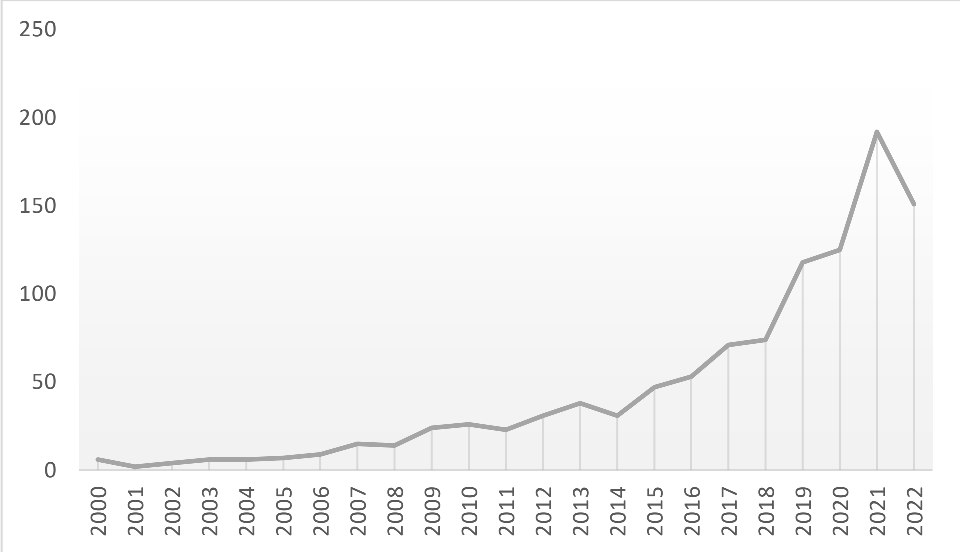

Figure 11: Number of publications published per year

This literature review included studies from 20 European countries, displayed in Figure 12, with the highest concentration of studies being conducted in Italy (18), Germany (10), The Netherlands (10), France (10), Spain (7) and European as a whole (10). Note that not all articles have mentioned specific location of the study. Figure 12 shows the location of the case studies reported in the selected articles.

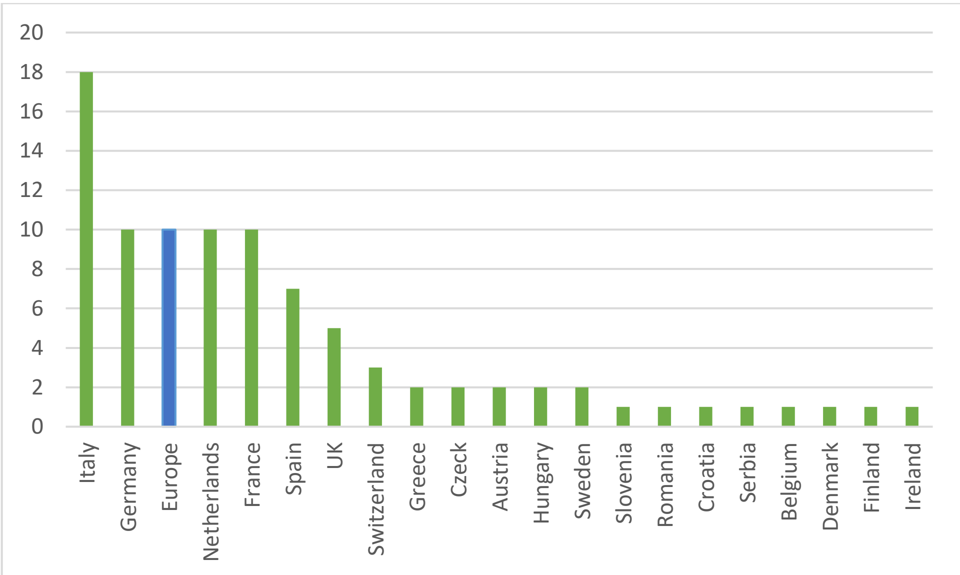

Figure 12: Number of publications published per country

Regarding the categorization of type of CSA technologies and practices (Figure 13), most of the studies (33%) focus on the "smart farming technologies" followed by "eco-innovations" (27%) and "organic agri-food" (24%). The rest 16% articles discussed "agroecology", "social innovation" and "short chains" as CSA practices.

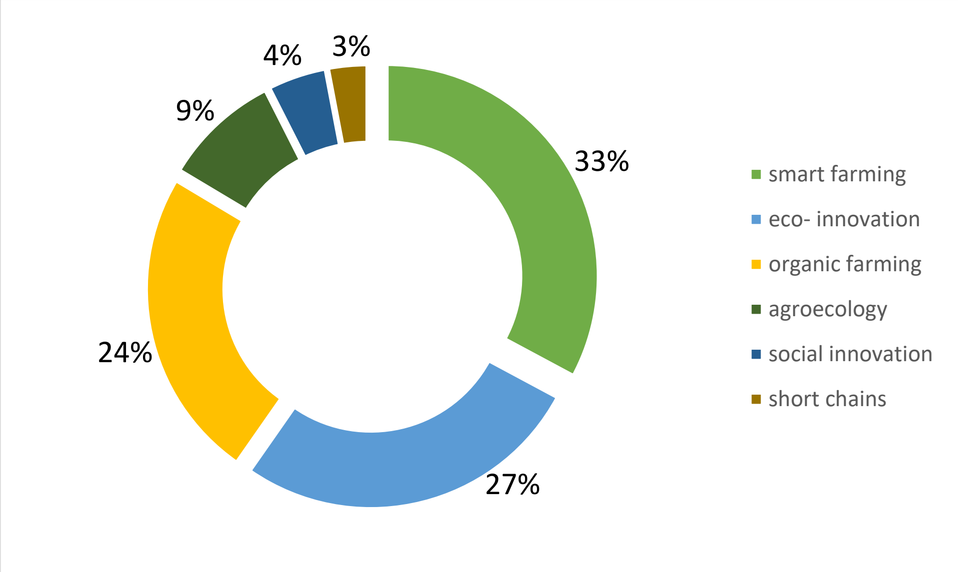

Figure 13: CSA practices studied in the articles

4.3.2 Multi-dimensionality of climate smart agrifood

In summary, the content analysis of the selected articles reveals the importance of multi-disciplinary stakeholder alignment when it comes to CSA practices and technologies in agriculture. Below we present different business strategies and discuss how multi-stakeholder approach functions in collaborative business networks for successful application of CSA.

4.3.3 Strategies for CSA

The literature suggests three main CSA strategies: Mitigation, Adaption and Resilience.

Mitigation:
Mitigation is a strategy that helps mitigate negative impact of agri-food production. Some examples of mitigation practices are agroforestry, conservation agriculture, improved crop and livestock management, use of renewable energy sources, organic farming, regenerative agriculture, agroecology, and use of digital technologies (smart farming) to mitigate negative externalities.

Adaption:
Agrifood production is impacted by a changing climate more than other sectors (Kiprutto, 2015). Climate change and global warming make primary production of food unpredictable and uncertain. In such environment, producers, especially the ones that operate in open field need to adapt production and farming systems to deal with the new, fluctuating and unpredictable circumstances. Some examples of adaptation are conservation agriculture, crop diversification, and improved water management.

Resilience:
To maintain the sustainable practices, agri-food needs to be climate resilient. Therefore, capacity building, knowledge, and innovation to adapt to climate change needs to consider multiple dimensions of resilience. Through e.g., cooperatives, ecosystems, (social) networks, and gender equality resilience strategies this brings agri-food towards sustainable and climate smart actions.

4.3.4 CSA innovation types

To meet the climate challenges, the literature provides three main **innovations** of CSA can be grouped as follows:

1. **Innovation in production methods**. As a new method of agricultural production, such as on-farm diversification, CSA combines the climate change challenges with agricultural productivity and efficiency (Long et al., 2019, Long et al., 2017, van Zonneveld et al., 2020). If traditionally, production focused on the efficiency to produce more, the new CSA methods suggest considering multiple goals, interests, and perspectives, including nature, and other sustainability goals.
2. **Innovation in products, services or techniques** (Long et al., 2019, van Zonneveld et al., 2020). New products, services and techniques increasingly rely on precision agriculture, such as smart devices and IoT systems (Latino et al.). Additionally, innovation in new crop variates that are climate resilient suggest sustainability outcomes (Tester and Langridge, 2010)
3. **Innovation in business strategies** to support specifically local small and medium size producers. Strategies, such as "eco-system network", "civic agriculture", "community supported agriculture", "market-garden" are examples of alternative strategies for food production supported by local communities and created for local markets (Navarrete et al., 2015, Medici et al., 2021, van Zonneveld et al., 2020, Long et al., 2017).

In sum, the innovation types of CSA can be applied for each type of CSA strategy. However, when combining various strategies and innovations at the same time, agri-food producers can build even more climate smart systems (Belda-Miquel et al., 2021).

4.3.5 Multi-stakeholder approach

In agrifood, supply chain, social, environmental, and economic systems are strongly interconnected (*32*). CSA integrates multiple goals that can often be conflicting. A successful CSA adoption therefore requires an integrated multi-stakeholder approach to negotiate trade-offs. Involving different actors is rather a prerequisite than a preference (*90*). CSA in the agrifood supply chain encompasses a complex network of multiple actors that have different roles, interests, powers, and priorities (*37, 58*). Starting from seed companies toward farmers, cooperatives, unions, resource providers, food processing, and retail companies, local and global consumers, policymakers, and civil society organizations (*90*). They all have significant impacts on how the agrifood sector can become climate smart and resilient (*28, 91*).

Due to the heterogeneity of engaged actors in terms of size and market power, fairness concerns rise of who carries the costs and who benefits from CSA actions (*90, 92*). Climate smart actions, therefore are advised to co-design fair solutions with all stakeholders independent on their size, competitive position and market power. By doing so, the climate smart actions can ensure the usefulness of the innovations, and guarantee the acceptance by small and medium enterprises, even if they are small and operate in rural and remote areas (*46, 93*). Yet another benefit of multi-stakeholder approach is the knowledge sharing and resource optimization (*28*). CSA is a knowledge intensive practice that often requires learning and learning to work across different disciplines (*91*). This requires a significant amount of labour and financial capital investments. Once stakeholders are included in decision-making processes for design, implementation, and monitoring, they are inclined to commit either via investing in learning and capacity development or via mobilizing their resources to create synergies.

Therefore, CSA requires multi-stakeholder coordination through collaborative business model to ensure the strategies of individual actors are harmonized and all actors are on the same page (*94, 95*). The networks of stakeholders engaged in CSA is presented in Figure 14.

Figure 14: Multi-stakeholder mapping for CSA strategy

Important to acknowledge that at each actor level value is created, shared, and captured by another actor. The value created, distributed, and captured at each actor needs to be aligned and assessed against the fairness for the individual actors, as well as for all stakeholders as a whole. Planko and Cramer (2021) suggest that **interconnected business models (BM)** at company and at network level, as a sustainable BM for both levels are important to ensure continuous collaboration.

4.3.6 Interconnected business models

Due to the multi-dimensionality of CSA and the involvement of multiple stakeholders from various disciplines with often conflicting interests, as well as the need to guard the environmentally friendly food production, the traditional business strategies and business models, such as CANVAS, do not function, and the need for a new strategy becomes urgent (Mahdad et al., 2022). Literature suggests several collaborative business strategies that need to target at sustainable business models for individual actors and for the entire multi-stakeholder network at the same time to create - deliver - capture environmental, social, and economic value (Oskam et al., 2021), considering the negative externalities as well (Breuer and Lüdeke-Freund, 2017). The value created is then not only monetary, but also non-monetary. Transition towards CSA herewith embeds farm business models in multi-actor collaboration networks, where business models get interconnected.

Multi-actor collaboration networks, however, comprise strategic activities of the actors and depend on the strategic decisions the actors make to invest in innovations for sustainability (Isakhanyan et al., 2017). As already mentioned, in CSA, farmers are unable to do this on their own. The engaged stakeholders need to combine their resources and align their strategic goals to trigger systemic changes and eventually contribute the transition towards climate smart actions in agrifood (Planko and Cramer, 2021).

When taking a multi-stakeholder approach, fairness of value propositions become part of the individual business models, as well as of the entire network. The following network business strategies are suggested by the literature in relation to the following types of CSA including: Agroecology, eco-innovation, smart farming, organic farming, short chains and social innovation.

4.3.7 Business Strategies for CSA

The literature discusses the several business strategies as a steering wheel for applying agroecology as type of CSA. These strategies often rely on interconnected models. **Collective strategies**, such as wisdom dialogue, combination of practical and political knowledge, building social movement network (Anderson et al., 2019) are the more discussed multi-stakeholder business modes strategies. The next one is **alignment of the goals and stakes**, not only for stakeholders, but also of nature and environment in an interdisciplinary setting (Boulestreau et al., 2021, Scherer and Verburg, 2017)

Learning and knowledge exchange to shift the farming practices towards more sustainable one is evaluated as crucial. Farmers that produce large quantities and focus on short term economic turnover only, have often less interest in integrating environmental or human health goals in their business models (Boulestreau et al., 2021). Therefore, to help farmers adopt agroecology, synergies via **local or regional collaboration**, **local associations**, need to be facilitated via together with research and education, experimental farms, training centres (Guareschi et al., 2020); (Polge and Pagès, 2022). Blasi et al (2015) concludes that combining efforts and joining forces of public, research institutions, private companies and social actors supports CSA adoption (Blasi et al., 2015). Similarly, Eastwood et al, (2021) recommends create multi-stakeholder networks, such as policy makers, farmers, consumers, and technology developers to support and promote a quick and efficient implementation of CSA (Eastwood et al., 2021).

Business strategies are not much different when we refer to organic farming as a CSA practice. For instance, Favilli et al, (2015) have concluded that **innovation networks** boost CSA through creating a trustable environment where actors can share and commit. Here, the common network principles are key with knowledge sharing, working together towards common goal and alignment of organisational structures as main activities (Favilli et al., 2015). In addition to common principles, the time-frame is also crucial. Farmers often prefer long-term interconnections. Such long-term networks can also create economic growth and attention to a new balance between agricultural industry and environment, for the benefit of producers/processors, consumers, and natural resources (Mantino and Forcina, 2018). Here, Bentivoglio et al, (2022) agrees that networks boost and support adoption of smart farming technologies, the ones that focus on reduction of environmental impact. Moreover, he concludes that collaborating with external actors and organizations brings successful digitalization (Bentivoglio et al., 2022). Regarding digitalization and smart farming as CSA, Giua et al. (2022) recommends that participation in data management plans where trust becomes key to adoption stimulate farmers to adopt CSA (Giua et al., 2022)

CSA practices require relatively large investments, while the guarantee for return on the capital investment often fails to create an attractive business case. However, when considering the other environmental and human benefits, then the CSA becomes attractive. Medici (2021) suggests members' subscriptions in community supported agricultural format. This membership fee by all engaged actors loosens the burden for the farmers, helps them overcome first-move barriers (Medici et al., 2021). Interestingly, the more members contribute to such CSA economic support, the fewer the contribution per member can become, which makes members' subscriptions the only way to mitigate production and market risks for the farmers.

Other scholars suggest **platforms**, **producer groups** or **associations** as network strategies to trigger interactions with various stakeholders and by doing so, reduce the social barriers for individual innovation decision (König, 2004, Laajimi and Albisu, 2000). Whereas, Navarrete et al, (2015) suggest creating **common market** to simulate farmers diversify the farm production, and Osman et al (2016) concludes that establishing new socio-economic partnerships can overcome current economic and legal barrier to CSA practices (Osman et al., 2016).

Last, but not least, the importance of understanding culture is very important. The farmers often consult and count on the information they receive from peers because they perceive it as reliable (Navarrete et al., 2015). Additionally, the opinion of e.g. family members and advisors are relevant (Naspetti et al., 2017). Therefore, understanding informal networks and the role of interactions among farmers, as well as among all stakeholders can help create reciprocity and articulation of principles among actors (Rover et al., 2020).

Finally, the business networks are often perceived fair by its members. Kröger and Schäfer (2014) studied a producer group of organic breweries with a membership of above 100 producers who integrate their purchase and establish a system of transparency in a fixed general conditions of 5 years, and quantities and prices in annual contracts (Kröger and Schäfer, 2014).

4.4 Conclusions

The main aim of this review was to explore the existing knowledge in the academic literature on innovative business strategies for CSA. Through the use of grounded theory we examined 142 studies that have been published within the year 2000-2022. The systematic methodology leads us to selecting studies with case studies and conceptual frameworks. From the results, we can conclude that the three different strategies of CSA (i.e., mitigation, adoption, resilience) requires three main types of innovations (i.e., innovation in production methods, innovation in products, services or techniques, innovation in business strategies). The farmers, however, are unable to apply CSA on their own, and need resources and support from key stakeholders. The recommendation is to combine several strategies and innovation types so that agri-food producers can build even better climate smart systems. We also conclude that multi-stakeholder coordination through collaborative business model to ensure the strategies of individual actors are harmonized and all actors are on the same page as main business strategy for CSA adoption. Such collaborations need to have several goals, such as raising awareness, knowledge, and experience exchange, creating trusted and safe conditions for farmers to collaborate, align multi-stakeholder goals, creating common markets and align the business strategies. Values created at each actor, shared and captured by other actors needs to be aligned and perceived as fair by the individual actors, as well as for the all stakeholders as a whole. Among the several multi-stakeholder business strategies (i.e. collective decision making, wisdom dialogues, social networks, informal networks, associations, innovation networks, platforms with membership subscriptions, common market, etc.) the choice remains to the stakeholder to find the most fitting business strategy that helps farmers to adopt CSA and benefits the network as a whole. Such approach is found to be perceived fair by the farmers and engaged stakeholders and stimulates CSA adoption.

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5. Systematic review of the consumer decision making factors

5.1 Introduction

The way we produce and consume food has a significant impact on the environment and surrounding society. Therefore, there is a need to change the way many agri-food systems currently operate. To do so, behavioural shifts of all involved stakeholders are needed to foster the adoption of climate smart agriculture (CSA), including smart farming technologies. This systematic review aims to identify the decision-making factors that influence consumer's behaviour towards environmentally friendly food products.

This review follows a systematic methodology, involving a search in Web of Science database for relevant studies, screening of the studies based on inclusion criteria, extraction of relevant data as well as analysis and synthesis of results. Based on 149 studies we examined factors that promote or hinder the purchase of environmentally friendly products among consumers and we divided those into six categories: socio-demographic factors, psychological factors, product characteristics, eating and buying context, systemic factors and policy factors. The review also discusses the importance of the development of strategies aimed at promoting environmentally friendly product consumption and incorporation of such strategies into policy recommendations which could have a significant effect on the demand of environmentally friendly food choices.

5.2 Methods

5.2.1 Study selection

The ambition of this systematic review is to identify empirical studies on decision-making factors influencing consumer's behavioural change towards environmentally friendly products. The systematic review was conducted in November 2022 using Web of Science database. The decision to use only one database was made based on a preliminary search and screening in two databases (Web of Science and SCOPUS), which revealed that the most relevant results were obtained in Web of Science. Therefore, it was decided to use only this database as we regard the number of results as sufficient for the purpose of this systematic review.

The search keywords used were related to consumers (consumer* OR buyer*), influencing factors (factor* OR driver* OR barrier* OR determinant* OR percept* OR motivat* OR knowledg* OR attitud*), behaviour (behavio*r OR chang* OR transition* OR adopt* OR choose OR choice* OR intention* OR decision* OR switch* OR shift* OR uptake OR conver* OR purchas* OR shop* OR buy* OR consumption OR willingness to pay OR prefer*) and environmentally friendly products ((green OR sustainab∗ OR environment∗ OR organic∗ OR ecol∗ OR climate friendly OR climate smart) AND (food OR product* OR grocer* OR diet). In order to limit the number of results Web of Science was filtered by filters relevant to our research question, including publication year (from 2018 to 2023), language (English) and document type (article). The search resulted in a total of 1.893 articles eligible for screening.

5.2.2 Screening process

The objective of this study is to provide a comprehensive overview of articles focusing on the decision-making factors that influence consumers' behavioural change towards environmentally friendly food products. The articles that were included fulfilled the following criteria: 1. the study population consists of consumers, 2. the dependent variable or outcome refers to the purchase of environmentally friendly products, 3. the products analysed include products produced with an environmentally friendly practice in the primary sector, 4. the data analysed is primary and it includes information gathered from surveys, questionnaires, interviews, experiments or focus groups, 5. the topic discussed is relevant to this study's research question and 6. the research is conducted in Europe, encompassing one or more of the following 50 countries: Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Kazakhstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, the United Kingdom (UK) and Vatican City.

The PRISMA diagram that depicts the search and screening process for this study is portrayed in Figure 15. Initially, 1.893 articles were identified from the Web of Science database. Out of these a total of 1.597 were excluded after screening of titles and abstracts. Hereafter, 115 were excluded because the research was not conducted at the consumer level, and 166 were excluded because they did not examine the purchase of environmentally friendly products as the dependent variable. 462 were excluded because they did not examine an environmentally friendly production practice in the primary sector, 89 because they did not involve primary data, 385 because the topic they investigated was not relevant to this study's research question and finally 380 were excluded because they did not take place in Europe. As a next step, the full text of 296 articles was assessed. 147 of those articles were excluded. 73 of the articles because they did not examine the purchase of environmentally friendly products, 57 were excluded because they did not examine a product produced with an environmentally friendly practice in the primary sector, 6 articles were excluded because they did not involve primary data. 8 articles were excluded because the topic they studied was irrelevant to this study's research question and 3 did not take place in Europe. Ultimately, 149 studies were included in the final review [1-149].

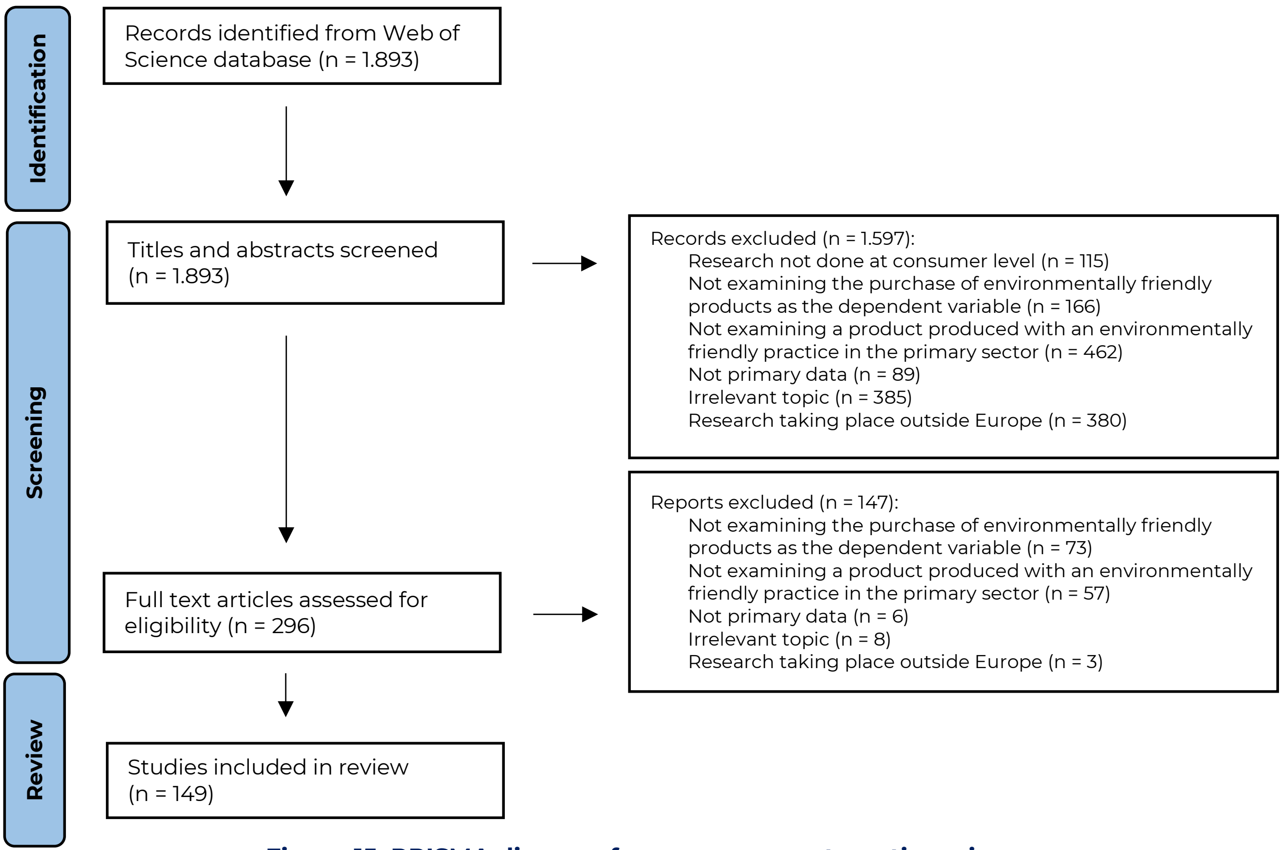

Figure 15: PRISMA diagram for consumer systematic review

5.2.3 *Data extraction and analysis*

For the 149 selected studies in the review, we have extracted a list of relevant information, which included authors, year of publication, country of research, type of environmentally friendly production practice and type of environmentally friendly product. To synthesize the findings from multiple sources, we counted the number of times a variable had a positive, negative or non-significant effect on consumer's behavioural change towards environmentally friendly products. We have also conducted in-depth analysis, focusing mostly on the results section and statistical analysis tables, and recorded factors affecting consumer's shift towards environmentally friendly food products and categorized them into six groups: socio-demographic factors, psychological factors, product characteristics, eating and buying context, systemic factors and policy factors.The accuracy of the extraction process was verified independently by the authors and any discrepancies were resolved by discussion.

5.3 Results

5.3.1 *Study characteristics*

Figure 16 illustrates the publication timeline of the included literature, which spans from 2018 to 2023, representing the most recent five-year period. The majority of the studies included were published in 2021, accounting for 42 publications. Additionally, there were 18 studies published in 2018, 26 studies in 2019, 32 studies in 2020, 29 studies in 2022, and 2 studies in 2023. These numbers indicate that the number of publications on this topic has in general increased steadily over the years, with a notable peak in 2021.

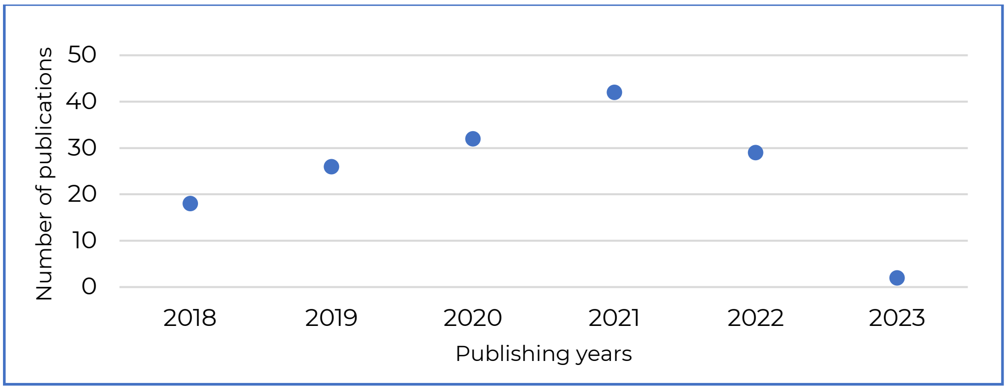

Figure 16: Number of included studies by publication year

This literature review includes studies from 37 different European countries, which is demonstrated in Figure 17. The majority of included studies were conducted in Italy (33), followed by Germany (27), Spain (20), Poland (19) and the UK (14). Other countries that contributed a significant number of studies include Romania (9), France (9), Hungary (8), Portugal (8), Turkey (7), Denmark (6), Switzerland (6), Greece (6) and Sweden (5). Additionally, Belgium, the Czech Republic, Norway, Slovakia and Serbia each contributed with 4 studies. The remaining countries included in this review contributed each with 3 or less studies.

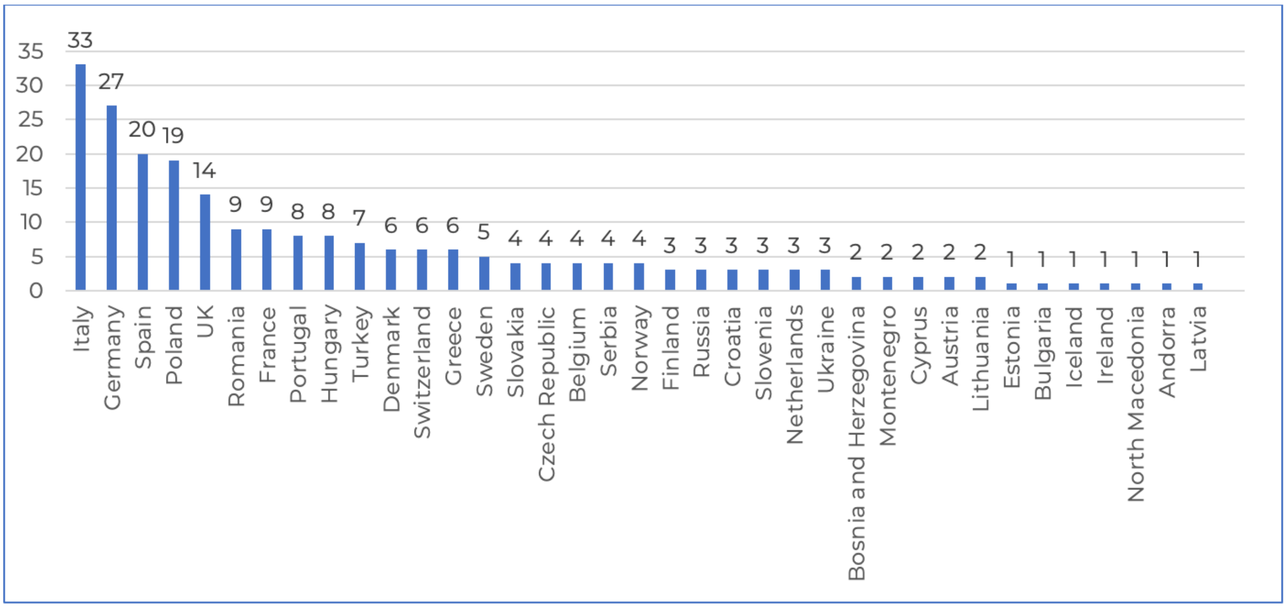

Figure 17: Number of included studies by country

Included studies cover different types of environmentally friendly production, which were grouped into three larger categories. Organic production is mentioned in 60% of all included articles (Figure 18). 3% studies include production of food focused on animal welfare, which involves products such as pasture raised or mountain products. Pasture-raised meat and dairy products are beneficial to the animals and the environment, as they allow for more natural behaviour and grazing patterns [44]. Mountain products refer to livestock raised in the mountains using traditional farming techniques, which can help protect biodiversity and take up less land than conventional farming practices [134].

Other environmentally friendly production types are touched upon within 37% of all included articles. Under this category we combined articles which use the terms as: environmentally friendly, sustainable, green, carbon-footprint friendly. These terms frequently appear in the selected articles as synonyms and are used interchangeably with their combined quality being friendly to the environment [14, 38, 98].

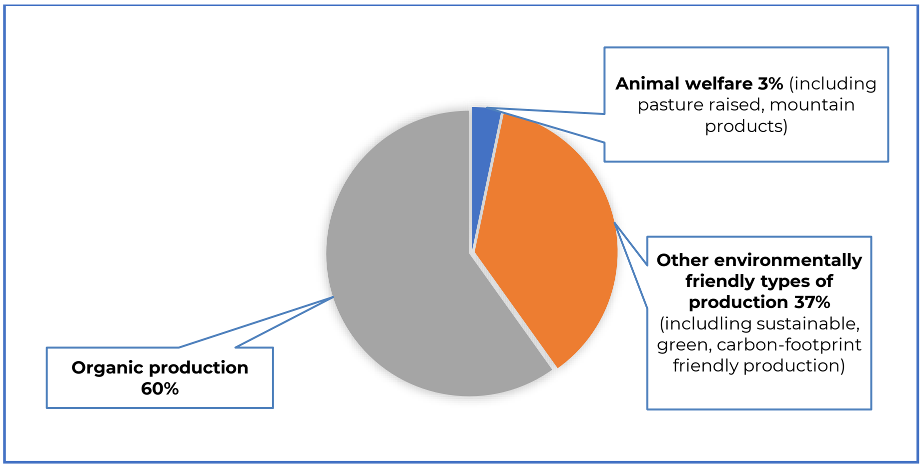

Figure 18: Type of environmentally friendly production mentioned in the included studies

Most of the studies in the systematic review (52%), discuss food in rather general terms. However, some studies included more specific examples (Figure 19). Fruits and vegetables were common topics, with 9% and 8% of the articles covering these categories, respectively. Other food types mentioned in the articles included milk and dairy products (8%), wine (6%), meat and meat products (5%) and specific types of food such as olive oil (3% of articles), eggs (2%), grain (2%), non-alcoholic beverages (2), honey (1), legumes (1), and herbs (1).

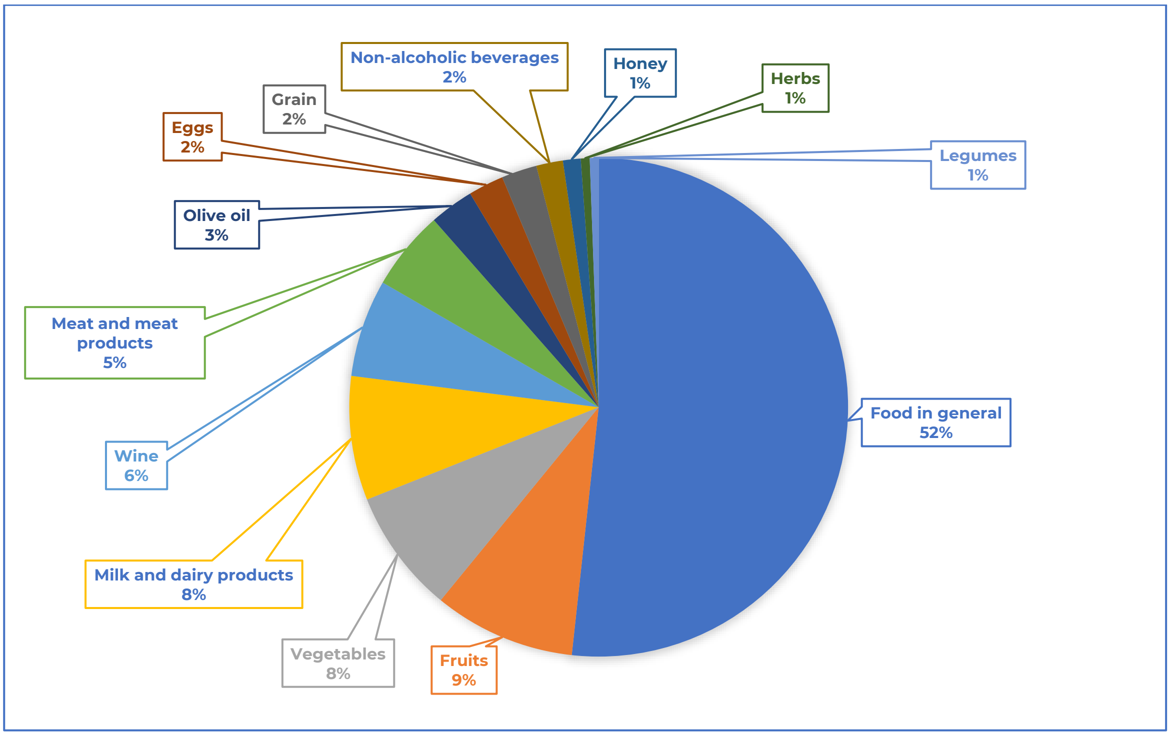

Figure 19: Type of environmentally friendly product mentioned in the included studies

5.3.2 Decision-making factors influencing consumer's behaviour towards environmentally friendly food products

5.3.2.1. Socio-demographic factors

Socio-demographic factors include consumer's individual characteristics (age, gender, education level) and household characteristics (income, place of residence, household size). Age of consumers has largely negative effect on consumption of environmentally friendly products. Younger consumers are more likely to adopt an environmentally friendly diet than older consumers. This could be explained by the fact that younger generations tend to be more attracted to environmentally friendly food products because of higher awareness of its health and environmental benefits, prompting them to buy such products more often [5, 32, 33, 37]. This shows that the young consumers should be considered key stakeholders in the transition towards more sustainable food systems [5]. Like age, gender has also been recognized as a significant factor. Men have been found to have a lower intensity of buying environmentally friendly products compared to women. Higher tendency for environmentally friendly food purchase in female consumers is mostly associated with their higher food involvement and greater interest in healthy diets as well as environmental concern [9, 56, 76, 141]. Most studies have found that level of education correlates with significant increase in environmentally friendly food consumption. Education is usually connected with higher knowledge which explains why well-educated consumers seem to be more sensitive towards environmental issues [56, 76, 79, 93].

In relation to household characteristics, higher household income is mostly associated with more frequent purchase of environmentally friendly food products. High income allows consumers to pay the premium price of environmentally friendly products [23, 26, 48]. It has also been identified that different places of residence can have an impact on consumer behaviour. Some studies have showed that people living outside cities are more prone to consume environmentally friendly products which could be explained by their connection to nature and environment [260]. Country of residence can also represent a relevant factor which might be related to greater knowledge and stronger attitudes towards environmentally friendly products in some European countries rather than in others. For example, one study showed that the percentage of frequent consumers of organic food products in Berlin (Germany) is significantly higher than in Lisbon (Portugal), which the authors contribute to a greater knowledge about organic food of consumers from Berlin [169]. Finally household size was found to have statistically insignificant effect on consumption of environmentally friendly food [48, 49].

Table 10 presents a summary of socio-demographic factors effect on purchase of environmentally friendly food products based on the literature we have included in our review. For each factor we calculated the number of studies that identified positive, negative, or non-significant correlation to consumer's behaviour towards environmentally friendly food products. Therefore, the positive effect column indicates the number of articles that have identified each factor as a driver for purchase of environmentally friendly food products, while the negative effect column shows the number of articles that have identified each factor as a barrier to such purchase. The »insignificant« column lists the number of articles that have not showed significant relationship between the factor behaviour change towards environmentally friendly food products. Finally, the "% significant" column presents the proportion of articles that have found a significant effect (either positive or negative) for each factor, relative to the total number of articles that have investigated that factor.

Socio-demographic factors	Positive effect	Negative effect	Insignificant	% Significant
Age	9	16	13	65.8
Gender (female)	20	4	16	60.0
Education level	23	0	10	69.7
Income	19	0	6	76.0
Place of residence	6	1	4	63.6
Household size	3	2	6	45.5

Table 10: Socio-demographic factors influencing consumer's behaviour towards environmentally friendly food products

5.3.2.2. Psychological factors

The systematic review reveals a wide range of psychological factors, including cognitive, affective, and dispositional factors, which were identified as significant determinants of consumer behaviour towards environmentally friendly products. Cognitive factors have received considerable attention, including knowledge, awareness and perceived behavioural control over engaging in sustainable behaviours. Consumers with more knowledge regarding the benefits of environmentally friendly products tend to be more concerned about the impact of their consumption on the environment and, therefore, are more likely to engage in environmentally friendly product consumption [10, 16, 24]. Similarly, consumers who are aware of environmental challenges, ethical means of production and food safety risks are more likely to prioritize environmentally friendly products in their purchasing decisions [37, 68]. Regarding perceived behavioural control, purchase of environmentally friendly products increases when consumers feel that they have greater resources, confidence and control over the ability to purchase such products [41, 52, 53].

In addition, attitudes and beliefs constitute prominent factors that have been thoroughly investigated across the articles included in this systematic review. The findings of these studies consistently demonstrate that consumers who have strong pro-environmental attitudes and beliefs towards environmentally friendly products are more likely to purchase such products [52, 69, 96, 117]. Moreover, the majority of studies suggested that motives can play a significant role in the process of purchasing. Particularly, consumers who are motivated by environmental concerns, ethical values, or health benefits are more likely to seek out environmentally friendly products [42, 88]. Moreover, subjective norms have been found to play a crucial role in consumer behaviour, as people tend to conform to social expectations to gain approval [23]. In addition, studies have revealed that different aspects of lifestyle have a clear impact on purchasing decisions. For example, people who are trying to improve their diet by eating more fruits and vegetables, may also be more likely to buy food produced in an environmentally friendly way, as they are more health-conscious and aware of the potential health benefits. Likewise, reducing meat consumption, which may be motivated by animal welfare concerns, increases the likelihood of orienting towards purchasing environmentally friendly meat [25, 34]. Finally, research have proved that past behaviour can be a strong predictor of future actions, due to the fact that previous behaviour can shape consumers' attitudes and beliefs about sustainability, as well as create habits and routines that are difficult to break. This means that consumers who are used to buying environmentally friendly products are more likely to continue doing so [87, 109].

Regarding dispositional factors, consumer environmental and health consciousness has been found to play a significant role in driving the demand for environmentally friendly products: the level of consumer concern about environmental and health issues increases the likelihood of their purchasing environmentally friendly products [5, 20, 99]. Moreover, studies have found that certain personality traits have a significant correlation with the intention to buy environmentally friendly products. For instance, people who are more open to new experiences and people who are less risk-averse may be more willing to try new and innovative products, including those that are friendly to the environment. This is due to their higher propensity to embrace novel and unconventional ideas, as well as their relatively lower concern about negative consequences associated with deviating from established behaviours [72, 86]. Studies have also shown that consumers place significant value on seller and brand credibility, environmentally friendly claims and certifications. Such trust-building factors provide assurance to consumers that the environmentally friendly products they purchase are of high quality, safe to consume and meet certain standards [34, 37, 58]. Finally, brand sensitivity, which is the ability of a brand to influence consumer behaviour and purchase decisions has been found to have an impact on buying environmentally friendly products. This means that consumers who are highly sensitive to brand image and reputation are more likely to seek out and purchase environmentally friendly products from brands that they perceive to be socially responsible and friendly to the environment [12, 20].

Table 11 provides the summary of papers that found a positive, negative, and insignificant effect for each psychological factor. Table 11 also presents the percentage of the total number of papers that found a significant effect (either positive or negative) in relation to the total number of articles that have investigated that factor.

Psychological factors	Positive effect	Negative effect	Insignificant	% Significant
Knowledge	36	0	2	94.7
Awareness	9	0	0	100
Perceived behavioural control	26	0	3	89.7
Attitudes and beliefs	47	4	1	98.1
Subjective norms	14	0	3	82.4
Lifestyle	14	3	1	94.4
Past behaviour	4	0	0	100
Environmental and health consciousness	49	0	2	96.1
Personality traits	5	1	0	100
Trust	21	0	4	84.0
Brand sensitivity	7	0	1	87.5

Table 11: Psychological factors influencing consumer's behaviour towards environmentally friendly food products

5.3.2.3. Product characteristic

Product characteristics emerged as a critical factor influencing consumer behaviour towards environmentally friendly products, as evidenced by numerous studies included in this systematic review. One key aspect of product characteristics is the claims made on environmentally friendly product packaging, which have been found to have a significant impact on consumer acceptance and purchase intention. In particular, studies have shown that packaging claims go beyond providing product-related information to consumers and can influence their decision-making by evoking emotional responses or providing factual information about the environmental impact of the product [1, 4, 39]. Similarly, certifications on products have a significant effect because they provide a reliable and objective third-party validation of a product's environmental and quality claims [9, 89, 106]. Additionally, several studies indicate that local origin can increase the likelihood of buying environmentally friendly products. This may be because people perceive locally produced products as being more environmentally friendly, as they require less transportation and have a smaller carbon footprint compared to products that are imported from far away. Consumers may also prefer to support local economies and sustainable agricultural practices by buying locally produced goods. Finally, locally produced products may be seen as fresher and of higher quality compared to imported goods [10, 21, 36, 114].

Multiple studies have examined how price affects consumers' willingness to pay for environmentally friendly products. These studies have consistently found that the influence of price is negative, indicating that the increased prices of environmentally friendly products would likely result in a decrease in consumer demand. This effect is especially pronounced for consumers who are less educated or have low-income, who may be more sensitive to price changes than their higher-educated or high-income counterparts [4, 34, 80]. Regarding nutritional value and quality, the findings consistently demonstrate a significant positive effect. In other words, consumers who perceive environmentally friendly products as possessing high-quality nutritional benefits are more inclined to make the purchase [102, 130, 147]. Moreover, numerous studies have shown that consumers are willing to pay a premium for environmentally friendly products that meet their sensory expectations. Specifically, products with more appealing taste and appearance are more likely to be purchased by consumers [12, 50, 116]. Furthermore, in our systematic review, we found a limited number of studies that have explored the impact of food safety on environmentally friendly food consumption. However, the available evidence suggests that consumers tend to have a more positive intention to purchase environmentally friendly products when they perceive them to be safer than conventional products [95]. Similarly, the perception of naturalness in environmentally friendly products, driven by the belief that they are free from chemicals and genetic modification, can also influence consumers' purchasing decisions and increase consumption of food produced in an environmentally friendly way [91, 119, 130]. In addition, short expiry time has been found to be a barrier to purchasing environmentally friendly products, as consumers may perceive these products as being less convenient or practical to use compared to their counterparts with longer shelf lives [130].

Last but not least, several studies have indicated that consumers' purchasing decisions towards environmentally friendly products are heavily influenced by their perception of the production process environmental impact and animal welfare practices. In other words, if consumers believe that a product has been produced sustainably and the animals involved were treated humanely, they are more likely to buy it [78, 106, 119, 125].

Table 12 provides the summary of papers that found a positive, negative, and insignificant effect for each product characteristics related factor. Table 12 also presents the percentage of the total number of papers that found a significant effect (either positive or negative) in relation to the total number of articles that have investigated that factor.

Product characteristics	Positive effect	Negative effect	Insignificant	% Significant
Claims on packaging	21	0	0	100
Certification	16	0	1	94.1
Geographical origin	21	0	3	87.5
Price	0	27	6	81.8
Quality / nutritional value	38	0	3	92.7
Taste	17	0	3	85.0
Appearance	6	2	1	88.9
Food safety	4	0	0	100
Naturalness	2	0	0	100
Short expiry time	0	2	0	100
Environmental impact of production	9	0	0	100
Animal welfare	9	0	0	100

Table 12: Product characteristics influencing consumer's behaviour towards environmentally friendly food products

5.3.2.4. Eating and buying context

This systematic review indicated that the context in which consumers make food choices has a significant impact on their willingness to choose environmentally friendly options. Availability of environmentally friendly products has been found to be the most crucial out of these factors. When local markets or supermarkets offer a wide range of environmentally friendly products, consumers are more likely to choose them [18, 20, 23, 25, 37, 46, 50, 58, 62, 68, 88, 106]. Moreover, better access to such products has a better likelihood of those products being consumed [145]. Strategic placement of environmentally friendly products within the store also leads to a better and effortless experience for consumers. Therefore, the concept of convenience (if no extra effort has to be made when shopping for environmentally friendly products) has been shown to exert a considerable positive effect on purchasing of such products [7, 20, 55, 58, 97, 107].

In addition, the purchase channels also affect consumer's food choices [77, 95, 129]. The purchase channels that have been found to positively impact consumer behaviours include local farmers markets [80, 112] and speciality organic food stores [125]. The availability of environmentally friendly products is these speciality stores increases their purchase [112, 125].

Table 13 provides the summary of papers that found a positive, negative, and insignificant effect for each eating and buying context related factor. Table also presents the percentage of the total number of papers that found a significant effect (either positive or negative) in relation to the total number of articles that have investigated that factor.

Eating and buying context	Positive effect	Negative effect	Insignificant	% Significant
Convenience	8	1	1	90.0
Availability	17	1	5	78.3
Access to product	1	0	1	50.0
Purchase channels	6	1	0	100

Table 13: Eating and buying context influencing consumer's behaviour towards environmentally friendly food products

5.3.2.5. Systemic factors

This systematic review underscores the crucial role of social norms in influencing consumer behaviour towards environmentally friendly food choices. Individuals who value others' opinion are more likely to purchase environmentally friendly products if such behaviour is approved. In addition, social norms have the potential to foster a sense of community and encourage individuals to adopt environmentally friendly food practices, thereby promoting pro-environmental behaviours [3, 4, 44]. Friends and family in particular are critical coefficients for consumers' decision-making process [110, 115]. Additionally, research on advertising and promotion has consistently supported the idea that they have a positive impact on market size by stimulating consumer demand for environmentally friendly products. In addition, informative and persuasive communication often serves an educational function by enhancing consumers' understanding of the nutritional and environmental benefits associated with such products [111, 142].

Table 14 provides the summary of papers that found a positive, negative, and insignificant effect for each systemic factor. Table also presents the percentage of the total number of papers that found a significant effect (either positive or negative) in relation to the total number of articles that have investigated that factor.

Systemic factors	Positive effect	Negative effect	Insignificant	% Significant
Social norms	14	1	1	93.8
Advertising and promotion	7	0	0	100
Information sources	2	0	0	100

Table 14: Systemic factors influencing consumer's behaviour towards environmentally friendly food products

5.3.2.6. Policy factors

Policy factors have not been studied extensively in this systematic review. However, the papers suggested that policy interventions can have a positive impact on sustainable consumer behaviour, as they can provide them with incentives to make more environmentally friendly food choices. Specifically, government actions supporting the growth and accessibility of environmentally friendly food, or enhancing consumer awareness and trust in them, could boost consumers' willingness to pay a premium for such products. One study suggest that governmental agencies should include organic products in their public procurement criteria and in their canteen facilities for public hospitals, schools, residences, etc. to encourage people to consume environmentally friendly products. Moreover, policies that offer tax incentives for sustainable practices and government subsidies for climate smart agricultural producers can lower the cost of environmentally friendly goods, rendering them more affordable for consumers and more financially appealing for businesses, ultimately contributing to the increased production and availability of environmentally friendly products [40, 58, 77].

Table 15 provides the summary of papers that found a positive, negative, and insignificant effect for the mentioned policy factor. Table also presents the percentage of the total number of papers that found a significant effect (either positive or negative) in relation to the total number of articles that have investigated that factor.

Policy factors	Positive effect	Negative effect	Insignificant	% Significant
Government actions	5	0	0	100

Table 15: Policy factors influencing consumer's behaviour towards environmentally friendly food products

5.4 Conclusions

The aim of this paper was to analyse the drivers and barriers to environmentally friendly food consumption through a systematic review of studies based on primary data carried out in the last five years in Europe. This study highlights six different categories of factors, which are: sociodemographic factors, psychological factors, product characteristics, eating and buying context, systemic and policy factors, that influence consumer decision-making processes for environmentally friendly products. The literature shows considerable interest in this, increasing the number of publications steadily over the years. Most of the articles are from Italy, Germany, Spain, Poland and the UK. Furthermore, most studies have centred on organic food production, followed by other environmentally friendly food productions (for example green, sustainable, climate-friendly production), while relatively fewer studies specifically investigate animal welfare in relation to food consumption.

Regarding the factors influencing decision-making in the consumption of environmentally friendly foods, the review identifies some determinants that are of greater importance and have been subjected to more frequent analysis.

Among the psychological factors, firstly, knowledge has been found as an important factor for the consumption of environmentally friendly foods. Higher level of knowledge as well as better awareness and positive attitude towards food produced in environmentally friendly way were often identified as reasons that explained why younger generations, women and consumers with higher education purchase environmentally friendly food more often [5, 9, 32, 33, 37, 56, 76, 79, 93, 141]. This highlights the need for educating consumers about the environmental and health benefits of environmentally friendly products [10, 16, 24]. Similarly, perceived behavioural control has been identified as one of the most important factors in several studies, highlighting the need to empower consumers through guidelines for more environmentally friendly food choices, increasing their confidence and control over the purchases of environmentally friendly products [41, 52, 53]. In addition, environmental and health consciousness has been recorded as an essential driver, underscoring the need for labelling requirements for environmentally friendly and healthy products which helps consumers to make informed choices and drives demand for these products [37, 68]. Finally, consumer trust in the product and in those who sell it has been found to be crucial in shaping consumer behaviour. This highlights the need to implement transparent communication with consumers and provide information about the products, their ingredients and their environmental and health impact. Packaging claims, certifications and branding can all contribute to building consumer trust and increasing brand loyalty [34, 37, 58]. All the above will boost pro-environmental and health attitudes, which have also been shown to be key factors in increasing the likelihood of purchasing environmentally friendly foods [52, 69, 96, 117].

Among product attributes, claims on packaging seems to have a great significance and have been extensively analysed, meaning that their presence on the food product increases the likelihood of purchasing. Hence, affective and cognitive claims on packaging could effectively capture the attention of consumers and motivate them to purchase the product [1, 4, 39]. In addition, local origin, has been captured in a significant number of articles as a considerable driver for environmentally friendly food consumption, indicating that consumers value local products more and are more likely to purchase environmentally friendly product if it comes from their domestic origin. Therefore, it is vital for producers to consider the importance of local origin when developing and promoting environmentally friendly products, highlighting the domestic origin of their products and targeting local consumers [10, 21, 36, 114]. Moreover, the importance of food quality, taste and appearance is highlighted many times. Environmentally friendly products that are perceived to have a high nutritional value, better taste and appealing appearance can have a competitive advantage in the market. To facilitate consumer choice, it would be beneficial to implement labelling schemes that provide information about the nutritional content, while also focusing on enhancing the taste and appearance of the food [12, 50, 102, 116, 130, 147]. Finally, it was found that price is the most frequently cited and significant barrier to environmentally friendly food consumption. That is also the reason why lower household income is mostly associated with less frequent purchase of environmentally friendly food products [23, 26, 48]. Thus, to increase consumption of environmentally friendly foods, it is necessary to address this barrier by supporting producers to lower their prices or promoting marketing campaigns to demonstrate that environmentally friendly products are good value for money [4, 34, 80].

In the context of eating and buying, the availability of environmentally friendly products has also been observed to have a significant impact on consumer decision-making. Hence it is important to make it easier for producers to sell their products in physical or online stores, open their own stores, or partner with companies and restaurants to sell their products, as this will help increase consumer availability of these products [18, 20, 23, 25, 37, 46, 50, 58, 62, 68, 88, 106]. Finally, from systemic factors, social norms have been found to have a major impact on consumer decision making. This underscores the need to promote and encourage environmentally friendly consumption behaviour as a social norm. For instance, initiatives such as launching public awareness campaigns that highlight the benefits of environmentally friendly products and encourage individuals to make sustainable choices, through various channels such as social and media, could prove effective [3, 4, 44].

In summary, these findings highlight the importance of understanding the determinants of consumer decision-making when developing strategies aimed at promoting consumption patterns of foods produced with environmentally friendly practices. Incorporating these strategies into policy recommendations can help increase consumer confidence in environmentally friendly products, leading to increased market demand.

5.5 References

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6. Systematic review on policies and regulatory framework

6.1 Introduction

This systematic mapping of published literature aims to identify the existing "lock-ins" and levers in the existing policies, mainly at EU level through the prism of the EU Common Agricultural Policy affecting the introduction of climate-smart agriculture practices and how these influence behavioural shifts towards sustainable food systems.

As this is a very broad issue, the main focus has been primarily on the Common Agricultural Policy (hereinafter referred to as CAP) as the main economic and behavioural change incentive that exists not only at EU level (1/3 of the EU budget) but also at national level and in specific value chains. It is through it that the existing EU sustainability goals particularly those set out in the EU Green Deal, are delivered; indeed, the CAP is often the prime vehicle for implementing these policies.

The design of CAP incentives, barriers and lock-ins, and their translation to the individual Member States, specific geographical areas and value chains have a disproportionate effect on the uptake of climate-smart agricultural practices (CSA) and behaviours.

The present overview, of peer reviewed literature since 2014 (the first year of the preceding CAP programming period) seeks to provide an overview in assessing the adequacy of CAP and its incentives in the adoption of climate smart agriculture at country, farming sector and farmer level in terms of their behaviour towards CSA adoption.

6.2 Methodological Issues

The following search string was used to produce, after various stages using the PRISMA process 100 peer reviewed articles that were individually reviewed to produce the present systematic mapping report:

> (TITLE-ABS-KEY ("precision agriculture" OR "precision farming" OR "smart farming" OR "smart agriculture" OR "precision livestock farming" OR "sustainable agriculture" OR "sustainable farming" OR "organic agriculture" OR "organic farming" OR "digital agriculture" OR "climate-smart farming" OR "climate-smart agriculture") AND TITLE-ABS-KEY (cap OR "Common Agricultural Policy" OR "greening" OR "Green Deal") AND TITLE-ABS-KEY ("EU" OR "Europe" OR "European Union")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014))

The search criteria used were as follows:

- **Start date 2014 until end 2022**. The reason is that this would be the first year that data relating to the 2014-2020 programming period of the EU's Common Agricultural Policy (CAP) would be available. Given the time lag for publication in peer-reviewed journals, this would include some evaluations of the previous period (2007-2013) and the preparations for the 2014-2020 period, for which regulatory proposals were outlined two years earlier. Full ex-post evaluations are carried out by the Commission in the first two years of a new programming period (2007-2013 in this case, as the 2014-2020 one were not carried out due to the extension of this period to end 2022) and would therefore have been captured in the observed period.

- **Climate smart agriculture (CSA) was initially used as the key search word** applied to that time interval. This yielded a large number of results (589 hits), even if linked with CAP as search term, many of which were not directly relevant (i.e. not linked to policies), producing circa 589 hits. For this initial scoping Google Scholar was used.

Scopus was used for a more granular search and the fits found through it were the ones that were subject to systematic review. Given the limited number of relevant hits previously used using CSA as the main keyword a set of additional criteria were used as proxies for CSA ("precision agriculture" OR "precision farming" OR "smart farming" OR "smart agriculture" OR "precision livestock farming" OR "sustainable agriculture" OR "sustainable farming" OR "organic agriculture" OR "organic farming" OR "digital agriculture" OR "climate-smart farming"). This resulted in in 158 hits that were then examined individually in depth.

Given the small number of hits it was judged not necessary to make the search more granular, such as including specific search keywords issues such as distinguishing between Pillar I (direct income support payments to farmers and sectoral interventions) or Pillar II (rural development measures), or adding performance-related payments, enhanced conditionality, cross-compliance as the possible hits covered by those categories would have been also covered by the above keywords. The examination of 158 individual peer reviewed research outputs was judged feasible in the timescale of this Deliverable.

6.2.1 Criteria for inclusion and exclusion

A further set of 58 peer-reviewed journal articles were excluded, most of them because they were not or tenuously linked to policies. Thus, the exclusion criteria at this stage of the review is whether CAP and related EU policies are

- the central subject matter of the peer-reviewed article;
- a key explanatory variable;
- part of the conclusions and recommendations;
- the text is in English.

If any of these three criteria are met, the article is further reviewed; if not, it is excluded. Thus, these 58 articles excluded at that stage did not take into account CAP and related EU policies, but they only received a passing mention or added as a general background to that particular article.

The use of the terms "Green Deal" and "Greening" outside the context of the CAP creates the situation of identifying articles by keywords that are referring to other non-policy contexts (e.g. technological use or agricultural databases) in such a way that these articles have to be discarded. In addition, the tendency among the rejected literature to use these terms as a marker to highlight the topicality of their research topic. Therefore, 100 selected studies fully met the research question and the above search criteria (Figure 20).

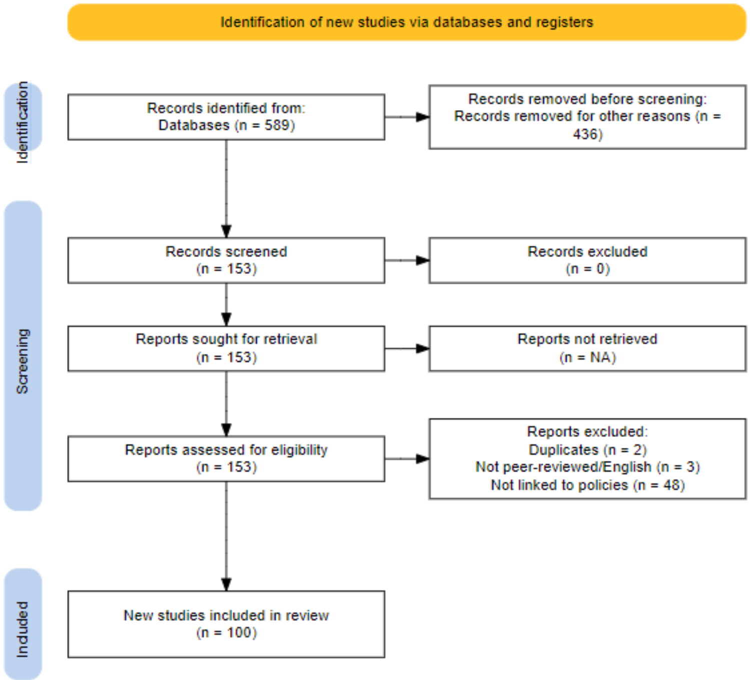

Figure 20: PRISMA flow diagram for policy review

6.3 Results

Given the specific nature of this research question, the 100 peer-reviewed research results selected were grouped into two overlapping classifications:

- Whether these 100 items were EU wide (54) or national case-specific (46). This is a second-order typology so was therefore not used in the evaluation of CSA drivers and barriers presented below.

- Whether these 100 items were mainly about wide CAP policy frameworks, i.e. they had CAP as their primary research subject (56) or their prime focus of the research was some of the key aspect of climate smart agriculture (e.g. a case study of a specific value chain in a given country) but also include CAP as a factor or explanatory variable (44).

The 56 articles whose prime focus is CAP and governance (which we call "CAP incentives" in the below table), they were broken down further into CSA-related subcategories: farm behaviour; incentive and perceptions; the role of rural development measures (Pillar II) in CSA such as organic farming, agri–environmental-climate and areas with natural constrains; the payment instrument Greening of direct payments (Pilar I) as well as more cross-cutting studies on governance and of incentives to sustainability. The findings of each of these subcategories are summarised in the below table.

The 44 more case-specific articles were further broken down into some of the key topics under CSA: agro-forestry, biodiversity, bioeconomy, climate, greening, habitat, organic farming, pesticides, precision farming, smart agriculture, soil and sustainability. The findings of each of these subcategories are summarised in the below table.

The PRISMA excel table with the final choice includes these two criteria (geographic and content) as well as a short description of each item, as to allow other partners to also peruse this material.

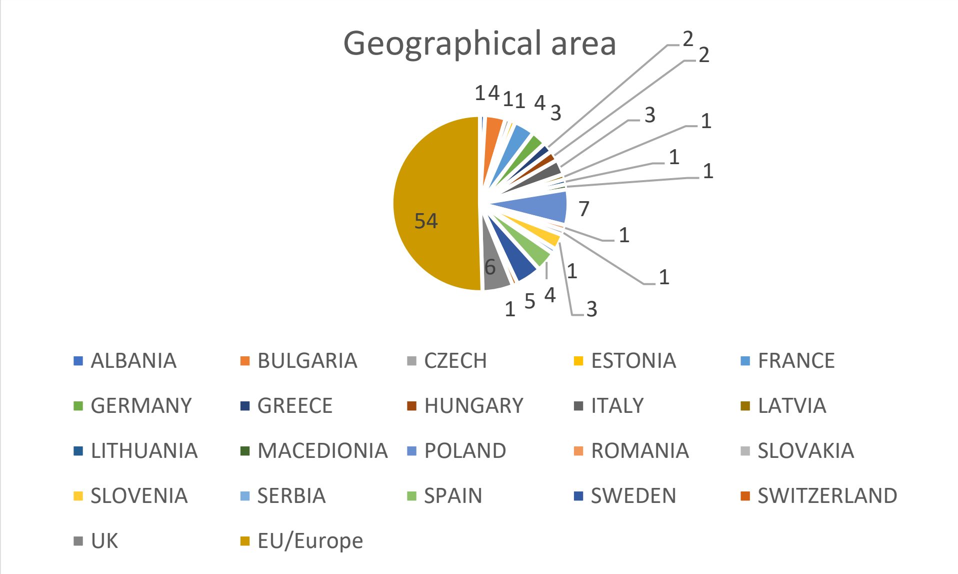

Figure 21: Geographical area

Most of the reviewed studies, just over half, are a pan-European scale, of those largely focused on the EU. This is to be expected, given that the keywords used prioritise studies dealing with the implications of the CAP and its role as the main driver of market and behavioural change in the agricultural sector and rural areas.

In the timescale covered in this review there is a fairly even spread of a small number of countries represented, with slightly more from Eastern Europe, as there is a research interest was higher due to the fact that they had to adapt their production models the most, due to the transformations of the agricultural sector as a result of transition from a planned economy, foreign investments in agricultural extension and adapting to CAP framework both in terms of market regulation and food production but also towards the adoption of sustainable practices. Most of the shortlisted studies focus on sustainability rather than smart agriculture. As regard to the country-specific studies their field research focuses more often at regional rather than at national level, even if these regional studies are then used as a proxy to identify findings that are applicable to the entire country (Figure 21).

6.4 Overview of reviewed literature

The tables below classify the reviewed literature in the two above-mentioned categories: general studies about CAP and its relevance for CSA, and case-specific studies on CSA where CAP plays a role. Within those a range of sub-categories is spelled out.

These tables aim to summarise all the evidence that was gathered, which will then be examined in more detail in the discussion section further below, as regards to their role as barriers or drivers of CSA.

Topic	Contribution to CSA	References
CAP Incentives	Role of CAP market regulation directly or via shaping national policies to provide incentives to	Rudnicki; *et al.* 2021; Pastusiak; *et al.* 2021; Glowinkel , *et al.* 2021; Gaymard, *et al.* 2020; Scown, *et al.* 2020; Pe'er, *et al.* 2020; Howe, *et al.* 2019; Turlakova,2019; Baur, *et al.* 2018; Lobley,

(this overall list is broken down in the below sub categories – in italics)	sustainable agriculture at aggregated or farm level	*et al.* 2018; Whitfield, *et al.* 2017; Zafeiriou, *et al.* 2017; Slabe-Erker, *et al.* 2017; Jaime, *et al.* 2016; Lefebvre , *et al.* 2015; Popp , *et al.* 2015; Papadopoulos , *et al.* 2015; Öhlund , *et al.* 2015; Pacini , *et al.* 2015;Popescu,2017; Bartulović, *et al.* 2014; Marja, *et al.* 2014; Rocamora-Montiel, *et al.* 2014; Horrocks , *et al.*2014; Escribano , *et al.* 2015; Mitropoulos , *et al.*2015; Xiao , *et al.* 2015; Passeri , *et al.* 2016; Delmotte , *et al.* 2017; Öhlund *et al.* 2017; Hočevar,2018; Papadopoulos , *et al.* 2018; Baur *et al.* 2018; Verhees, *et al.*2018; Baležentis , *et al.* 2019; Bartolini , *et al.*2019; Dessart , *et al.*2019; Lazíková; J. , *et al.* 2019; Grzelak et al. 2019; Kazakova-Mateva;2020; Pawlewicz , *et al.* 2020; Lampkin , *et al.*2020; Dudek , *et al.*2020; Dos Santos , *et al.*2020; Gebska , *et al.*2020; Liberati , *et al.*2021; Buttinelli , *et al.*2021; Varia , *et al.* 2021; Cammarata , *et al.* 2021; Gazzani; 2021; Auzins , *et al.* 2022; Pilvere , *et al.* 2022; Spiegel , *et al.* 2022; Paulus , *et al.* 2022; Jahrl , *et al.* 2016
- *farmers*	*Farmer-centred studies, their behaviour is both constrained and incentivised by the CAP subsidies and regulatory framework, however there is a strong influence of perceptions, social capital and local/domestic market conditions*	*Gaymard, et al. 2020; Howe, et al. 2019; Baur, et al. 2018 ; Mitropoulos et al., 2015 ; Delmotte, et al. 2017 ; Öhlund et al. 2017; Verhees, et al. 2018; Frueh-Mueller, et al., 2018; Baležentis, et al. 2019; Dessart, et al. 2019; Gebska et al. 2020 ; Paulus, et al. 2022; Bartulović, et al.2014 ; Hočevar, et al. 2018 ; Papadopoulos, et al. 2018 ; Dudek, et al. 2020 ; Lobley et al. 2018*
- *Rural development (Pilar II)*[1]	*Pillar II is a key driver to adopt sustainability practices, but it is often a constraint as there is often a mismatch between EU policy aims and conditions on the ground*	*Popescu et al., 2020; Passeri, et al. 2016 ; Liberati et al., 202; Kazatova-Mateva, 2020*
- *Organic farming measures*	*CAP remains the main driver for the adoption of organic farming, but market demand remains a key factor and*	*Jaime et al. 2016; Popescu et al., 2017 ; Rocamora-Montiel, et al. 2014 ; Escribano, et al. 2015 ; Baležentis , et al. 2019; Varia, et al. 2021 ; Auzins et al. 2022 ; Spiegel, et al. 2022; Jahrl, et al. 2016 ;*

[1] CAP Pillar II provided the framework and the funding for the Rural Development Programmes which are managed at national and regional level (and unlike Pillar II for farm support it is co-financed in part by the Member States). Its key priorities are: Fostering agricultural competitiveness; Ensuring sustainable management of natural resources and climate action; Achieving balanced territorial development of rural economies and communities, including the creation and maintenance of employment. At 100bn euro for 2023-2027 it amounts to about one quarter of the total CAP budget, the rest being Pillar I for Direct payments and agricultural market measures.

	productive and geographical constraints	*Pawlewicz, et al. 2020 ; Buttinelli, et al. 2021 ; Cammarata, et al. 2021*
- *agri–environmental-climate measures*	*CAP agri-environmental measures are a main driver for behavioural change but they are often insufficient to motivate farmers to provide a broader portfolio of ecosystem services*	*Öhlund , et al., 2015; Pacini, et al. 2015 ; Frueh-Mueller, et al., 2018; Baur et al. 2018; Marja, et al. 2014 ; Passeri, et al. 2016 ; Bartolini, et al. 2019 ; Kazatova-Mateva, 2020 ; Lampkin, et al. 2020 ; Turlatova, et al. 2019*
- *areas with natural constrains measures*	*Effectiveness of CAP support in ANC is significantly affected by very local conditions*	*Pastusiak, et al. 2021; Bartulovic, et al. 2014; Lazíková , et al. 2019.*
- *Greening direct payments (Pilar I)*	*EU agricultural subsidies currently not being spent where they are most needed. They often result in distortive outcomes. More support for environment- and climate-friendly practices is required. Result-based payments and better monitoring of outcomes is necessary*	*Paulus, et al. 2022; Spiegel, et al. 2022; Popp, et al. 2015; Gazzani, et al. 2021 ; Slabe-Erker, et al. 2017*
Governance, incentives to sustainability	*CAP continues to encourage intensive agriculture- instead of smaller scale and less environmentally damaging forms of agriculture, it allows national incentives that are detrimental to CSA, there is insufficient evidence-based governance and overreliance of one-size-fits-all and insufficient understanding of trade-offs*	*Pilvere, et al. 2021; Rudnicki, et al. 2021; Scown, et al. 2021; Gazzani, et al. 2021 ; Pe'er, et al. 2020 ; Howe, et al. 2019 ; Whitfield et al. 2019; Lefebvre, et al. 2015; Popp et al. 2015; Rocamora-Montiel, et al. 2014 ; Xiao et al. 2015 ; Lampkin, et al. 2020 ; Dos Santos, et al., 2020*

Table 16: Reviewed articles focusing on CAP as policy instrument

Topic	Contribution to CSA	References
Agroforestry	The promotion of agroforestry practices at European level is still not well addressed by the CAP	Santiago-Freijanes, *et al.* 2021; Hernández-Morcillo 2018

Biodiversity	The present conservation model including AES should change in farmland areas in order to fill the ambition of the EU Biodiversity Strategy. This needs to take into account wider aspects beyond farm management. However, farmers having ownership of such schemes is key.	Díaz, *et al.* 2021; Palacín , *et al.* 2018; Batáry , *et al.*2015; Lefebvre , *et al.*2015; Grass , *et al.* 2021; Abeli , *et al.* 2022; Lombardo, *et al.* 2022; Di Guardo , *et al.* 2022.
Bioeconomy	Bioeconomical practices require a combination of factors, from market rules to very context specific socioeconomic determinants in order to work.	Jezierska-Thöle, *et al.*2021
Climate	The negative indirect effects of additional land-use change may outweigh the positive direct effects on global climate and biodiversity, so that a large-scale switch to organic farming in the EU could possibly turn out to be a disservice to global sustainability. Similarly, the increase in agricultural output gels with difficulty with reducing the demands on the environment and of GHG emission.	Purnhagen;*et al.* 2018;Verschuuren, 2018; Zaferiou; 2018; Rickard,2015
Greening	The Green Deal's aspirational stated goals go in the right direction but overreliance of CAP reform to achieve it on issues such as pollution is a concern, particularly without understanding the wider set of factors at play in, for instance, water quality. New instruments will be needed to close the gaps in the pollution continuum 'from source to impact', but with a farm-centred perspective.	Zieliński , *et al.*2022;Bieroza , *et al.* 2021; Singh, *et al.*2014; Baddeley , *et al.*2017; Klusáček , *et al.* 2021
Habitat	There is a complex and rather case-specific relationship between rules for habitat	Wiśniewski, *et al.* 2021 ; Šumrada , *et al.* 2021

	protection, including those of CAP provision of financial support for agricultural activities aimed at protecting valuable plant and animal habitats and species, and physico-geographical characteristics.	
Organic	Organic farming in the EU is a subject to development under the influence of the strategies related to the European Green Deal. However wider factors such as barriers are poor connections between farmers and distributors, bureaucratic procedures and low profitability as well as insufficient farmer ownership are key factors, only compensated by the growing public demand for this produce acting as a driver. EU rules need to be better spatially targeted. At present and contrary to perception these tend to favour larger scale production than small scale.	Kociszewski; 2022; Wiśniewski , *et al.* 2021; Ferasso;*et al.* 2021; Konstantinidis; 2018;Álvarez-Lorente; T. 2019
Pesticides	Present EU targets to reduce the use of fertilizers and pesticides are very challenging and it is an open question that can be deliverable.	Pańka, *et al.* 2021
Precision	Precision agriculture technologies have long been recognised as win-win solutions for environmental and socio-economic goals but their diffusion progresses at a slow rate.	Takácsné, *et al.* 2018
Smart	The existing EU governance does not fully exploit the potentials of digitalisation for environmental protection. The CAP should be designed in such a way that it links digitalisation-related objectives more closely	Garske, *et al.* 2021

	with sustainability targets.	
Soil	Soil degradation is addressed only indirectly in environmental policies and through the CAP promotion of farming practices that support soil conservation. There are deficits in monitoring and governance as well as incentives, introduction of precision farming and crop rotation practices that could complement them.	Costantini , *et al.* 2020; Garske , *et al.* 2020; Josefsson *et al.* 2017; Virto, *et al.* 2015; Macháč , *et al.* 2021;Schröder , *et al.* 2022
Sustainability	The EU Green Deal and Farm to Fork strategies recognise a new and important role for the agriculture and agri-food sectors and to invite farmers to engage consumers' interest. However, the integration between agricultural productivity and resource conservation is a challenge that tends to be context specific making it difficult to measure agricultural eco-efficiency in a comprehensive, comparative way.	Gargano , *et al.* 2021;Czyżewski , *et al.* 2021;Vasa; *et al.* 2017; Eksvärd , *et al.* 2018;Coluccia , *et al.* 2020; Martinho; 2020;Mitova; 2021; Gancone , *et al.* 2022.

Table 17: Reviewed articles focussing on specific topics and sectors

Almost two thirds of the studies surveyed address CAP incentives either explicitly or through the national programmes that implement them (Figure 22). This considers both the macro aspect (EU wide incentives towards more sustainability) as well as farm level behaviours, with focus evenly split between both. Almost all the surveyed research items dealt with climate/sustainability angle, whereas the smart element is almost testimonial. This has been observed both at the first stage and second stage of exclusion or works where most smart/digital, deal with technological solutions rather than explicit policies at EU or domestic level that foster their implementation, resulting most of those articles being excluded from the review. This was expected given that during the 2014-2020 period smart agriculture did not have specifically targeted measures, as opposed to sustainability which had agri-environment and climate, organic farming, payments to areas with natural constraint, NATURA 2000 and Water Framework Directive payments as specific measures.

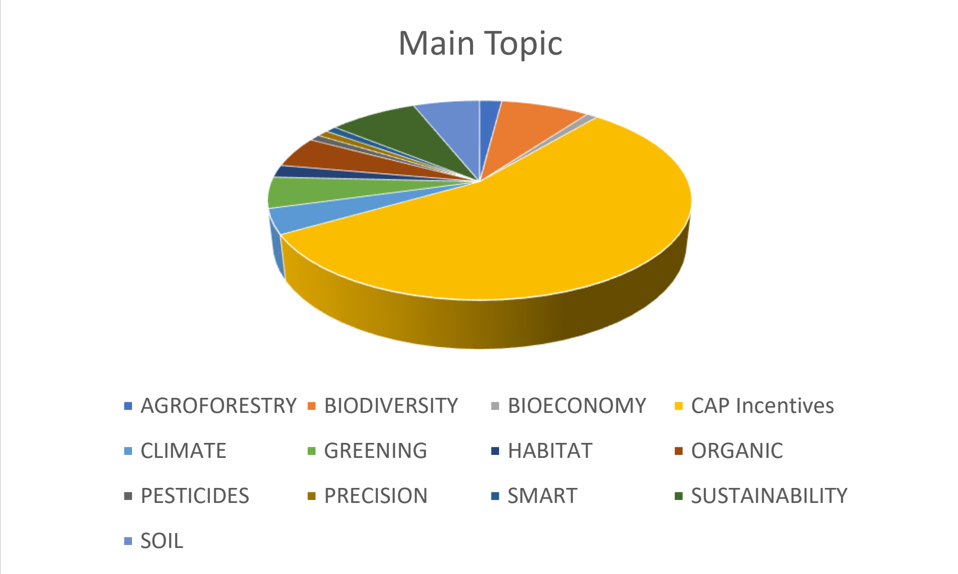

Figure 22: Main topic on policy review

6.5 Discussion

6.5.1 Introduction

This part of the Systematic Review for D1.1 is focused of the policy dimension of lock-ins and drivers for the adoption of CSA. The main prism to do so is the EU CAP as the key financial and behavioural incentive for the adoption of CSA that exists in Europe, as CAP is in fact the main delivery instrument to finance and implement the ambition contained in the wider EU strategies for climate and energy whose most recent iteration is the 2020 EU Green Deal. About half of the reviewed evidence deals with CAP as a policy and roughly the other half focuses on specific studies at national/subnational level or from a value chain angle.

A challenge which has been consistent in the different stages of PRISMA selection was the fact that Climate Smart Agriculture is a UN term that has little currency at EU level and thus CAP and the national rural policies (of which RDPs are often a key part) that largely rely on the CAP framework and subsidies. This is quite common as the EU regards itself as a *sui generis* international legal order that is not comfortable to accommodate to international (i.e. UN) law, policy and frameworks, hence the need to use a large range of proxies that could yield relevant results in lieu of using CSA as a search term, such as notably "smart farming" or "digital agriculture" which were search terms used in this review.

6.5.2 Detailed assessment of results

A more qualitative assessment of the findings summarised above suggests that existing CSA measures under CAP (themselves meant to be delivering critical aspects of EU environmental, sustainability and climate policies, the latest iteration of those is Green Deal) fail to meet the broader policy objectives set by the EU climate, Farm to Fork and Biodiversity Strategies and digital agendas. This is quite relevant as CAP is one third of the EU budget (€387bn across the above-mentioned period), and indeed it is much larger than the EU thematic funds (e.g., the LIFE programme, which is the EU funding instrument for the environment and climate action amounts to only €5,4bn). Given its size, the leverage that CAP can potentially provide for the adoption of climate smart practices is much higher than the policies and funds specifically gearing to the adoption of smart and sustainable practices.

The following discussion will focus first on the holistic aspects of CAP in the first instance, and specific aspects of sustainability linked to sustainability in the second instance, before providing some conclusions. It will finally consider some of the limitations of the study itself.

6.5.3 Overall contribution of CAP as driver for CSA

Considering the more holistic aspects of CAP as a driver for CSA, as many authors note (Glowinkel *et al.*, 2021; Gaymard *et al.* 2020, Scown *et al.* 2020, Pe´er *et al.* 2020), CAP is not capable to help achieve the EU own climate and nature protection goals, so much that the funding system act as a disincentive for small and medium sized farms and other sectors in the rural economy most in need which are then pressed out of the market or not being sufficiently supported (Verhees *et al.* 2018).

The economic and environmental impact of CAP in terms of improving environmental outcomes is without a doubt. However, in some cases, agricultural payments act as disincentive or do not take into account the adoption of sustainability practices (e.g. Slave-Erker *et al.* 2017) where agricultural payments were not associated with groundwater pollution with nitrates or as in Gazzani (2021) the unalignment between tax incentives and CAP subsidies that not only do not prevent but constitute a perverse incentive for the intensive use of fertilizers. Czyżewski *et al.* (2021) go as far as saying that with the exception of the cross-sectional impact of environmental subsidies, CAP payments may exert a negative effect on environmentally sustainable value.

Popp and Jambor (2015) note that CAP direct payments do not align with the EU food security goal, while greening measures or agri-environmental measures (Frueh-Mueller *et al.* 2018) are insufficient to meet the environmental challenges of EU agriculture, l*et al.*one the wider environmental challenges beyond agriculture.

Scown *et al.* (2020) speak of billions misspent in EU agricultural subsidies to improve sustainability (or spent in the wrong location and sector) thus making more results-based payments and better monitoring of outcomes a necessity in CAP.

Furthermore, the design of Less Favoured Areas payments may have a negative effect both in terms of sustainability outcomes but also in the economic incentives of local producers and the relationships between them; sometimes reducing the area covered by Less Favoured Areas (LFA) schemes but increase the aid intensity of those and increase the information to producers about them may be beneficial in economic and environmental terms (Pastusiak *et al.* 2021).

Indeed, the purpose of sustainable intensification under CAP is precisely to increase the scale of farms so that they can increase natural resource productivity growth, increase profitability, and ensure food security and minimise prices. In addition to some proactive measures (e.g., irrigation extension) achieving sustainable intensification would require phasing out direct payments in CAP (Rickard, 2015) no doubt a very controversial move.

That said, CAP is not a uniform policy and the incentives and disincentives it introduces also change over time. This can be exemplified by the extensive study by Xiao *et al.* (2015) whereby CAP has favoured both the loss of grassland for the period 1992-2003 and the restoration or re-expansion of grassland (2006–2010) in mainland France. This was coupled with the increase in the proportion of cropland in the total agricultural land use due to the demand of fodder as a result of conversion to grazing livestock to feeding livestock while continuing the intensification of livestock farming systems.

In conducting an extensive stakeholder exercise (105 stakeholders in 15 cases across Europe) the study of Linares-Quero *et al.* (2022) on the added value of CAP Pillar II (Rural development measures that support the processing and marketing of organic products, producer organisations, and short value chain, —regional development policies (e.g., LEADER programme), —practice-based payments (agri-environmental instruments and organic farming), R&D/advice/training/information provision compared to CAP Pillar I (area based payments -farm subsidies) stakeholders' perception show much better understanding of the added value of Pillar II instruments to support agroecological transitions (the agri-environmental and organic measures, the support for information and advisory services, and the support to organic market and short value chains for the development of sustainable food systems), but the above mentioned study of Linares-Quero *et al.* note key weaknesses such as insufficient funding and not sufficient spatial targeting of CAP to address local needs, as CAP overall still focused on large to large-scale, high-input, and capital-intensive agriculture, which prevents the transition to agroecological farming systems.

Verhschuuren (2018) also has a mitigated evaluation of the present EU regulatory framework for climate-smart agriculture particularly as regards to soil carbon sequestration, pointing out they are too generic, having too short timescales, not properly embedded in CAP and unevenly applied across the EU and does not include agriculture in emissions trading. The EU level of ambition and policy detail is below that of Australia's best practice which has extensive methodologies on a range of carbon farming methods, such as soil carbon sequestration.

Furthermore, there remains a deficit in the introduction via CAP of economic incentives -subsidies and other forms of economic support- to prevent soil degradation and of rigorous economic assessment on climate-smart agriculture, nature-friendly agricultural technologies and implementation of a range of nature-based solutions to protect soil, retain water in landscape, etc. This is clearly missing compared to the abundance of qualitative assessment of the current state and impacts of climate smart agricultural technologies (Macháč *et al.* 2021).

In considering the adoption of precision agriculture in Hungary Gyorgy *et al.* (2018) do find a positive correlation in the adoption of these techniques and increasing yields and benefits, but respondents believe that investment costs are a major barrier, information and subsidies are insufficient, with the Rural Development Programmes under CAP seen as a critical factor for the spread of this technology given the financial and policy leverage effect that CAP has compared with exclusive domestic policies and practices.

In the case of digitalisation of agriculture Garkske *et al.* (2021) find that a robust legal framework is not yet in place both in terms of product safety data privacy, access and security and as regards of CAP digitalisation-related objectives are still not sufficiently aligned with sustainability targets even overlooking possible negative side effects such as rebound and shifting effects.

In short, the role of CAP in introducing CSA is without a doubt. Given its wide policy scope and large size (indeed its budget is larger than the budget of many Member States) it can act as a driver of behavioural change at value chain and individual farmer level. However, its very size, path dependencies and trade-offs in what is a large multilevel and multipurpose policy (food production, market regulation, driver environmental, social and trading standards) result in that many of its instruments are too generic and often implemented very differently across Member States.

6.5.4 CAP evaluation

That said, CAP efforts to encourage more respectful environmental behaviour among farmers and cropping system, though showing a positive correlation, remain quite difficult to evaluate (Passeri *et al.*, 2016). Indeed, as Baur *et al.* 2018; Whitfield *et al.* (2017) note the complexity and interaction of the policy aims, the public goods that are meant to be provided and the instruments available to deliver them is complex so much that "evaluations of agri-environment support at the European level are still rare" let alone factoring in the trade-offs that in real life need to be operated between the above mentioned factors.

There is a lack of sufficient evaluation of eco-efficiency in agriculture particular at subnational or value-chain specific levels. To better understand the differences between geographical areas

Coluccia *et al.* (2020) propose a Data Envelopment Analysis (DEA) to develop a support tool for policy makers and managers that assesses the integration between agricultural productivity and resource conservation. Martinho (2020) proposes a model for decision makers that marries agricultural energy and farming indicators. This is even more needed in the newer Member States where there is a lack of comprehensive studies on environmental sustainability of farms both as a sector or in different value chains. This requires a multi-principle, multicriteria and multi-indicator framework that is targeted to various types of farm size, legal form, production specialisation and geo ecological context (Mitova, 2021).

6.5.5 CAP Governance

As regards to the governance of CAP despite increasing decentralisation of decision making and allowing them more flexibility in implementation decisions towards the Member States (MS) CAP is still not working in practice to achieve the wider stated sustainability goals that CAP is meant to achieve (Grzelak *et al.* 2019).

CAP is also often not granular enough in terms of addressing the needs of specific countries/regions and value chains in order to provide the desired sustainability outcomes.

Local and market factors do have play as the size of Rural Development Programmes (RDP) environmental support funding available in a given country and region, the availability of land and labour are often the most significant factors determining environmental measures uptake (Kazatova-Matera 2020; Dudek *et al.* 2020). A key issue, as Rudnicki *et al.* (2021) find in the case of Poland is the gap between the EU sustainability goals (e.g., 25% of EU total agricultural area devoted to organic funding) and the funding available, which only 9% of Polish agricultural land devoted to such agri-environmental measures.

At an EU-wide scale it can be noted that they contribute to the adoption of more sustainable practices in Western and southern Member States than they do in Central and Eastern ones where aid intensity and market conditions result in the biggest added value of CAP is in economic terms (Dos Santos *et al.* 2020). The structure of a given value chain also is crucial to the impact of CAP financial incentives (as seen for instance by Gebska *et al.* (2020) when assessing the impact and understanding of CAP sustainable practices in dairy and pork farmers compared to those involved in cropping).

Participatory tools that put producers at the centre of developing agricultural sustainability have great potential in improving CAP measures such as RDP schemes, such as that the tool designed by Lombardo *et al.* (2022) for the quality olive oil supply chain sector in Italy with compliance percentages approaching 100% in all four pillars of sustainability (environmental, food quality/supply, social and economic). Similarly, Delmotte *et al.* (2017) apply in southern France an approach consisting of combining the participation of local stakeholders in the design of narrative scenarios, and an integrated assessment of scenarios through the calculation of indicators at different scale with a bio-economic model.

Hence a more farmer centered approach is needed to implement and manage greening measures, as otherwise the incentive for investment over the need to reap the benefit of their investments (Singh *et al.* 2014). Similarly, Hočevar (2018) considers that the farmer-centred approach that incorporates their own narratives (even family histories) is essential to foster more sustainable farming practices.

6.5.6 EU Green Deal and CAP

With respect of the very recent introduction in the EU policy landscape of the Farm to Form and Green Deal policy framework (and within it the Farm to Fork strategy) and ambition, the limited litetature available so far provides a mitigated assessment of their translation in practical delivery terms. Authors such as Purnhagen *et al.* (2021) believe that these new EU strategies and the introduction of organic farming may have contradicting effects in terms of achieving global sustainability ambitions such as the Sustainable Development Goals (SDGs) because, despite their nominal contribution to certain sustainability goals, the trade-off of additional land-use change may outweigh the positive direct effects on global climate and biodiversity, resulting in that CAP-incentivised large-scale switch to organic farming in the EU could possibly turn out to be a disservice to global sustainability. Indeed, there is a positive relationship between GHG emissions and agricultural income (Zaferiou *et al.* 2018).

Other authors that are less critical believe that the framework provided by the Green Deal and the support of CAP in Areas Facing Natural Constraints (ANC) does compensate for some of the additional cost and lost income due to the adoption of more sustainable practices (Zielinski, 2022) A similar view is shared by Bieroza *et al.* (2021) as the Green Deal and its translation to CAP measures is a positive one, on issues such as water quality , even if it recognised that present measures under CAP lack granularity to tackle diffuse environmental problems such as water pollution. Díaz *et al.* (2021) in examining the Spanish Strategic Plan 2023-2027 that direct assessments of environmental objectives are technically and economically feasible, can be attractive to farmers, and are socially fair and of great interest for improving the environmental effectiveness of CAP measures.

The existing EU Green Deal and within it the Farm to Fork Strategy try to marry agricultural practice with ethical and social standards and invite farmers to address shifting consumer interest (and demand) towards sustainability (Gargano *et al.* 2021).

6.5.7 Agro-Environmental Schemes

Batáry *et al.* (2018), in conducting a pan-European review of agro-environmental schemes (AES) under CAP -whose overall effectiveness was questioned in a landmark review back in 2003- affirm that they demonstrate general increases in farmland biodiversity but with great variation depending not only on the quality of farm management but the on the structure and management of the surrounding landscape. Still, as Lefebvre *et al.* (2015) provide evidence, CAP policy and funding frameworks have not been detailed enough, requiring further coordinated actions at the landscape level and EU policy level. They point out the need to develop new policy instruments to coordinate actions of individual landowners (e.g., collective bonus in agro-environmental contracts or support to environmental cooperatives) and further recognition and transposition of the European Landscape Convention

In fact, in newer EU Member States a so-called Kuznets curve (Slabe-Erker, *et al.* 2017) exists, as the adoption of environment-friendly farming practices and crops' selection does not secure simultaneous high economic and environmental performance at least in the short run and in some cases necessitating more targeted agro-environmental measures (AEM) in the longer term.

Lefebvre *et al.* (2015) point out the lack of sufficiently tailored incentives such as agro-environmental contracts for landowners for landscape protection. Territorial Management Contracts which are *agreements between a group of farmers and the public administration that require the farmers within the group to meet a number of commitments to improve both production-related conditions and ecological, cultural and socio-economic aspects of their farms* (Rocamora-Montiel, *et al.* 2014) may be particularly beneficial in marginally productive areas while being fully in line with CAP governance and policy aims. This also applies to other areas that are not marginally productive, where the sustainable land stewardship has contributed to CSA.

In performing an extensive two-step scanning of agroforestry-based solutions for climate change mitigation and adaptation in Europe Hernández-Morcillo *et al.* (2018) have found that the key barriers were a lack of knowledge and reliable financial support whereas training programmes for agroforestry managers and development of safe economic routes are key solutions to promote sustainable agroforestry systems. In particular, improved soil organic carbon pools and implementation of multifunctional hedgerows were identified as the solutions having the greatest mitigation and adaptation potential respectively.

There is still a lack of knowledge transfer that promotes agroforestry at on the ground level, by using stakeholder integration within the policy development as it is currently done by the EIP-Agri (Santiago-Freijanes *et al.* 2021). Integrated, systems-based approaches of land management with sustainable redevelopment of agriculture, including central ecosystem services is particularly necessary particular on areas neglected by current policy frameworks: neglected grassland, set aside land, and marginal lands, paying attention to their connectivity with natural areas (Schröder *et al.* 2022).

More specifically, Marja *et al.* (2014) in the case of Estonia and Pacini *et al.* (2015) based on prior empirical research in Italy suggest that the, the design of efficient and effective AEMs should *(i) entail an outcome oriented approach with evidence available on the environmental benefits achieved under the shape of state or impact, performance indicators, (ii) allow for comparisons of alternative land use options in terms of resource use efficiencies, (iii) be compatible with policy changes in direct payments and market instruments, (iv) consider the extremely heterogeneous contexts of EU* (ibid.).

6.5.8 Organic farming and CAP

Despite its limitations the incentives of CAP to adopt sustainable practices or organic farming are the primary prime and, in some cases, the sole behavioural change driver available (Varia *et al.* ,2021). This requires a combination of a strong regulatory regime and in the case of organic farming robust product certification, understanding the cultural and heritage factors, the social and educational capital of the surrounding rural and farming environmental and a pro greening innovation drive value chain, particularly in the newer Member States that still deal with the consequences of economic transition from a planned economy (Klusáček *et al.* 2021).

In the case of organic farming the barriers for farmers are poor connections between farmers and distributors, bureaucratic procedures and low profitability, insufficient farming organisations. A comparative study for central and eastern Europe, indicated that while progress has been made towards organic farming this is not conceived as a systemic change from traditional agriculture but developed within that wider context (Jarl *et al.* 2016) For instance, Azurins *et al.* (2022) highlight that for organic pig production in Latvia the main barrier is insufficient knowledge.

On a more positive note, Kociszewski (2022) finds that at least for Poland that these challenges are balanced with expected demand growth and an environmental benefits and lower use of labour. This needs to be coupled with an appropriate spatial targeting of organic farming support CAP Rural Development subsidies by making it better suited to the environmental conditions prevailing in a specific area (Wiśniewski *et al.* 2021).

In reviewing the Polish agricultural economy Jezierska-Thöle *et al.* (2021) used the CAP Agri-Environmental Climate Measures for Organic Farming Systems (AECM/OFS) synthetic indicator which showed a strong spatial differentiation, determined by the impact of several conditions: the level of socioeconomic development, the level of agriculture development, natural conditions of agriculture, land with significant natural and ecological values, and pro-environmental forms of land use on farms.

Furthermore, moving from organic farming to agroecology as a model to achieve sustainable development requires not only a change in agricultural practices but also a change in the way actors conceive the world towards social and intergenerational responsibility (Álvarez-Lorente 2019).

However, authors such as Konstantinidis (2018) are more critical, depicting the European organic farming landscape tending towards large farm size, lower labour intensity, higher prevalence of mechanisation and tendency towards monoculture than a more sustainable agrarian management model where peasants and not only farmers have a place. Konstantinidis (2018) argues that European organic farms display features (large farm size, low labour intensity, high prevalence of mechanisation, and adoption of monocultures) that are characteristic of industrialised farming and other forms of intensification rather than peasant farms. These features raise doubts about whether European organic farming exemplifies what he calls “repeasantisation” (a form of smaller scale non industrial agriculture).

When considering the pig farming sector in Sweden Öhlund *et al.* (2017) find that the greatest divide is between conventional farmers focused on resource efficiency and organic farmers who prioritise animal welfare, multifunctionality and ecosystem service delivery. To address this divide they suggest to improve communication -in terms of social interaction but also as regards to specific forms of cooperation- between the different types of farms and to introduce more CAP incentives in terms of implementing payments for ecosystem services or multifunctionality. Still, the trade-offs are not always win-win as the ultimate goal should be to decrease the total production of pork to lower the emissions per land unit.

That said, research in Lithuania by Baležentis *et al.* (2019) shows that organic farming is less profitable and the gap between farm income in organic and conventional farms has increased during the observed period. This requires that the new CAP 2023-2027, which allows each Member State to develop their own eco-schemes to support and/or incentivise farmers to observe agricultural practices beyond mandatory requirements for climate and environment goals needs to factor in this income differential. Pawlewicz *et al.* (2020) in examining the differential in the take up of organic farming in Lithuania compared to Poland identify the design of CAP incentives as key, for if they have not a medium-term perspective of ensuring self-sustainable organic farming such practices would stop as soon as subsidies schemes are withdrawn.

More specifically about Sweden, Jaime *et al.* (2016) find that CAP support to organic farming post the 2003 reform has been positive, but that the effects of support is different between certified and non-certified organic production, with the former being exclusively driven by agri-environmental subsidies.

That said agroforestry production models such as extensive cattle farming can benefit from the move towards organic farming stimulated by CAP policy aims and policy aims and public demand if they reduce the dependence on external feed, implement more environmentally friendly farming practices, and pursue farm diversification as this will both lessen the farm's vulnerability and increase its production of environmental and social public goods (Escribano *et al.* 2015).

Karelakis *et al.* (2018) extensive survey in Greece points out that adoption of organic farming is much more a value-driven question (farmer attitude towards organic farming practices) and a mere question of economic indeed CAP-incentive driven behaviour. This is supported by the wider research carried out by Dessart *et al.* (2020) in reviewing 20 years of literature on behavioural factors that influence farmers’ decisions to adopt sustainable practices find that understanding behavioural factors influencing farmer decisions to be more sustainable is essential as existing CAP agri-environmental incentives are assuming a primarily rational choice approach by farmers, which then results in unrealistic expectations in policy planning and then lower than expected take-up.

6.5.9 Biodiversity and CAP

Concerning the relationship between CAP and biodiversity Palacín *et al.* (2018) alert about the insufficiencies of the present CAP promoted biodiversity conservation model in farmland areas, which is unable to prevent the decline of affect common farmland bird species in others agricultural protected areas.

Also, the split between land-sparing and land-sharing measures for the purpose of biodiversity conservation is an artificial one that fails to recognise the complexity of agricultural landscapes (Grass *et al.* 2021), and such coexistence is better addressed if farmers and local stakeholders are involved from the outset of the design of CAP schemes to protect biodiversity and a clear consideration of how this will affect their outcome (Abeli *et al.* 2022).

To do so, Di Guardo *et al.* (2022) have developed MIMERA a user-friendly tool, that combines field-specific information on selected parcels (pesticide usage, soil properties, slope, crop typology, and distance from surface water), and the physical-chemical and ecotoxicological properties of the pesticides.

6.5.10 Soil protection and CAP

As regards to the role of CAP in soil protection the starting point is to consider that EU Soil policy remains primarily the domain of EU environmental policy and CAP, which indirectly addresses the issue of soil degradation in addition to many other policy outcomes, including productivity in food production, with still a deficit in soil monitoring networks and decision-support systems (Virto *et al.* 2015). CAP has recognised that increasing or maintaining soil organic carbon (SOC) content under arable farming is a priority, and this needs to be tailored to local conditions such as the environmental factors (climate and soil characteristics), to the farming system (land use type, farm specialization, crop management), but also to the social and cultural context.

Constantini *et al.* (2021) believe that in the case of SOC storage in irrigated systems this require the extension of precision farming and other high-tech solutions that are genuinely adapted to local conditions and local strategies, together with extending soil cover periods and introducing rotation of cover crops in areas with limited water or harsh conditions. Understanding of relationships between the number (compositional heterogeneity) and spatial arrangement (configurational heterogeneity) of crop fields and biodiversity is generally poor, making the claims of the CAP greening measures for 2015-2020 relatively unfounded (Josefsson, *et al.* 2017).

In providing a comprehensive review of phosphorus governance of CAP incentives as well as in EU and national soil conservation , water conservation , fertiliser , circular economy and organic farming legislation Garske *et al.* (2020) show that there is still too many path dependencies in sustainable phosphorus management and identify the potential for improvement better recognising this problem in existing legislation as well as in the establishing of economic instruments might help to overcome governance deficit s of existing phosphorus regulation.

6.5.11 Summing up of key policy recommendations from the reviewed literature

There are a number of studies including in this mapping that provide some useful recommendations that are overall consistent with the above-mentioned findings, hence they are reproduced here.

In the extensive review of agroecology practices in France, Germany and the UK Lampkin *et al.* (2020) identify a number of key policy changes that are needed:

- a whole-food-system approach that considers the synergies between agricultural, environmental, food and public health policy;
- *reducing the use of problematic inputs and practices, for example by encouraging more use of legumes fixing nitrogen biologically to replace synthetic nitrogen fertiliser use across the whole value farming system and not in isolated farms;*
- *foster diversification of production and food systems, as well as farm autonomy and adaptive capability, to improve farm resilience and capacity to absorb shocks;*

- *integrate biodiversity and habitat conservation within farming systems, as well as the conservation of natural resources, with a land sharing approach to agriculture and the environment;*
- *tackle questions about the role of livestock in farming systems and human diets (Aubert et al., 2019), with a focus on complementarity and moderation of consumption; address issues of economic exploitation and power relations as well as problems of overconsumption and food waste in food chains, with implications for public health;*
- *social justice and food security;consider shifting the emphasis of support from land area to people employed in agriculture and related food businesses, which would make it possible to favour "job-rich"-farms, with the capacity to implement environmental and other public good actions;*
- *support the process of transition, in particular recognising the different stages and the need for both learning new approaches and 'unlearning' previous convictions, requiring a fresh approach to advice, training, education, and information services, for practitioners, their support agencies and more widely in society (Padel et al., 2020).*

Perhaps by way of summing up a significant part of the body of literature reviewed above it may be appropriate to cite a paper Pe´er *et al.* (2020) where they do recognise the value of the Commission´s proposals for CAP post 2020 in terms of enhanced sustainability but reckon that this does not go far enough, and propose the following 10 key measures, summarised here:

1. *Transform Direct Payments into payments for public goods, to align both environmental and socio-environmental dimensions of sustainability, given the poor performance of Direct Payments for both;*
2. *Provide sufficient support for effective climate change mitigation, aiming to reduce GHG emissions in the agricultural sector with a focus on improved nitrogen fertilizer application, rewetting of peatlands and improved GHG balances from livestock husbandry;*
3. *Provide sufficient support for effective instruments to maintain biodiversity and ecosystems, aiming to halt and reverse ongoing declines in farmland biodiversity (Mace et al., 2018). By securing and enhancing budgets for AECM and Eco-Schemes and other environmental measures in both Pillars; restoring the pre-2009 requirements for Member States to set aside at least 10% of Utilised Agricultural Area for nature and semi-natural habitats; expanding support for low-input production without or with minimal chemical fertilizers or pesticides (e.g. organic farming), expansion and longer-term maintenance of fallow land (Pe'er, Zinngrebe, et al., 2017) and extensive grazing on High Nature Value farmland; channelling support to efficient (so-called 'dark green') measures; and achieving a coherent and synergistic policy design across Pillars (e.g. Lakner, Holst, Dittrich, Hoyer, & Pe'er, 2019).*
4. *Promote innovative approaches to design and implement measures addressing the environmental challenges, such as result-based remuneration of AECM (e.g. oriented to target species or habitats, Herzon et al., 2018), or the introduction of a points system to reward farmers for their ambition and/or investments, as also proposed by several farmer organizations (e.g. Neumann, Dierking, & Taube, 2017).*
5. *Enhance spatial planning and collaborative implementation of landscape-level measures, as such approaches have been shown to be successful with respect to environmental aims (Westerink et al., 2017). such as maintaining water quality (Jones et al., 2017; Lomba et al., 2020), reducing fire hazard (Moreira & Pe'er, 2018) and contributing*

to the EU's strategy on Green Infrastructure. Such approaches should entail longer-term contracts with farmers to improve income security and ecological benefits.

6. *Require Member States to set S.M.A.R.T. targets in their Strategic Plans (i.e. specific, measurable, ambitious, realistic and time-bound; Green et al., 2019) in order to fulfil all CAP objectives. Member States should be obliged to demonstrate how they address trade-offs between objectives (see Supporting Information in: Pe'er et al., 2019).*
7. *Revise the set of indicators to ensure they are supported by the best available science and comply with the indicators of the Sustainable Development Goals (SDGs), the Convention for Biological Diversity (CBD) and the United Nations' Framework Convention on Climate Change (UNFCCC). Implementing a result-based approach requires both result and impact indicators to be adequate and meaningful (Herzon et al., 2018). For example, well-established biodiversity indicators such as the Butterfly Grassland Indicator (Van Swaay et al., 2019) should be added to complement the Farmland Bird Index, and the indicator of High Nature Value farming should be maintained and improved.*
8. *Strengthen environmental monitoring and enforcement to ensure that CAP instruments lead to desirable results, including EU annual monitoring (e.g. using the EU's reporting system to account for yearly changes in land-use/cover and management).*
9. *Identify and address global impacts of the CAP especially in the global South, to achieve a reduction of environmental leakage and global negative land-use effects as well as market distortions by EU agriculture, and to comply with the EU's principle of 'Policy Coherence for Development' (Article 208 of the Treaty of the European Union; EC, 2019a; Matthews 2018a, 2018b). The EU needs to strive for a better understanding of the impacts of its agricultural sector on developing countries' ability to meet the SDGs, and the roles of agricultural payments (Yang, Lupi, Zhang, Chen, & Liu, 2018) and unsustainable imports, especially of animal-derived products, feed and biofuel (Barthel et al., 2018; Matthews 2018a, 2018b; Schulmeister, 2015). Beyond the CAP, strengthening international agreements and environmental governance systems, as well as communicating about sustainable consumption levels that reflect European and global capacity, are options here.*
10. *Improve governance of the CAP and its reform in order to enhance transparency, accountability, participation and knowledge-uptake in line with SDG 16, and thereby regain legitimacy and public trust (Pe'er et al., 2019).*

6.6 Conclusions

As the detailed assessment summarised in the table and particularly in the discussion above show, CAP policies and funds have a significant when not determinant in incentivising behavioural changes, and management practices adopted, towards CSA at farm but also industry, region/Member Sate and EU level. That said, the shortlisted peer-reviewed research outputs show that in the main the current policy frameworks are insufficient in the case of sustainability driven behavioural change (including digital and smart agriculture).

This mapping exercise primarily focused, as shown in the keywords used, to assess the overall alignment of CAP and related rural policies in delivering EU environmental and climate goals by way of incentivising climate-smart agriculture.

Thus, it aims to provide a baseline to support the start of BEATLES and assess the relevance of its research questions against existing literature on CAP as a whole, rather than a detailed analysis of specific lock ins and incentives, as this would require a more granular, sector by sector assessment of direct payments (decoupled and coupled) and rural development funding, bureaucracy, advisory services, training, voluntary vs mandatory schemes to come up and how these have affected adoption of climate-smart agriculture.

A second limitation of this review is that clearly, the peer-reviewed papers contain a limited number of scientific articles that specifically refer to the Green Deal for this new iteration of EU sustainability policies while it builds of the plans from the Barroso and Juncker Commission was only put in place in early 2020 with the entry into office of the Von der Leyen Commission in December of the previous year. Together with the COVID-19 related delay in launching the new CAP for 2023-2027 and the time lag of peer-reviewed publication process it is not surprising that mentions of Green Deal in peer-reviewed, specialised literature is still less abundant than in general non peer reviewed policy papers, as shown by our selection.

Despite these methodological limitations, the findings across the surveyed literature are quite consistent both those that have a more holistic, pan-European focus and those that are more country or value-chain-specific.

A significant body of the surveyed research shows that still today CAP favours intensification or is not able to avoid outputs contrary to enhanced climate sustainability in agriculture. This is rather consistent in both pan-European policy-focused studies as well as those pieces of research that is case-, country/region- or sector- specific.

Of particular interest for BEATLES are those farm and farm-centred research outputs, as they show the complexity of factors that affect behavioural change, of which CAP rules (or national ones such as fiscal incentives) are a key but by no means an exclusive factor for behavioural change, as this is combined with sector and geographical specific factors and, more still, with under-researched and usually difficult to grasp social , cultural and perception factors that can in some times have a key driver in promoting or preventing behavioural change.

This validates the planned BEATLES field research, and it will provide outputs that can be then transposed into policy recommendations in WP5.

6.7 References

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7. Farmer survey of the decision-making factors for CSA adoption

7.1 Introduction

The main aim of this study was to provide empirical evidence about the decision-making factors that affect farmers' behavioural change towards climate-smart agricultural practices (CSA). The study focused on European farmers and their intentions to adopt CSA were elicited through a farmer survey focusing on farmers from 6 UCs (Denmark, Germany, Lithuania, the Netherlands, Spain, and Slovenia). The survey focused on eliciting farmers' views on individual, systemic, and policy and institutional decision-making factors as determinants of behavioural change for adoption of climate-smart agriculture.

7.2. Research Methodology

The survey was designed by a team of researchers from Agricultural University of Athens, Wageningen University and Research and University of Copenhagen as BEATLES project partners. The survey questionnaire contained a brief description of the BEATLES project, including research objectives and a brief description of CSA. The questionnaire was formulated in English and subsequently translated to local languages (Danish, Dutch, German, Lithuanian, Spanish, Slovenian) (see Appendix table FS4). The questionnaire was distributed using Qualtrics and administrated by Wageningen University. The UC leaders and partner institutions communicated the survey link to their personal networks, farmer associations and on their social networks (Linkedin, Twitter, Facebook). The data collection period was from January 2023 to March 2023. After collecting the data, the open questions were translated back into English.

The farmer survey included questions involving individual, systemic, and policy-related decision-making factors for adoption of climate smart agricultural practices and technologies. The survey started with a definition of what CSA is with some examples of CSA practices and smart farming technologies. The first question of the survey asked farmers whether they know what CSA is and whether they have used CSA practices in the past five years. Farmers who reported using CSA before were then asked to describe the CSA practices they have used. The questions aimed to identify whether farmers are adopters or non-adopters of CSA. Regarding individual decision-making factors questions on age, gender, level of formal education, household income, household size, experience in farming are considered as well as psychological factors such as perceived behavioural control, farming motives, risk tolerance, perception on their financial situation and self-responsibility. Factors related to the farm were also measured including farm size, farm ownership status, annual farm income, main production system and participation in a farmer cooperative. Technology-related variables considered included perceived technology usefulness, perceived ease to use and perceived compatibility are elicited as unobserved individual decision-making factors for adoption of CSA.

Systemic factors examined included subjective norms, perceived equity (perceptions on fair share of the various agri-food stakeholders' contribution to sustainability), perceived honesty about agri-food value chain stakeholders to sustainability, and perceived contribution to sustainability of the various agri-food stakeholders. Moreover, information sources use, extension and advisory services, availability of certification, market prices and access to market were examined as part of the systemic factors. Finally, the perception on the policy and institutional framework that focused on policy support towards CSA adoption and access to creed in case of financial need are also examined. The dependent variable of the survey was the stated intention to adopt CSA in the future. To determine the importance of the decision-making factors, the seven-point Likert scale is used including the response categories namely completely disagree (1), disagree (2), somewhat disagree (3), neither disagree nor agree (4), somewhat agree (5), agree (6) and completely agree (7).

Data from 721 farmers was analysed, with 631 fully answered observations and 90 not fully answered observations. The 90 observations were included because the farmers answered most of the decision-making factors relevant to our analysis. To understand the factors affecting adoption intention, we used descriptive statistics and correlation analysis. Cronbach's alpha was applied to measure the reliability for a group of questions (items) on a scale, and an alpha value above 0.70 is taken as evidence that a collection of items consistently measures the same characteristic (see Appendix table FS1). Based on reliability analysis, we computed mean to construct composite variable for those items whose alpha value greater than 0.7. We did the frequency and percentage for categorical variables included in this survey. We also included the items-based mean and standard deviation of those all Likert scale type variables for further reference (see appendix table FS2).

For correlation analysis, we used Spearman's ranks correlation coefficients to see the correlations of the hypothesized decision-making factors with adoption intention of CSA. The Spearman's correlation (r_s) with the absolute value of 00-0.19="very weak", 0.20-.39="weak", 0.40-.59="moderate", 0.60-.79="strong", 0.80-1.0="very strong" was used to decide the correlation between the variables. The results were analysed and presented at aggregate level.

7.3. Results and discussions

7.3.1. Descriptive statistics

The main result this farmers survey analysis focuses on decision making factors for adoption of CSA. Accordingly, the decision-making factors like individual, systemic and policy are discussed in below sections.

Knowledge and stated adoption.

The current knowledge about CSA, past behaviour and their intentions are discussed before going to further factors. Concerning farmers' knowledge of climate smart agriculture practises of technology, about 73% of the sample's farmers had heard of the term. Regarding the past behaviour of the sampled farmers, about 46% of the farmers have used CSA practises and technologies before (Table 18). This indicates that, even though the majority of farmers have heard about the CSA, some have not yet used it on their farms.

Knowledge-Have you heard of the term climate-smart agriculture practice or technology before?		
Yes, I have	No, I haven't	Total
523	198	721
72.54	27.46	100.00
Past behavior-Have you used a climate-smart agriculture practice or technology in the last five years?		
334	387	721
46.32	53.68	100.00

Table 18: CSA knowledge and past behaviour

Stated intention towards adoption of CSA.

Based on reliability test for hypothesized items questions to measure stated intentions of farmers towards adoption of CSA, Cronbach's alpha (0.919) was accepted to construct a composite variable. Therefore, the results of the three items used to measure intention were summed and the mean used to represent this composite variable. Accordingly, the mean of 4.95 for stated intention to adopt CSA shows that majority of sampled farmers are somehow agree with to adopt CSA (Table 19).

Stated intentions	N	Mean	Std. Deviation
Composite mean	721	4.952	1.369

Table 19: Stated intention towards adoption of CSA

7.3.1.1. Individual Factors

Socio-economic characteristics of sampled farmers

Regarding gender distribution (Table 20), majority (about 71%) of the sampled farmers are males. In terms of age, in Table 20, 4.78%, 12.22%, 13.76%, 21.21%, 30.06%, and 17.98% of those survey participant farmers are under the age of 20 years, 20–29 years, 30-39 years, 40–49 years, 50–59 years, and over 60 years old, respectively. Regarding education levels, 0.84%, 3.50%, 11.06%, 32.91%, 31.23% and 20.45% of the sampled farmers have no training, primary school, secondary school, vocation, a bachelor's degree, and a master's degree, respectively. So, our sample consists of a high number of highly educated farmers. Regarding income level, Table 20 indicates that 11.34%, 12.32%, 18.07%, 12.46%, 7.28% and 13.87% of the sampled farmers have incomes of EUR 10.000 or less, EUR 10.001 to EUR 25.000, EUR 25.001 to EUR 50.000, EUR 50.001 to EUR 75.000, EUR 75.001 to EUR 100.000, and EUR 100.001 or more, respectively. While 3.08%, 7.56%, and 14.01% of the sampled farmers indicate that they have no income, they don't really know and they chose rather not to say, respectively. Regarding farming experience in Table 20, about 11.34, 17.23, 13.45, 9.94, and 48.04 percent of the sampled farmers have been working in farming for less than 5 years, 5 to 10 years, 11 to 15 years, 16 to 20 years, and more than 20 years, respectively.

Variables categories	Variables with their response categories						
	Gender						
	Male	Female	Other	I would rather not say	Total		
Individual	512	191	1	10	714		
	71.71	26.75	0.14	1.40	100.00		
	Age						
	Less than 20	20-29	30-39	40-49	50-59	Greater than 60	Total
	34	87	98	151	214	128	712
	4.78	12.22	13.76	21.21	30.06	17.98	100.00
	What is your highest education level						
	No training	primary school	Secondary school	Vocation	bachelor	masters	Total
	6	25	79	235	223	146	714
	0.84	3.50	11.06	32.91	31.23	20.45	100.00
	The number of persons in my household are						
	One person	two persons	three persons	four persons	five persons	Six or more	Total
	54	211	121	173	98	57	714
	7.56	29.55	16.95	24.23	13.73	7.98	100.00
	For how long have you been working in farming? In years						
	less than 5	5 to 10 years	11 to 15	16 to 20	more than 20	Total	
	81	123	96	71	343	714	

	11.34	17.23	13.45	9.94	48.04	100.00				
Farm related	**What is your farm size? In hectare (ha)**									
	less than 2ha	2 to 10 ha	11 to 50ha	51 to 100 ha	101 to 200ha	201 to 500ha	More than 500ha			
	60	106	176	131	111	74	56			
	8.40	14.85	24.65	18.35	15.55	10.36	7.84			
	The main production system of the farm is									
	Arable crops	Open field vegetable	Orchards	Vineyards	Livestock	Mixed farming	Total			
	317	55	27	18	125	172	714			
	44.40	7.70	3.78	2.52	17.51	24.09	100.00			
	The annual farm income of my household is:									
	No income	EUR 10.000 or less	EUR 10.001 to 25	EUR 25.001 to 50	EUR 50.001 to 75	EUR 75.001 to 100	EUR 100.001 or more	I really don't know	I'd rather not say	Total
	22	81	88	129	89	52	99	54	100	714
	3.08	11.34	12.32	18.07	12.46	7.28	13.87	7.56	14.01	100.00
	The ownership status of your farm? Largest percentage of the land									
	Privately	Rented	Total							
	503	211	714							
	70.45	29.55	100.00							
	Do you belong to a farmers' cooperative?									
	Yes, I do	No, I don't	Total							
	282	432	714							

Table 20: Socioeconomic characteristics of survey respondents

Note: in each variable presented the first rows represent frequency while second rows represent percentage. E.g., 512 farmers in the sample are male which constitutes 71.71 % of the whole sample.

The other category of individual decision-making factors is farm related including household size, farm size, farm ownership status, the main production system of the farm and cooperative membership are also described in table 20. In terms of household size, table 20 shows that 7.56%, 29.55%, 16.95%, 24.23%, 13.73% and 7.98% of sampled farmers have one person, two people, three people, four people, five people, or six or more in their households, respectively. Regarding farm size, in table 20, 8.40%, 14.85%, 24.65%, 18.35%, 15.55%, 10.36% and 7.84% of sampled farmers have less than 2 hectares, 2 to 10, 11 to 50, 51 to 100, 101 to 200, 201 to 500 and more than 500 hectares of farmland, respectively. Regarding the largest percentage of the land under farm ownership status, 70.45% of the sampled farmers have privately owned farmland, while for the remaining 29.55% of the sampled farmers land is rented (Table 20). In terms of farm production type, descriptive result in table 20 shows that arable crops, open field vegetables, orchards, vineyards, livestock, and mixed farming are the dominant production systems for 44.40%, 7.70%, 3.78%, 2.52%, 17.51%, and 24.09% of sampled farmers, respectively. Membership in cooperatives is another farm related observed variable hypothesized to have an influence on the CSA adoption decision and the descriptive result on the sampled respondents indicated that about 40% of the participants farmers are members of the farm cooperative while about 60 percent of the sampled farmers don't (Table 20).

Individual psychological variables

For reporting a mean and standard deviation, Cronbach's alpha was used to determine whether they can be combined into a scale or Likert-scored items. Based on Cronbach's alpha for reliability test (see Appendix Table FS1) for a group of items questions supposed to capture unobserved individual decision-making variables towards adoption of CSA, items of questions under behavioral control, farming motives, and self-responsibility are accepted to construct composite latent variable. While items of questions that are supposed to indicate risk tolerance and perception on individual financial situation are not accepted to construct composite variable as their Cronbach's alpha value is below 0.7. Accordingly, the mean and standard deviation for these two variables is presented in their individual Likert-scored items.

The descriptive statistics for the farmer-specific psychological decision-making factors are presented in Table 21. Accordingly, the mean of 4.65 for perceived behavioral control that is constructed by composing the farmer's perception of farmers ability to implement CSA, their confidence, availability resources, time, and willingness to apply CSA indicate that the majority of farmers somehow agree with it as a decision-making factor for adoption intention. Farm motives for running farm business that was constructed by items of questions that focus agreement on low labour need, high yields, and income, maintains the traditions of their family, low production costs, the highest quality products, environmentally friendliness, care of animal welfare, public health, and fairly priced products as an important farm motive is other considered individual decision-making factor. According to the result in table 21, the mean of 5.6786 shows that the majority of sampled farmers agree with considering farming motives for running their farm business. Regarding perceived self-responsibility, the composite mean of 5.685 in table 21 indicates that majority of sampled farmers agree that farmers are self-responsible to contribute to a better environment, better animal welfare, fairly priced products, better public health and more jobs for people in my local area. Regarding the extent of agreement on risk tolerance with a mean of 5.80 (Table 21) show that the majority of the sampled farmers agree with their preference towards certainty over uncertainty while making their farm business decisions. While the majority of the sampled farmers somehow disagree with the statement "I like to take financial risks" and majority of sampled farmers somehow agree with the statement "I avoid risks in my investments" while making their farm business decisions. With regard to individual farmers' perceptions on their financial situations (Table 21), the majority of farmers neither disagree nor agree with the sufficiency of their financial resources and household's income for their needs. While the majority of the sampled farmers somehow agree that they are investing less in their farms than they used to due to the current economic circumstances.

Perception of CSA as a technology is another individual decision-making factors presented in table 21. Accordingly, the mean of 5.25 indicates that the majority of sampled respondents somehow agree with their perception of the ease of use of CSA technology that they are going to adopt in terms of its ease of learning, controlling, and understanding how it is used. Regarding perceived CSA technology usefulness, with a mean of 5.52, the majority of sampled farmers agree that the CSA technologies that will lower production costs, increase productivity, reduce workload, and be useful for their farm operations are considerations for making adoption decision. Perceived compatibility that captures consistency with farming goals and that suits the way farmers like it: the majority of sampled farmers agree with compatibility of CSA technologies with their farming goals for adoption decision making.

Category	Construct / variables	N	Mean	Std. Deviation
Individual	Perceived behavioral control	721	4.652	1.278
	Farming motives	689	5.679	0.828
	Perceived self-responsibility	689	5.685	0.964

	Risk tolerance			
	I prefer certainty over uncertainty	689	5.80	1,174
	I like to take financial risks	689	3,33	1,721
	I avoid risks in my investments	689	5,15	1,417
	Perception on individual finance situation			
	My financial resources are sufficient	633	3.91	1.581
	I can get by with the income of my household	632	4.22	1.678
	Because of the economic situation, I invest less in my farm than I used to do	633	4.63	1.686
Technology related	Perceived ease to use	721	5.2507	1.46299
	Perceived compatibility	721	5.5208	1.32651
	Perceived technology usefulness	721	5.3172	1.51248

Table 21: Composite mean for individual psychological variables

7.3.1.2. Systematic decision-making factors

Descriptive statistics on systemic factors for decision making towards adoption intention are presented below table 22. Membership of the farm cooperative is one of the observed systemic factors considered and the descriptive result on the sampled respondents indicated that about 40% of the participants farmers are members of the farm cooperative (Table 22). The subject norm that is constructed by composing the perception of farmers on the influence of the surrounding and similar farmers' CSA adoption behaviour, valuation of people opinions who are important to them on CSA, and their approval for use of CSA (Table 22) shows that the majority of sampled farmers neither disagree nor agree with it while making their adoption decisions. Regarding perceived equity that used to capture the fair contribution of farmers based on other stakeholders' contribution, table 22 shows that most sampled farmers somehow agree if they surely know that other farmers, supermarkets, food industries, and consumers also make a fair contribution to a better environment, animal welfare, and fair trade. Regarding farmers perceived contribution to a better future as decision-making systemic factor, the mean of 5.29 (Table 22) indicates that majority of the sampled farmers agree that farmers do more for a betterment of climate, animal welfare, and fair trade than the supermarket, food industry (such as dairy companies, fruit and vegetable processors, and meat industries) and consumers.

Construct /variables	N	Mean	Std. Deviation
Perceived equity	650	5.053	1.512
Perceived contributions	650	5.292	1.336
Subjective norm	650	4.128	1.202
Perceived honesty	650	3.533	1.137
Perception on CSA certification	673	3.444	1.198
Perception on access to market	673	3.570	1.266
Perception on fair price_WTP	672	2.877	1.369
Perception on information sources	636	4.859	0.867
Perception of extension and advisory services	636	4.397	1.205

Table 22: Composite mean for systemic decision making factors

This decision-making factors category also includes information and extension or advisory service sources to capture to what extent farmers use these sources in their farming-related activities for adoption decision making. The extent of the use of the internet or social media, family and friends, mass media, other farmers, farmer associations, training courses, trade events, fairs on agriculture, and agricultural advisors as information sources for farm business-related queries was used to construct the extent of the information source. The mean of 4.86 in table 22 for information source indicates that the majority of the sampled farmers somehow agree on the use of these information sources for farm business-related inquiries. While regarding extension or advisory services (table 22), the majority of sampled farmers neither disagree nor agree on extent of their use on farmer trainings, farm visits, field demonstrations, field/farmer days, workshops or open discussions, advisory services, and other sources for the agricultural training and advice. Regarding perception on the certification of climate-smart agriculture (Table 22), majority of the sampled farmers are somehow disagree on the availability of certification when required, ease of obtaining certification for CSA based farm production and cost of obtaining certification for CSA based production. Perception on the fair price of the CSA products, table 22 indicates that majority of sampled farmers somehow disagree with easiness of finding buyers (wholesalers and retailers) and consumers who are willing to pay fair prices for climate-smart agricultural production. Concerning perception on the access to market, majority of the sampled farmers neither disagree nor agree with the statement of easier to sell their products on the internet, reach a physical marketplace and access the input markets needed for their agricultural production (Table 22).

7.3.1.3. Policy and institutional frameworks

Perceptions on the governmental financial support in terms of schemes, tax reductions, subsidies, and existing policy and regulation support for CSA in Table 23 show that the majority of sample farmers somehow disagree on the adequacy of financial support policies and regulations for climate-smart agriculture applications (Table 23). Regarding credit access perception, the majority of the sampled somehow disagree with the statement about the ease of getting access to a loan to support their financial needs and the transparency of the loan-receiving bureaucracy (Table 23).

Construct /variables	N	Mean	Std. Deviation
Perception on governmental support and existing policy	673	3,4220	1,55080
Perception on accessing loan needed	673	3,4398	1,45176

Table 23: Composite mean for policy decision making factors

7.3.2. Correlation analysis

We conducted the correlation analysis of hypothesized independent variables with the stated intention of CSA adoption to test the null hypothesis (H_0) that the stated adoption intention of CSA and the hypothesised independent variables are independent. We used the Spearman's correlation (r_s) with the absolute value of 00-0.19="very weak", 0.20-.39="weak", 0.40-.59="moderate", 0.60-.79="strong",0.80-1.0="very strong" to decide the extent of the correlations between the dependent and independent variables.

Correlation analysis for individual decision-making factors.

Regarding correlation analysis of socioeconomic variables and stated adoption intention, a Spearman's correlation (r_s) was run to assess the relationship. Accordingly, the age and gender farm household head are negatively and significantly correlated with adoption intention (Table 24). Farming experience of sampled farmers, however, was not significantly correlated with adoption intention. Regarding the extent of correlation, gender and age of farmers have a very week negative correlation with stated CSA adoption intention as value of r_s evident. This indicates that farmers with younger age group have higher adoption tendency towards CSA. The negative relation of gender and adoption intention shows that females farm households have lower adoption intentions for adoption of CSA.

While the correlation analysis of education level, household size and farm income level of farm household with stated adoption intentions shows positive and significant interdependence (Table 24). With extent of interdependence, they have weak correlation. This indicates that for higher education and income level, the adoption intention increases. Among the farm characterics related hypothesized variables, farm size and farm ownership are significantly and positively correlated with CSA adoption intentions. This indicated that farmers with large farm size and private owned farmland have higher adoption intentions of CSA as compared to the counter parts.

Regarding correlation of individual psychological variables and adoption intention, perception of self-responsibility, farm motives, in table 24 shows a significant and weak positive interdependence. Correlation regarding risk tolerance, perception of financial risk taking is positively and significantly related with adoption intention. While regarding financial situations, perception of the financial resources' sufficiency and perception on sufficiency of household's income are significantly and positively correlated with adoption intention (table 24). While the preference of certainty over uncertainty as risk tolerance of sampled farmers, however, was not significantly correlated with adoption intention. Regarding to technological perception of farmers, significant and positive correlation was found between the farmers perceptions on CSA technologies, perceived ease to use, perceived compatibility, perceived technological usefulness and their adoption intentions (table 24). This indicates that compatibility of new technology with existing farming goals of farmers and its easiness to use and understand will increase adoption intention CSA technology.

Variables	N	Correlation coefficient	Significance
Socioeconomic characteristics			
Age	713	-0.0669	0.0741
Gender	713	-0.1078	0.0040
Education level	713	0.1362	0.0003
Household size	713	0.1444	0.0001
Farm income level	713	0.1354	0.0003
Farming experience	713	-0.0191	0.6112
Farm characteristics			
Farm size	715	0.2235	0.0000
Farm ownership	715	0.1019	0.0064
Farm production type	715	-0.0176	0.6381
Farm cooperative membership	715	-0.0488	0.1922
CSA technologies related variables			
Perceived ease to use	721	0.209	0.000
Perceived compatibility	721	0.365	0.000
Perceived technological usefulness	721	0.180	0.000
Psychological variables			
Perception of self-responsibility	689	0.2221	0.000
Farm motives	689	0.2336	0.000
Risk tolerance-prefer certainty over uncertainty	689	0.058	0.129
Risk tolerance - avoid risks in my investments	689	-0.003	0.941
Risk tolerance- like to take financial risks	689	0.110	0.004
Perception of the financial resources' sufficiency	633	0.154	0.000
Perception on sufficiency of household's income	632	0.169	0.000
Perception of investing less in their farm than they used to due to the economic situation.	633	0.010	0.795

Table 24: Individual decision-making factors and intention correlation

Systemic decision-making factors

The correlation analysis of adoption intention and subjective norm that was used to capture the descriptive norm of farmers in terms of what the surrounding and similar other farmers are applying and the injunctive norm that represented the valuation of people's opinions for those who use CSA and the approval of people who are important to them reveals a significant and positive relationship (Table 25). Regarding perceived equity, where farmers only want to contribute to a better environment, animal welfare, and fair trade if they know that stakeholders within the food value chain also contribute fairly, Spearman's correlation indicated that it has a weak positive correlation with CSA adoption intention (Table 25). The correlation analysis intention with farmers perceived contribution to a better future and perceived honesty on other stakeholders' contributions to a better climate, animal welfare, and fair-trade show reveals a significant and positive correlation. Regarding the correlation between intention and perception on certification CSA products, it is a significant and positive indicating that availability and easily getting CSA product certification will increase the adoption intention of CSA Correlation analysis for perception on buyers' willingness to pay for CSA products and stated adoption intention reveals a positive and significant correlation. This shows that having a premium price for their CSA-based products will increase their adoption intentions. Regarding perception on market access and intentions, the correlation analysis in Table 25 reveals that there is significant positive interdependence. Regarding the correlation between farmers perception on the extent of extension and advisory service sources for agricultural training or advice and CSA adoption intention (Table 25), there is a significant and positive correlation with adoption intention. Finally, the correlation between the farmers' perception on information sources used for farming business queries and adoption intention shows a positive and significant correlation (Table 25).

Construct	N	Correlation coefficient	Significance
Perceived equity	650	0.1356	0.0005
Perceived contributions	650	0.1013	0.0098
Perceived honesty	650	0.1405	0.0003
Subjective norm	650	0.3867	0.0000
Perception on CSA certification	673	0.1190	0.0027
Perception on market access	673	0.1354	0.0006
Perception on WTP for CSA products by buyers	672	0.0829	0.0368
Information use	636	0.2170	0.0000
Extension and advisory serves	636	0.1966	0.0000

Table 25: Systemic decision-making factors and intention correlation

Policy and institutional framework on CSA

The correlation analysis for the adoption intention and farmers perception on the governmental financial support adequacy in terms of schemes, tax reductions, subsidies, and existing policy and regulation for CSA shows that they are positive and significant (Table 26). This indicates that adequate governmental support in terms of finances and regulations increases farmers' adoption of climate-smart agriculture. Finally, correlation analysis of perceptions of credit access for financial need and adoption intention shows a significant and positive correlation. This indicates that accessing loans to meet the financial need for agricultural production increases the adoption intention of CSA.

Construct	N	Correlation coefficient	Significance
Perception on governmental support on CSA	673	0.117	0.002
Perception on credit access for CSA	673	0.166	0.000

Table 26: Policy and institutional farmwork and intention correlation

7.3.3. CSAs identified from farmers survey

Based on the farmers' survey, we found several CSA practises that farmers are actively utilising. The identified CSA from famers survey are summarized below, see Appendix table FS3 for frequency distribution. The categorization below is based on similarity of their potential towards CSA outcome and farming type.

Agroecological farming practises

Farmers are practising different agroecological production systems and practices that are CSA. The identified practices from the survey result are: - catch crops, cover crops, crop diversification, crop rotation, ecological agriculture, follow-up crops, greening, integrated fruit production, intercropping, permaculture farming, planting nitrogen-fixing crops, regenerative farming, vegetative cover maintenance.

Conservation tillage

conservation till, eco-friendly engines for no tillage, incorporation of fertilizer during tillage, leaving stems of cut cereals in the soil, minimal till, no till, no till with technology, reduced till and strip till

Decision support systems (DSS) for farm management

Allocation files, allocation map, aquapin (measuring salinization), drone-based nitrogen determining, DSS, Farmtracking, feed table, FIELDVIEW, precision feeding, seed monitoring, simulation modelling, smart cow, smart monitoring, smart pest monitoring, surveillance cameras for livestock monitoring, use of autotrack, using soil maps and satellites images, weeding camera, yield map, big data, drones and satellite images.

Guidance systems (GS)

With the help of the Global Navigation Satellite System, Guidance Systems (GS) are used to place and move machines in a precise way (GNSS). This can be used by all kinds of farm equipment, including tractors, combine harvesters, sprayers, planters, and so on. GS allows automatic steering, precise movement of machinery between rows of plants, precise drilling, sowing, planting, spraying, mechanical weeding, auto guided sprayer with section control, GPS based sprayer and mapping of the field. The identified guiding system-based climate smart initiatives from farmers survey are direct sowing, direct drilling, GPS based fertilizer spreader, GPS based machinery, GPS based tractors, GPS based sprayer, tractors and implements with GPS, Auto driving, EURO 4 tractors, less polluting machinery, precision sowing.

Climate smart fertilizers

Under this category the alternative fertilizers to the mineral fertilizers were included. Accordingly, bio fertilizers, compost, graduated fertilizer, green manure, manure as fertilizer, organic fertilizer, organic microbiomes (bacteria and fungi), organic waste fertilizer, use bioproducts are the identified initiatives from the farmers survey.

Feed improvement

organic hay, cultivation of crops with high protein content, alfalfa for livestock feeding, extensive cropping plan with straw chopping, feed table, organic livestock feed.

Pasture management

conservation grazing, grassland grazing, grassland maintenance, grassland management, rotational grazing, pasture grazing, permanent grassland are the identified initiatives from the farmers survey.

Climate pest and weed management.

Use of pheromones for confusing pests, use of field robot for mechanical weeding, integrated protection, integrated control, integrated pest management (IPM), minimum use of pesticides, onion-fly control, phytosanitary applications, precision spraying, precision spraying, precision chemical applications, smart spraying, spot spraying, spraying by drone, variable GBM spraying, variable pesticide application are the identified initiatives from the farmers survey.

Smart fertilization
auto guided fertilizer with section control, allocation card on the fertilizer spreader, changing fertilizer type and amounts, fertilization based on allocation map, GPS based fertilization, GPS based lime application, less fertilization, lime application based on allocation map, location-specific fertilization, precision fertilization, row fertilization, variable fertilizer application.

Smart irrigation
DSS based irrigation, drip irrigation, GPS-based solution for irrigation, micro spray irrigation, precision irrigation.

Manure management
manure management for biodynamic farming, use of manure nitrogen-stabilizer, manure treatment with nitrogen-fixing agent, manure treatment technologies, nitrification inhibitor, slurry ground application, slurry cooling, use of manure and slurry as fertilizer

Renewable energy
bioenergy, biogas, biomass deliver, deep bedding for biogas, solar panels, solar panels on the roof, sun batteries use.

Other categories: organic agriculture, carbon farming, eco-farming, direct sowing

The categories for the identified CSAs from the survey are summarized in the figure 23 below. Accordingly, conservation tillage, agroecological farming techniques, guidance systems, smart fertilization, smart crop protection, organic agriculture, and DSS farm management, which are mostly identified.

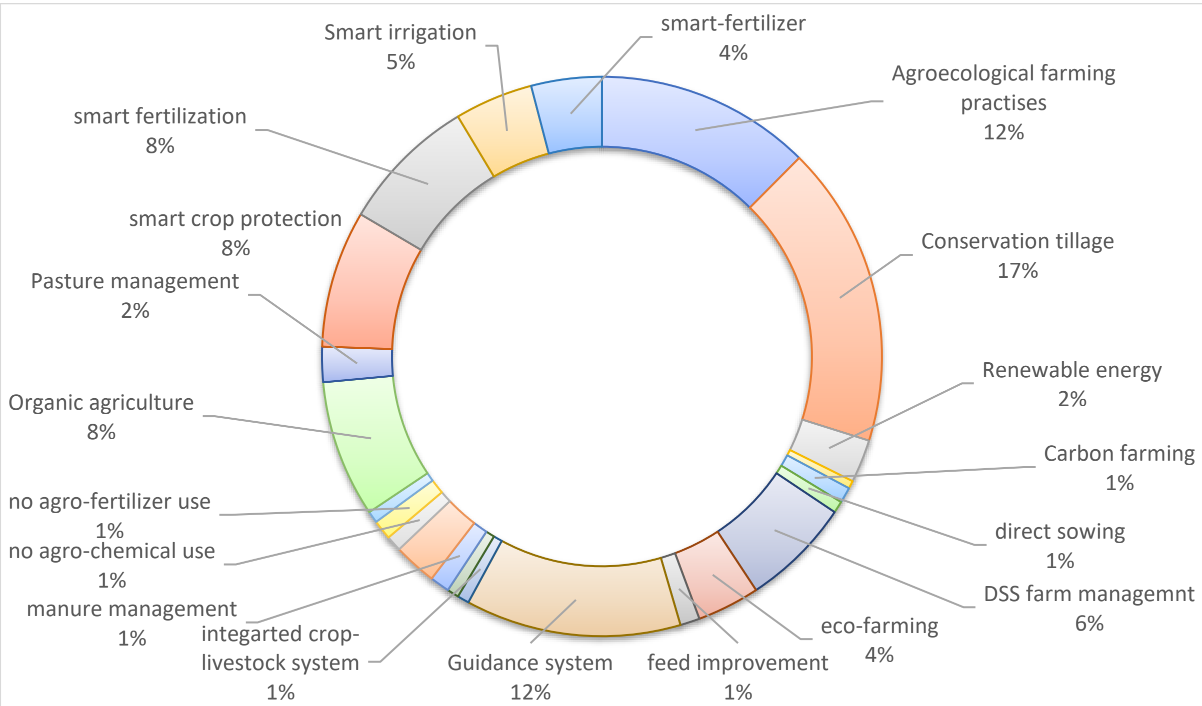

Figure 23: The distribution of the categorized CSA from farmers' survey

The distribution of the identified CSA practices and technologies from survey the raw data indicated that organic agriculture dominatingly practises CSA with the range of sampled farmers. The word cloud for the identified CSA from farmers survey shows that organic agriculture, no till, crop rotation, precision fertilization are the top four dominatingly practises CSA with the range of included farmers (see Figure 24).

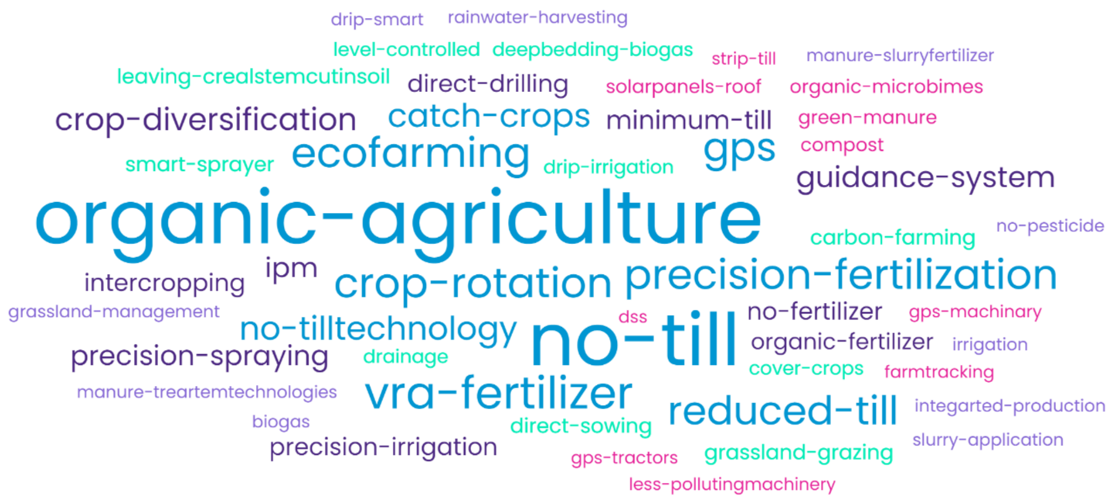

Figure 24: The identified practices and technologies from farmers' survey

Additional CSA from the farmers survey on top of the CSA from SM.

The following farming practices are potential CSA practices and technologies that were identified from the farmer survey but were not included in the systematic mapping. This is the advantage of assessing CSA practices and technologies using multiple data sources. Nitrogen-reducing crop breeding, carbon farming, vegetative cover maintenance, planting nitrogen-fixing crops, regenerative farming, circular economy, level-controlled drainage, biodynamic agriculture, eco-farming, permaculture farming, organic hay, rainwater harvesting, nitrification inhibitor, deep bedding for biogas, graduated fertilizer, conservation grazing, slurry cooling, GPS based lime application, GPS based tractors, direct sowing, direct drilling, GPS based fertilizer spreader, GPS based sprayer, variable rate of application of seeds, surveillance cameras for livestock monitoring, smart cow, spot spraying, ecological agriculture, direct sowing, phytosanitary applications, drip irrigation, manure nitrogen stabilizer, mulching, alfalfa for livestock feeding, green manure, leaving stems of cut cereals in the soil, row fertilization.

7.4. Conclusions

Individual, systemic and policy and institutional framework are the hypothesized decision-making factors for adoption of CSA. From the correlation analysis of adoption intention with these decision-making factors, positive and negative significant correlations were found. The farmers' income level, education level, farm size and farm ownership were found to be positively correlated with CSA adoption intention while the age of sampled farmers was negatively correlated with CSA adoption intention indicating that farmers with younger age group might have better adoption tendency towards CSA practices and technologies. Furthermore, the correlation analysis reveals the positive interdependence of the adoption intention and perception of self-responsibility and farm motives.

Regarding risk tolerance, farmers' perception on financial risk taking is positively correlated with adoption intention. In addition, regarding financial situations, the perception on the financial resources' sufficiency is positively correlated with adoption intention. The farmers perceptions on CSA technologies like perceived ease to use, perceived compatibility, perceived technological usefulness and their adoption intentions are positively correlated indicating the compatibility of new technology with existing farming goals of farmers and its easiness to use and to understand will increase adoption intention of CSA.

With the systemic decision-making factors, the positive correlation of adoption intention and subjective norm indicates that farmers will follow the surrounding and similar farmers and that they value opinion and approval of people who are important to them before they adopt CSA. Perceived equity, contributions and honesty positively correlated with adoption intention indicating that fair share contribution of other stakeholders towards better climate along the food value chain increase adoption intention of CSA. Perception on certification CSA products has a positive correlation with adoption intention indicating that availability and easily getting CSA product certification will increase the adoption of CSA. Farmers' perception on buyers' willingness to pay premium price for CSA products and adoption intention is positively correlated indicating that farmers perceiving that consumers are willing to pay a premium price for their CSA-based products will increase their adoption intentions. Farmers perception on the extent of information and extension service sources for farming business queries and agricultural training or advice and CSA adoption intention is positively correlated with adoption intention.

Finally, regarding policy and institutional framework, farmers' perception on governmental financial support has a positive correlation with the adoption of CSA. Perception on the adequacy governmental financial support in terms of schemes, tax reductions, subsidies, and existing policy and regulation support for CSA is positively correlated with adoption intention. Perception on accessing credit for a financial need is also positively correlated with adoption intention indicating that having access to a loan to cover the financial need for agricultural production increases adoption intention of CSA.

8. Consumer survey of decision-making factors for buying environmentally-friendly food products

8.1. Introduction

The main aim of this study was to investigate the decision-making factors that affect consumers' behavioural change towards purchasing food products that support climate-smart agricultural practices. The study focused on European consumers and their preferences were elicited through a consumer survey in six European countries (Denmark, Germany, Lithuania, the Netherlands, Slovenia and Spain) in early 2023. In the text below, the data collection, type of data and analytical approach are presented together with a presentation and discussion of the results.

8.2. Data and Method

The questionnaire was designed by authors of the paper with input from other project partners. The questionnaire was formulated in English and subsequently translated to local languages (Danish, Dutch, German, Lithuanian, Slovenian and Spanish). The questionnaire was distributed using Qualtrics and administrated by Wageningen University. Answers to open questions were translated to English after the data collection period had ended.

Informed consent to participate in the survey was obtained from all respondents and answers to the questions in the survey were pseudomized before access was given to project partners for data analysis.

The data collection period was from January 2023 to start March 2023. The goal was 100 respondents in each of the six countries. In order to reach this goal, new platforms were introduced in several steps of the data collection. Various free digital platforms were used including personal Facebook/Linkedin, Twitter profiles together with mailing lists for colleagues, student lists, homepages etc. To boosts number of responses, the project participants (including the authors and their colleagues) also filled out the questionnaire. Thereby, the data collection was a non-systematic and dynamic process that provided a great deal of experience in terms of which distribution channels worked – and which did not.

In total, 230 respondents who had not answered all questions in the questionnaire were excluded from the analysis. Almost all of these respondents (225) lived in another country than Germany, Denmark, Spain, Lithuania, the Netherland or Slovenia. Altogether 1219 respondents were included in the analyses.

The design of the questionnaire involved a large number of decisions. First, it was chosen to not include a 'don't know' option in the questions in order to force respondents to answer. Second, even though the focus of the project was on climate impacts the main parts of the questions were formulated as 'environmentally friendly' rather than in terms of climate impact specifically. This was done in order to capture the broader perspective of safeguarding the environment – including the global climate as one of several environmental issues. Only, in the introductory explanation of the term climate-smart and in the willingness-to-pay experiment using potations as an example were the word 'climate-smart' used. Third, in order not to put too much focus on environmental concern, the questionnaire did not reveal what the respondents link to the word 'environmentally friendly' – e.g. did the respondents think of local or global environment, aquatic versus terrestrial versus air pollution, did they think of biodiversity, climate change, etc. Fourth, even though there are three pillars of CSA according to the FAO (2017) definition, we have focused on consumers' interest in 'environmentally friendly' products, and to some extend also sustainable production. Thus, in order to limit the length of the questionnaire, the climate adaption and resilience part of CSA was not covered in the present survey. Fifth, as the importance of fairness for respondents' willingness to take responsibility was of particular attention in the BEATLES project, questions related to the respondents' perception of the entire supply chain were included. Taken together, the questions aimed at identifying individual, systemic and policy-related decision-making factors that could affect consumers' willingness to buy food products that are produced using CSA practices or technologies.

Regarding individual decision-making factors, unobservable factors included consumers' stated preference for climate smart agricultural practices or technologies. Such preferences were elicited as their willingness-to-pay for various types of potatoes in the context of a supermarket shopping situation. Other unobservable individual decision-making factors that were elicited included food choice motives, habit formation, self-efficacy and self-responsibility, perceived financial situation and perceived control. The questionnaire also included observable individual decision-making factors in terms of gender, age, net income, education, type of household.

The questionnaire also contained a range of systemic factors for consumer decision making including a range of social norm related factors (such as 'people I know do/belief/approve of me if..'). Moreover, it included a range of questions related to the consumers' perceptions of themselves and other parts of the supply chain regarding perceived ability, perceived equity/fairness, perceived honesty, perceived contributions in making changes regarding environmental impact and other sustainability related topics. Yet another group of questions focused on information as a systemic decision-making factor including choice of information source with particular focus on labelling. The consumer questionnaire in its full length is found in Appendix table CA1.

In the design of the questionnaire, several individual questions (also called items) were expected to be highly correlated and to measure the same characteristic. In the data analysis, a reliability test was conducted for each construct (the composite variable of several individual questions) using the Cronbach alpha coefficients to indicate the internal consistency between the individual items in measuring the given characteristic. A Cronbach's alpha higher than 0.7 was taken as the cut-off level for passing the reliability tests and thereby have a relatively high internal consistency (similarly to the analysis of the farmer survey).

For the correlation analysis, we used Spearman's ranks correlation coefficients to test correlations between the 'willingness to buy' construct and all other variables. For constructs passing the Cronbach reliability test, the correlation analyses were estimated between constructs. For constructs not passing the test, individual items were presented in the correlation tests. The following categorization of the strength of correlations was used: Absolut values from 0-0.39 were regarded as weak correlations, 0.40-0.59 as moderate correlations, 0.6-1 were categorized as strong correlation and a correlation of 1 is categorized as perfect correlation. Note that all results were analysed and presented at aggregate level across respondents in the different countries.

Table 27 contains a list of all individual decision-making factors items from the questionnaire while Table 28 lists all systemic decision-making item from the questionnaire. The two tables show the formulation of the question presented in the questionnaire as well as the label that we use to refer to the item is this document. Also, the response categories for each variable are presented in the table. For example, using a 7-points Likert scale (1: complete disagree – 7: completely agree) for a given statement would imply that a score of 4 represents 'neither agree nor disagree', a score below 4 indicates some degree of disagreement with the statement while a score above 4 would indicate some degree of agreement.

Label	**Question (response category)**
Willingnesstobuy_1	To what extent do you agree or disagree with the following statements? - I am willing to purchase environmentally friendly products *(1: complete disagree – 7: completely agree)*
Willingnesstobuy_2	To what extent do you agree or disagree with the following statements? - I buy environmentally friendly products if I can *(1: complete disagree – 7: completely agree)*
Willingnesstobuy_3	To what extent do you agree or disagree with the following statements? - I enjoy buying environmentally friendly products *(1: complete disagree – 7: completely agree)*
Frequentie_1	How frequently do you eat – potatoes *(1: every day – 7: never)*
knowledgeTerm	Have you heard of the term climate-smart agriculture practice or technology before? *(1: yes - 2: no)*
CSA_equalprice	Suppose that you are in a shopping situation, where the regular and newly produced potato can be produced for the same price. As a result the prices of the two options are the same as is shown below. Which potato type would you prefer? Reg *(1: certainly the regular produced option - 7: certainly the newly produced option)*
CSA_premium	Suppose that you are in a shopping situation, where the use of the climate-smart practice or technology leads to higher costs for the farmer. As a result, the price for the newly produced potato is higher than the regular produced potato, as is shown below. Which potato type would you prefer in this situation? *(1: certainly the regular produced option - 7: certainly the newly produced option)*
Regular_discount	Suppose that you are in a shopping situation, where the regular and newly produced potato can be produced for the same price, but that

	the regular produced option has a price promotion. As a result, the newly produced potato has the normal price, but the regular produced potato has a discount price, as is shown below. Which potato type would you prefer in this situation? *(1: certainly the regular produced option - 7: certainly the newly produced option)*
CSA_subsidy	Suppose that you are in a shopping situation, where the regular and newly produced potato can be produced for the same price, but that the newly produced option has a subsidy by the government to stimulate its sales. As a result, the regular produced potato has the normal price, but the newly produced potato has a lower price, as is shown below. Which potato type would you prefer in this situation? *(1: certainly the regular produced option - 7: certainly the newly produced option)*
Healthy	It is important to me that the food product that I buy: - is healthy *(1: complete disagree – 7: completely agree)*
Natural	It is important to me that the food product that I buy: - contains few or no artificial additives *(1: complete disagree – 7: completely agree)*
Fairtrade	It is important to me that the food product that I buy: - has been traded in a fair way *(1: complete disagree – 7: completely agree)*
Environfriendly	It is important to me that the food product that I buy: - has been produced in an environmentally friendly way *(1: complete disagree – 7: completely agree)*
Cheap	It is important to me that the food product that I buy: - is cheap *(1: complete disagree – 7: completely agree)*
Appearance	It is important to me that the food product that I buy: - looks nice *(1: complete disagree – 7: completely agree)*
Nutricious	It is important to me that the food product that I buy: - is nutritious *(1: complete disagree – 7: completely agree)*
Publicwellfare	It is important to me that the food product that I buy: - is produced with care for the public health *(1: complete disagree – 7: completely agree)*
Habits_1	I am used to buy food products that contribute to: - a better environment *(1: complete disagree – 7: completely agree)*
Habits_2	I am used to buy food products that contribute to: - a better animal welfare *(1: complete disagree – 7: completely agree)*
Habits_3	I am used to buy food products that contribute to: - fair trade *(1: complete disagree – 7: completely agree)*
Habits_4	I am used to buy food products that contribute to: - a better public health *(1: complete disagree – 7: completely agree)*
wtp_1	I am willing to pay extra money for food products that contribute to: - a better environment *(1: complete disagree – 7: completely agree)*
wtp_2	I am willing to pay extra money for food products that contribute to: - a better animal welfare *(1: complete disagree – 7: completely agree)*
wtp_3	I am willing to pay extra money for food products that contribute to: - fair trade *(1: complete disagree – 7: completely agree)*
wtp_4	I am willing to pay extra money for food products that contribute to: - a better public health *(1: complete disagree – 7: completely agree)*
Self_efficacy2_1	Even if I buy environmentally friendly food products, my contributions will be too small for: - a better environment *(1: complete disagree – 7: completely agree)*
Self_efficacy2_2	Even if I buy environmentally friendly food products, my contributions will be too small for: - a better animal welfare *(1: complete disagree – 7: completely agree)*
Self_efficacy2_3	Even if I buy environmentally friendly food products, my contributions will be too small for: - a contribution to fair trade *(1: complete disagree – 7: completely agree)*

Self_efficacy2_4	Even if I buy environmentally friendly food products, my contributions will be too small for: - a better public health *(1: complete disagree – 7: completely agree)*
Self_responsibility_1	As a consumer, it is my responsibility to contribute to: - a better environment *(1: complete disagree – 7: completely agree)*
Self_responsibility_2	As a consumer, it is my responsibility to contribute to: - a better animal welfare *(1: complete disagree – 7: completely agree)*
Self_responsibility_3	As a consumer, it is my responsibility to contribute to: - fair trade *(1: complete disagree – 7: completely agree)*
Self_responsibility_4	As a consumer, it is my responsibility to contribute to: - a better public health *(1: complete disagree – 7: completely agree)*
PBC_1	The following statements are about environmentally friendly food products. To what extent do you agree or disagree with the following statements? - I am able to buy environmentally friendly food products *(1: complete disagree – 7: completely agree)*
PBC_2	The following statements are about environmentally friendly food products. To what extent do you agree or disagree with the following statements? - If it is entirely up to me, I will buy environmentally friendly food products *(1: complete disagree – 7: completely agree)*
PBC_3	The following statements are about environmentally friendly food products. To what extent do you agree or disagree with the following statements? - I have the resources, time and willingness to purchase environmentally friendly food products *(1: complete disagree – 7: completely agree)*
Gender	What is your gender? - Selected Choice *(1: male, 2: female, 3 other, 4: I would rather not say)*
Agegroup	Agegroup *(1: 18-37 - 3: 57 or older)*
Employed	I am *(1: full-time employed (30 hours per week or more), 2: part-time employed (less than 30 hours per week), 3: retired, 4: unemployed)*
Ancome	The net monthly income of my household is *(1: No income, 2: EUR 500 or less - 13: EUR 7501 or more, 14: I really don't know, 15: I'd rather not say)*
Aducation	My highest education level is - Selected Choice *(1: no training completed, 2: primary school, 3: secondary school, 4: vocational training, 5: bachelor degree, 6: master's degree, 7: doctorate degree; 8: something else, namely)*
MoneySaving_1	The following statements consider finances. To what extent do you agree or disagree with the following statements? - My financial resources are sufficient *(1: complete disagree – 7: completely agree)*
MoneySaving_2	The following statements consider finances. To what extent do you agree or disagree with the following statements? - I can get by with the income of my household *(1: complete disagree – 7: completely agree)*
MoneySaving_3	The following statements consider finances. To what extent do you agree or disagree with the following statements? - Because of inflation, I spend less money on food products than I used to do *(1: complete disagree – 7: completely agree)*

Table 27: List of individual decision-making factor items from survey

Label	Question
Innovativeness_1	To what extent do you agree or disagree with the following statements? - I am eager to buy new food products as soon as they come out *(1: complete disagree – 7: completely agree)*
Innovativeness_2	To what extent do you agree or disagree with the following statements? - others often ask me for advice about new food products *(1: complete disagree – 7: completely agree)*
Innovativeness_3	To what extent do you agree or disagree with the following statements? - I enjoy the novelty of trying out new food products *(1: complete disagree – 7: completely agree)*

marketaccess_1	To what extent do you agree or disagree with the following statements? - Sometimes, I do not know where environmentally friendly food products can be found *(1: complete disagree – 7: completely agree)*
marketaccess_2	To what extent do you agree or disagree with the following statements? - Environmentally friendly food products are not readily available at the stores where I do my shopping *(1: complete disagree – 7: completely agree)*
labeling_1	The following statements are about labels on environmentally friendly food products. To what extent do you agree or disagree with the following statements? The information on food labels that indicate that the food products are environmentally friendly are: informative *(1: complete disagree – 7: completely agree)*
labeling_2	The following statements are about labels on environmentally friendly food products. To what extent do you agree or disagree with the following statements? The information on food labels that indicate that the food products are environmentally friendly are: easy to understand *(1: complete disagree – 7: completely agree)*
trust_1	The claims on food labels that indicate that the food products are environmentally friendly are: - trustworthy *(1: complete disagree – 7: completely agree)*
trust_2	The claims on food labels that indicate that the food products are environmentally friendly are: - realistic *(1: complete disagree – 7: completely agree)*
valueformoney	As compared to regular produced products, products with food labels that indicate that they are environmentally friendly have: - a better value for money *(1: complete disagree – 7: completely agree)*
reasonableprice	As compared to regular produced products, products with food labels that indicate that they are environmentally friendly have: - a reasonable price *(1: complete disagree – 7: completely agree)*
betterquality	As compared to regular produced products, products with food labels that indicate that they are environmentally friendly have: - a better product quality *(1: complete disagree – 7: completely agree)*
moreappeal	As compared to regular produced products, products with food labels that indicate that they are environmentally friendly have: - more appeal *(1: complete disagree – 7: completely agree)*
bettertaste	As compared to regular produced products, products with food labels that indicate that they are environmentally friendly have: - a better taste *(1: complete disagree – 7: completely agree)*
highernutritional	As compared to regular produced products, products with food labels that indicate that they are environmentally friendly have: - a higher nutritional value *(1: complete disagree – 7: completely agree)*
generaltrust_1	To what extent do you agree or disagree with the following statements? - I feel that environmentally friendly products' environmental claims are generally trustworthy *(1: complete disagree – 7: completely agree)*
generaltrust_2	To what extent do you agree or disagree with the following statements? - I feel that environmentally friendly products' environmental reputation is generally reliable *(1: complete disagree – 7: completely agree)*
generaltrust_3	To what extent do you agree or disagree with the following statements? - Environmentally friendly products keep promises and commitments for environmental protection *(1: complete disagree – 7: completely agree)*
norm1_1	The following statements are about people, other than yourself. To what extent do you agree or disagree with the following statements? - People in my surroundings often buy environmentally friendly food products *(1: complete disagree – 7: completely agree)*)
norm1_2	The following statements are about people, other than yourself. To what extent do you agree or disagree with the following statements? - People

	who are similar to me often buy environmentally friendly food products *(1: complete disagree – 7: completely agree)*
norm1_3	The following statements are about people, other than yourself. To what extent do you agree or disagree with the following statements? - People, who are important to me, approve if I buy environmentally friendly food products *(1: complete disagree – 7: completely agree)*
norm1_4	The following statements are about people, other than yourself. To what extent do you agree or disagree with the following statements? - People, who's opinion I value, believe that I should buy environmentally friendly food products *(1: complete disagree – 7: completely agree)*
benevolencesupermarkets	The following statements are about groups in society. To what extent do you agree or disagree with the following statements? Though circumstances may change, I believe that the following groups remain willing to contribute to a better environment, animal welfare, public health, and fair trade: supermarkets *(1: complete disagree – 7: completely agree)*
benevolenceindustry	The following statements are about groups in society. To what extent do you agree or disagree with the following statements? Though circumstances may change, I believe that the following groups remain willing to contribute to a better environment, animal welfare, public health, and fair trade: food industry, such as dairy companies, fruit and vegetable processors, and meat industries *(1: complete disagree – 7: completely agree)*
benevolencegovernments	The following statements are about groups in society. To what extent do you agree or disagree with the following statements? Though circumstances may change, I believe that the following groups remain willing to contribute to a better environment, animal welfare, public health, and fair trade: governments *(1: complete disagree – 7: completely agree)*
benevolencefarmers	The following statements are about groups in society. To what extent do you agree or disagree with the following statements? Though circumstances may change, I believe that the following groups remain willing to contribute to a better environment, animal welfare, public health, and fair trade: farmers *(1: complete disagree – 7: completely agree)*
benevolenceconsumers	The following statements are about groups in society. To what extent do you agree or disagree with the following statements? Though circumstances may change, I believe that the following groups remain willing to contribute to a better environment, animal welfare, public health, and fair trade: consumers, other than myself *(1: complete disagree – 7: completely agree)*
fairsharesupermarkets	I only want to contribute to a better environment, animal welfare, public health and fair trade, if I surely know that the following groups also make a fair contribution: - supermarkets *(1: complete disagree – 7: completely agree)*
fairshareindustry	I only want to contribute to a better environment, animal welfare, public health and fair trade, if I surely know that the following groups also make a fair contribution: - food industry, such as dairy companies, fruit and vegetable processors, and meat industries *(1: complete disagree – 7: completely agree)*
fairsharegovernments	I only want to contribute to a better environment, animal welfare, public health and fair trade, if I surely know that the following groups also make a fair contribution: - governments *(1: complete disagree – 7: completely agree)*
fairsharefarmers	I only want to contribute to a better environment, animal welfare, public health and fair trade, if I surely know that the following groups also make a fair contribution: - farmers *(1: complete disagree – 7: completely agree)*

fairshareconsumers	I only want to contribute to a better environment, animal welfare, public health and fair trade, if I surely know that the following groups also make a fair contribution: - other consumers *(1: complete disagree – 7: completely agree)*
performancesupermarkets	Consumers do more for a better environment, animal welfare, public health, and fair trade, than the following groups: - supermarkets *(1: complete disagree – 7: completely agree)*
performanceindustries	Consumers do more for a better environment, animal welfare, public health, and fair trade, than the following groups: - food industry, such as dairy companies, fruit and vegetable processors, and meat industries *(1: complete disagree – 7: completely agree)*
performancegovernments	Consumers do more for a better environment, animal welfare, public health, and fair trade, than the following groups: - governments *(1: complete disagree – 7: completely agree)*
performancefarmers	Consumers do more for a better environment, animal welfare, public health, and fair trade, than the following groups: - farmers *(1: complete disagree – 7: completely agree)*
trustsupermarkets	I believe that the following groups are honest about their contributions to a better environment, animal welfare, public health, and fair trade: - supermarkets *(1: complete disagree – 7: completely agree)*
trustindustry	I believe that the following groups are honest about their contributions to a better environment, animal welfare, public health, and fair trade: - food industry, such as dairy companies, fruit and vegetable processors, and meat industries *(1: complete disagree – 7: completely agree)*
trustgovernments	I believe that the following groups are honest about their contributions to a better environment, animal welfare, public health, and fair trade: - governments *(1: complete disagree – 7: completely agree)*
trustfarmers	I believe that the following groups are honest about their contributions to a better environment, animal welfare, public health, and fair trade: - farmers *(1: complete disagree – 7: completely agree)*
trustconsumers	I believe that the following groups are honest about their contributions to a better environment, animal welfare, public health, and fair trade: - consumers, other than myself *(1: complete disagree – 7: completely agree)*
infointerestsupermarkets	I want to be kept up-to-date about the contributions of the following groups to a better environment, better animal welfare, better public health, or fair trade: - supermarkets *(1: complete disagree – 7: completely agree)*
infointerestindustry	I want to be kept up-to-date about the contributions of the following groups to a better environment, better animal welfare, better public health, or fair trade: - food industry, such as dairy companies, fruit and vegetable processors, and meat industries *(1: complete disagree – 7: completely agree)*
infointerestgovernments	I want to be kept up-to-date about the contributions of the following groups to a better environment, better animal welfare, better public health, or fair trade: - governments *(1: complete disagree – 7: completely agree)*
inforinterestfarmers	I want to be kept up-to-date about the contributions of the following groups to a better environment, better animal welfare, better public health, or fair trade: - farmers *(1: complete disagree – 7: completely agree)*
infointerestconsumers	I want to be kept up-to-date about the contributions of the following groups to a better environment, better animal welfare, better public health, or fair trade: - consumers, other than myself *(1: complete disagree – 7: completely agree)*
socialmedia	Suppose that you have a question about environmentally-friendly food products. To what extent are you going to use one of the following sources of information? - Social media (for example facebook or Twitter) *(1: never – 7: always)*

familyfriends	Suppose that you have a question about environmentally-friendly food products. To what extent are you going to use one of the following sources of information? - Family and friends *(1: never – 7: always)*
newspapers	Suppose that you have a question about environmentally-friendly food products. To what extent are you going to use one of the following sources of information? - Physical or online newspapers *(1: never – 7: always)*
people	Suppose that you have a question about environmentally-friendly food products. To what extent are you going to use one of the following sources of information? - People I know *(1: never – 7: always)*
radio	Suppose that you have a question about environmentally-friendly food products. To what extent are you going to use one of the following sources of information? – Radio *(1: never – 7: always)*
television	Suppose that you have a question about environmentally-friendly food products. To what extent are you going to use one of the following sources of information? – Television *(1: never – 7: always)*
internet	Suppose that you have a question about environmentally-friendly food products. To what extent are you going to use one of the following sources of information? - Internet (for example, google or governmental websites) *(1: never – 7: always)*
Facebook	I make use of the following social media if I have a question about environmentally-friendly food products (more than one answer possible) – Facebook *(0: not chosen – 1: chosen)*
Twitter	I make use of the following social media if I have a question about environmentally-friendly food products (more than one answer possible) – Twitter *(0: not chosen – 1: chosen)*
LinkedIn	I make use of the following social media if I have a question about environmentally-friendly food products (more than one answer possible) – LinkedIn *(0: not chosen – 1: chosen)*
Instagram	I make use of the following social media if I have a question about environmentally-friendly food products (more than one answer possible) – Instagram *(0: not chosen – 1: chosen)*
Snapchat	I make use of the following social media if I have a question about environmentally-friendly food products (more than one answer possible) – Snapchat *(0: not chosen – 1: chosen)*
Whatsapp	I make use of the following social media if I have a question about environmentally-friendly food products (more than one answer possible) – Whatsapp *(0: not chosen – 1: chosen)*
TikTok	I make use of the following social media if I have a question about environmentally-friendly food products (more than one answer possible) – TikTok *(0: not chosen – 1: chosen)*
YouTube	I make use of the following social media if I have a question about environmentally-friendly food products (more than one answer possible) – YouTube *(0: not chosen – 1: chosen)*
Pinterest	I make use of the following social media if I have a question about environmentally-friendly food products (more than one answer possible) – Pinterest *(0: not chosen – 1: chosen)*
hh_persons	Number of persons in my household are *(1: one person – 6: six or more persons)*
hh_children	Number of children that live in my household *(1: none – 6: five or more children)*
agglomeration	In what type of area do you live? *(1: urban area, 2: suburban area, 3: small village or rural area)*
residence	In what country do you currently live? *(open answer)*

Table 28: List of systemic decision-making factor items

8.3. Results

The results are presented in the following order: First socio-demographic characteristics are presented followed by Cronbach's coefficients for constructs are presented. Finally, descriptive statistics and correlations between 'willingness to buy' and constructs and individual items, respectively. All results, except country of residence, are presented in aggregate terms. For information about country specific differences, Appendix CA2, which is country-wise frequency tables can be obtained from authors as supplementary document.

Socio-demography

Table 29 shows that half of the 1219 respondents live in Slovenia whereas around 13% are from the Netherlands. Respondents from Germany, Denmark, Spain and Lithuania accounted for 10%, respectively, while around 5% of the total sample live in other countries.

In what country do you currently live? (residence)							
Germany	Denmark	Spain	Lithuania	The Netherlands	Slovenia	Other	Total
107	108	82	123	157	584	58	1219
8.78	8.86	6.73	10.09	12.88	47.91	4.76	100

Table 29: Division of consumer respondents according to country of residence

Note: The first row presents the number of respondents in the respective categories while second row present share of sample.

Tables 30-37 show socio-demographic distributions of the aggregate sample.Table 30 indicates that two third of the respondents are females while one third are males. Table 31 below shows that a little more than 22% of the respondents belonged to the youngest age group while around 80% were almost equally divided between two older age groups. Table 32 shows that around 40% of the respondents live in households with two members. Only a small proportion of the households altogether have more than four members. Table 33 shows that the majority of the respondents do not have any children living at home. The second most common is way of living, is to have one or two children living at home, while few have more than two. Table 34 suggests that two third of respondents are full-time employed. Table 35 shows that 40% of the respondents have a net monthly income between 1000 – 3000 EUR. Table 36 reveals that two third of the respondents have a bachelor degree or a master degree. Table 37 shows that almost half of the respondents live in an urban area.

What is your gender? - Selected Choice (gender)				
Male	Female	Other	I would rather not say	Total
403	798	5	13	1219
33.06	65.46	0.41	1.07	100

Table 30: Division of the respondents according to gender

Note: The first row presents the number of respondents in the respective categories while second row present share of sample.

Age group (agegroup)			
18 to 37	38 to 56	57 or older	Total
270	478	463	1211
22.30	39.47	38.23	100

Table 31: Division of the respondents according to age group

Note: The first row presents the number of respondents in the respective categories while second row present share of sample.

Number of persons in my household are (hh_persons)						
One person	Two persons	Three persons	Four persons	Five persons	Six or more persons	Total
179	473	220	247	64	36	1219
14.68	38.80	18.05	20.26	5.25	2.95	100

Table 32: Division of the respondents according to number of household members

Note: The first row presents the number of respondents in the respective categories while second row present share of sample.

Number of children that live in my household (hh_children)						
None	One child	Two children	Three children	Four children	Five or more children	Total
720	193	240	50	13	3	1219
59.06	15.83	19.69	4.10	1.07	0.25	100

Table 33: Division of the respondents according to number of children that live in the household

Note: The first row presents the number of respondents in the respective categories while second row present share of sample.

I am (employed)				
Full-time employed (30 hours per week or more)	Part-time employed (less than 30 hours per week)	Retired	Unemployed	Total
802	106	257	54	1219
65.79	8.70	21.08	4.43	

Table 34: Division of the respondents according to employment

Note: The first row presents the number of respondents in the respective categories while second row present share of sample.

The net monthly income of my household is, in EUR (income)															
No income	500 or less	501 to 1000	1001 to 1500	1501 to 2000	2001 to 2500	2501 to 3000	3001 to 3500	3501 to 4000	4001 to 4500	4501 to 5000	5001 to 7500	7501 or more	I really do not know	I would rather not say	Total
10	19	54	114	132	133	142	96	83	46	56	82	67	31	154	1219
0.82	1.56	4.43	9.35	10.83	10.91	11.65	7.88	6.81	3.77	4.59	6.73	5.50	2.54	12.63	100

Table 35: Division of the respondents according to income.

Note: The first row presents the number of respondents in the respective categories while second row present share of sample.

My highest education level is – (education)								
No training completed	Primary school	Secondary school	Vocational training	Bachelor degree	Master degree	Doctorate degree	Something else	Total
1	4	141	103	459	371	102	38	1219
0.08	0.33	11.57	8.45	37.65	30.43	8.37	3.12	100

Table 36: Division of the respondents according to education

Note: The first row presents the number of respondents in the respective categories while second row present share of sample.

In what type of area do you live? (agglomeration)			
Urban area	Suburban area	Small village or rural area	Total
593	274	352	1219
48.65	22.48	28.88	100

Table 37: Division of the respondents according to agglomeration

Note: The first row presents the number of respondents in the respective categories while second row present share of sample.

Table 38 shows the items that are included in different constructs which is an aggregate variable consisting of several individual questions (often called items). The design of the constructs were prepared in the design of the questionnaire. For each construct, a reliability test was conducted using the Cronbach alpha coefficients to indicate how closely related the items are. These reliability coefficients suggest that most constructs have a Cronbach's alpha higher than 0.7 and thereby have a relatively high internal consistency. Three constructs are found to have a low internal consistency (injunctive norm, information use and social media use) and the items are thus treated as individual item in the following analyses.

Construct	Items	Cronbach's alpha
willingness to buy	willingnesstobuy_1 willingnesstobuy_2 willingnesstobuy_3	0.873
willingness to pay	CSA_equalprice CSA_premium regular_discount CSA_subsidy	0.844
food choices	Healthy natural fairtrade environfriendly cheap appearance Nutricious publicwellfare	0.746
habit formation	habits_1 habits_2 habits_3 habits_4	0.877
stated preference	wtp_1 wtp_2 wtp_3 wtp_4	0.915
self-efficacy	Self_efficacy2_1 Self_efficacy2_2 Self_efficacy2_3 Self_efficacy2_4	0.963
self-responsibility	Self_responsibility_1 Self_responsibility_2 Self_responsibility_3 Self_responsibility_4	0.932
innovativeness	Innovativeness_1 Innovativeness_2 Innovativeness_3	0.754
perceived behavioral control	PBC_1 PBC_2 PBC_3	0.728
market access	marketaccess_1 marketaccess_2	0.719
labeling	labeling_1 labeling_2	0.802
trust	trust_1 trust_2	0.944
product attributes	valueformoney reasonableprice betterquality moreappeal bettertaste highernutritional	0.861
general trust	generaltrust_1 generaltrust_2 generaltrust_3	0.932
descriptive norm	norm1_1 norm1_2	0.690
injunctive norm	norm1_3 norm1_4	0.710
Benevolence	Benevolencesupermarkets benevolenceindustry Benevolencegovernments benevolencefarmers benevolenceconsumers	0.805
perceived equity	Fairsharesupermarkets fairshareindustry Fairsharegovernments fairsharefarmers fairshareconsumers	0.970
perceived contribution	Performancesupermarkets performanceindustries Performancegovernments performancefarmers	0.843
perceived honesty	Trustsupermarkets trustindustry trustgovernments Trustfarmers trustconsumers	0.821
info interest	Infointerestsupermarkets infointerestindustry Infointerestgovernments inforinterestfarmers infointerestconsumers	0.947

information use	Socialmedia familyfriends newspapers People radio television internet Informationsources_8	0.685
social media use	Facebook Twitter LinkedIn Instagram Snapchat Whatsapp TikTok YouTube Pinterest	0.544

Table 38: Cronbach's alpha for constructs

Note: willingness to buy: N=1184 , general trust: N=1218, all other constructs: N = 1219.

Table 39 shows descriptive statistics of all constructs with a Cronbach's alpha coefficient higher than 0.7. The mean scores and standard deviations for these constructs are shown together with the response categories (numerical values), the Spearman's correlation coefficient (and associated p-value) shows correlation between the construct 'willingness to buy' and all other constructs. It was found that none of the constructs are strongly correlated with the 'willingness to buy'. However, a number of the constructs are moderately correlated (correlation coefficient between 0.4 and 0.59) including the following constructs: willingness to pay, stated preferences, habit formation, self-responsibility, and perceived behavioural control.

Construct	Mean	Std Dev	Min	Max	Spearman's correlation coefficient	Prob > |r| under H0: Rho=0
willingness to buy	5.921	1.054	1	7		
willingness to pay	5.116	1.806	1	7	0.408	<.0001
food choices	5.760	0.648	1	7	0.310	<.0001
stated preference	5.601	1.149	1	7	0.560	<.0001
habit formation	5.664	1.049	1	7	0.576	<.0001
self-efficacy	4.175	1.698	1	7	-0.158	<.0001
self-responsibility	5.816	1.123	1	7	0.435	<.0001
Innovativeness	3.959	1.331	1	7	0.196	<.0001
perceived behavioral control	5.323	1.069	1	7	0.574	<.0001
market access	4.092	1.495	1	7	-0.061	0.0327
Labelling	4.249	1.349	1	7	0.082	0.0042
Trust	3.977	1.338	1	7	0.116	<.0001
product attributes	4.441	1.087	1	7	0.382	<.0001
general trust	4.317	1.271	1	7	0.213	<.0001
perceived equity	4.728	1.783	1	7	-0.055	0.0562
perceived contribution	4.653	1.185	1	7	0.113	<.0001
perceived honesty	3.728	1.074	1	7	-0.017	0.545
injunctive norm	4.889	1.193	1	7	0.366	<.0001
Benevolence	4.136	1.144	1	7	-0.025	0.3764
Infointerest	5.450	1.272	1	7	0.304	<.0001

Table 39: Descriptive statistics for constructs and correlation with the construct 'willingness to buy'

Note. Willingness to buy: N=1215, general trust: N=1218, all other constructs: N=1219.

Descriptive statistics of all decision-making factors, Spearman's correlation coefficient (and associated p-value) of correlations between the decision-making factors and the construct willingness to buy are shown in appendix. Appendix Table CA2 shows statistics of all individual decision-making factors and Appendix Table CA3 shows statistics for all systemic decision-making factors. Further details on country-specific frequency tables can be found in supplementary table CA4 (please, contact first author for access to supplementary).

8.4. Conclusions

Altogether 1219 consumers participated in the consumer survey. The data are presented in aggregate terms across countries in order to provide an overview of consumer attitudes towards and choices of environmentally friendly food products. We found that 63% of the respondents stated that they had heard about climate smart agricultural practices and technologies as described to them. On average, the respondents 'agree' that they are willing to buy environmentally friendly products (mean 5.9). Considering this high support for buying environmentally friendly products, it would be interesting to dig into how they define environmentally friendly products in their every-day purchases.

We found that the majority of the constructs designed in the questionnaire passed the reliability tests and thereby showed high internal consistency in measuring the construct. Only three constructs were found to have a low internal consistency (descriptive norm, information use and social media use).

In order to identify, possible decision-making factors for adoption of CSA practices and technologies we estimated correlations between 'willingness to buy' and various variables. While none of the constructs or individual items were strongly correlated with the construct 'willingness to buy', we found five moderately correlated constructs: Perceived behavioural control, habit formation, stated preferences, perceived self-responsibility and willingness to pay for potatoes. The perceived behavioural control construct was linked to environmentally friendly food only, while habit formation, stated preferences and perceived self-responsibility were linked broader to also include animal welfare, fair trade and better public health. The fifth moderately correlated constructs were linked more specifically to willingness to buy a new potato produced with CSA practices and technologies.

The self-efficacy construct had a mean of 4.175 which indicates that the respondents don't have a strong belief in that their actions make a contribution to better environment etc. This could be a barrier even though the correlation with willingness to buy was only weak. The high self-responsibility indicating that consumers feel responsibility for better environments etc. can be seen as a driver. The relatively low score on market access (4.092) indicates that consumers are likely not to find it easy to navigate towards environmentally friendly products which can be seen as a barrier. Also, that labels only score 4.249 indicates that they are not very informative which could be seen as a barrier even though correlations with willingness to buy were low. A relatively high score on the injunctive norm (4.880) indicates that social pressure could be used as a driver.

9. Stakeholder interviews about CSA adoption in the primary production

9.1. Introduction

The main aim of conducting interviews with industry stakeholders was to understand drivers and barriers along the supply chain for CSA adoption in primary production. To address this overall research question, the interview guide was designed to answer the following three research questions:

1) What is the industry stakeholders' knowledge about which climate smart farming practices, technologies and initiatives used in the primary sector in their field?

2) What is the industry stakeholders' knowledge about which practices and initiatives in their part of the supply chain enable climate-smart farming practices in primary production?

3) What is the industry stakeholders' view on drivers and barriers for the uptake of practices and initiatives in their part of the supply chain that enable climate smart farming practices in the primary production?

For each of the five use case countries (Denmark, Germany, Netherlands, Lithuania and Spain), the aim was to include stakeholders that represent various parts and links in the food supply chain. Types of stakeholders that could be recruited to be interviewed included representatives for processing, packaging, retail, labelling, storage, transport, advertising, investors, waste/reuse systems in the primary production, fertilizer company, equipment companies, farmers with farm sales, farmers, farmers' organizations, consumer organizations, environmental organizations, feed suppliers, manure suppliers, abattoirs, canteens and restaurants, etc.

Five different food systems representing the major crop and livestock farming systems in Europe involving the productions of cereals, dairy, apples, pigs, vegetables (potatoes) in various EU regions (Western, Eastern, Southern and Northern Europe) were studied to account for the diversity in agri-food systems and conditions in the EU.

The main aim of the interviews was to outline drivers and barriers for the uptake of CSA practices and technologies in relation to individual, systemic and policy drivers and barriers which can be described as follows:

- ***Individual/organizational drivers and barriers*** *include e.g. revenues, organizational goals, leadership, organizational structure and current operations, organizational culture, attitudes, awareness/knowledge, capacity and skills, availability of labor, innovativeness, risk tolerance/aversion, environmental consciousness, lack of information, interpersonal issues, opportunistic behavior). Barriers related to the characteristics of the practice (e.g. practices are complex/difficult to implement/need a lot of resources/expensive, technical failure)*

- ***Systemic drivers and barriers*** *include existing social norms (e.g., a country where the norm is to use environmentally-friendly practices), other companies that are using environmentally-friendly practices create a peer pressure, conflicting interests between value chain stakeholders, consumer demand for paying for sustainable practices, training and education, access to market, access to credit (loans), social pressure from interest groups, mass media (what they promote as the right way to do things), premium price for climate friendly products, advisory services.*

- ***Policy drivers and barriers*** *include e.g. policy measures, regulations and incentives, financial support (subsidies) and investments and fair trade initiatives.*

9.2. Data

All interviews were conducted by use case partners in the five countries from January to March 2023. A common interview-guide (see appendix table IR1) for all use-cases was formulated in English by all WP1 partners in the BEATLES project and hereafter translated to Dutch, German, Danish, Lithuanian and Spanish. Afterwards summary notes of answers from each interview were written by the interviewer. Before the interviews, informed consent to participate in the interview was obtained from the respondents. Recordings of the interviews were stored safely by use case partners while anonymized versions of summaries of the interviews (translated back to English by the use case partners) were uploaded to the project multi-stakeholder platform.

If the interviewees were interested in seeing the interview-guide, it was sent to them prior to the interviews. To guide the use case partners in carrying out the interviews, additional information about the kind of results that were expected from the interviews and how CSA is defined and used in the BEATLES project was circulated to all use cases (see appendix table IR1).

The use case partners were responsible for recruitment of interviewees in their local networks so e.g. interviewees from Denmark were preferably part of or linked to the Danish pig production and pork supply chain. The aim was to reach as close to 20 interviews as possible.

Altogether, 78 interviews were conducted with stakeholders distributed as follows: Denmark (14), Netherland (15), Germany (15), Lithuania (12) and Spain (12). The supplementary appendix table IR2 provides more details about the types of stakeholders and results from the interviews regarding their suggested initiatives, drivers and barriers for each use (please, contact to first author to access supplementary). All stakeholders are kept anonymous but their place in the supply chain is identified and a short name for each stakeholder is given to identify their role.

9.3. Results and discussions

Results are presented separately for each of the five use cases using the following structure: first, types of stakeholders that were interviewed are listed. Second, initiatives mentioned by the stakeholders are presented (both those mentioned as current initiatives and as promising initiatives) by the stakeholders. Third, perceived drivers and barriers for adoption of CSA practices and technologies are described.

Germany (organic dairy)

The German use case is organic dairy production. The list below presents the interviewed stakeholders that represent various parts of the organic dairy supply chain. The short names indicated with an () are used as a reference throughout the text for each use case.

1. Trader selling animals to farmers (trader)
2. A dairy cooperative (coop)
3. Trader in gastronomy and catering (trader/catering)
4. Organic wholesaler (wholesaler)
5. Company that is producing and processing of organic products (processing)
6. Farmer (farmer1)
7. Farmer producing butter and cheese (farmer 2).
8. Mix feed producer (feed producer)
9. City advisor that advice public institutions about providing food services (city advisor)
10. Production cooperative (coop prod.)
11. Gastronomy - providing services to hotels, restaurants and event areas (gastronomy1)
12. Research project (researcher)
13. Gastronomy (gastronomy 2)
14. Advisor for organic agriculture (advisor)
15. Organic feed mill (mill).

Initiatives

Several of the mentioned initiatives for the dairy sector focused on livestock production and productivity such as to increase the longevity of cows. The idea with this initiative is to optimize life-long output regarding milk and calves instead of focusing on milk per year as is often done (trader). However, in order to focus more on longeivity, the farmers need more advice on the topic of breeding for longevity and pasture management (advisor).

A number of stakeholders mentioned local production and short distances for marketing and thus less emission from transport as CSA initiatives (trader). Mobile slaughtering (processing) and local dairies around cities (for instance Berlin as an example) to help create a more regional processing was also suggested as an initiative for climate smart production (wholesaler). It was also suggested to let the producer decide when to deliver the commodities according to their own plans to better organize the logistics.

At the field level, no-tillage during autumn and to have the soil covered to avoid erosion were suggested as a CSA initiative (farmer1). Climate crisis and climate conditions are already changing and therefore there is a need for adapted grazing (farmer1).

It was also suggested to create a better market for calves from organic dairy cows - in particular the male "brother calves" that cannot be used for milk production - that are typically reared on grassland and slaughtered after two years (coop prod.) The better marketing of "brother calves" in organic production should be supported by forcing/inspiring customers to only use high quality products (trader/catering).

Several new and local produced crops were suggested to reduce GHG, such as local production of sorghum in Germany, which was considered to be suitable as climate smart initiative (related to GHG mitigation) as well as cultivation with lentils and chickpeas in the region. The idea was basically to promote regional crop varieties (wholesaler). Also, more local protein feed supply to avoid imported protein such as soy was suggested as a solution. In particular promoting protein from grassland but also on arable farmland such as regional soy (processing, mill). In addition, alfalfa was mentioned as a specific climate smart crop and it was suggested to establish local/on-farm grass drying facilities as a climate smart domestic protein source (farmer1). However, it is stressed that it is important to use crops that are already needed in organic crop rotations. When farmers use these crops for feed, a market is then created and farmers who cultivate these crops may then increase their soil fertility (mill). Furthermore, increased feed production from hay and grass/maize silage as well as using concentrated feed without soy was also suggested as a relevant initiative (farmer1). One stakeholder offered a processing plant for soy grown in Germany and thereby reducing the amount of imported soy (mill).

Promoting methane reducing feed production and using plant extract to reduce methane emissions were also suggested as CSA initiatives (feed producer).

At the field level, compost could be made by building up humus to make organic fertilizer on the field (farmer1). It was further argued that building up humus can bind GHG in the soil (farmer2). In general, there is a need for advisory services aimed at farmers to minimize nutrient loss (mill).

Increasing biodiversity by planting hedges by the fields and more CO2 storage in the soil might go hand in hand but requires more advice about biodiversity on the farm (advisor). Another specific solution to increase biodiversity was to apply more insect-friendly mowing in the field (farmer1). Grassland management and forests can be used as CO2 sinks – here it should be considered to include agriculture as part of the solution (coop).

As an ecological friendly initiative that is not directly aimed for the dairy sector, photovoltaics on the farm roofs was mentioned as a climate smart solution (trader, farmer 1). Another stakeholder mentioned more specifically that drying hay by using photovoltaic energy could be a specific climate smart solution (farmer2).

Reducing waste was also regarded as a key area mentioned by several stakeholders. In the retail sector it was suggested to raise awareness among consumers on the topic of food waste (coop). There is a need to optimize the use of left-over food, especially in buffet situations (gastronomy1). A more specific solution was that waste products from e.g. wheat production should be utilized better (processing) and it was suggested that feed for dairy cows is made 100% out of by-products from the food industry (mill). For animal feed, one solution is to use leftovers from the food industry, such as by-products from wheat, sugar beets, rape seed and sunflower products in food processing (mill).

Promoting CSA food was also mentioned as a solution, such as marketing of organic beef raised on pasture (processing) and it was further suggested to raise awareness about CSA practices and technologies among farmers and in the dairy's (coop). One initiative could be to recruit farmers and consumers as ambassadors of the products (coop).

In addition, it was mentioned to provide a fair certification with stricter standards than the current EU organic certification mark provides (trader/catering). Proposed initiatives to increase adoption of CSA included the need for more “consumer education” (city advisor), promoting organic certification and supporting the use of organic inputs in kitchens (gastronomy2).

In schools, the share of organic food is not that high yet in Bavaria, some reasons are that each school is responsible themselves to allocate their catering services (city advisor). Specifically, one solution to increase organic food in schools could be to establish specific kitchens to supply the schools with organic food (city advisor). It was also suggested to promote seasonal and regional purchasing, and this needed to go hand in hand with a changed nutrition pattern within the population (city advisor). More focus should be put on vegetable and vegan options. However to consume more vegetables, time is needed to convince the chefs and also convince consumers (gastronomy1).

It was also suggested to order commodities well in advance to improve logistics and it was argued that a specific delivery date may not be that important (gastronomy 2). Using suppliers that are as close as possible to the users could improve production in a climate-smart way (gastronomy 2).

Farmers need to be aware of the problem about climate change and aware of the contribution to GHG emissions. It should be emphasized to farmers that GHG reduction is often linked to more efficiency and thereby that reducing GHG emissions could also lead to more financial efficiency (researchers).

Drivers

As a key-driver it was highlighted that farmers need financial incentives to adopt CSA practices. It was also stressed that advice, expertise and support is needed from outside farmers’ organization, which also include political goals (farmer 2). It was further mentioned that profitability may increase on farms where cows are “long-living” and produce a lot of milk per cow – and this should be communicated (trader). If marketing of organic products is made efficient, more farmers will then have the financial incentive to produce and also benefit from fair partnerships, more farmers will then convert to organic farming, hence enable a more climate smart friendly agricultural production (coop prod).

More organic farming can only be achieved through political action such as public procurement for public canteens and restaurants etc. and there is still a lot of potential to increase the consumption of organic products in these areas (trader/catering, processing). Politically it was mentioned that there could be more actions towards increasing the organic share of food being consumed (gastronomy1). Other drivers could come from the company itself and be related to the philosophy of the company where external influences like climate change are regarded as drivers (wholesaler).

Another driver that was mentioned is awareness among consumers. Therefore, a suggestion was to make a campaign to increase awareness of specific benefits in relation to organic products. Often it is not allowed to do marketing that is damaging the conventional farmers because communicating the benefits of organic may offend other farmers (processing). It was further suggested to educate consumers about sustainable food production through kitchen parties where the producers can meet the guests and educate them (gastronomy1). Furthermore, it was suggested to, in a pedagogical way, provide more information to people in the city to change their buying behaviour (city advisor). It was also suggested to provide information for schools about organic suppliers for their canteens (city advisor). At the farm level, it was mentioned that a neighboring effect is important. If there is a pioneer close-by that is doing innovative initiatives, farmers are more likely to adapt as well as willing to educate themselves on new topics and methods (researcher). Education and advice for farmers is regarded as a major lever/driver, but also communication towards customers is important (coop). There is a need to develop guidelines with practical ideas from science that the advisors can promote in their organization (advisor). Moreover, there is a need to increase the importance of science and decision-making based on scientific knowledge, education in general as an important lever (coop). More agricultural advice and know-how are needed – and farmers often have this know-how (wholesaler). There is also a need to analyse and calculate costs and benefits more precisely – not just what a cow is emitting; but by calculating emissions from feed production, organic farming with grazing etc. it overall creates less methane since there is a lot of carbon storage in grassland and the feed is produced more environmentally friendly (mill).

Finally, it was suggested that more restaurants should become organically certified and offer more organic products. They have an important role in bringing changes to society and they could help to enable a more climate friendly agriculture and consumption (gastronomy1).

Barriers

One general barrier that was mentioned is that it can often be hard to find farmers that are willing to try new things (feed producer). Many organic calves do not find a market, because the rearing and fattening of organic cattle is not economically viable. Therefore, there are modest local fattening on the farms. This is also the case for the conventional dairy sector (trader).

From a technical point of view there are some specific barriers mentioned like: It is difficult to process sorghum, because there is currently no mill that is able to do so (sorghum). It requires special technology and no company has access to that technology at the moment (wholesaler). More insect-friendly mowing method require high costs and more workload is also regarded as a barrier (farmer1). In relation to methane reduction from using more feed from plant extract – here a barrier might be that this type of feed might not be allowed in organic agriculture (feed producer).

Another barrier is that some people may not be able to afford high quality food as organic food, especially in regard to catering and food for old people in nursing homes (city advisor). It was also stated that people might not want to eat a lot of vegetables because they never did that in their life, and that it is important to understand people and to follow up on their preferences and to find out what makes them happy (city advisor). Budget limitations in public care is regarded as a barrier for consumption of organic food (trader/catering). However, it was also argued that higher prices are necessary to enable production of organic food and that this must be accompanied by the willingness of consumers to pay higher prices for climate-friendly products (coop). The price of organic calves is more expensive than conventional calves. With the current situation, it is not popular to come up with a new program that involves a higher consumer price (coop prod.).

It was further argued that the image of organic food is 'a bit dusty and old-fashioned' and that attempts have been made to change the menu and image – but it is a barrier that is taking time (gastronomy 2). In addition to this, there is a hype regarding vegan consumption where people often think that it is good for the environment to stop eating meat and that veganism can compensate for this (processing). Here it was mentioned that newspapers and journals could promote this trend more often (processing).

Finally, it was mentioned that if the focus is only on GHG balance then a higher efficiency in itself will reduce the GHG emission per kg milk. However, it should be taken into account that there is a dual purpose in dairy farming in that dairy cows are also producing a lot of meat through their calves which should also be reflected in the GHG balance to make it more fair and realistic (researcher). Moreover, there is too little time for in-depth research about new topics (such as improving organic agriculture in a climate smart direction) was mentioned as a barrierer for CSA adoption (advisor).

Regarding organic production, supply in sufficient quantities can be a problem: A considerable volume of a given product is often required in foodservice as otherwise a lot of different dishes needs to be used maybe some with non-suitable parts of the meat have to be used - then the quality of the dishes decreases (gastronomy 2). Only some butchers can provide these high quantities in a good organic quality (gastronomy 2).

Lithuania (wheat)

In Lithuania, stakeholders represent various parts of the wheat supply chain as outlined in the following:

1. A primary producer (farmer 1)
2. A provider of agro-technology for primary producers (agrotech provider1)
3. Provider of agro-technology for primary producers (agrotech provider2)
4. A company that produces Eco-labels and certificates for sustainable farming systems (supplier)
5. A company within logistics, that export, and connects producers and export companies (logistics)
6. Primary production (farmer 2)
7. Company that sells fertilizers, seeds, agrochemicals and selling grains (supply company)
8. Company that sells different grain products - bread, flour and other (sales cereals)
9. Primary production (farmer 3)
10. Primary production (farmer 4)
11. Online shop for the farmers (sales)
12. Company that buy raw materials from farmers and sell products to wholesalers and supermarkets (wholesaler).

Initiatives

A number of smart farming technologies like digital tools and data management systems (farmer 1, farmer 2, sales) as well as more focus on automation in the supply chain (logistics) are all mentioned as promising CSA solutions in the wheat supply chain. In particular, fertilization plans and smart fertilization equipment (N-spreaders) with soil testings and automatic steering systems (farmer 2) are suggested. The latter enable fuel savings due to less overlap and thereby less driving in the field (farmer 1). These initiatives are highlighted as solutions to reduce GHG. Field/soil-mapping to reduce the amount of spraying, (farmer 3) and finally robots that are implemented on small farms are mentioned as a sustainable solution as well (sales). Better and modern tractors to save fuels (farmer 4) and better utilization of existing machinery are also identified as climate smart practices (farmer 3).

In addition, it was suggested that practices that increase productivity and enable farmers to save money (farmer 3, wholesaler) such as reduced water consumption when spraying with fungicides and pesticides are sustainable solutions (agrotech provider1). Soil improvement practices are also mentioned as climate smart practices (agrotech provider1). Moreover, it is suggested that a specific selection (breeding) of wheat with large roots could increase the absorption of nutrients (agrotech provider1). In addition, better and more resistant seed varieties and micronutrient fertilizers and methods to replace non-organic fertilizer's (farmer 3) were mentioned as potential climate smart practices (supply company).

It was suggested that an increase in the amount of green area (farmer 3) and local production of fertilizer should be promoted in cereal production (farmer 1). Intercropping (farmer 1) and reduced/minimal tillage and smart drainage systems was also recommended (farmer 4).

Ideas for more technical solutions to improve CSA include solar panels and implementation of solar parks (wholesaler, logistics). Packaging alternatives and more circular solutions were also advocated for by one stakeholder (logistics). Technology to clean and dry grain without chemicals (sales cereals), waste-free production where grain residues are used for composting and humus production were also mentioned. More specifically, it was recommended to use buckwheat hulls instead of diesel fuel in boilers. Buckwheat hulls can also be used in greenhouse for compost humus (wholesaler).

One CSA initiative could be to introduce loyalty programs for farmers – so that all sustainable farmers get a discount after 2- 3 years (sales cereals)

Drivers

Several stakeholders mentioned that a main driver and incentive for farmers to take up climate smart practices are economic benefits - when it brings more benefits than costs compared to traditional farming. For many stakeholders a key driver is also governmental regulations or support (logistics, agrotech provider1, wholesaler, supplier, farmer 2.) either from national or EU authorities (agrotech provider2). Financial support from government or tax reductions are here regarded as important drivers (farmer 1, sales cereals). In particular, it was mentioned that a compensation for higher actual costs is needed (agrotech provider1).

Knowledge**,** education, and training are also regarded as key drivers (farmer 2) including knowledge/ information from universities (farmer 4). Clear understanding of the added value from the sustainably produced wheat is also mentioned as a driver (agrotech provider1). It is important to receive guidance from neutral consultants since many consultants are often biased with a hidden agenda when they sell certain products (farmer 2). New market trends for cereals could also be regarded as a potential driver for climate smart agriculture (supply company).

Barriers

The main barrier is lack of willingness to invest. Lack of financial incentives is therefore a barrier (sales cereals, farmer 1, farmer 4, wholesaler, sales logistics). Today the situation is that farmers do not have a market for eco-products, mostly because there is no high market demand and willingness to pay a premium price from the consumers (supply company).

In the wheat supply chain, another barrier that was emphasized was lack of trust in using automatic systems - especially when it comes to data security (farmer 1). It is also hard to invest in smart technology - it is expensive, and returns come very slowly (farmer 4).

The mindset among young farmer families is very entrepreneurial and they implement a lot of technology, but unfortunately this is not true for all farmers (sales). Therefore, education and collaboration are needed. There is a need to encourage the farmers to be more active, to be part of cooperatives and participate in educational programs so that they can see "the bigger picture" instead of only obtaining information from suppliers and salesmen (farmer 2). The organization of governmental institutions was also seen as a barrier in that governmental institutions follow certain governmental programs (supplier) which may be a barrier for changing behaviour.

In regard to specific technical solutions in the supply chain, it may be hard to find packaging solutions that would meet the hygiene standards and are able to fit in the production line, and also at the same time are profitable (logistics).

To provide climate smart solutions it was further mentioned that educational activities for farmers on sustainable farming are needed (supplier) – thereby indicating that lack of education is a barrier for CSA adoption.

Spain (apples)

In Spain, stakeholders represent various parts of the apple supply chain as outlined in the following:

1. A company that produces apples, cider and juice (prod.process1)
2. Apple producer (producer1)
3. Primary production, distribution and marketing (prod. and distrib)
4. Apple producer (producer2)
5. Primary production of apples, processing of apples (prod. process2)
6. Distribution of apples, vegetables, fruits, dry products (wholesale1)
7. Primary producer and processor, juice and beer (prod. Process3)
8. Distribution of products in large warehouses (wholesale2)
9. Production, processing and distribution to retailers and wholesalers (prod. Process4)
10. Production of grapes and sweet fruit (producer3)
11. Apples and kiwi-fruit producer (producer4)
12. Production of apples and apple juice (prod. process5).

Initiatives

Local production is advocated as a climate smart practice with self-sufficiency of raw material as a climate smart initiative. Processing with organic apple and local fruit varieties and sales in differentiated and local markets are also mentioned as CSA practices (short chain and direct sales) and more efficient machinery for processing to increase production and cultivated hectares (prod.process1). In addition, it is suggested to use products that are marketed locally and with a focus on seasonality (wholesale1) thereby also securing efficiency in the distribution of apples. Optimizing the routes to reduce mileage and use of the full capacity of vehicles is also suggested as a CSA practice (prod. and distrib). Another suggested initiative was to set up a collective warehouse to reduce GHG emissions by reducing the distance of transportation of organic apples (producer2). Also, producing cider from own apple production was suggested as a CSA practice (prod. process5).

In regard to machinery, it is suggested to employ mechanical weeding machinery (producer1) and use GPS machinery in apple production (producer1). Use of efficient machines in the application of plant protection products (producer3) and to use electrical machinery where possible was also a suggestion to approach a climate smart solution (producer4).

Installation of solar panels for energy savings (wholesale2 producer3) and optimization of water pumping and irrigation systems are recommended by several stakeholders (producer1, producer2 prod. process2, prod. process4). Recirculation with atomisers is also mentioned as a climate smart initiative in apple production (producer1).

Anti-phytosanitary and anti-pest nets to reduce pesticides and reduce water use from fruit trees (producer1) and treatments for fungi in apple tree production, which is regarded as more sustainable was also recommended by one stakeholder (prod. process2). Furthermore, grass cutting that leaves a central aisle in the field and serves as a reservoir for auxiliary fauna is mentioned as a sustainable practice (producer2).

One stakeholder suggested to focus on improved energy efficiency in the refrigerated storage of products (prod. and distrib) and to establish a collective refrigerated storage facility and sorting of apples in close proximity (prod. process2). Furthermore, reuse of packaging for vegetables is mentioned as a climate friendly practice (prod. and distrib) as well as reuse of packaging (oil, other dairy products, etc.) (prod. and distrib).

Better farm management and better use of implementation tools for crop planning were suggested as CSA practices and technologies (prod. and distrib) and to implement IT tools for order management (prod. and distrib). Also, implementation of computerized management for order management, stock control and storage is recommended as currently, everything is carried out manually and requires a lot of dedication (wholesale1).

Organic production and organic fertilization (producer3) as well as reduced crop treatments (prod. Process4) are mentioned as climate smart initiatives e.g. introduction of sheep and horses in apple orchards to maintain vegetation cover (prod. process2.,prod. process3) and use of home-made manure from livestock instead of processed fertilizers produced from far away (producer2, producer4). Planting of traditional varieties for seeking a better agro-climatic adaptation and efficient use of resources was also recommended by stakeholders (producer4). Moreover, to implement vegetation covers with different species (preferably legume family) was suggested (producer4) as well as closed-cycle management of waste from apple tree pruning (prod. process5).

It was suggested to acquire more knowledge on pollination of traditional varieties to improve pollination and increase fruit yields (prod. process5) while specific solutions regarding use of bees to improve pollination of apple crops were recommended (prod. process2).

A number of specific technologies were suggested: Use of green manures (prod. process3), reuse of glass from beer bottles (prod. process3), controlled atmosphere chambers to keep fruit longer in the correct temperature and with a humidity and respiration-controlled environment for the fruits (wholesale2). In addition, recirculation of fruit washing water in the field before entering the chamber (wholesale2), using machines for separating pallots according to fruit category (wholesale2) and using compostable plastic in packaging unit (prod. process4) as well as introduction of biodegradable cleaning products were mentioned (production and distribution).

Initiatives to improve social sustainability and stability for the producers such as long-term relationships in the supply chain, advanced payments, and wages for workers were also mentioned (prod. Process4). Furthermore, voluntary training courses for growers with topics being geared towards environmental protection were suggested (wholesale1). Other suggested initiatives for a more climate smart apple production included more rural housing and juice production and marketing – however time is needed to study the profitability (prod. process5).

Drivers

In the Spanish apple supply chain, income and financial incentives were recommended as a driver. In particularly, finances to carry out the project with the most appropriate technology are needed (prod. process1).

Another driver is to increase public subsidies for CSA adoption e.g. aid for equipment and infrastructure (prod.process1) and easier access to investments is needed (prod. process2). More help with technical support to try new initiatives to improve the organization in the apple supply chain is also mentioned as a driver (producer1) and targeted aid for the acquisition of new machinery or infrastructure were mentioned as well (prod. process2).

A number of stakeholders pointed toward the need for financial support to drive digital investments to enable climate smart production (wholesale1, producer3 prod, process3) e.g. funding to adapt the current cooling facilities such as installing solar panels, funding to replace engines or funding for establishing networks that can share the cooling facilities (prod. and distrib).

More knowledge about packaging is required - for instance labels that are easier to wash off when washing the bottles (prod. Process3) more knowledge about how to manage these activities (producer4.). Some of the CSA initiatives require an initial commitment in order to implement them (wholesale1) but also new ideas for processing to improve day-to-day operations (wholesale2).

Consumer appreciation of the product and farmer ability to access new markets are also seen as drivers (prod.process1).

Barriers

In the apple supply chain, lack of funding and investment capacity are seen as a barrier among several stakeholders (prod. process2, wholesale1, wholesale1) e.g. lack of funding to enable retro-fitting or installation of equipment (prod. and distrib).

In addition, regulation and policies, including lack of regulations and incentives, lack of financial support and lack of fair trade are also regarded as a barrier as well as bureaucracy (producer1, producer3, wholesale2, prod. process2). More specifically, one stakeholder argue that a River Management Agency was a barrier as it applies arbitrary regulations without assessing the individual cases (prod.process1). The same stakeholder also argue that the Hygienic-sanitary regulations are seen as a barrier as there are the same obligations for a large production plant as for a small processor, while regulations should be made more flexible to help production in the supply chain (prod.process1).

Barriers also include lack of knowledge about the production process (prod. process4). For instance, for some CSA initiatives there not sufficient technical knowledge or time that can be invested in better understanding the initiative and its implementation (producer4). Finally, environmental risk, such as flooding that could make a processing plant unusable can also be regarded as a barrier for development (prod.process1).

Better organisation of this sector is needed as mentioned by one stakeholder (prod. and distrib).

Denmark (pig production)

In Denmark, stakeholders represent various parts of the pig supply chain including:

1. Producer and manufacturer (prod.manufac.1)
2. Producer and manufacturer (prod.manufac.2)
3. Farmer (farmer1)
4. Farmer (farmer2)
5. Farmer (farmer3)
6. Farmer (farmer4)
7. Retailer (retailer)
8. Technology provider (tech.provider1)
9. Technology provider (tech.provider2)
10. Private organic association (association)
11. Technology developer (tech dev.)
12. Software developer (soft. dev)
13. Restaurants, catering services (catering)
14. Communication platform (comm. dev.).

Initiatives

Use of renewable energy was mentioned as a climate smart initiative (farmer2). In particular, energy optimization with electric engines for ventilation, including use of solar panels was an initiative suggested by one stakeholder (farmer1). It was suggested that hybrid ventilation gives improved energy consumption and a better and more stable indoor climate. Hybrid ventilation combines natural ventilation with a floor extraction and it significantly reduces energy consumption in ventilation systems (tech.provider1). Smart farming with ventilation, indoor climate control and air cleaning in one unit was also recommended (tech.provider1).

Likewise, frequent flushing of manure, performed automatically was suggested as a GHG mitigation practices, which at the same time means less odor from the stable and gives an easier daily life by avoiding heavy and time consuming operations and lifting of slurry plugs (tech.provider1). It was also argued that floor extraction supports and enables environmental approval (tech.provider1). Smart farm control systems, regulators and monitors of ventilation, heating and cooling in the stable on a central PC are also suggested as climate smart solutions – and they can be monitored on a smartphone or tablet (tech.provider1).

Several initiatives were related to slurry handling and to reduce emissions (including methane etc.) from storage (soft. dev). Technology can be used to separate dry matter from livestock slurry whereby the dry matter can be used for biogas production (prod.manufac.1) and technologies for cooling of slurry stored in animal houses, which also enable a reduction of methane emission and ammonia emission (tech dev.). When the dry matter is converted to biogas - emission of methane from the slurry during storage is reduced. In addition, biogas can substitute natural gas (tech.provider2) for heating as a climate smart alternative. Finally, technologies and management practices that secure manure to be quickly removed from the pig stables. This will reduce storage time in the stable and lead to reduced emission of methane from the manure (tech dev.) Acidification of slurry will also reduce both methane and ammonia emission from both animal houses and slurry storage tanks as suggested by one stakeholder. Acidification e.g. by adding sulfuric acid to the slurry under controlled conditions (tech dev.) Acidification of slurry is a tool to minimize ammonia emission, hereby improving the fertilizer and to enhance productivity in crop production (soft. dev). More specifically it was suggested to include software programs for handling logistics when moving and applying slurry and it was suggested to establish a cooperative to import sulfuric acid (soft. dev).

Overall, there should be a better balance between production and consumption (farmer1). Several stakeholders focused on local production, including locally produced protein (farmer2), local production and marketing to enable a short supply chain from farm to table (farmer4), improved logistics (retailer) and more specifically it was suggested to establish a local sawmill to produce fence posts and wood for housing (association). To minimize feed waste was suggested as a focus area (farmer2), to avoid ploughing and to plant more forests (farmer2). One stakeholder argued that residual products are better for animal feed than for biogas (farmer4). It was also suggested to develop a more circular use of residual products from feed in the organic system (farmer4) e.g. recycle materials as feed that have been produced for human consumption (farmer2). At the retail level it was suggested to reduce food waste and meat consumption. Rather use quality meat and less amounts than a lot of meat was an argument by one stakeholder (catering).

It was suggested that one way to get suppliers to commit themselves to CSA initiatives, would be to inspire them to set targets to reduce their carbon emissions (retailer). Also, help to customers is needed if they are to pursue a greener lifestyle using greener products and services (retailer). Furthermore, in order to engage employees in green action it is necessary to have a reward system and to promote green action e.g. by educating and making employees climate ambassadors (retailer).

In addition to the above initiatives, a number of specific initiatives were mentioned including recycled equipment on the farm such as feed trough, water trough, etc. (association). Developing technology for smart field work and precision agriculture (farmer3) e.g. spot spraying individual weed species based on recognition and online data analysis with scanning/mapping of fields to optimize crop production (Prod.Manufac.2). One stakeholder suggested to include conservation agriculture in different degrees (farmer1). Another stakeholder proposed setting aside low-lying areas fields from crop production as a CSA practice (farmer2). Better irrigation systems were also mentioned as a climate smart initiative (association). A very specific initiative was related to better use of coffee ground. At the moment, it is taken to DAKA (company that treat animal waste etc.), but this is poor utilization according to one stakeholder (catering). Gathering data from the agricultural production into a software platform so that users can point on their phones on the end product in the supermarket and see e.g. CO2 emissions etc. was also recommended as a relevant CSA initiative (comm. dev.).

Drivers

There are several drivers to promote climate smart farming in pig production. The Government or EU could introduce a subsidy scheme to motivate farmers (Prod.Manufac.1). More active political interaction that can encourage farmers towards a more climate-optimal operation in the primary production via economic redistribution of agricultural support (farmer2). Fair allocation of subsidies was also mentioned (tech.provider1). Government or EU could introduce a subsidy scheme to motivate farmers to invest in climate smart solutions for agriculture (tech.provider2) and subsidies that enable more farmers to afford precision technology (prod.manufac.2). It was also suggested to introduce a bonus fee to those farmers who have invested in climate smart technologies, which lead to reduced greenhouse-gas emissions (tech.provider2).

Financial incentives are also regarded as a main driver. Climate smart practices need to be profitable (farmer3, farmer1, soft. dev) and there is currently a lack of funding. Some initiatives are already financed through crowd-lending (funding) according to one stakeholder (farmer4). It was recommended that incentive schemes must be implemented to motivate farmers to invest in climate smart technologies. For example, financial support schemes from the EU or national governments to farmers who want to buy and install the technology (tech dev.).

Local support (farmer4) and satisfaction with own work (farmer4) and the joy of succeeding as well as professional pride (catering) are also mentioned as drivers for adoption of CSA. Commitment from producers and retailers as well as consumers starting to use climate smart services was recommended (comm. dev.) By having suppliers to commit to initiatives and if these initiatives align with the ambition of the company – then the company may have a better chance to progress (retailer). In addition, it was suggested that meat producing companies could motivate livestock farmers to produce more climate smart. This can be done by introducing a bonus fee to those farmers (prod.manufac.1). An investigation of the possibilities must be carried out and then there must be agreement in the group of users/farmers (association).

Barriers

As outlined above an incentive to use climate smart farming systems could be a either a financial benefit or maybe a direct subsidy. Likewise, a barrier could be a lack of finance or subsidies (farmer2, prod.manufac 1,tech dev, comm. dev.). Most farmers will not invest in new technologies unless there is a strong incentive (tech.provider2). There needs to be a financial incentive to implement and practice CSA. It is not sufficient with subsidies as one stakeholder mentioned (farmer3). If it is not possible to find payable financing, then the risk becomes too great (farmer4). Rules, legislation, regulations are often regarded as a barrier. There are few subsidies favoring climate smart initiatives at farm level as one stakeholder argued. As indicated above, depending on how the CO2 tax is designed, it can both be a barrier and a driver. It can or must be expensive to do the wrong thing and it should be cheaper to do the right thing (soft. dev). National and EU framework conditions for pig production including CO2 tax is regarded as barriers for production (farmer1). Alternatively, the national government or EU could implement legislation so that it is a legal requirement that farmers reduce their climate impact (prod.manufac.1). Barriers can also be related to a wrong political agenda for allocation and prioritization of areas. E.g. in 2020 subsidies and support schemes were only be given to acidification of slurry – which is regarded as too narrow (tech.provider1). Subsidies seems to be allocated to what is 'hot and new' and not necessarily considered in a bigger picture (system perspective), where initiatives can support each other instead of competing (tech.provider1)

Furthermore, it is difficult to find expert knowledge and get the best use of field and soil data (farmer1). Many systems are not able to 'talk together' and valuable data is then lost if the system or operator of data handling and storage is changed or replaced (farmer1). There is also a need for installers of equipment, as stated by one stakeholder, they simply do not keep up! (prod.manufac.2). Time must be found to examine the possibilities and present them to the users (association).

Documentation requirements for manufacturers is also a main barrier for adoption of climate smart initiatives. Producers must be able to say how much they produce and deliver, and there are requirements about production etc. (catering). Another example is given where a barrier could be about technical verification e.g., estimates from biological air cleaners - that are given are not always reliant (tech.provider1).

Constraints from neighbors is also a significant barrier for many farmers, especially when farms get bigger, even though the air cleaner applications are used and announced to be part of the construction (tech.provider1).

Netherlands (potatoes)

In the Netherlands, stakeholders represent various parts of the potato supply chain as outlined in the following (note that due to communication problem, only 9 out of 16 interviews are analysed so far):

1. A unit that supports social development and prosperity in the province (province)
2. Environmental Federation (env. fed)
3. Advisor that represents the interests and purchase conditions between the grower and buyer (advisor)
4. Test on research farm (research)
5. Food foundation network (foundation)
6. Producer as well as a processor and wholesaler of potatoes (prod. proc)
7. Potato processor selling frozen fries (processor)
8. Advisor in cultivation, soil and drainage (crop adv.)
9. Producer of French fries and flakes (manufac.).

Initiatives

One of the initiatives that were suggested was to enable long-term CO2 storage, for example in woody crops used as landscape elements and from agroforestry but also fiber crops from which products are made (province). Regarding fiber crops, it was recommended to use for instance Miscantus (crop adv.). For short-cycle crops, this can be done through improved measures to increase organic matter.

Reduced tillage such as tilling with direct sowing was also mentioned as a CSA solution (prod. proc) as well as strip cropping and more mechanical weed control. It was also suggested to use cultivation-free zones so that fewer pesticides end up in the ditch (env. fed).

Robust potato varieties that require lower nitrogen inputs could enable climate friendly production. These varieties need to be more resistant to drought as it is becoming more common in the region. Breeding should be used in the right way and not just be done by those parties and companies that want to sell their products (advisor).

Drip irrigation, soil and water management, level-controlled drainage and underground water storage were also mentioned. Green manure choice plays an increasingly important role (manufac, advisor).

Precision farming and robots is seen as a climate smart initiative where many growers already use GPS on their tractors – it enables less and better driving. This technology can also be used to perform precise weeding in organic farming (province), including, the identification of plots that need more or less care by using plant-specific technologies. Site-specific application of nitrogen from measuring of biomass with sensors on the sprayer and using this to control nitrogen application was also mentioned. In addition, it is recommended as a specific initiative that more advice about tyres to reduce fuel consumption is needed.

Several other initiatives about digital solutions were also recommended. One solution is bottom scans for place-specific planting to get as many potatoes in the right size as possible. Self-learning algorithms e.g. in hoeing and plant recognition and footprint data valorization was also suggested as a climate smart solution (prod. proc). To do this, the data must first be properly mapped to add value for different stakeholders in the production chain.

Also, reducing waste was mentioned as an initiative (foundation) and to provide short links in the chain to reduce transport. Furthermore, solar panels on storage facilities were mentioned as a climate smart solution. The water supply could also be more efficient, for example by saving water that falls in winter to be used in the summer season. Surface water monitoring and looking for a way to reduce pollution (processer). Another solution from one stakeholder was to use tax reservation for weather extremes, (advisor). Farmer-citizen communication on plant protection products and explaining plant quality requirements is also recommended by one stakeholder (processor).

Drivers

A key driver that was mentioned for several of these initiatives is long-term policy commitment to ensure stable long-term conditions for producers and processors to make investments. This is also related to another key driver, which is a clear agricultural vision among policy makers (prod. proc). Another driver is social interest, which remains a driving force for adopting CSA (province).

It was mentioned as important that customers are willing to pay more for sustainable products (manufac.) Climate-smart agriculture is challenging in the supply chain because there is no direct long-term link between growers and buyers. In that regard, it is suggested that a driver could be a long-term commitment between potato growers and processors.

One mentioned that in general, it was suggested that smarter resource use basically involves looking at the point at which greenhouse gases are released and where savings can be made.

Barriers

A key barrier that was mentioned by most stakeholders is lack of finance and the cost of implementing climate smart agricultural practices and initiatives (province, prod. proc). Lack of governmental intervention is also mentioned as a barrier among stakeholders. In the processing link, lack of availability of raw material is preventing production of climate smart potato products (processor).

9.4. Conclusions

Across countries and types of agriculture, the lack of financial incentives, lack of knowledge within the supply chain of ways to adopt CSA practices or technologies were stated as major barriers for increased adoption of CSA practices or technologies. Many ideas for increased adoption of CSA practices and technologies came forward ranging from very farm-specific changes e.g. frequent flushing of manure in pig stables to broader initiatives involving e.g. more local sourcing of food and increasing organic or more plant based food in public foodservice.

More details on the main findings from the interviews regarding stakeholders’ view on adoption of CSA practices and technologies as well as drivers and barriers (individual, systemic and policy factors) from the five use cases are summarized below.

Climate smart initiatives in the **German dairy production** include local production, photovoltaics, market for calves, focusing on life-long production for cows, local protein feed supply, awareness, organic certification, waste, promoting seasonal and regional purchasing and advising about biodiversity.

As an individual driver it was highlighted that farmers need a financial incentive to adopt climate smart farming systems. It was also highlighted that farmers need financial incentives to join projects. It was further stressed that advise and expertise is needed from outside the farmers' organization as drivers, which also include setting political goals (policy driver). Key systemic drivers are education and communication as well as advise and expertise. Education and advice for farmers is regarded as a major driver, but also communication towards customers is important. Political action and public procurement are both policy drivers and it was mentioned that an increase in organic farming can only be achieved through political action in the area of public procurement for public canteens and restaurants etc.

As individual barriers, limited access to specific technologies at the moment was mentioned. Among systemic barriers, it was argued that higher prices to farmers are necessary to enable production of organic food. This must be accompanied by the willingness of consumers to pay higher prices for climate-friendly and organic products. Image may also be a systemic barrier – where some stakeholders argued that the image of organic food is still 'a bit dusty and old-fashioned'– it is a barrier that is taking time to change. Furthermore, lack of research and little time for in-depth research was mentioned as a systemic barrier.

Climate smart initiatives in the **Lithuanian wheat production** include smart farming technologies, higher productivity, resistant seed varieties, replace non-organic fertilizers, local production, waste-free production, and specific educational activities.

As individual drivers economic and financial benefits were highlighted as key drivers. In addition, education, and training (systemic driver) was also a focus area among stakeholders to enable adoption of climate smart initiatives. Barriers include lack of financial incentives (individual). In the wheat supply chain, a barrier that was emphasized is lack of trust in using automatic systems - especially when it comes to data security (systemic). There is also a need for unbiased and independent education and collaboration (systemic). As a policy driver and barriers focus should also be on governmental institutions and regulation (policy).

Climate smart initiatives in the **Spanish apple production** include local production, efficient machines, solar panels, energy efficiency, organic production, specific technologies and social sustainability. Financial incentives and specific numerous activities (individual) are seen as drivers for adoption of climate smart initiatives. More specifically, finances to choose the most appropriate technology are needed. Knowledge (systemic) about packaging is required – and new ideas for processing so that companies can advance and improve their day-to-day operations. Public subsidies (policy drivers) to support projects of this type such as aid for equipment and infrastructure is also mentioned. Lack of funding and investment capacity is seen as a barrier among several stakeholders (policy) and lack of individual knowledge (individual). Among barriers are also regulation (policy), including policy measures, lack of regulations and incentives, lack of financial support and investment and lack of fair trade is also regarded as a barrier as well as bureaucracy is seen as a major barrier in the supply chain.

Climate smart initiatives in the **Danish pig production** include renewable energy, better ventilation, local production, reduced feed waste, education and advice, slurry handling and software development.

Key drivers include financial incentives, access to finance (individual) as well as satisfaction with own work was seen as a key individual driver for adoption of CSA. Subsidy schemes and bonus fees (policy) could also be drivers for adoption just as incentive schemes should be implemented to motivate farmers to invest in climate smart technologies. For example, financial support schemes from the EU or national governments to farmers who want to buy and install the technology. Lack of financial benefits and expert knowledge (individual) could also be a barrier. It was mentioned that it could be difficult to find expert knowledge about specific field data etc. Problems with technical verification may also be a barrier (individual). Constraints from neighbors are a significant systemic barrier for many farmers, especially when farms get bigger. Legislation and regulation (policy), rules, legislation, regulations are often regarded as a key barrier. There are few subsidies favoring climate smart initiatives at farm level as one stakeholder argued. And tax on GHG could also be a major barrier depending on how the CO2 tax is designed.

Climate smart initiatives in **Dutch potato production** include improved irrigation, robust potato varieties, digitalization and precision farming, water monitoring and savings. It is important that customers are willing to pay more for sustainable products (systemic driver). Climate-smart agriculture is challenging in the supply chain because there is no direct long-term link between growers and buyers. A key driver that was mentioned for several of these initiatives is long-term policy commitment so that the long-term conditions for producers and processors are stable for making investments (policy). A key barrier that seems to be mentioned by most stakeholders is lack of finances (individual/systemic) and cost of implementing climate smart agricultural practices and initiatives. In the processing link, availability of raw material is preventing production of climate smart potato products (systemic). Lack of government (policy) is also mentioned as a barrier among stakeholders in the Dutch potato supply chain.

10. General Conclusions

In conclusion, five systematic reviews have been conducted with the aim to map: i) farmers decision making process towards CSA, ii) business strategies for CSA, iii) consumer decision making process with regards to choices of environmentally-friendly products, iv) current CSA practices and technologies used by farmers, v) current policy and regulatory framework for CSA. The reviews highlight the importance of adopting a food system approach in understanding transitions to CSA. In particular, farmers are influenced by socio-demographic and psychological factors when deciding on whether to adopt CSA practices. Most importantly though, they are affected by systemic factors such as social norms, information provision, extension and advisory services, market conditions, regulatory framework, among others, which pose barriers or drivers for their transition to CSA. With regards to effective business strategies, the review stresses the importance of multi-stakeholder coordination through collaborative business models. This approach ensures the strategies of individual actors are harmonized, that values created at each actor, shared and captured by other actors' needs are aligned and perceived as fair by all stakeholders and therefore collective transitions to CSA are facilitated. Consumers as agri-food value chain stakeholders play a major role in the farmer adoption of CSA since they are potential buyers of food products produced with CSA. Consumers' individual characteristics, such as motives, personality traits, demographics affect their decisions to purchase environmentally-friendly products. Even more importantly, product characteristics, such as quality, price, freshness, labelling of environmentally-friendly products increase purchases by consumers as well as the increased availability of such products in various purchase points (e.g., local stores, local markets, specialty shops). The review also suggests that various CSA practices are used for crops, livestock, soil management and irrigation with the aim to achieve the triple win of CSA and that smart farming technologies play a significant role in increasing productivity, reducing GHG emissions and boosting resilience to climate change. Finally, the review has focused on the evaluation of CAP as the main EU policy instrument to foster transition to sustainable agriculture. The review suggests that climate-smart agriculture is a relatively new term for CAP and that although CAP measures have provided support to farmers, they should be better adjusted to fit the needs of different countries, include more measures for the digitalisation of the agricultural sector and also add monitoring systems to allow evaluation of their effectiveness and progress towards the EU ambitious sustainability goals.

A consumer survey complemented the systematic reviews with additional knowledge of decision-making factors that influence consumer's behaviour towards environmentally friendly food products. While the reviews were based on published studies of consumer behaviour, the consumer survey was conducted in 2023 and elicited information directly from consumers. The contribution of the consumer survey was partly to elicit up-to-date information as information extracted from peer-reviewed articles by definition are a few years old. Also, the consumer survey contributed with targeted information on knowledge of CSA and attitudes towards environmentally friendly food products – topics that are at the heart of the Beatles project.

Based on the 1219 sampled consumers from mainly six countries (Denmark, Germany, Lithuania, Netherlands, Slovenia, Spain) we found a general interest in buying food that contributes to a better environment, better animal welfare, public health, and fairness throughout the supply chain. While none of the variables (constructs or items) were strongly correlated with willingness to buy environmentally friendly food, a number of the consumer-based constructs were moderately correlated: Perceived behavioural control of buying situations, habits regarding buying environmentally friendly products, stated willingness to pay for environmentally friendly food etc., perceived self-responsibility and willingness to pay for CSA grown potatoes. Barriers could include a relatively low self-efficacy construct; the samples consumers were not too happy with the supply of environmentally friendly food and the information level offered by labels. At the same time, relatively high scores on self-responsibility and a relatively high feeling of pressure from surrounding people, constitute promising drivers.

The farm survey was based on data from 721 farmers from the five use cases (Denmark, Germany, Lithuania, Netherlands, and Spain). Concerning farmers' knowledge of climate smart agriculture practises, the majority of the sampled farmers have information about the practices and technologies. While less than half of them have applied CSA practices and technologies in the last five years. Regarding sampled farmers intentions, the majority farmers have indicated that they intend to adopt CSA.

Almost half of the sampled farmers agreed to adopt CSA practises and technologies that will lower production costs, increase productivity, reduce workload, and be useful for their farm operations. While perceived ease of use of the CSA is another adoption decision making factors that farmers considered and agreed that the CSA will be easy to learn, control, and understand how it is applied. Also the majority of the sampled farmers agreed that the compatibility of CSA practices and technologies should suit the way farmers like and be consistent with farming goal to make adoption decision.

Behavioural control has strong correlation with adoption intention of farmers. While faming motives self-responsibility, technology perceived usefulness, perceived ease of use, perceived compatibility have positive and significant correlation with stated CSA adoption intention - both are not strongly correlated. The farmers income level and education level and stated CSA adoption intention are related positively and significantly. While age of sampled farmers has a negative correlation with stated CSA adoption intention indicating that farmers with younger age group have better adoption tendency towards CSA practices and technologies. In addition, the correlation between the stated adoption intention and farming experience is negative indicating that farmers with higher farming experience have lower intention towards adoption of CSA.

The correlation analysis of main farming type and adoption intention shows a negative correlation, indicating farmers with livestock and mixed farming types, as their main production systems, have low adoption intentions. Governmental financial support has a positive correlation with the adoption of CSA. There is a significant and positive correlation between stated intention and the availability of certification and the ease with which it can be obtained. Regarding market access and stated intentions correlations, internet-based product sales have an insignificant but positive correlation. While physical marketplace sales of agricultural products and input market access have a positive and significant correlation with adoption intentions of the CSA. Participation in farmer training, farm visits, field demonstrations, field/farmer days, workshops/open discussions and advisory services have a significant and positive correlation with adoption intention. Finally, the information sources used farming business inquiry like internet or social media (Facebook or Twitter), requesting family and friends, following mass media, taking training courses, attending trade events, attending agricultural fairs, and requesting other farmers, farmer associations, and agricultural advisors have positive correlation with CSA adoption intention.

The findings from the interviews supplement the outcome from the farm and consumer surveys and the five systematic mappings. It was found, that different stakeholders in the supply chain suggest different solutions, but also that they have several suggestions for climate smart initiatives in common, such as: Local production and feed supply, better waste handling, seasonal production, smart farming technologies and digitalization, replace non-organic fertilizers, energy efficiency and renewable energy like solar panels, organic production, social sustainability, better ventilation, slurry handling and software development. In addition, improved irrigation, robust crop varieties, water monitoring and savings and targeted/specific educational activities.

Financial incentives and access to finance as well as satisfaction with own work was seen as a key individual driver for adoption of CSA. It was also found that subsidy scheme and bonus fees are seen as promising drivers of adoption. It was recommended, that incentive schemes must be implemented to motivate farmers to invest in climate smart technologies - such as financial support schemes from EU or national governments to farmers who want to buy and install the technology. Some of the key systemic drivers are education and communication as well as advise, expertise and public subsidies to support projects adoption of CSA practices and technologies. The general opinion was that it is important that, customers are willing to pay more for sustainable products. Long-term policy commitments are also important so that the long-term conditions for producers and processors are stable for making investments.

A key barrier that seems to be mentioned by most stakeholders is lack of finances and cost of implementing climate smart agricultural practices and initiatives. Taxes and levies on GHG could also be a barrier depending on how it is designed. Individual barriers for adoption of CSA technologies included e.g. lack of specialized knowledge or technology or that only a few companies have access to those technologies at the moment. Barriers could also be lack of trust in using automatic systems - especially due to uncertainty about data security, and there is a need for unbiased and independent education and collaboration.

Appendices

Appendix Table 1: SM1_Search strings.

Database	Search String
Scopus	TITLE-ABS-KEY ("climate smart agricultur*" OR "sustainable agricultur*" OR "conservation agriculture" OR "intercropping" OR "crop rotation" OR "fallow management" OR "zero tillage" OR "contour farming" OR "terrace farming" OR "cross-slope barriers" OR "vertical farming" OR "integrated food energy system*" OR "nutrient management" OR "breeding for climate change" OR "irrigation" OR "nutrient balancing" OR "manure management" OR "buffer zones" OR "farm pond*" OR "bunding" OR "trenching" OR "mulching" OR "organic farming" OR "crop rotation" OR "crop diversification" OR "diversification" OR "conservation tillage" OR "green manure*" OR " bio fertilizer*" OR "organic amendment*" OR " smart fertilizer*" OR "organic fertiliser*" OR "nitrogen fixation" OR "bio* pest control" OR " integrated pest management*" OR "mechanical weeding*" OR " pasture grazing" OR "feed additive*" OR "rainwater harvesting") AND TITLE-ABS-KEY ("Decision support" OR "Digital technolog*") OR "Robot" OR "Sensor" OR "Database" OR "ICT" OR "GPS" OR "GNSS" OR "Information system" OR "image analysis" OR "image processing" OR "camera" OR "video" OR "RFID" OR "Eid" OR "ruminal bolus" OR "drafting" OR "walk over weigh" OR "thermistor" OR "UAV" OR "UAS" OR "accelerometer" OR "pedometer" OR "virtual fencing" OR "RGB" OR "multispectral" OR "hyperspectral" OR "thermal" OR "LIDAR" OR "RADAR" OR "EMI" OR "satellite" OR "UGV" OR "recording" OR "guidance" OR "steering" OR "reacting" OR "variable rate" OR "monitoring" OR "platform" OR "aerial" OR "proximal" OR "ground" OR "FMIS" OR "Farm Management Information System" OR "internet of things" OR "cloud computing" OR "big data" OR "artificial intelligence" OR "machine learning" OR "simulation" OR "augmented reality") AND TITLE-ABS-KEY ("open agriculture" OR "precision agriculture" OR "precision farming" OR "smart farming" OR "smart agriculture" OR "livestock farming" OR "precision livestock farming" OR "precision livestock") AND TITLE-ABS-KEY ("arable" OR "open field" OR "vegetable*" OR "orchard*" OR "legume*" OR "cereal" OR "forage*" OR "fodder" OR " fruit" OR "vineyard*" OR "horticulture" OR "crop*" OR "animal*" OR "animal husbandry" OR "ruminant" OR "poultry" OR "cattle" OR "beef" OR "pig*" OR "dairy")
Web of Science Core Collection	(TS=(climate smart agriculture*) OR TS=(sustainable agricultur*) OR TS=(conservation agriculture) OR TS=(intercropping) OR TS=(crop rotation) OR TS=(fallow management) OR TS=(zero tillage) OR TS=(contour farming) OR TS=(terrace farming) OR TS=(nutrient management) OR TS=(cross-slope barriers) OR TS=(vertical farming) OR TS=(integrated food energy system) OR TS=(breeding for climate change) OR TS=(irrigation) OR TS=(nutrient balancing) OR TS=(manure management) OR TS=(buffer zones) OR TS=(farm pond) OR TS=(integrated pest management*) OR TS=(bunding) AND (TS=(trenching) OR TS=(mulching) OR TS=(organic farming) OR TS=(pasture grazing) OR TS=(crop diversification) OR TS=(feed additive) OR TS=(conservation tillage) OR TS=(green manure) OR TS=(smart fertilizer*) OR TS=(organic fertiliser) OR TS=(nitrogen fixation) OR TS=(bio* pest control) OR TS=(rainwater harvesting)) AND (TS=(Decision Support) OR TS=(Digital technolog*) OR TS=(Sensor) OR TS=(Database) OR TS=(ICT) OR TS=(Robot) OR TS=(GPS) OR TS=(GNSS) OR TS=(Information system) OR TS=(image analysis) OR TS=(image processing) OR TS=(camera) OR TS=(video) OR TS=(RFID) OR TS=(Eid) OR TS=(ruminal bolus) OR TS=(drafting) OR TS=(walk over weigh) OR TS=(thermistor) OR TS=(UAV) OR TS=(UAS) OR TS=(accelerometer) OR TS=(pedometer) OR TS=(virtual fencing) OR TS=(RGB) OR TS=(multispectral) OR TS=(hyperspectral) OR TS=(thermal) OR TS=(LIDAR) OR TS=(RADAR) OR TS=(EMI) OR TS=(satellite) OR TS=(UGV) OR TS=(recording) OR TS=(guidance) OR TS=(steering) OR TS=(reacting) OR TS=(variable rate) OR TS=(monitoring) OR TS=(platform) OR TS=(aerial) OR TS=(proximal) OR TS=(ground) OR TS=(FMIS) OR TS=(Farm Management Information System) OR TS=(internet of things) OR TS=(cloud computing) OR TS=(big data) OR TS=(artificial intelligence) OR TS=(machine learning) OR TS=(simulation) OR TS=(augmented reality)) AND (TS=(open agriculture) OR TS=(precision agriculture) OR TS=(precision farming) OR TS=(smart farming) OR TS=(smart agriculture) OR TS=(livestock farming) OR TS=(precision livestock farming) OR TS=(precision livestock)) AND (TS=(arable) OR TS=(open field) OR TS=(vegetable) OR TS=(orchard) OR TS=(fruit) OR TS=(vineyard) OR TS=(horticulture) OR TS=(legume) OR TS=(creal) OR TS=(crop) OR TS=(forage) OR TS=(fodder) OR TS=(animal*) OR TS=(animal husbandry) OR TS=(ruminant) OR TS=(poultry) OR TS=(cattle) OR TS=(beef) OR TS=(pig) OR TS=(dairy))
Publication Year	2016-2023 because our focus is on current existing climate-smart agriculture
Document Type	The article, Review and Conference paper
Source type	Journal and Conference Proceeding
Subject area	Agricultural and Biological Sciences; Environmental Science; Earth and Planetary Sciences; Social science; Engineering; Computer science; Energy; Economics; Econometrics and Finance; Biochemistry; Genetics and Molecular Biology; Decision Science; Multidisciplinary; Veterinary Science; Materials Science; Business, Management and Accounting, Arts and Humanities
Publication stage	Final and Article in Press

Appendix Table 2: SM2_Discrepancies between the pre-registration plan and its actual implementation

	Pre-registration plan	Actual implementation	Justification
Screening	In a first step, the titles of all identified records were screened.	In the first step, titles and abstracts of all identified abstracts were screened	The aim was to keep the risk of unintentionally excluding suitable records as low as possible
Screening	Abstracts and full text of the selected papers were screened independently by two reviewers	Full texts of the selected papers were screened independently by two reviewers	Titles and abstracts had already been screened in the preceding step
Eligibility check	In case of a disagreement concerning the exclusion of studies, a third reviewer will be consulted	Only two reviewers made the decisions	No disagreements occurred
Eligibility criteria	Studies were included regardless of whether conducted based on primary production or not	Studies were only included if the agricultural practices and smart technologies focus on primary production only	We discovered that this criterion was overly lax throughout the screening process because it would have included most
Research question	What are the existing climate smart agricultural practices in Europe?	One addition research question in Section 'Search strategy and eligibility criteria' was included	Based on the suggestion of one reviewer.

Appendix Table 3: SM3_Indicators used to decide on CSA outcomes.

CSA outcomes	Indicators	References
Sustainable Productivity and income	Increment in yield and income, reduction of input cost, reduction in yield losses,	Selbonne et al 2023b, Matteoli et al 2021
Building resilience and adaptation	Soil organic carbon (SOC) stock variation, Inter-annual variation of yield, water and nutrient availability in the soil, efficient nutrient cycling, improved soil quality, feed improvement through legumes and changes in cropping/livestock activities; adaptation to climate risk	FAO,2021, van Wijk et al 2020, Selbonne et al 2023b
Reduce or remove GHG emissions	Enteric fermentation, Carbo sequestration, methane, ammonia, nitrate leaching, soil carbon dioxide (CO2), nitrous oxide (N2O) nitrogen leaching, reduce use of agrochemicals and synthetic fertilisers	Matteoli et al 2021, Selbonne et al 2023b, van der Weerden et al 2018
Improves biodiversity	Conservation of variety and variability of animals, plants and, soil microorganisms at species and ecosystem levels, improvement in the preservation and maintain landscape features, a biophysical aspect	Garske et al, 2021, Julia et al 2021
Improves animal welfare	Housing systems and space allowance, feeding and handling of animals, shelter and a comfortable resting area, access to pasture, rapid diagnosis and health interventions,	Bozzo et al 2022, Runge et al., 2022, Molnár 2022
Energy use Efficiency	Focus on renewable energy, own energy through solar panels, turning biomass from feed production into biofuel, biogas from manure management, minimize energy use in production process	Bas et al., 2022; Takacs-Gyorgy & Takacs 2022, López-Morales et al., 2021; Dabkienė et al., 2021
Water use efficiency	systemic water management, optimal water use, reducing evaporation, use of alternative water source	Martín et al., 2021; Visconti et al., 2020, Suciu et al., 2019;

Appendix Table 4: FS1_Reliability Statistics

Composite varibales	Cronbach's Alpha	N of Items
Stated intentions	0.919	3
Behavioral control	0.813	3
Perceived ease to use	0.9309	3
Perceived compatibility	0.8407	2
Perceived technology usefulness	0.9177	4
Farm motives	0.8798	11
Risk tolerance	0.5976	3
Self-responsibility	0.8457	5
Certification of CSA	0.8390	3
Subjective norm	0.8318	4
Perceived equity	0.9291	5
Perceived contribution	0.8942	4
Perceived honesty	0.7489	4
Information source	0.7651	9
Extension and advice	0.8567	7
Perception on financial situation	0.639	3
certifications	0.8390	3
Perception on access market	0.7131	3
Perception on WTP of buyers and consumers	0.7816	2

Appendix Table 5: FS2_Descriptive Statistics for item of questions

Variables	N	Mean	Std.Deviation
Stated intentions			
I plan to adopt a climate-smart agriculture practice or technology	721	4.90	1.487
I will regularly try to apply a climate-smart agriculture practice or technology in the near future	721	4,99	1.457
If it were entirely up to me, I am confident that I will adopt a climate-smart agriculture practice or technology	721	5,10	1.380
Behavioural control			
I have the ability to implement a CSA	721	4,69	1,479
If it were entirely up to me, I am confident that I will adopt a CSA	721	5,10	1,380
I have the resources, time, and willingness to apply a CSA on my farming activities	721	4,16	1,625
Farm motives: -It is important to me that running my farm business:			
has a low labour need	689	5,36	1,371
results in high yields	689	5,69	1,227
results in a high income	689	5,69	1,237
is good for the employment in my rural area	689	5,04	1,463
maintains the tradition of my family	689	5,38	1,367
has low production costs	689	5,57	1,313
produces the highest quality products	689	6,08	1,004
produces in an environmental-friendly way	689	5,88	1,102
produces with care for animal welfare	689	5,83	1,192
produces fairly priced products	689	5,90	1,115
produces with care for public health	689	6,04	1,027
Perceived ease to use			
I think that it will: - be easy to learn	721	5,25	1,554
I think that it will: - be easy to control	721	5,17	1,579
I think that it will: - be easy to understand how it is used	721	5,32	1,548
Perceived compatibility			
I think that it will: - be consistent with the farming goals I find relevant	721	5,54	1,422
I think that it will: - suit in the way I like to work	721	5,50	1,433

Perceived technology usefulness			
I think that it will: - lower production costs	721	5,16	1,838
I think that it will: - increase productivity	721	5,33	1,651
I think that it will: - reduce workload	721	5,19	1,764
I think that it will: - be useful for farm operations	721	5,59	1,476
Self-responsibility: - As a farmer it is my responsibility to contribute to:			
- a better environment	689	5,86	1,024
- better animal welfare	689	5,87	1,089
- fairly priced products	689	5,66	1,345
- better public health	689	5,82	1,193
- more jobs for people in my local area	689	5,21	1,430
Subjective norm: about people, other than yourself, what extent do you agree or disagree			
many farmers in my surroundings apply a CSA	650	3,63	1,526
farmers similar to me mostly use a CSA	650	3,89	1,515
people, who's opinion I value, think that I should apply a CSA	650	4,22	1,459
people, who are important to me, would approve the use of a CSA	650	4,78	1,392
Perceived equity: - only want to contribute to a better environment, animal welfare, public health, and fair trade, if I surely know that the following groups also make a fair contribution:			
supermarkets	650	4,92	1,877
food industry, such as dairy companies, fruit and vegetable processors, and meat industries	650	4,99	1,786
governments	650	5,02	1,890
farmers, other than myself	650	5,04	1,440
consumers	650	5,30	1,519
Perceived contribution: Farmers do more for a better environment, animal welfare, public health, and fair trade, than the following groups:			
supermarkets	650	5,41	1,487
food industry, such as dairy companies, fruit and vegetable processors, and meat industries	650	5,12	1,506
governments	650	5,16	1,700
consumers	650	5,14	1,428
Perceived honesty: I believe that the following groups are honest about their contributions to a better environment, animal welfare, public health, and fair trade			
supermarkets	650	2,96	1,524
food industry, such as dairy companies, fruit and vegetable processors, and meat industries	650	3,39	1,590
governments	650	3,00	1,565
farmers, other than myself	650	4,52	1,307
consumers	650	3,80	1,513
Certification: A certification for climate-smart agriculture practices and technologies is			
always available	673	3,74	1,392
easy to get	673	3,45	1,350
is cheap to get	673	3,14	1,389
WTP of buyers: - To what extent do you agree or disagree with			
- it is easy to find business buyers (for instance, wholesalers, retailers) who are willing to pay fair prices for CSA production	671	2,84	1,495
consumers are willing to pay fair prices for CSA production	670	2,91	1,530
Market access: It is easy for me to:			
sell my products on the internet	673	3,14	1,492
reach a physical marketplace to sell my products	673	3,56	1,625
access the input markets for my agricultural production	673	3,86	1,642
Policy support: -what extent do you agree or disagree with the following statements?			
governmental financial support (schemes, tax reduction, subsidies) to climate-smart agriculture is adequate	673	3,62	1,800
existing policies and regulations to support adoption of climate-smart agriculture are adequate	673	3,22	1,598
Access to credit			
getting access to a loan to support my financial needs is easy	673	3,38	1,582
the bureaucracy surrounding receiving a loan is transparent	673	3,50	1,597

Descriptive Statistics on information and extension services sources

Variables	N	Mean	Std.Deviation
Information sources: - To what extent are you going to use one of the following sources of information farming business question.			
Internet or social media (for example Facebook or Twitter)	636	5,07	1,637
family and friends	636	5,27	1,257
mass media (for example, physical or online newspapers, radio, television, magazines)	636	4,62	1,498
other farmers	636	5,37	1,066
farmer associations	636	4,79	1,570
training courses	636	5,00	1,319
trade events and fares on agriculture	636	4,75	1,361
agricultural advisors	636	4,97	1,485
other source, namely	636	3,50	1,899
Extension advice: To what extent did you made use of the following sources for your agricultural training in the last five years?			
farmer trainings	636	4,72	1,612
farm visits	636	4,65	1,565
field demonstrations	636	4,47	1,611
field/farmer days	636	4,42	1,652
workshops/open discussions	636	4,43	1,542
advisory services	636	4,71	1,569
other source, namely	636	3,39	1,917

Appendix Table 6: FS3_Summary of CSA identified from farmers survey

Main Category	Identified CSA list	frequency
Agro-ecological farming practices	catch crops	11
	cover crops	3
	Crop diversification	9
	intercropping	6
	crop rotation	16
	Follow up crops	1
	Planting nitrogen-fixing crops	1
	Vegetative cover	2
	greening	1
	Ecological agriculture	1
	Integrated fruit production	1
	Agroecological production systems and practices	1
Conservation tillage	No-till	34
	Reduced till	17
	No-till with technology	11
	Zero till	2
	Minimal till	7
	incorporation of fertilizer during tillage	1
	leaving stems of cut cereals in the soil	4
	Strip-till	2
	direct drilling	7
	eco-friendly engines for no-tillage	1
Organic agriculture	Organic agriculture	35
Smart fertilizers	organic fertilizers	5
	biofertilizers	1
	compost	3
	Green manure	3
	bioproduct	1
	Graduated fertilizer	2
	no agrochemical use	4

No-agro-chemicals & mineral fertilizers use	no fertilizer use	6
Smart fertilization	Smart/precision fertilization	11
	Row fertilization	2
	Auto-guided fertilizer with section control	1
	GPS-based lime application.	2
	Variable fertilizer application	11
smart crop protection	GPS based spraying	3
	spot spraying	2
	Precision sprayer	10
	Variable pesticide application	3
	Confusing pests with pheromones	1
	Phytosanitary applications	1
	IPM	7
	variable GBM spraying	2
Smart irrigation	drip irrigation	1
	DSS based irrigation	1
	GPS-based solution for irrigation	1
	micro spray irrigation	1
	Smart/precision irrigation	6
	drip irrigation	2
Guidance system	tractor with parallel driving system	1
	GPS based sprayer	4
	GPS based fertilizer	2
	GPS based tractors	5
	Tractor with adblue	1
	Tractors and implements with GPS	15
	GPS based machinery	10
	Auto driving	2
	EURO 4 tractors	1
	Non-polluting agricultural machinery	3
	automatic steering tractor	2
	Direct sowing	4
	Direct drilling	6
	precision sowing	2
Renewable energy	Biogas	3
	Bioenergy	1
	Biomass	1
	Solar energy	4
DSS farm management	Farm tracking	2
	smart pest monitoring	2
	Drone-based nitrogen determining	1
	Using smart sensors and weeding camera	3
	DSS (simulation modelling FIELDVIEW yield map)	5
	surveillance cameras for livestock monitoring	2
	smart cow	1
	Allocation files	1
	drones and satellite images	1
	image analysis	1
	smart monitoring	3
	precision feeding	1
	image analysis	1
feed improvement	feed table	1
	organic hay	1
	cultivation of crops with high protein content	1
	alfalfa for livestock feeding	1
	extensive cropping plan with straw chopping	1
	organic livestock feed	1
pasture management	pasture grazing	3

	grassland management	2
	conservation grazing	1
	Maintenance of grassland	1
	Permanent grassland	2
Others	Organic agriculture	35
	Carbon farming	4
	level-controlled drainage	3
	integrated crop-livestock system	3
	breed improvement	2
	eco-farming	16
	mulching	2
	Circular economy	1
	regenerative farming	1
	permaculture farming	1
	Biodynamic agriculture	1
	preservative treatment	1

Appendix Table 7: FS4_Farmers survey Questionnaire

Thank you very much for participating in this research of Wageningen University & Research (The Netherlands).
The answers that you give to our questions are completely confidential. This research is performed on behalf of Wageningen University & Research (WUR). The aim of this research is to evaluate consumer choices. This research is a part of a larger project (Beatles project) that is financed by the European Commission (EU). Only pseudonymized data can be processed by us (WUR), and only anonymized data will be used in publications. Results are only published at an aggregated level in, among others, public reports, such as scientific articles and EU publications. The data in these publications can never be traced back to individual persons.

Please, press “I agree”, if you wish to participate in this research. Please, press “I do not agree”, if you wish to stop.
Please, choose here, if you want to participate in this research, or stop

- I agree
- I do not agree

This research is about new practices or technologies that farmers can use to increase farm yields in such a way that it is also better for climate and animal welfare. For example:

- ✓ a practice that optimizes fertilizer use
- ✓ a practice increase farm income in such a way that it is also better for climate and animal welfare.
- ✓ a technology that reduces the costs of crop watering.
- ✓ a technology increase farm resilience to a climate change.
- ✓ a feeding practice that makes animals healthier during their lifetime.
- ✓ a practice or technology that reduce gas emissions that harm the climate.
- ✓ a practice of integrating croplands with trees.

Have you invested in such a new practice or technology in the last two years?

- Yes, I did
- No, I didn't

You indicated that you haven't invested in such a new practice or technology. Could you please answer the following statements? For me, these type of investments:

	completely disagree			neither completely disagree/nor agree			complete agree
are too costly	○	○	○	○	○	○	○
are not easy to perform	○	○	○	○	○	○	○
do not fit in my regular job practice	○	○	○	○	○	○	○
are easy to understand	○	○	○	○	○	○	○
are not supported by people who's opinion I value	○	○	○	○	○	○	○
takes too much time	○	○	○	○	○	○	○
do not suit in the way I like to work	○	○	○	○	○	○	○
are not consistent with the goals I find relevant	○	○	○	○	○	○	○

You indicated that you have invested in such a new practice or technology. The following questions are about your most recent investment in such a new practice or technology. Could you please shortly describe this new practice or technology?

How successful was this investment?

	completely unsuccessful			neither unsuccessful/nor successful			completely successful
The investment was	○	○	○	○	○	○	○

What were the goals of this investment?
The goals of this investment were to:

	completely disagree			neither disagree/nor agree			completely agree
increase farm yield	○	○	○	○	○	○	○
increase farm income	○	○	○	○	○	○	○
make crops more resilient to climate change	○	○	○	○	○	○	○
make animals more resilient to climate change	○	○	○	○	○	○	○
reduce gas emissions	○	○	○	○	○	○	○
reduce production waste	○	○	○	○	○	○	○
increase animal welfare	○	○	○	○	○	○	○
reduce production costs	○	○	○	○	○	○	○
make production more environmental friendly	○	○	○	○	○	○	○
reduce labour need	○	○	○	○	○	○	○

For me, this investment

	completely disagree			neither completely disagree/nor agree			completely agree
was too costly	○	○	○	○	○	○	○
was easy to perform	○	○	○	○	○	○	○
fitted in my regular job practice	○	○	○	○	○	○	○
was easy to understand	○	○	○	○	○	○	○
was supported by people who's opinion I value	○	○	○	○	○	○	○
took too much time	○	○	○	○	○	○	○
suited in the way I like to work	○	○	○	○	○	○	○
were consistent with the goals I find relevant	○	○	○	○	○	○	○

When you started to invest in this new practice or technology, to what extent do you make use of the following?

	never					very intensively
extension services	○	○	○	○	○	○
governmental subsidies	○	○	○	○	○	○
specific training courses	○	○	○	○	○	○
meetings with other farmers	○	○	○	○	○	○

Could you indicate the total costs of this investment for your farm?

- EUR 500 or less
- EUR 501 to EUR 1000
- EUR 1001 to EUR 5000
- EUR 5001 to EUR 25000

- EUR 25001 to EUR 50000
- EUR 50000 to EUR 100000
- EUR 100001 to EUR 500000
- EUR 5000001 or more
- I really don't know
- I'd rather not say

The following statements are about the output of your farm in general. Do you disagree or agree with the following statements?

It is important to me that the output of my farm

	completely disagree			neither disagree, nor agree			completely agree
is healthy	○	○	○	○	○	○	○
has a high yield	○	○	○	○	○	○	○
has low labor need	○	○	○	○	○	○	○
has been produced in an environmentally friendly way	○	○	○	○	○	○	○
is cheap for consumers	○	○	○	○	○	○	○
has been produced in an animal friendly way	○	○	○	○	○	○	○
has a stable yield over the years	○	○	○	○	○	○	○

I am used to produce products that contribute to

	completely disagree			neither disagree, nor agree			completely agree
a better climate	○	○	○	○	○	○	○
a better animal welfare	○	○	○	○	○	○	○
a high quality	○	○	○	○	○	○	○

Even if I invest in the right practices or technologies, my contributions will be too small

	completely disagree			neither disagree, nor agree			completely agree
for a better climate	◯	◯	◯	◯	◯	◯	◯
for a better animal welfare	◯	◯	◯	◯	◯	◯	◯
for a fair price for consumers	◯	◯	◯	◯	◯	◯	◯

As a farmer I'm obliged to contribute to a

	completely disagree			neither disagree, nor agree			completely agree
better climate	◯	◯	◯	◯	◯	◯	◯
better animal welfare	◯	◯	◯	◯	◯	◯	◯
fair price for consumers	◯	◯	◯	◯	◯	◯	◯

The following statements are about farmers, other than yourself. Do you disagree or agree with the following statements?

Farmers, who I personally know, are going to invest more in practices and technologies that contribute to a

	completely disagree			neither disagree, nor agree			completely agree
better climate	◯	◯	◯	◯	◯	◯	◯
better animal welfare	◯	◯	◯	◯	◯	◯	◯
fair price for consumers	◯	◯	◯	◯	◯	◯	◯

People around me often worry about problems regarding

	completely disagree			neither disagree, nor agree			completely agree
climate change							
animal welfare							
fair price for consumers							

People, who's opinion I value, approve if I invest in practices and technologies that contribute to a

	completely disagree			neither disagree, nor agree			completely agree
better climate							
better animal welfare							
fair price for consumers							

People, who's opinion I value, believe that problems regarding

	completely disagree			neither disagree, nor agree			completely agree
climate change are exaggerated							
animal welfare are exaggerated							
fair price for consumes are exaggerated							

The following statements consider finances. Do you disagree or agree with the following statements?

	completely disagree			neither disagree, nor agree			completely agree
My financial resources are sufficient	○	○	○	○	○	○	○
I can get by with the income of my household	○	○	○	○	○	○	○
Because of the economic situation, I invest less in my farm than I used to do	○	○	○	○	○	○	○

The following statements are about organizations that are involved in the production of our foods. Do you disagree or agree with the following statements?

Supermarkets are honest about their contributions to a

	completely disagree			neither disagree, nor agree			completely agree
better cilmate	○	○	○	○	○	○	○
animal welfare	○	○	○	○	○	○	○
fair price for farmers	○	○	○	○	○	○	○

Food producers, such as dairy compagnies, fruit and vegetable industries, and slaughterhouses, are honest about their contributions to a

	completely disagree			neither disagree, nor agree			completely agree
better cilmate	○	○	○	○	○	○	○
animal welfare	○	○	○	○	○	○	○
fair price for farmers	○	○	○	○	○	○	○

My government is honest about its contribution to a

	completely disagree			neither disagree, nor agree			completely agree
better cilmate	○	○	○	○	○	○	○
animal welfare	○	○	○	○	○	○	○
fair price for farmers	○	○	○	○	○	○	○

Farmers are honest about their contributions to a

	completely disagree			neither disagree, nor agree			completely agree
better cilmate	○	○	○	○	○	○	○
animal welfare	○	○	○	○	○	○	○
fair price for farmers	○	○	○	○	○	○	○

The following statements are about behaviour in general with respect to a better climate, animal welfare and fair trade. Do you disagree or agree with the following statements?

If they want to, the following groups can do more for a better climate, animal welfare, and fair trade

	completely disagree			neither disagree, nor agree			completely agree
supermarkets	○	○	○	○	○	○	○
food industry, such as dairy compagnies, fruit and vegetable processors, and meat industries	○	○	○	○	○	○	○
governments	○	○	○	○	○	○	○
farmers	○	○	○	○	○	○	○
consumers	○	○	○	○	○	○	○

I only want to contribute to a better climate, animal welfare and fair trade, if I surely know that the following groups also make a fair contribution

	completely disagree			neither disagree, nor agree			completely agree
supermarkets	○	○	○	○	○	○	○
food industry, such as dairy compagnies, fruit and vegetable industries, and slaughterhouses	○	○	○	○	○	○	○
governments	○	○	○	○	○	○	○
farmers, other than myself	○	○	○	○	○	○	○
consumers	○	○	○	○	○	○	○

Farmers do more for a better climate, animal welfare and fair trade, than the following groups

	completely disagree			neither disagree, nor agree			completely agree
supermarkets	○	○	○	○	○	○	○
food industry, such as dairy compagnies, fruit and vegetable industries, and slaughterhouses	○	○	○	○	○	○	○
governments	○	○	○	○	○	○	○
consumers	○	○	○	○	○	○	○

Consumers do more for a better climate, animal welfare and fair trade, than the following groups

	completely disagree			neither disagree, nor agree			completely agree
supermarkets	○	○	○	○	○	○	○
food industry, such as dairy compagnies, fruit and vegetable industries, and slaughterhouses	○	○	○	○	○	○	○
governments	○	○	○	○	○	○	○
farmers	○	○	○	○	○	○	○

Food producers, such as dairy compagnies, fruit and vegetable industries, and slaughterhouses, are honest about their contributions to a

	completely disagree			neither disagree, nor agree			completely agree
better cilmate	○	○	○	○	○	○	○
animal welfare	○	○	○	○	○	○	○
fair price for farmers	○	○	○	○	○	○	○

My government is honest about its contribution to a

	completely disagree			neither disagree, nor agree			completely agree
better cilmate	○	○	○	○	○	○	○
animal welfare	○	○	○	○	○	○	○
fair price for farmers	○	○	○	○	○	○	○

Farmers are honest about their contributions to a

	completely disagree			neither disagree, nor agree			completely agree
better cilmate	○	○	○	○	○	○	○
animal welfare	○	○	○	○	○	○	○
fair price for farmers	○	○	○	○	○	○	○

Supermarkets are honest about their contributions to a

	completely disagree			neither disagree, nor agree			completely agree
better cilmate	○	○	○	○	○	○	○
animal welfare	○	○	○	○	○	○	○
fair price for farmers	○	○	○	○	○	○	○

I have a clear picture about

	completely disagree			neither disagree, nor agree			completely agree
problems with our climate	○	○	○	○	○	○	○
problems with animal welfare	○	○	○	○	○	○	○
problems with fair trade	○	○	○	○	○	○	○
investments that farmers make to improve our environment	○	○	○	○	○	○	○
investments that food industries make to improve our environment	○	○	○	○	○	○	○
investments that my government makes to improve our environment	○	○	○	○	○	○	○
investments within the food supply chain	○	○	○	○	○	○	○
problems with our economy	○	○	○	○	○	○	○
investments that make farms more resilient to climate change	○	○	○	○	○	○	○
investments that reduce gas emissions	○	○	○	○	○	○	○

Suppose that you have a question about new types of investment for your farm.

To what extent are you going to use one of the following sources of information?

	never						always
Social media (for example facebook or Twitter)	◯	◯	◯	◯	◯	◯	◯
Family and friends	◯	◯	◯	◯	◯	◯	◯
Physical or online newspapers	◯	◯	◯	◯	◯	◯	◯
People I know	◯	◯	◯	◯	◯	◯	◯
Radio	◯	◯	◯	◯	◯	◯	◯
Television	◯	◯	◯	◯	◯	◯	◯
Internet (for example, google or governmental websites)	◯	◯	◯	◯	◯	◯	◯
Andere bron, namelijk	◯	◯	◯	◯	◯	◯	◯

I make use of the following social media if I have a question about new production methods in the food supply chain (more than one answer possible)

- ☐ Facebook
- ☐ Twitter
- ☐ LinkedIn
- ☐ Instagram
- ☐ Snapchat
- ☐ Whatsapp
- ☐ TikTok
- ☐ YouTube
- ☐ Pinterest

The following questions are about your background as a farmer.
Where do you currently live?

- o Denmark
- o Germany
- o The Netherlands
- o Lithunia
- o Spain
- o other, namely

What is your gender?

- o Male
- o Female
- o Other, namely ____
- o I would rather not say

What is your year of birth?__________________________

Number of persons in my household are

- o one person
- o two persons
- o three persons
- o four persons
- o five persons
- o six or more persons

The net monthly income of my household is

- o No income

- EUR 500 or less
- EUR 501 to EUR 1000
- EUR 1001 to EUR 1500
- EUR 1501 to EUR 2000
- EUR 2001 to EUR 2500
- EUR 2501 to EUR 3000
- EUR 3001 to EUR 3500
- EUR 3501 to EUR 4000
- EUR 4001 to EUR 4500
- EUR 4501 to EUR 5000
- EUR 5001 to EUR 7500
- EUR 7501 or more
- I really don't know
- I'd rather not say

The average total farm revenue in the last five years is

- EUR 500.000 or less
- EUR 500.001 to EUR 1.000.000
- EUR 1.000.001 to EUR 1.500.000
- EUR 1.500.001 to EUR 2.000.000
- EUR 2.000.001 or more
- I really don't know
- I'd rather not say

My highest education level is

- no training was completed
- elementary school graduated
- high school graduated
- University degree
- Master's degree or higher

For how long have you been working in farming?

- less than 5 years
- 5 to 10 years
- 11 to 15 years
- 16 to 20 years
- more than 20 years

What is your farm size?

- less than 2 ha
- 2 to 10 ha
- 11 to 50 ha
- 51 to 100 ha
- 101 to 200 ha
- 201 to 500 ha
- more than 500 ha

What is the ownership status of your farm? The largest percentage of the land that I use for my farming activities is

- privately owned
- rented

The main production system of my farm is

- Arable crops
- Open field vegetables
- Orchards
- Vineyards
- Livestock
- Mixed farming

The following questions are about your farm. Do you belong to a farmers cooperative?

- yes, I do
- no, I don't

Thank you very much for answering the questionnaire!

Finally, do you have remarks concerning this questionnaire?

- Yes, I do
- No, I don't

You can give your remark(s) in the text box below:_________________

Appendix Table 8: CA1_Consumer questionnaire

Thank you very much for participating in this research. Your contribution is much appreciated!
This research is a part of a larger project (BEATLES project) that is financed by the European Commission (EU). Wageningen University and Research as member of the project collects the data.The aim of this research is to evaluate consumer choices of environmentally-friendly food products. The survey will last about **15 minutes**.Your answers to the questions are completely confidential and will be used only for research purposes. There are no right or wrong answers, so please fill in your true opinion.

Please, choose here, if you want to participate in this research, read more background information, or stop
- o I agree to participate in this research (1)
- o I do not agree to participate in this research (2)
- o Before I decide, I would like to have more information about the project (3)

The BEATLES project will investigate the behavioral shift to climate-smart agriculture and smart farming technologies. Within the BEATLES project, five different food systems representing the major European crop and livestock farming systems (cereals, dairy, stone fruits, livestock, vegetables) in various EU regions (Western, Eastern, Southern, and Northern Europe), will be studied to account for the diversity in agri-food systems and conditions in the EU. Consumers play an important role in agri-food systems, because they buy and eat the produced food products. The BEATLES project will provide a set of business strategies establishing roadmaps for a fair shift towards climate-smart agriculture, based on environmental, social, and economic sustainability assessments. Moreover, a series of policy recommendations and tools will be developed to foster behaviorally informed policy designs and implementations.

Please, choose here, if you want to participate in this research, or stop
- o I agree to participate in this research (1)
- o I do not agree to participate in this research (2)

How frequently do you eat

	every day (1)	few times a week (2)	once a week (3)	few times a month (4)	once a month (5)	less than once a month (6)	never (7)
potatoes (1)	○	○	○	○	○	○	○

If How frequently do you eat = never

Goodbye Unfortunately, you do not belong to the target group of the research. Thank you very much for your time!

Explanation CSA
This questionnaire is about climate-smart agriculture practices and technologies that farmers can use to increase farm productivity and income in such a way that protects the environment and animal welfare as well as reduces greenhouse gas emissions.

Some examples of these practices are: organic farming, integrated pest management, crop diversification, variable rate application of fertilizers, precision irrigation, intercropping, manure management to reduce greenhouse gas emissions, carbon soil farming, and reduced tillage.

Some examples of these technologies are: robotic systems, drones, satellite images analysis, smart farming sensors, big data, Internet of Things (IoT), smart sprayers (for irrigation).

Have you heard of the term climate-smart agriculture practice or technology before?
- o yes, I have (1)
- o no, I haven't (2)

Imagine that you are in a supermarket to buy potatoes. You are standing in front of the assortment and you can choose between two types of the same potato. One option is the regular potato type that you are used to buy. The other option is the same potato, but, here, farmers have used a new climate-smart practice or technology. This is a newly produced potato.

We ask you to indicate your preference for one of these two types in four different situations.

Suppose that you are in a shopping situation, where the regular and newly produced potato can be produced for the same price. As a result the prices of the two options are the same as is shown below.
Which potato type would you prefer?

Regular produced option	Newly produced option
€ 0.55 for 1 kilogram	€ 0.55 for 1 kilogram

o certainly the regular produced option (1)
o (2)
o (3)
o No preference (4)
o (5)
o (6)
o certainly the newly produced option (7)

If Suppose that you are in a shopping situation, where the regular and newly produced potato can be... = No preference
You indicated that you don't have a preference for one of the two options. Could you please indicate why you don't have a preference?____________

Suppose that you are in a shopping situation, where the use of the climate-smart practice or technology leads to higher costs for the farmer. As a result, the price for the newly produced potato is higher than the regular produced potato, as is shown below.
Which potato type would you prefer in this situation?

Regular produced option	Newly produced option
€ 0.55 for 1 kilogram	€ 0.60 for 1 kilogram

o certainly the regular produced option (1)
o (2)
o (3)
o No preference (4)
o (5)
o (6)
o certainly the newly produced option (7)

If Suppose that you are in a shopping situation, where the regular and newly produced potato can be... = No preference
You indicated that you don't have a preference for one of the two options. Could you please indicate why you don't have a preference?____________

Suppose that you are in a shopping situation, where the regular and newly produced potato can be produced for the same price, but that the regular produced option has a price promotion. As a result, the newly produced potato has the normal price, but the regular produced potato has a discount price, as is shown below.

Which potato type would you prefer in this situation?

Regular produced option	Newly produced option
€ 0.50 for 1 kilogram	€ 0.55 for 1 kilogram

o certainly the regular produced option (1)
o (2)

- o (3)
- o No preference (4)
- o (5)
- o (6)
- o certainly the newly produced option (7)

If Suppose that you are in a shopping situation, where the regular and newly produced potato can be... = No preference
You indicated that you don't have a preference for one of the two options. Could you please indicate why you don't have a preference?________________
Suppose that you are in a shopping situation, where the regular and newly produced potato can be produced for the same price, but that the newly produced option has a subsidy by the government to stimulate its sales. As a result, the regular produced potato has the normal price, but the newly produced potato has a lower price, as is shown below.
Which potato type would you prefer in this situation?
.

Regular produced option	Newly produced option
€ 0.55 for 1 kilogram	€ 0.50 for 1 kilogram

- o certainly the regular produced option (1)
- o (2)
- o (3)
- o No preference (4)
- o (5)
- o (6)
- o certainly the newly produced option (7)

If Suppose that you are in a shopping situation, where the regular and newly produced potato can be... = No preference
You indicated that you don't have a preference for one of the two options. Could you please indicate why you don't have a preference?________________

To what extent do you agree or disagree with the following statements?

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
m willing to purchase ironmentally friendly roducts (1)	○	○	○	○	○	○	○
I buy ironmentally friendly ducts if I can (2)	○	○	○	○	○	○	○
njoy buying ironmentally friendly roducts (4)	○	○	○	○	○	○	○

Food choice motives
It is important to me that the food product that I buy:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
is healthy (1)	○	○	○	○	○	○	○
contains few or no artificial aditives (2)	○	○	○	○	○	○	○
has been traded in a fair way (3)	○	○	○	○	○	○	○
has been produced in an environmentally friendly way (4)	○	○	○	○	○	○	○
is cheap (8)	○	○	○	○	○	○	○
looks nice (16)	○	○	○	○	○	○	○
is nutritious (17)	○	○	○	○	○	○	○
is produced with care for the public health (18)	○	○	○	○	○	○	○

I am used to buy food products that contribute to:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
a better environment (1)	○	○	○	○	○	○	○
a better animal welfare (2)	○	○	○	○	○	○	○
fair trade (3)	○	○	○	○	○	○	○
a better public health (18)	○	○	○	○	○	○	○

I am willing to pay extra money for food products that contribute to:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
a better environment (1)	◯	◯	◯	◯	◯	◯	◯
a better animal welfare (2)	◯	◯	◯	◯	◯	◯	◯
fair trade (3)	◯	◯	◯	◯	◯	◯	◯
a better public health (18)	◯	◯	◯	◯	◯	◯	◯

Even if I buy environmentally friendly food products, my contributions will be too small for:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
a better environment (1)	◯	◯	◯	◯	◯	◯	◯
a better animal welfare (16)	◯	◯	◯	◯	◯	◯	◯
a contribution to fair trade (2)	◯	◯	◯	◯	◯	◯	◯
a better public health (17)	◯	◯	◯	◯	◯	◯	◯

As a consumer, it is my responsibility to contribute to:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
a better environment (1)	◯	◯	◯	◯	◯	◯	◯
a better animal welfare (16)	◯	◯	◯	◯	◯	◯	◯
fair trade (2)	◯	◯	◯	◯	◯	◯	◯
a better public health (17)	◯	◯	◯	◯	◯	◯	◯

To what extent do you agree or disagree with the following statements?

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
I am eager to buy new food products as soon as they come out (1)	◯	◯	◯	◯	◯	◯	◯
others often ask me for advice about new food products (16)	◯	◯	◯	◯	◯	◯	◯
I enjoy the novelty of trying out new food products (2)	◯	◯	◯	◯	◯	◯	◯

The following statements are about environmentally friendly food products.
To what extent do you agree or disagree with the following statements?

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
I am able to buy environmentally friendly food products. (1)	◯	◯	◯	◯	◯	◯	◯
If it is entirely up to me, I will buy environmentally friendly food products. (16)	◯	◯	◯	◯	◯	◯	◯
I have the resources, time and willingness to purchase environmentally friendly food products. (2)	◯	◯	◯	◯	◯	◯	◯

To what extent do you agree or disagree with the following statements?

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
Sometimes, I do not know where environmentally friendly food products can be found (1)	◯	◯	◯	◯	◯	◯	◯
Environmentally friendly food products are not readily available at the stores where I do my shopping (16)	◯	◯	◯	◯	◯	◯	◯

The following statements are about labels on environmentally-friendly food products.
To what extent do you agree or disagree with the following statements?
The information on food labels that indicate that the food products are environmentally friendly are:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
informative (1)	○	○	○	○	○	○	○
easy to understand (2)	○	○	○	○	○	○	○

The claims on food labels that indicate that the food products are environmentally friendly are:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
trustworthy (1)	○	○	○	○	○	○	○
realistic (2)	○	○	○	○	○	○	○

As compared to regular produced products, products with food labels that indicate that they are environmentally friendly have:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
a better value for money (1)	○	○	○	○	○	○	○
a reasonable price (2)	○	○	○	○	○	○	○
a better product quality (3)	○	○	○	○	○	○	○
more appeal (4)	○	○	○	○	○	○	○
a better taste (8)	○	○	○	○	○	○	○
a higher nutritional value (16)	○	○	○	○	○	○	○

To what extent do you agree or disagree with the following statements?

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
I feel that environmentally friendly products' environmental claims are generally trustworthy (1)	○	○	○	○	○	○	○
I feel that environmentally friendly products' environmental reputation is generally reliable (2)	○	○	○	○	○	○	○
Environmentally friendly products keep promises and commitments for environmental protection (3)	○	○	○	○	○	○	○

The following statements are about people, other than yourself. To what extent do you agree or disagree with the following statements?

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
People in my surroundings often buy environmentally friendly food products (1)	○	○	○	○	○	○	○
People who are similar to me often buy environmentally friendly food products (2)	○	○	○	○	○	○	○
People, who are important to me, approve if I buy environmentally friendly food products (3)	○	○	○	○	○	○	○
People, who's opinion I value, believe that I should buy environmentally friendly food products (5)	○	○	○	○	○	○	○

The following statements are about groups in society. To what extent do you agree or disagree with the following statements?

Though circumstances may change, I believe that the following groups remain willing to contribute to a better environment, animal welfare, public health, and fair trade:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
supermarkets (2)	○	○	○	○	○	○	○
food industry, such as dairy companies, fruit and vegetable processors, and meat industries (17)	○	○	○	○	○	○	○
governments (18)	○	○	○	○	○	○	○
farmers (19)	○	○	○	○	○	○	○
consumers, other than myself (20)	○	○	○	○	○	○	○

I only want to contribute to a better environment, animal welfare, public health and fair trade, if I surely know that the following groups also make a fair contribution:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
supermarkets (2)	○	○	○	○	○	○	○
food industry, such as dairy companies, fruit and vegetable processors, and meat industries (17)	○	○	○	○	○	○	○
governments (18)	○	○	○	○	○	○	○
farmers (19)	○	○	○	○	○	○	○
other consumers (20)	○	○	○	○	○	○	○

Consumers do more for a better environment, animal welfare, public health, and fair trade, than the following groups:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
supermarkets (2)	○	○	○	○	○	○	○
food industry, such as dairy companies, fruit and vegetable processors, and meat industries (17)	○	○	○	○	○	○	○
governments (18)	○	○	○	○	○	○	○
farmers (19)	○	○	○	○	○	○	○

I believe that the following groups are honest about their contributions to a better environment, animal welfare, public health, and fair trade:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
supermarkets (2)	○	○	○	○	○	○	○
food industry, such as dairy companies, fruit and vegetable processors, and meat industries (17)	○	○	○	○	○	○	○
governments (18)	○	○	○	○	○	○	○
farmers (19)	○	○	○	○	○	○	○
consumers, other then myself (20)	○	○	○	○	○	○	○

I want to be kept up-to-date about the contributions of the following groups to a better environment, better animal welfare, better public health, or fair trade:

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
supermarkets (2)	○	○	○	○	○	○	○
food industry, such as dairy companies, fruit and vegetable processors, and meat industries (17)	○	○	○	○	○	○	○
governments (18)	○	○	○	○	○	○	○
farmers (19)	○	○	○	○	○	○	○
consumers, other than myself (20)	○	○	○	○	○	○	○

Suppose that you have a question about environmentally-friendly food products.

To what extent are you going to use one of the following sources of information?

	never (1)	very rarely (2)	rarely (3)	neutral (4)	occasionally (5)	very frequently (6)	always (7)
Social media (for example facebook or Twitter) (20)	○	○	○	○	○	○	○
Family and friends (1)	○	○	○	○	○	○	○
Physical or online newspapers (3)	○	○	○	○	○	○	○
People I know (22)	○	○	○	○	○	○	○
Radio (18)	○	○	○	○	○	○	○
Television (5)	○	○	○	○	○	○	○
Internet (for example, google or governmental websites) (11)	○	○	○	○	○	○	○
other source, namely (19)	○	○	○	○	○	○	○

If Suppose that you have a question about environmentally-friendly food products.To what extent are... = Social media (for example facebook or Twitter) [neutral]

Or Suppose that you have a question about environmentally-friendly food products.To what extent are... = Social media (for example facebook or Twitter) [occasionally]

Or Suppose that you have a question about environmentally-friendly food products.To what extent are... = Social media (for example facebook or Twitter) [very frequently]

Or Suppose that you have a question about environmentally-friendly food products.To what extent are... = Social media (for example facebook or Twitter) [very frequently]

Or Suppose that you have a question about environmentally-friendly food products.To what extent are... = Social media (for example facebook or Twitter) [always]

Or Suppose that you have a question about environmentally-friendly food products.To what extent are... = Social media (for example facebook or Twitter) [very rarely]

Or Suppose that you have a question about environmentally-friendly food products.To what extent are... = Social media (for example facebook or Twitter) [rarely]

Social media
I make use of the following social media if I have a question about environmentally-friendly food products (more than one answer possible)
▢ Facebook (1)
▢ Twitter (2)
▢ LinkedIn (3)
▢ Instagram (4)
▢ Snapchat (5)
▢ Whatsapp (6)
▢ TikTok (7)
▢ YouTube (8)
▢ Pinterest (9)

What is your nationality?
o Danish (1)
o German (2)
o Dutch (3)
o Lithuanian (4)
o Spanish (5)
o other, namely (6) ____

What is your gender?
o Male (1)
o Female (2)
o Other, namely (3) ____
o I would rather not say (4)

What is your year of birth?_______________

Number of persons in my household are
o one person (1)
o two persons (2)
o three persons (3)
o four persons (4)
o five persons (5)
o six or more persons (6)

Number of children that live in my household
o none (1)
o one chld (2)
o two children (3)
o three children (4)
o four children (5)
o five or more children (6)

Employed I am
o full-time employed (30 hours per week or more) (1)
o part-time employed (less than 30 hours per week) (2)
o retired (3)
o unemployed (4)

The net monthly income of my household is

- o No income (1)
- o EUR 500 or less (2)
- o EUR 501 to EUR 1000 (3)
- o EUR 1001 to EUR 1500 (4)
- o EUR 1501 to EUR 2000 (5)
- o EUR 2001 to EUR 2500 (6)
- o EUR 2501 to EUR 3000 (7)
- o EUR 3001 to EUR 3500 (8)
- o EUR 3501 to EUR 4000 (9)
- o EUR 4001 to EUR 4500 (10)
- o EUR 4501 to EUR 5000 (11)
- o EUR 5001 to EUR 7500 (12)
- o EUR 7501 or more (13)
- o I really don't know (14)
- o I'd rather not say (15)

My highest education level is

- o no training completed (1)
- o primary school (2)
- o secondary school (3)
- o vocational training (4)
- o bachelor degre (5)
- o master's degree (6)
- o doctorate degree (7)
- o something else, namely (8) ____

In what type of area do you live?

- o urban area (1)
- o suburban area (2)
- o small village or rural area (3)

The following statements consider finances. To what extent do you agree or disagree with the following statements?

	completely disagree (1)	disagree (2)	somewhat disagree (3)	neither disagree, nor agree (4)	somewhat agree (5)	agree (6)	completely agree (7)
My financial resources are sufficient (1)	o	o	o	o	o	o	o
I can get by with the income of my household (2)	o	o	o	o	o	o	o
Because of inflation, I spend less money on food products than I used to do (16)	o	o	o	o	o	o	o

In what country do you currently live?__________

Thank you very much for answering the questionnaire!

Do you have remarks concerning this questionnaire?

- o Yes, I do (1)
- o No, I don't (2)

If Do you have remarks concerning this questionnaire? = Yes, I do

You can give your remark(s) in the text box below:

____

Appendix Table 9: CA2_Descriptive statistics for individual items and correlation with construct 'willingness to buy

Items	Mean	Std Dev	Min	Max	Spearman's correlation coefficient	Prob > |r| under H0: Rho=0
Individual decision-making factors						
willingnesstobuy_1	6.081	1.093	1	7		
willingnesstobuy_2	5.798	1.178	1	7		
willingnesstobuy_3	5.882	1.273	1	7		
frequentie_1	2.648	1.028	1	6	0.091	0.0015
knowledgeTerm	1.371	0.483	1	2	-0.061	0.0336
CSA_equalprice	5.735	2.025	1	7	0.243	<.0001
CSA_premium	3.938	2.432	1	7	0.380	<.0001
regular_discount	4.836	2.383	1	7	0.378	<.0001
CSA_subsidy	5.957	1.919	1	7	0.149	<.0001
Healthy	6.336	0.840	1	7	0.333	<.0001
Natural	6.106	1.085	1	7	0.386	<.0001
Fairtrade	6.014	1.063	1	7	0.445	<.0001
Environfriendly	6.094	0.970	1	7	0.596	<.0001
Cheap	4.893	1.472	1	7	-0.204	<.0001
Appearance	4.502	1.508	1	7	-0.130	<.0001
Nutricious	6.071	0.950	1	7	0.223	<.0001
Publicwelfare	6.062	1.068	1	7	0.361	<.0001
habits_1	5.590	1.239	1	7	0.635	<.0001
habits_2	5.738	1.258	1	7	0.529	<.0001
habits_3	5.633	1.198	1	7	0.439	<.0001
habits_4	5.696	1.214	1	7	0.400	<.0001
wtp_1	5.507	1.316	1	7	0.576	<.0001
wtp_2	5.671	1.308	1	7	0.512	<.0001
wtp_3	5.612	1.273	1	7	0.477	<.0001
wtp_4	5.614	1.256	1	7	0.399	<.0001
self_efficacy2_1	4.177	1.780	1	7	-0.160	<.0001
self_efficacy2_2	4.130	1.823	1	7	-0.165	<.0001
self_efficacy2_3	4.194	1.771	1	7	-0.145	<.0001
self_efficacy2_4	4.196	1.782	1	7	-0.132	<.0001
self_responsibility_1	5.897	1.178	1	7	0.439	<.0001
self_responsibility_2	5.906	1.177	1	7	0.420	<.0001
self_responsibility_3	5.797	1.236	1	7	0.427	<.0001
self_responsibility_4	5.665	1.343	1	7	0.346	<.0001
PBC_1	5.492	1.189	1	7	0.377	<.0001
PBC_2	5.578	1.298	1	7	0.618	<.0001
PBC_3	4.901	1.484	1	7	0.434	<.0001
Agegroup	2.159	0.762	1	3	-0.018	0.5309
moneySaving_1	4.976	1.687	1	7	0.095	0.0009
moneySaving_2	5.514	1.420	1	7	0.164	<.0001
moneySaving_3	3.539	1.958	1	7	-0.131	<.0001

Appendix Table 10: CA3_Descriptive statistics for systemic items and correlation with the construct 'willingness to buy

Variables	Mean	Std Dev	Min	Max	Spearman Correlation Coefficients	Prob > |r| under H0: Rho=0
Innovativeness_1	3.869	1.604	1	7	0.173	<.0001
Innovativeness_2	3.506	1.636	1	7	0.147	<.0001
Innovativeness_3	4.502	1.637	1	7	0.162	<.0001
marketaccess_1	4.254	1.753	1	7	-0.058	0.0450
marketaccess_2	3.929	1.630	1	7	-0.046	0.1111
labeling_1	4.435	1.465	1	7	0.078	0.0064
labeling_2	4.064	1.489	1	7	0.069	0.0156
trust_1	4.012	1.406	1	7	0.115	<.0001
trust_2	3.941	1.343	1	7	0.111	0.0001
Valueformoney	4.216	1.425	1	7	0.260	<.0001
Reasonableprice	3.978	1.402	1	7	0.259	<.0001
Betterquality	4.756	1.402	1	7	0.318	<.0001
Moreappeal	4.421	1.361	1	7	0.285	<.0001
Bettertaste	4.628	1.443	1	7	0.324	<.0001
Highernutritional	4.651	1.453	1	7	0.304	<.0001
generaltrust_1	4.290	1.376	1	7	0.198	<.0001
generaltrust_2	4.340	1.363	1	7	0.208	<.0001
generaltrust_3	4.320	1.323	1	7	0.195	<.0001
norm1_1	3.957	1.390	1	7	0.172	<.0001
norm1_2	4.651	1.301	1	7	0.411	<.0001
norm1_3	5.142	1.320	1	7	0.342	<.0001
norm1_4	4.636	1.390	1	7	0.304	<.0001
benevolencesupermarkets	3.795	1.599	1	7	0.010	0.7383
benevolenceindustry	3.858	1.608	1	7	-0.061	0.0326
benevolencegovernments	3.997	1.642	1	7	-0.043	0.1375
Benevolencefarmers	4.642	1.410	1	7	-0.046	0.1109
benevolenceconsumers	4.388	1.302	1	7	0.052	0.0723
fairsharesupermarkets	4.637	1.901	1	7	-0.063	0.0269
Fairshareindustry	4.771	1.908	1	7	-0.066	0.0206
fairsharegovernments	4.765	1.933	1	7	-0.064	0.0268
Fairsharefarmers	4.885	1.864	1	7	-0.068	0.0173
Fairshareconsumers	4.581	1.827	1	7	-0.055	0.0545
performancesupermarkets	4.806	1.400	1	7	0.118	<.0001
performanceindustries	4.726	1.437	1	7	0.108	0.0002
performancegovernments	4.703	1.511	1	7	0.078	0.0066
Performancefarmers	4.376	1.405	1	7	0.099	0.0006
Trustsupermarkets	3.285	1.438	1	7	-0.022	0.4407
Trustindustry	3.373	1.459	1	7	-0.050	0.0846
Trustgovernments	3.413	1.467	1	7	-0.018	0.5415
Trustfarmers	4.333	1.370	1	7	-0.014	0.6179
Trustconsumers	4.236	1.260	1	7	0.060	0.0365

infointerestsupermarkets	5.406	1.418	1	7	0.287	<.0001
Infointerestindustry	5.509	1.382	1	7	0.289	<.0001
infointerestgovernments	5.604	1.369	1	7	0.278	<.0001
Inforinterestfarmers	5.578	1.340	1	7	0.299	<.0001
infointerestconsumers	5.153	1.499	1	7	0.261	<.0001
Socialmedia	3.276	2.019	1	7	0.005	0.8702
Familyfriends	5.094	1.294	1	7	0.113	<.0001
Newspapers	4.550	1.562	1	7	0.101	0.0004
People	5.114	1.166	1	7	0.135	<.0001
Radio	4.007	1.734	1	7	0.070	0.0144
Television	4.079	1.709	1	7	-0.003	0.9202
Internet	5.353	1.417	1	7	0.100	0.0005
Facebook	0.355	0.479	0	1	-0.012	0.682
Twitter	0.071	0.256	0	1	0.057	0.047
LinkedIn	0.101	0.301	0	1	0.056	0.052
Instagram	0.144	0.352	0	1	0.045	0.118
Snapchat	0.004	0.064	0	1	-0.026	0.360
Whatsapp	0.089	0.285	0	1	-0.020	0.488
TikTok	0.023	0.150	0	1	0.017	0.552
YouTube	0.285	0.452	0	1	0.030	0.291
Pinterest	0.044	0.206	0	1	0.029	0.314
hh_persons	2.715	1.254	1	6	-0.033	0.2517
hh_children	1.730	1.007	1	6	-0.012	0.6735
Agglomeration	1.802	0.858	1	3	-0.073	0.0109

Appendix Table 11: IR1_Interview-guide

STAKEHOLDER NAME_____________________________DATE OF INTERVIEW________________________
MODE OF INTERVIEW (FACE-TO-FACE, PHONE, TEAMS,...) _______________

YOUR ORGANIZATION

1. **Which products/services do you primarily produce or sell to get a turnover?**
____

2. **What is your place in the supply chain? From whom do you buy your main input and to whom do you sell your main products?** ____

The following questions are divided into 2 main categories of climate smart agriculture.
What do we mean by climate smart agriculture? We use the FAO definition. According to FAO, climate-smart agriculture is an approach based on three pillars:

1. increase productivity and income in primary production in a sustainable way
2. improve resilience towards climate changes in primary production
3. reduce GHG emissions in primary production

The first category of questions will deal with climate smart agricultural initiatives in the primary production.
The second category of questions will deal with initiatives in your organization that can support or hinder the use of climate smart initiatives in the primary production.

CLIMATE SMART AGRICULTURAL PRODUCTION IN THE PRIMARY PRODUCTION

3. **Have you heard the term climate-smart agricultural production?**
Yes ___________ (if yes, go to question 4) **No** __________ (if no, present example below)
4. **If yes, can you provide some examples of what do you see as a climate smart agricultural production (remember, we mean in the primary production)?** ____

CURRENT SUCCESFUL PRACTICES OR TECHNOLOGIES IN YOUR ORGANIZATION SUPPORTING OR ENABLING CLIMATE SMART AGRICULTURAL PRODUCTION

5. **Can you name some successful practices or technologies (in short, initiatives) that you have implemented in your organization that have enabled or supported climate smart agricultural production in the primary production. Please, name up to 4 practices or technologies that your organization has implemented.**

Initiative 1____
Initiative 2____
Initiative 3____
Initiative 4____

For the most recent initiative that you have just mentioned, please answer a few additional questions:

5.1 Can you explain to me the implementation process of this initiative in your organization, from the beginning of the process (introduction) to its current status? ____
____

5.2 What were the drivers that enabled the uptake of this practice or technology in your organisation ? Drivers can be individual/organizational, systemic (e.g., socio-cultural/economic, institutions) and policy factors?
____

5.3 Which benefits did your organization experience after engaging in this practice?
____

PRACTICES OR TECHNOLOGIES IN YOUR ORGANIZATION THAT FAILED TO SUPPORT OR ENABLE CLIMATE SMART AGRICULTURAL PRODUCTION

6. **Can you name some practices or technologies in your organization that could have supported or enabled climate smart agricultural production, but have failed when implemented in your organization? Feel free to name more than one if you can.**

Initiative 1____
Initiative 2____
Initiative 3____
Initiative 4____

For the most recent of the initiatives that you have just mentioned, please answer a few additional questions:

1. **Why did the implementation in your organization fail? Barriers can be individual/organizational, systemic (e.g., socio-cultural/economic, institutions) and policy factors.**
____

PRACTICES OR TECHNOLOGIES IN YOUR ORGANIZATION THAT ARE PROMISING IN SUPPORTING OR ENABLING CLIMATE SMART AGRICULTURAL PRODUCTION

7. **Can you think of any promising practices or technologies to consider in your organization that could potentially enable climate smart agricultural production in the primary production (if needed, the interviewer can provide examples again). Feel free to name more than one if you can.**

Initiative 1____
Initiative 2____
Initiative 3____
Initiative 4____

For the most promising practice or technology in your organization that you have mentioned, please answer a few additional questions:

7.1 Please explain how you see the usefulness of this initiative in your organization to support or enable climate smart agriculture. More specifically, how does the initiative support or enable

- the reduction of GHGs in the primary sector?
- increased resilience to climate change in the primary sector?
- Improved productivity in a sustainable way?

____

7.2 What do you think is needed to motivate your organization to engage in this initiative (what are the drivers)? Drivers can be can be individual/organizational, systemic (e.g., socio-cultural/economic, institutions) and policy factors. Please specify ____

3. **What do you think could prevent your organization from engaging in this initiative (what are the barriers)? Barriers can be can be individual/organizational, systemic (e.g., socio-cultural/economic, institutions) and policy factors. Please specify** ____

FINALLY

8. If there anything else you want to tell me, then please let me know now? ____

Thank you very much!