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WP2 – Developing a system-dynamic understanding of mechanisms, lock-ins and levers in the broader food system

D2.1: Cross-case identified lock ins and potential levers from a food systems' perspective

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List of abbreviations

CAP – Common Agriculture Policy

CF - Conceptual Framework

EC – European Commission

GA – Grant Agreement

MLP - Multilevel Perspective

SFS – Sustainable Farming System

WP – Work Package

CSC - Case Study Coordinator

Executive summary

The ENFASYS project, aims to promote a transition to sustainable, productive, climate-neutral, biodiversity-friendly, and resilient farming systems across Europe. This document presents the findings of the first two tasks of Work Package 2 (WP2), which is focused on building a comprehensive, system-dynamic understanding of the mechanisms, lock-ins, and leverage points that influence the transition towards sustainable farming systems. This work package seeks to uncover the complex interactions and feedback loops within farming and food systems that create barriers to change, as well as opportunities for intervention. By using case study research across multiple contexts in Europe, WP2 will provide insights into how these factors either facilitate or hinder progress toward sustainability goals. The WP aims at developing dynamic system maps for each case study to visualize the key elements, interactions, and feedback loops that define current agricultural systems. Through the analysis of the economic, social, and political lock-ins that prevent farmers from adopting sustainable practices, such as market pressures, policy constraints, or cultural norms the WP identifies potential leverage points where strategic interventions (policy, technological, or social) could catalyse significant changes within the system.

The first section details the methodology used to create Causal Loop Diagrams (CLDs) for each case study, which includes key variables essential for understanding the dynamics within different farming systems. These visual representations, developed with the Case Study Coordinators (CSC), facilitate in understanding the complex interactions of systemic barriers and potential levers.

The second section focuses on the identification of systemic lock-ins and potential levers based on the CLDs within various agricultural contexts. Barriers and potential levers were firstly identified by CSCs from ten European case studies within Task 2.1 and then through comprehensive cross-case analysis, key barriers to sustainability and strategic levers that can potentially overcome them were re-assessed and integrated in the CLDs. The analysis reveals several common lock-ins that hinder the adoption of sustainable farming practices clustered within the following categories: economic dependencies on high-input farming methods, regulatory barriers that favour conventional agriculture, cultural practices deeply rooted in traditional farming, technological constraints that limit access to sustainable innovations, and limited market access for sustainably produced goods. Context-specific lock-ins are also presented for each case study, reflecting the unique challenges faced by different regions and agricultural systems.

The report highlights the interdependent nature of these lock-ins, suggesting that addressing them in isolation is unlikely to yield significant progress. Instead, a holistic approach is necessary, tackling multiple lock-ins simultaneously through coordinated efforts at both the policy and community levels.

1 Introduction

The ENFASYS project is designed to stimulate a just and robust transition to sustainable, productive, climate-neutral, biodiversity-friendly, and resilient farming systems. This goal is pursued through the development of improved policies and business strategies that actively encourage farmers to shift their production systems towards sustainability. The project recognizes the complexity of agricultural systems and the need for comprehensive approaches that address the economic, environmental, and social dimensions of farming. The deliverable provides a static picture of the overall farming systems across all the 10 case studies in the form of a Causal Loop Diagram (CLD).

1.1 Aims and scope of the deliverable

The primary objective of this deliverable is to identify and analyse the systemic lock-ins that hinder the transition to sustainable food systems. Lock-ins are defined as networks of interconnected barriers that collectively create self-reinforcing barriers that prevent or slow down the adoption of sustainable agricultural practices. This deliverable focuses on delineating these lock-ins by examining the connection between barriers to propose potential levers that can effectively facilitate transitions across different agricultural contexts and case studies.

This deliverable results from the integration of findings from Tasks 2.1 and 2.2:

- Task 2.1: Mapping and Surveying Stakeholder Ecosystem: This task involves mapping the stakeholder ecosystem and engaging stakeholders through focus groups and interviews to understand the barriers and enables to sustainable food systems.
- Task 2.2: Developing a Cross-Case System Dynamic Analysis: Building on the findings from Task 2.1, this task operationalizes a participatory system dynamics methodology to construct Causal Loop Diagrams (CLDs) for each case study, capturing both the feedback mechanisms that underlie systemic lock-ins and the potential levers.

In Subtask 2.2.1 NIBIO develops a protocol for the system-based methodology to build the CLD with nodes/variables and interrelations to enable a further in-depth analysis the food system´s dynamics and co-identification of lock-ins within and across cases. It is based on core systems theory and methodology, such as Senge, 2000, Senge et al. 2010; Wolstenholme, 2004; Sterman, 2000. Mechanisms are analysed and compared across the various innovation settings, including mainstream value chains, niche value chains and farmers' networks (Morel et al., 2020).

Based on the literature review (Task 1.1) and the cross-case dimensions, Subtask 2.2 employs an iterative and participatory process, the CLD is developed to co-identify and co-select the system´s lock-ins and levers. This process supports the design of a first CLD draft based on the results of T2.1, which was further developed in collaboration with case study stakeholders in a workshop to deliver for each case study a validated CLD, a list of identified lock ins, and potential levers from a food systems perspective.

In Subtask 2.2.3, a comparative analysis of the CLDs, identified lock-ins and potential levers is conducted by the Task 2.2 team, resulting in an initial internal report (M2.2) taken up by WP4 (Task 4.2). Deliverable (D5.1) reports on both the methodology and the results from the cross-case analyses, integrating the literature and survey results of Task 2.1 and the conducted systemic analyses of Task 2.2.

The deliverable provides insights and recommendations that inform policy-making and strategic interventions, with the goal of overcoming the identified lock-ins and promoting sustainable farming systems across Europe.

2 Theoretical framework

2.1 The Concept and Definition of Lock-ins

Lock-ins are a self-reinforcing mechanism that perpetuates the dominance of a particular technology, practice, or system over time, hindering the shift to more sustainable alternatives. They arise when a set of intertwined barriers hinders the evolution of a system or the adoption of innovations to the point where the effort to change is too high for any single actor. Systems may remain locked-in—evolving only within a limited range of options that do not imply significant reconfiguration—until impactful changes occur, opening new opportunities or rendering existing practices obsolete (Antier et al., 2021; Vanloqueren & Baret, 2008). Lock-ins can be identified through the analysis of causal loop diagrams representing the interlinking of identified barriers (Dentoni et al., 2022)

In agriculture, lock-ins often manifest through the dominant use of industrial farming practices, which rely heavily on chemical inputs like synthetic fertilizers and pesticides. These practices have created a self-reinforcing cycle that is difficult to break due to the strong interdependencies between agricultural policies, market incentives, and the agrochemical industry. For example, farmers who adopt high-input farming systems become reliant on these chemicals to maintain productivity, leading to soil degradation and a reduced ability to transition to more sustainable, agroecological methods (Wilson & Tisdell, 2001).

2.1.1 System lock-ins

Kuokkanen et al. (2017) identify a "food system lock-in" at the systemic level, describing it as a transformation of the food system into a theoretically irreversible, self-perpetuating process that threatens planetary boundaries and food security. Their empirical examination is grounded in the historical transition of Finland's food system, emphasizing how this lock-in can undermine the system's capacity to manage resource scarcity and environmental instability.

Similarly, Anderson and Leach (2019) advocate for systemic approaches and power analysis in studying food system changes. Their paper discusses various lock-ins that prevent societal transformation of food systems, despite the adverse impacts on health, quality of life, and ecological integrity. Klerkx and Begemann (2020) refer to “food regimes,” indicating that dominant food system structures and practices create lock-ins that hinder the shift to more sustainable and resilient food systems. (Calo et al., 2021) further emphasizes global North property regimes as significant lock-in that dilutes ambitions for food system reform.

2.1.2 Technology and practice lock-ins - the mechanisms in various sectors

Lock-ins refer to the self-reinforcing mechanisms that perpetuate the dominance of certain technologies or practices over time. Understanding these mechanisms is crucial for analysing path dependency and regulatory frameworks in various sectors (Ejderyan et al., 2023).

Walloon Dairy Cooperatives: De Herde et al. (2022) highlight the evolution of Walloon dairy cooperatives, emphasizing how lock-ins can shape their trajectory and hinder diversification towards higher-value products. The study underscores the importance of understanding path dependency and lock-in effects within the context of collective action and regulatory frameworks.

Intensive Agriculture: Sutherland et al. (2012) discuss technological lock-in in the context of intensive agriculture. Significant investments in machinery can create a lock-in situation, making farmers reluctant to switch to organic farming due to potential financial losses from selling their spraying equipment. This example illustrates a technology lock-in that obstructs the adoption of alternative practices.

French Varietal Innovation System: Akimowicz et al. (2022) explore potential lock-ins within the French varietal innovation system. Although the focus is on governance, the study indirectly addresses lock-ins related to the adoption of specific technologies or practices. The research examines the interplay of private, collective, and public resources within the innovation system, highlighting the need to assess governance legitimacy and the potential for lock-ins to impede adaptation to climate changes.

Agri-Food Sector: Kuokkanen et al. (2017) discuss the impact of chemical fertilizers on production logic in the agri-food sector. The adoption of chemical fertilizers has driven the intensification and specialization of production, creating expectations of continuously increasing yields. This example indicates a practice lock-in that reinforces dependence on chemical fertilizers, thus hindering the adoption of alternative practices.

2.1.3 Knowledge and Cultural lock-ins

Knowledge and cultural factors play a crucial role in shaping agricultural practices and can often lead to lock-ins that hinder the transition to more sustainable farming methods. Several studies have explored these aspects, providing valuable insights into how knowledge acquisition, socio-cultural contexts, and historical trajectories can create and reinforce lock-ins in agricultural systems.

Sutherland et al. (2012) emphasize that farming knowledge, shaped by both practical experience and formal education, can result in decision-making lock-ins for farmers. The selection of agricultural colleges and specific courses influences farmers' methods and can restrict the exploration of alternative practices. In our analysis, we should examine how educational pathways and knowledge transfer mechanisms in our case studies might be contributing to lock-ins or limiting exposure to sustainable farming practices.

Vanloqueren and Baret (2017) extend this concept to research systems, demonstrating how they can create knowledge lock-ins by favouring certain technologies over others. Their work shows how research priorities can shape a technological regime that develops certain innovations (like genetic engineering) while marginalizing others (such as agroecological approaches). This insight prompts us to investigate how current research priorities in our case studies might be influencing the adoption or rejection of sustainable practices.

Ingram (2017) provides a nuanced understanding of knowledge systems in agricultural transitions, examining the boundary dynamics between niche and regime knowledge. This perspective is valuable for our analysis as it suggests we should look for instances where traditional farming knowledge and innovative sustainable practices clash or complement each other. Understanding these dynamics can help identify opportunities for knowledge integration and transfer that could break existing lock-ins.

Huttunen (2020) explores the socio-cultural aspects of farming and suggests ways to overcome related lock-ins through sustainability transition research. Although the primary focus is on socio-cultural lock-ins, the study also highlights the implications of knowledge lock-ins. It stresses the need to understand the socio-cultural context of farming to create policies and interventions that encourage changes in farming practices. This understanding acknowledges the existence of knowledge lock-ins that can be tackled with targeted measures.

De Herde et al. (2022) underline the significance of historical trajectories and cooperative dynamics in understanding lock-ins. Although their focus is on technological or practice lock-ins, they also touch upon cultural lock-ins. The study highlights how past habits, narratives, and legitimacies contribute to lock-ins, creating self-reinforcing mechanisms that sustain the dominance of certain technologies or practices over time.

2.1.4 ENFASYS' Definition of Lock-ins

From these illustrative examples, we propose the following operational definition of lock-ins:

Lock-ins are persistent systemic factors that generate reinforcing feedback mechanisms, creating self-reinforcing barriers to behavioural change and the adoption of innovations. By understanding lock-ins as a causally self-reinforcing set of barriers to change behaviour, lock-ins can be identified through the analysis of CLDs that represent the interlinking of these identified barriers. These factors arise from the interplay of technological, social, economic, and cultural dimensions within a given system, making it challenging to transition to more sustainable alternatives.

This definition encapsulates the essence of lock-ins as interconnected phenomena and sets the stage for operationalization through the analysis of CLDs. By illustrating the interlinking of these barriers, CLDs can provide a framework for identifying levers for change.

2.2 Identification of levers

In the context of sustainable agriculture, identifying levers or enabling environments for transformation involves understanding the complex interplay between economic, social, and environmental factors. The theoretical basis for this process is grounded in systems thinking and the theory of change (Williams et al., 2024). While systems thinking provides a lens for examining complex, interrelated agricultural systems, the theories of change developed within the ENFASYS, offer pathways for operationalizing interventions, ensuring they are aligned with long-term sustainability goals.

2.2.1 Systems Thinking

Systems thinking is an approach that views agriculture as a complex system composed of interrelated and interdependent components, including ecological, economic, and social subsystems. It emphasizes the importance of understanding the relationships and feedback loops within these systems. Identifying levers in this context involves pinpointing critical points within the system where interventions can lead to significant and positive changes. This approach helps in recognizing the multifaceted nature of agricultural challenges and the need for holistic solutions (Meadows, 2008).

The idea of leverage points within systems thinking suggests that certain places within a complex system can be targeted to bring about systemic change. These points might involve changing the rules of the system, improving the flow of information, or altering the mindset out of which the system arises. In agriculture, leverage points could range from policy adjustments to shifts in market dynamics and technological innovations. For instance, policy reforms (like those limiting harmful pesticides) or market innovations (like the introduction of carbon credits) can shift agricultural practices toward sustainability. These leverage points are not isolated; they interact across the system's ecological, economic, and social dimensions (Linnér & Wibeck, 2021).

2.2.2 Theory of Change

The theory of change complements system thinking by offering a structured framework for planning, implementing, and evaluating interventions by mapping out the pathways through which change occurs. It defines the desired long-term goals, identifying the preconditions necessary to achieve these goals, and determining the interventions that can create these conditions. In sustainable agriculture, this means outlining the steps needed to transition from conventional to sustainable practices and identifying the key interventions (levers) that can facilitate this transition (Anderson, 2006). By employing the theory of change, stakeholders can construct a logical model that connects agricultural interventions with their intended outcomes. This helps in clarifying how and why a desired change is expected to happen in a particular context, thereby ensuring that the strategies implemented are both targeted and effective. The theory of change also facilitates continuous monitoring and adjustment of strategies, enhancing the adaptability and responsiveness of agricultural interventions.

2.2.3 Integrating levers

To operationalise the theory of change, levers must be integrated to effectively transition to sustainable agricultural systems and various types of levers can be employed. To cohesively align with the principles of system thinking the levers to include are those related to policy, business, and social.

2.2.4 Policy Levers

Policy levers are mechanisms through which governments and regulatory bodies can influence agricultural practices. These include introducing supportive regulations, providing financial incentives, and reforming existing policies to promote sustainability. Implementing **policies that mandate sustainable practices**, such as crop rotation or organic farming standards, can directly influence farming behaviours, ensuring that sustainable practices are integrated into the agricultural framework. Environmental regulations that limit the use of harmful pesticides and fertilizers can significantly reduce the environmental impact of agriculture. By setting strict guidelines, these policies can protect biodiversity, improve soil health, and ensure the long-term sustainability of agricultural practices.

Financial incentives, such as subsidies for adopting sustainable technologies like precision agriculture tools or renewable energy systems, can lower the financial barriers to sustainable farming. By reducing the initial costs associated with these technologies, farmers are more likely to adopt practices that improve efficiency and reduce environmental impact. Additionally, tax breaks and grants for farmers who implement conservation practices or reduce their carbon footprint can provide additional financial motivation, making it economically viable for farmers to invest in sustainable practices, fostering widespread adoption (Swinnen, 2016).

Aligning national agricultural policies with international sustainability goals, such as the United Nations Sustainable Development Goals (SDGs), ensures that local practices contribute to global efforts. This alignment helps create a cohesive approach to sustainability that is recognized and supported worldwide. **Reforming trade policies** to support local and sustainable food systems can enhance food security and reduce environmental impacts. By prioritizing sustainable practices in trade agreements, governments can promote local production and reduce the carbon footprint associated with long-distance food transportation (Beddington et al., 2012).

2.2.5 Business Levers

Business levers involve market-based approaches and economic incentives that encourage farmers and agribusinesses to adopt sustainable practices. Developing **business models that integrate sustainability** into core operations, such as circular agriculture, which reuses waste products as inputs, can enhance both profitability and environmental health. These models reduce waste, lower costs, and create value from by-products. Promoting value-added products that enhance profitability while supporting sustainability, such as organic or fair-trade certifications, can open new markets and increase revenue for farmers. These certifications often allow producers to charge premium prices, reflecting the higher standards and benefits of sustainable practices (Porter & Kramer, 2011).

Creating and strengthening local and regional markets for sustainably produced goods ensures that farmers have reliable outlets for their products, reducing reliance on long supply chains and enhancing local food security. Building supply chains that prioritize sustainability, and fair-trade practices can improve transparency and trust between producers and consumers. By ensuring that all stages of the supply chain adhere to sustainable practices, these initiatives can enhance the overall impact of sustainable agriculture (Elkington & Rowlands, 1999)**. Encouraging private investment in research and development** of sustainable agricultural technologies can drive innovation and improve practices. Investments in technologies like drought-resistant crops or precision irrigation can make farming more resilient and efficient. Providing venture capital and financing options for startups focused on sustainable innovations can accelerate the development and adoption of new technologies. These investments support entrepreneurial efforts that address specific sustainability challenges in agriculture (Pretty et al., 2018).

2.2.6 Social Levers

Social levers focus on changing behaviours and attitudes towards sustainability through education, community engagement, and cultural shifts. **Programs to educate farmers and stakeholders** about sustainable practices and their benefits are fundamental for fostering long-term change. These programs can cover a range of topics, from soil health to water management, providing farmers with the knowledge they need to implement sustainable practices. Community-based workshops and extension services are excellent tools for disseminating this knowledge. By providing hands-on training and continuous support, these programs empower farmers to make informed decisions that benefit both their livelihoods and the environment (Tilman et al., 2011).

Encouraging community-supported agriculture (CSA) and cooperative models that involve local communities in sustainable farming can enhance social capital and collective action. CSAs and cooperatives foster a sense of ownership and responsibility towards the environment, ensuring that sustainable practices are maintained and valued. Promoting participatory approaches where local knowledge and practices are integrated into sustainable agricultural development ensures that interventions are culturally relevant and widely accepted. These approaches recognize the value of indigenous knowledge and local experiences in achieving sustainability (Pretty, 1995).

Campaigns to **raise awareness about the environmental and health benefits of sustainable agriculture** can change consumer behaviours and increase demand for sustainably produced goods. By highlighting the positive impacts of sustainable farming, these campaigns can build a strong market for sustainable products. Encouraging consumer behaviour changes that support sustainability, such as purchasing locally produced and organic foods, can drive demand for sustainable agricultural practices. When consumers prioritize sustainability in their purchasing decisions, it creates a powerful incentive for producers to adopt sustainable methods (Thøgersen, 2011).

2.3 Use of Causal Loop Diagram (CLD) in Sustainable Farming Transitions

Sustainable agricultural transitions are essential for improving the resilience and sustainability of food systems. However, transitions to such systems are complex due to multiple interrelated factors that can either facilitate or hinder the implementation of sustainable practices. Recognizing this complexity, the notions of "lock-ins" and "levers" are critical. Lock-ins are systemic barriers that prevent change, while levers are strategic interventions that can potentially overcome these barriers and promote transition.

To identify these lock-ins and levers, various methodologies have been employed in the literature. These include:

(i) **Behavioural and Cognitive studies**, which explore how individual decision-making processes contribute to lock-ins focusing on factors like habitual thinking, risk aversion, and conflicting goals. For instance, (Weituschat et al., 2022) and Vanloqueren and Baret (Vanloqueren & Baret, 2017) highlight how risk-averse behaviours and entrenched technological paradigms prevent farmers from adopting more sustainable agricultural practices;

(ii) **Experimental methods**, including discrete choice experiments and randomized trials, simulate how farmers and consumers respond to policy interventions or market incentives, providing evidence on which levers are most effective in breaking lock-ins and promoting sustainable practices. For example, (Greiner & Gregg, 2011) and (Läpple & Van Rensburg, 2011) conducted experiments assessing farmers' preferences for environmental policies and the adoption of agri-environmental schemes, respectively, to identify key levers for encouraging sustainable agricultural practices; and

(iii) **Systems Analysis and System Dynamics Modelling**, including **CLD**, is a key tool for identifying structural and institutional lock-ins. CLDs help visualize feedback loops that either sustain unsustainable practices or offer leverage points for interventions. For example, Guariguata et al. (2023) use CLD to engage stakeholders in mapping the dynamic feedback loops and interdependencies between human health, ecosystem health, and food systems in Small Island Developing States. By illustrating feedback loops—where actions can reinforce or counteract themselves over time—CLDs allow stakeholders to better understand the long-term impacts of different factors within food systems. This approach is particularly useful for identifying key leverage points, making CLDs an invaluable tool for planning and implementing sustainable farming transitions. Through CLDs, stakeholders can visualize the complexities of food systems, which aids in co-creating interventions aimed at breaking lock-ins and promoting sustainable faming transitions.

In the context of ENFASYS project, CLDs play a key role in identifying specific lock-ins and levers related to food system transitions. The strength of CLDs lies in their ability to visualize complex relationships between farming practices, market dynamics, policy frameworks, and ecological processes. By mapping out interconnections during a workshop, CLDs will help engage stakeholders in understanding how different elements interact to either support or hinder the adoption of sustainable practices (Guariguata et al., 2023).

This participatory approach aligns with co-design methodologies, which emphasize the importance of involving local stakeholders in the assessment and planning processes to ensure that interventions are contextually relevant. The effectiveness of this approach is highlighted by (Darmaun et al., 2023), where the assessment a method for assessing agroecological transitions was co-designed with local stakeholders, allowing for the adaptation of assessment tools to the specific needs and conditions of the community. By incorporating CLDs into such participatory processes, practitioners can ensure that the complexities of food system transitions are fully accounted for, leading to more sustainable and effective outcomes.

Moreover, the integration of CLDs into participatory processes allows stakeholders to visualize the complexities of food systems while fostering collaborative efforts to identify and implement interventions that can effectively break lock-ins and promote sustainable practices. The use of CLDs enhances understanding and facilitates a shared language among diverse stakeholders, facilitating more effective collaboration and consensus-building.

To maximize the effectiveness of CLDs in supporting sustainable food system transitions, it is essential to continuously refine and adapt the methodology. One key area of development is the refinement of case-level CLD, which represents specific problem situations unique to different food systems. Each CLD captures the complexities and dynamics inherent to its respective context, reflecting the unique interconnections and feedback loops associated with that particular food system.

While these CLDs do not present multiple perspectives on the same phenomenon, they serve as critical tools for understanding distinct challenges and identifying potential levers for change within their respective contexts. More importantly, CLDs need to be validated by stakeholders to ensure their accuracy and relevance. Engaging stakeholders in this validation process enhances the credibility of the CLDs and fosters a shared understanding of the complexities involved (Inam et al., 2015).

After developing and refining the individual case-level CLDs and obtaining stakeholder approval, the next step involves aggregating insights from these diverse diagrams to create a more comprehensive model that captures a broad range of dynamics within food systems (Task 2.3). By comparing and integrating CLDs from different contexts, researchers can identify common patterns and unique challenges, leading to more robust and generalizable insights for promoting sustainable transitions (Rocha et al., 2019). By emphasizing both the uniqueness of each case-level CLD and the importance of stakeholder validation, practitioners can ensure that interventions are tailored to specific contexts while leveraging broader insights from multiple food systems.

Participatory action research (PAR) fosters trust and long-term collaboration between researchers and farmers, which is crucial for identifying drivers and barriers to agroecological practices (Sachet et al., 2021) and the refinement of CLDs through iterative feedback from stakeholders ensures that the diagrams remain relevant and accurate over time. This iterative process is critical in dynamic systems, where conditions and relationships can change rapidly. By continuously updating CLDs to reflect new data and stakeholder inputs, practitioners can ensure that their strategies remain responsive to emerging challenges and opportunities.

3 Methodological approach

The methodological approach in WP2 is designed to develop a system-dynamic understanding of the key barriers and levers within agricultural systems, facilitating the transition towards sustainable farming systems (SFS). This approach integrates a range of analytical methods and stakeholder input to create and refine Causal Loop Diagrams (CLDs) that capture the complexities of food systems, focusing on the identification of feedback loops, lock-ins, and potential leverage points for intervention. It included data collection through interviews, surveys, and literature reviews (Task 2.1), followed by analysis using a framework that creates Causal loop diagrams and identifies lock-ins and potential levers within the food system (Task 2.2). The methodological approach followed 9 consecutive steps

Step 1: Data Collection

The data collection process implemented in Task 2.1, was carried out from March 2023 to January 2024. The data was gathered using a structured data collection protocol developed by WP2 partners UCL and NIBIO (see annex 1) and reported by case study coordinators. The data collection focused on several key areas:

Policy Space Analysis: In line with our theoretical understanding of policy levers (Darnhofer et al., 2010) (Candel & Biesbroek, 2018), we analysed the policy landscape influencing each case study. This involved identifying relevant policies and examining their objectives, implementing bodies, governance schemes, instrument types, and jurisdictional levels (international, EU, national, regional, or local). This comprehensive approach allowed us to understand how policy levers operate across different scales, aligning with our theoretical framework's emphasis on multi-level governance in sustainable agriculture.

Governance Environment Mapping: Drawing on theories of stakeholder engagement and collaborative governance in sustainable agriculture (Dentoni et al., 2018; Knickel et al., 2018), we examined the governance environments of each case study. This approach aligns with Dentoni's work on multi-stakeholder partnerships and systems thinking in addressing complex agricultural challenges (Dentoni et al., 2022). We identified key actors and stakeholders, understanding their roles and interactions within governance structures, and analysing their influence on the transition towards sustainable farming systems.

Dentoni et al. (2018) emphasises the importance of understanding how diverse stakeholders interact and collaborate to address 'wicked problems' in food systems. This perspective informed our analysis of how different actors navigate and influence the transition towards sustainable farming practices. Furthermore, Dentoni's work on systems mapping (Dentoni et al., 2022) provided a framework for visualizing and analysing the complex relationships between stakeholders, policies, and practices in each case study.

Actors' Network Analysis: Informed by network theories in agricultural innovation systems (Klerkx & Begemann, 2020) and building on systemic approaches to agricultural transitions, we conducted a detailed mapping of actors' networks for each case study. This approach aligns with Baret's emphasis on understanding the complex interplay of actors in agricultural systems and their role in sustainability transitions.

Step 2: Variable Mapping and Relationship Mapping

Stakeholders were categorized into nine groups: private sector organizations, upstream inputs providers, transversal service providers, farming and support to farming, industry representatives, distribution and marketing, consumers and citizens, public sector/government institutions, and research/scientific organizations. This comprehensive categorization reflects Baret's work on the multi-level perspective of socio-technical transitions in agriculture (Vanloqueren & Baret, 2017), allowing us to examine how business and social levers operate through diverse stakeholder interactions across different levels of the agricultural system.

Task 2.2 kicked off with a critical text analysis (CTA) of case studies descriptions and secondary data, including published literature, grey literature reports, and policy papers to build the initial version of the CLDs. The CTA allowed us to extract key elements, concepts, and relationships within the narratives, laying the foundation for constructing the CLDs. This step ensured a detailed understanding of policy levers, governance structures, and stakeholder interactions. By electing CTA in the methodological approach, we can uncover implicit dimensions embedded within qualitative data, much like how review text provides deeper insights into users' preferences in recommender systems. Similar to how the abstract highlights the importance of integrating review text with latent dimensions in predicting user preferences, CTA allows us to extract hidden relationships and variables within the case studies (McAuley & Leskovec, 2013). .

In ENFASYS much of the critical data regarding policy environments, stakeholder interactions, and governance structures is embedded within descriptive text, interviews, and reports. Traditional methods that focus solely on quantitative data or overlook textual narratives risk missing out on these key insights. By applying CTA, we ensure that the nuances, assumptions, and contextual factors described in the case study narratives are systematically uncovered and analysed. Just as combining latent review topics with numerical ratings in the recommender system example enhances both interpretability and predictive accuracy, combining CTA with quantitative tools like the adjacency matrix allows us to:

- Justify the identified relationships between variables with textual evidence, ensuring that each variable is contextually grounded in the data.
- Accurately map interactions between different system components, drawing on qualitative insights that may not be immediately evident in numeric or coded data alone.
- Reveal hidden patterns and dynamics that are critical to understanding the complex agricultural systems in transition, much like how topic modelling can reveal underlying themes in product reviews.

This approach ensures that the CLDs developed are not only theoretically sound but also deeply rooted in the empirical context of each case study.

Following the data collection, variables central to each case study were found based on the insights from the CTA. These variables spanned policy, business, and social domains, reflecting the multi-dimensional nature of the targeted agricultural systems addressed by each case study. The developed CLDs will form the basis for building stock and flow models (Task 2.3) which are crucial for the dynamic simulation of system behaviours over time. To ensure the validity of these models and their use in constructing the Theory of Change, we promoted the choice of variables that were measurable. Additionally, to reduce complexity in the system, we applied structural equivalence analysis to identify variables with similar roles (Byrne & Van de Vijver, 2010; Lorrain & White, 1971; Sailer, 1978), allowing us to streamline the CLDs by merging or simplifying redundant variables without losing essential dynamics. This ensured that the models are both comprehensive and manageable for dynamic modelling and scenario analysis.

Step 3: Mathematical Method: Structural Equivalence Analysis

Proposals of the relationships between variables were drafted by mapping their interactions and exploring cause-and-effect dynamics within the system. To ensure a structured representation of relationships between variables, structural equivalence analysis was conducted (Annex 1). This analysis included the use of adjacency matrices, correlation matrices, and Euclidean distance measures. These matrices collectively capture the direct and indirect influences among variables, offering a structured representation of the system's interactions:

- *Adjacency Matrix*: Maps the direct relationships between variables, indicating whether a relationship exists. The matrix was filled with binary values (0 or 1) to indicate the presence or absence of direct influence between pairs of variables. This provided a structural representation of the relationships, supporting both the initial CLD construction and its refinement through further analysis. The adjacency matrix was a key tool for organizing the relationships in a way that was easy to interpret and analyse.
- *Correlation Matrix*: Assesses the strength and direction of relationships between variables, identifying positive or negative correlations.
- *Euclidean Distance*: Measures the similarity in interaction patterns between variables, revealing those with similar roles or influences in the system.

Step 4: Initial construction of CLD

Using the results from the text analysis and structural equivalence analysis, we built initial CLDs for each case study using Vensim. This process began with defining the situation, identifying how it could be understood, and transforming key elements into variables. These variables were then connected through causal links. The diagrams were developed by combining primary data from interviews and surveys with secondary data from literature reviews, policy documents, and reports. The initial CLDs illustrated the complex cause-and-effect relationships and interactions between policy, business, and social variables. The construction of these CLDs involved transforming interrelationship diagrams into comprehensive system diagrams that captured both reinforcing and balancing feedback loops. The first CLD drafts were then circulated with the CSC to have their feedback. The guidelines from the CLD development framework ensure consistency in capturing the complexities of each case study (Annex 2).

Step 5: Feedback Loop Identification

Once the feedback by the CSC was given on the proposed variables and their relationships for the first version of the CLDs, we focused on identifying the feedback loops within each system. Feedback loops are essential to understanding how certain behaviours within the system are either perpetuated (reinforcing loops) or balanced out (balancing loops) allowing us to identify patterns of relationships between variables that indicated systemic lock-ins or potential leverage points. In this step, the project identifies:

- **Reinforcing Loops:** These loops amplify changes, leading to growth or decline within the system. For instance, increased environmental awareness may lead to more adoption of sustainable practices, which further raises awareness.

- **Balancing Loops:** These loops stabilize the system by counteracting changes, promoting equilibrium. For example, as more farmers adopt a practice, the financial resources available per farmer may decrease, slowing further adoption.

Again, structural equivalence analysis was used to further support this process (Rocha et al., 2019), allowing us to identify patterns of relationships between variables that indicated systemic lock-ins or potential leverage points. Insights from the structural equivalence analysis were used to justify these feedback mechanisms, ensuring that the CLDs accurately represented systemic dynamics and interactions.

Step 6: Identification of lock-ins

After the feedback loops are identified, the next step is identifying lock-ins, i.e., persistent, self-reinforcing barriers that hinder change. The identification of lock-ins is grounded in both qualitative insights from feedback loop analysis and quantitative measures from structural equivalence analysis, offering a comprehensive approach to pinpointing challenges in the transition to sustainable farming practices.

Structural equivalence analysis helps in identifying nodes (variables) that play similar roles within a system by analysing their relationships and positions in the network (Burns & Musa, 2001). This is particularly useful when building CLDs because it allows modellers to uncover hidden patterns of interaction, reduce complexity by merging equivalent nodes, and ensure that the relationships between variables are accurately represented.

In the reiteration of the identification process for the “across case” analysis, for clustering purposes the identified lock-ins at case level, were clustered into the 6 categories determined in the data collection activities of Task 2.1 – output C1 (Annex X).

Step 7: Identification of Potential Levers

Building on the understanding of lock-ins, we moved on to assess the existence of leverage points, i.e. areas within the system where strategic interventions could have a disproportionate impact. Insights from Task 2.1 about possible interventions are integrated with the results of the CLD analysis to develop actionable strategies. These levers were categorized into policy, business, and social domains. For instance, policy levers might involve revising regulatory frameworks, business levers could focus on market incentives, and social levers might involve community-driven initiatives. These levers could be mapped onto the CLDs, highlighting the points where interventions could break the existing lock-ins and facilitate system-wide change.

In the context of causal loop diagrams, structural equivalence analysis can highlight key variables that serve as leverage points for interventions. For example, studies have shown that applying network metrics like betweenness and closeness centrality to CLDs can inform where to intervene for maximum system-wide impact. This method provides a rigorous, quantitative foundation that complements traditional qualitative approaches, such as stakeholder interviews and literature reviews, enhancing the validity of the CLD structure. Moreover, integrating this analysis ensures that the feedback loops and systemic lock-ins identified in the CLD are well-supported by the underlying data (Dhirasasna & Sahin, 2019).

Also the levers were clustered according to the templates used in task 2.1.

Step 8: Revision and final consensus

The development of CLDs was an iterative process, involving multiple rounds of feedback and refinement with CSC. The initial CLDs were refined through bilateral meetings, where disagreements regarding variables and relationships were addressed in most of the cases. This iterative process ensured that the CLDs accurately reflected the diverse perspectives of stakeholders and the complexities of each case study. Stakeholder involvement was a critical step in this process, as it ensured that the CLDs were not only theoretically sound but also practical and relevant to the real-world challenges faced by each agricultural system. Because of the heterogeneity of the cases not all CSC were able to discuss their CLD externally within the timeframe of WP2, but this process will happen in the framework of WP4.

Ideally, the preliminary CLDs should be validated through workshops with case study coordinators and key stakeholders. A back-to-back workshop during the General Assembly meeting in Novi Sad enabled some coordinators to assess their diagrams. However, some coordinators were unable to complete this process during the session and are continuing the validation with their stakeholders. A validation checklist guides this process, ensuring that stakeholders review the diagrams for completeness, clarity, consistency, and accuracy in capturing feedback loops and levers (Annex 2).

Step 9: Cross Case Study Analysis for CLD aggregation

Following the iterative refinement of each case study's CLD, then we produced the base data and methodology to aggregate the ten CLDs using structural equivalence analysis which will be done in Task 2.3. This process involved hierarchical clustering of similar nodes based on their centrality in the network, providing a general systems-based account of the mechanisms underlying food systems. The aggregated CLD captured the feedback mechanisms that contribute to systemic lock-ins and highlighted the leverage points identified across all case studies. The detailed methodological approach can be found in Annex 3.

4 The ENFASYS case studies as Foundation for System Dynamic and Behavioural and Systems Theories of Change

The ten cases were preselected on the basis of the feedback from the partners during the project drafting (Figure 1)

		CASE 1	CASE 2	CASE 3	CASE 4	CASE 5
Objective:		facilitating uptake eco-schemes by cereal farmers in France	CAP-proofing Serbian agriculture	Incentivizing climate neutral cattle farming	shift to feed protein autonomy French dairy farmers	creating a regional brand to strengthen dairy cattle grazing
Partner		UCL	ABE	Fibl	Idele	HUB
local stakeholders taking initiative		Intercereales cooperative	100P+ farmer group, Tamis research institute and wider RS AKIS	52 farms involved in different pilot carbon farming IA projects	Agricultural chambers, technical and food chain actors, 12 dairy farmers	Brandenburg Farmers Association, Cluster Food Economy
Pedo-climatic zone		Atlantic	Pannonian	Alpine South	Atlantic	Continental
Region, Country		FR	Volvodina, RS	Zurich and Grisons, CH	W-/NW-France, FR	Brandenburg, DE
Commodity/sector		cereals	arable and orchards	beef, dairy	dairy	(mixed) Dairy
Farm size		large industrial farms	medium and small-sized family farms	Mixed, family farms	Mixed, family or associative farms	Large corporate and medium-size family
Practices to be scaled up/maintained		greening measures on arable land	intergrated pest and nutrient management	variety of GHG emission reducing practices	fodder production and feeding practices	biodiverse grassland-based livestock systems
Benefits		climate, biodiversity, resource use, ghg,	water quality, health food, biodiversity, resource use	climate, biodiversity	resource use, climate, feed-food comp., healthy food	biodiversity, animal welfare
Lock-in Cond.	**Farming system**	chemical input based	chemical input based	all types, mostly biological	conventional and organic	chemical input & org
	value chain	global commodity markets	circular economy	national market and supply chain	national and globalised commodities --> local	National and globalised comm
	governance	high capacities, moderate/hight intensions	limited capacities (?) unknown intensions	low intentions in the past, high capacities	high capacities, high intensions	moderate capacities, mod to high intentions
Lock-in Solutions	**business side strategies**	increase sus of weat value-chain at national level	farm ec optimization, cost-cutting	CO2-certificates, climate labels	dairy quality schemes, non-GMO labels	Creation of a regional brand
	policy side strategies	national policies, cert. and lobbying on CAP	voluntary schemes, access to IPARD support	inn promotion & potential for nat agricul policies	national program on protein autonomy	state support & buss. promotion agency
	Other strategies		AKIS to enhance know-how	technological improv., inc. fodder varieties & breeds	mobilize the French AKIS in a new protein strategy	collaborations with regional AKIS
Stage in transition		initiated to medium	limited	very small or no uptake	medium	initiated
		CASE 6	**CASE 7**	**CASE 8**	**CASE 9**	**CASE 10**
Objective:		shift to sustanable practices accross the EU through consumer brands	boosting direct selling in East-Slovenia	enhancing profitability of organic wheat produciton in Italy	support sustainability in small agri-food producers in the west of Ireland	enable robust shifts to redesign practices in organic vegetable sector
Partner		GAIA	CEJA	UNIBO	Teagasc	ILVO
local stakeholders taking initiative		Poios Einai to Afentiko, partners of C'est Qui le Patron-initiative	Pomurje region direct selling farmers	local producers and stakeholders in VALCEA initiative	BIA Innovator Campus and involved producers	Bioforum
Pedo-climatic zone		Mediterranean S	Pannonian	Mediterranean N	Atlantic	Atlantic
Region, Country		Peloponnese region, GR & MK + 7 countries	Pomurje region, SI	Emilia-Romagna, IT	West of Ireland, IR	Flanders, BE
Commodity/sector		Orchards, veg. & livestock	orchards & veg	cereals	Hort., beef, sheep	vegetables for industry
Farm size		small-very small, family-labor/owned	small family farms		small farmers	medium to large, mostly family owned
Practices to be scaled up/maintained		practices to reduce water, pesticide and energy use	direct selling, sustainable farming practices	organic production with ancient wheat varieties	direct selling, sustainable farming practices	minimum til, organic varieties, biopesticides
Benefits		water, energy use, fair ec. return, biodiversity	climate, farir economic returns, healthy food	fair ec returns,climate, biodiversity, healthy food	climate, fair economic returns, healthy food	biodiversity, resource use, climate, fair ec returns
Lock-in Cond.	**Farming system**	chemical input based		biological based	chemical input based	biological & biodiv.-based
	value chain	globalized commodity markets	alternative food systems	national to global	EU commodity markets, nascent circular economy and AFNs	EU and national commodities, AFNs
	governance	Limited capacities and high intensions	moderate capactieis, high intensions	unknown	unknown	low intensions, moderate capacity
Lock-in Solutions	**business side strategies**	consumer brand	local label, commercial promotion campaigns	co-op seed company, price guarantees	innovative short food supply chain models	negotiation with retailers on quality standards
	policy side strategies	assisting measures to upscale initiative	online direct-selling platform, public support	public support for local and organic farming	regulations, financial, material and training	EFSA regulationm, organic farming regulation
	Other strategies	Gaiasense Smart Farming solution to supportfarmers	AKIS to pass on know-how		innovation campus for co-creation dissemination	communication of economic risks to farmers
Stage in transition		limited uptake	high	initiated	initiated	low

Figure 1 Case studies pre-selection- from the project proposal

During the first year of the project, adjustments were made to several initial case studies based on partner feedback and emerging needs to maximize project impact. These adjustments, accepted for cases in Switzerland, Ireland, Germany, and Italy, aimed to enhance engagement with stakeholder groups, increase survey and workshop participation, and maximize the potential impact of target practices. The modifications for Italy were specifically due to extreme weather events that impacted the area of the initial case study. The final list of the case study is presented below (Figure 2 and Figure 3):

		Country	Partner	Objective	Local stakeholders taking initiative
CS1		France, Belgium	UCLouvain	Facilitating uptake eco-schemes by cereal farmers in France and Belgium	DRAAF, Regional Council & others
CS2		Serbia	ABE	CAP-proofing Serbian agriculture	Pioneer movement of regenerative farmers
CS3		Switzerland	FiBL	Biodiversity promotion using locally adapted practices	30 farmers, biodiversity advisors, Cantonal administration, agricultural school, farmers' association; BLW (national agricultural administration) enabling the project
CS4		France	Idele	Promote protein autonomy in French BL farms (evaluate and disseminate new varieties of legumes, increase the competitiveness and sustainability of oilseed and protein production, respond to the food transition with local products)	Technical institutes, advisors, support organizations, agricultural education, breeders, seed producers
CS5		Germany	HUB	Creating regional production-consumption cycles (regional value chains for pig meat) and enhance sustainability in farming systems via guaranteed remuneration through the new value chains and through political funding instruments for implemented measures.	Regional farmers' association (Landesbauernverband Brandenburg)
CS6		Greece	GAIA	Shift to sustainable practices across the EU through consumer brands	Poios Einai to Afentiko, partners of C'est Qui le Patron-initiative
CS7		Slovenia	CEJA	Boosting direct selling in Slovenia	Young Farmers of Slovenia
CS8		Italy	UNIBO	Produce their own food directly as a community of citizens with the goal of eating what is produced. The goal is fair pay for the farmer, safeguarding the balance with the land and the environment; responsible consumption and offering healthy and affordable food.	CSA - Community supported agriculture. Cooperative of which everyone (users and growers are equals) and adopts internal solidarity mechanism taken from the experiences from csa's in northern Europe.
CS9		Ireland	TEAGASC	Grow the organic dairy farming sector in Ireland	Teagasc Organic Farm Advisors National Organic Training Skillnet Department of Agriculture, Food and the Marine (DAFM) Organic Unit Organic Trust

	Country	Partner	Objective	Local stakeholders taking initiative
				Irish Organic Association The Organic College Individual organic dairy producers
CS10	Belgium	EV-ILVO	Increase in organic certified vegetable production while maintaining environmental and social benefits associated with OF	Bioforum

Figure 2 Revised objectives of the ENFASYS case studies

	CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	CASE 6	CASE 7	CASE 8	CASE 9	CASE 10
Location										
Country	France	Serbia	Switzerla	France	Germany	Greece	Slovenia	Italia	Ireland	Belgium
Type of commodity/sector										
Crops	x	x	x	x				x		
Vegetables			x			x	x		x	x
Orchards		x				x	x			
Pastures					x					
Livestock, animal-based products			x	x	x	x			x	
Other										
Farm size										
Small-sized farms		x	x	x		x	x		x	
Medium-sized farms		x	x	x	x					x
Large farms	x				x					
Governance of farms										
Family farms		x	x	x	x	x	x		x	x
Associative farms				x						
Industrial / corporate farms	x				x					
Farming system										
Conventional*	x	x	x	x	x	x	x		x	
Organic			x	x	x		x	x	x	x
Value chain configuration										
Global commodity markets	x			x	x	x		x	x	x
National supply chain			x	x	x			x	x	x
Local / alternative food systems / circular economy		?		x			x		x	x
Stage in transition										
Initiated	x	x	x		x	x		x	x	x
Medium	x			x						
Advanced							x			

Figure 3 Case study revised characteristics

The case studies were developed through a rigorous process that included stakeholder engagement, data collection, variable identification, and relationship mapping. The development and refinement of Causal Loop Diagrams (CLDs) using Vensim software played a crucial role in capturing the complexities of each case. The process was iterative, with continuous input from case study coordinators, particularly during a validation seminar in Serbia in June 2024, ensuring the accuracy and relevance of our findings. This structured approach has been fundamental in understanding and depicting the intricate dynamics of European agricultural systems, paving the way for comprehensive analyses and effective solution identification.

Table 1 provides a detailed breakdown of the 310 stakeholders involved across all case studies, representing diverse sectors of the agricultural system. This comprehensive stakeholder involvement underscores the breadth and depth of engagement crucial to the project's success.

Table 1 The different stakeholders included in the data collection process

Categories of actors	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10	Total	
Upstream	0	5	0	5	11	2	0	7	3	0	33	10%
Farming and support to farming	4	4	35	6	15	3	7	2	14	3	93	27%
Collectors, Logistics	0	1	0	1	5	0	0	2	0	0	9	3%
Processors	0	0	0	1	10	0	0	5	4	4	24	7%
Distribution and marketing	0	0	0	1	15	0	1	4	3	21	45	13%
Consumers', citizens' and voters'	0	0	0	1	4	1	2	2	0	0	10	3%
Civil society organizations or NGOs	5	0	0	1	3	0	0	3	3	3	18	5%
Public sector/government institutions	7	1	5	2	10	0	5	5	2	14	51	15%
Research/scientific organizations	2	2	2	7	6	0	1	2	1	3	26	8%
Education	0	0	1	0	4	0	1	1	1	1	9	3%
Other	1	0	2	0	0	0	2	0	3	15	23	7%
TOTAL	19	13	45	25	83	6	19	33	34	64	341	

The presentation of these case studies is a crucial first step in our analytical process. By providing rich, contextual information on each case, we set the stage for a comprehensive cross-case analysis. This analysis will identify common themes, unique challenges, and potential levers for change across different agricultural contexts.

The insights gained from both the individual case studies and the subsequent cross-case analysis will directly inform:

1. UNIBO's ex-ante system dynamics model, providing the necessary data and relationships to simulate complex agricultural systems (Task 2.3).

2. MBS's development of case study theories of change (ToC) and its cross-case analysis (Task 4.2), offering empirical grounding for understanding transition pathways in different contexts.

In the following sections, we present each of the ten case studies in detail. These descriptions form the critical foundation upon which our further analysis and modelling work will build, ensuring that ENFASYS outputs are firmly rooted in the diverse realities of European agricultural systems.

4.1 Case Study 1: France and Belgium - Facilitating Uptake of Agri-Environment Climate Measures (AECMS)

Objective: The primary objective of this case study is to facilitate the adoption of **agri-environment climate measures** (**AECM**) by farmers in targeted regions of France and Belgium. This initiative seeks to enhance environmental sustainability across various agri-environmental practices without limiting the scope to specific value chains.

Local Stakeholders: DRAAF, Regional Council, and other local stakeholders.

Geographic Scope: The study focuses on specific regions within France and Belgium (Hauts-de-France and Wallonia, respectively), each with distinct environmental and agricultural dynamics. These regions are characterized by diverse ecosystems and agricultural practices, necessitating tailored approaches to AECM adoption.

Description: This case study explores on the initiative to encourage farmers to adopt environmentally friendly agricultural practices, focusing on AECMs for biodiversity. The initiative involves collaboration with regional councils and other stakeholders to provide the necessary support and resources for farmers to transition to these practices.

The region, characterized by a relatively flat terrain with an average elevation of approximately 100 meters above sea level, features a landscape of low-lying plains and rolling hills that contribute to a diverse range of natural ecosystems, including forests, wetlands, grasslands, and coastal habitats. The temperate maritime climate of Hauts-de-France, with mild winters and cool summers and with a moderate precipitation, supports a variety of regional nature parks, such as the Scarpe-Escaut and Avesnois.

Hauts-de-France is a major agricultural centre, with a highly diverse sector characterized by varying soil types, ranging from rich alluvial soils to poorer sandy soils that affect the suitability of different crops. The region is known for its production of cereals, sugar beets, potatoes, dairy and beef cattle, pigs, and poultry. Moreover, some areas contribute with vineyards, orchards, and vegetable gardens, while coastal regions are crucial for fishing and seafood production.

Despite its agricultural richness, the sector faces challenges, including an aging workforce, rural depopulation, and lower-than-average income levels for agricultural workers. These issues are compounded by significant challenges in preserving natural capital, as indicated by literature and interviews. There is a prevalent low adoption of AECMs, intensive high-input production, and a lack of agro-ecological practices.

Furthermore, the study highlights concerns related to social, human, and financial capital.

Social capital: There is a noted lack of coordination among private and public initiatives, which affects the effective implementation of AECMs. This coordination issue primarily stems from misaligned efforts and strategies across various stakeholder groups, requiring more integrated approaches to policy and practice.

Human capital: Farmers face a shortage of knowledge and skills related to the implementation of AECMs, and farmer advisors often lack the necessary expertise. Public authorities also face challenges in designing effective subsidy schemes that comprehensively support the transition to environmentally sustainable practices.

Financial capital: Funding for AECMs often fails to fully cover the costs incurred by farmers, and administrative barriers sometimes prevent access to subsidy schemes. Banks also tend to be hesitant to provide loans for non-conventional farming practices. In Hauts-de-France, AECMs are designed to enhance biodiversity through sustainable farming practices such as creating ecological networks, establishing non-productive areas, and developing refuge zones for wildlife. While the AECMs in Hauts-de-France are financially supported by subsidies, these measures inherently lead to some loss of income of farmers. Implementing environmentally sustainable practices often involves using land in ways that are less immediately profitable than traditional practices. For example, setting aside areas for ecological networks or wildlife refuges means that less land is available for crops that could be sold for income. Given such, the subsidies and financial support to farmers not only cover the costs associated with implementing these measures but also compensate for the potential income not earned. The case study contributes to this effort by enhancing the understanding of regional and local dynamics and by providing insights into the governance structures that impact the implementation of AECMs. It focuses on identifying key interactions and barriers within existing frameworks, which helps in identifying areas where better alignment of actions across various decision-making levels might be achieved. Thereby, this informs future strategies aimed at achieving common objectives in biodiversity protection.

Based on the analysis of the case study narrative and the dialogue with the case study coordinators the following variables were identified as relevant, and their relationship were outlines as in the table below:

Table 2 Facilitating Uptake of Agri-Environment Climate Measures: Key variables

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Rate of Agri-Environment Climate Measures (AECM) Adoption	RAA	Proportion of farmers adopting AECM	Subsidies, Compliance Costs, Penalties, Cultural Factors, Advisory Services, Administrative Costs	Central to AECM adoption, influenced by financial, cultural, and advisory factors
EU Budget Allocation for AECM	EUB	EU budget allocated for AECM	Total Allocated Budget for AECM (TABA)	Determines the EU's financial contribution to AECM
Member State Budget Allocation for AECM	MSB	Budget from French government for AECM	Total Allocated Budget for AECM (TABA)	Affects the national budget contribution to AECM initiatives
Total Allocated Budget for AECM	TABA	Combined EU and French government budget for AECM	Subsidies Available for Farm Advisors (SAFA), Total Subsidies Available for Farmer Per Measure (TSAF)	Total budget that influences direct subsidies and advisory services funding
Subsidies Available for Farm Advisors	SAFA	Budget for farm advisory services	Effectiveness of Advisory Services, Total Number of Advisors	Funds advisory support, affecting the advisory service capacity and effectiveness
Effectiveness of Advisory Services	EAS	Quality and impact of advisory services	Rate of AECM Adoption (RAA)	Crucial for effective implementation and farmer support
Environmental Awareness	EAC	Level of environmental concern among farmers	Rate of AECM Adoption (RAA)	Boosts adoption as awareness of environmental issues increases
Total Number of Advisors	(TNA)	Number of advisors available	Effectiveness of Advisory Services (EAS)	More advisors improve the coverage and effectiveness of advisory services
Quota of Advising Service per Farmer for Each Advisor	(QASF)	Advisory capacity per advisor	Effectiveness of Advisory Services (EAS)	Influences the individual attention each farmer can receive
Total Subsidies Available for Farmer Per Measure	(TSAF)	Subsidies distribution for AECM practices	Subsidy Allocation Based on Program Participation	Determines how subsidies are allocated to individual farmers
Subsidies Received by Each Farmer	(SF)	Financial support received by farmers for AECM	Compliance Costs for Adoption (CC), Rate of AECM Adoption (RAA)	Direct financial motivation for farmers to adopt AECM
Compliance Costs for Adoption	(CC)	AECM scheme entrance costs, operational costs to meet AECM standards; Hours of labour required, time spent on compliance reporting/ documentation, number of training and	Rate of AECM Adoption (RAA)	High costs can deter adoption unless offset by subsidies

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
		advisory sessions attended		
Farmer Administrative Burden	(AB)	Documentation and planning burdens for AECM	Rate of AECM Adoption (RAA)	High burden can reduce attractiveness and adoption rate
Penalties related to AECM Contracts	(PEN)	Financial sanctions for non-compliance	Rate of AECM Adoption (RAA)	Penalties can discourage adoption if too stringent or not covered by subsidies
Access to Knowledge and Expertise	AKE	Availability of AECM-related information	Environmental Awareness, Effectiveness of Advisory Services	Enhances understanding and implementation of AECM practices
Training & Education	TE	Training programs for advisors and farmers	Effectiveness of Advisory Services	Improves advisory capabilities and farmer readiness for AECM
Yield-increase mindset vs. sustainability mindset	Y	Farmer focus on yield vs. sustainability	Rate of AECM Adoption (RAA)	A sustainability mindset supports AECM adoption, while a yield-increase mindset may conflict with AECM goals
Sense of ownership and gratitude	SOG	Farmer engagement and commitment levels	Rate of AECM Adoption (RAA)	Affects farmer motivation and thus adoption rates
Biodiversity and Ecosystem Services	BES	Impact on on-farm biodiversity and ecosystem services	Environmental resilience and climate shocks	Improves farm sustainability and resilience against environmental shocks
Territorial Initiatives	TI	Local efforts to support sustainability	Rate of AECM Adoption (RAA)	Tailored local solutions boost adoption by addressing specific regional needs

4.1.1 Final Causal Loop Diagram for Facilitating Uptake of

Table 3 provides an overview of the evolution of the CLD for AECM in France from the initial (Figure 1) to the final version (Figure 2). Initially, the CLD was driven by a straightforward storyline that financial incentives were seen as the primary driver of eco-scheme adoption, but administrative burdens posed significant barriers. As the CLD evolved, the narrative became more complex, reflecting the interlinkages among financial incentives, environmental awareness, advisory services, and the critical roles of regulatory and cultural factors in influencing AECM adoption.

Table 3 Evolution of the CLD for AECM in France

Aspect	Initial CLD	Final CLD	Key Advancements
Focus	Broad focus on eco-schemes in France	Specific focus on Agri-Environment-Climate Measures (AECMs) in Hauts-de-France	Narrowed focus to region-specific AECMs for a detailed analysis
Key Variables	Budget allocation, compliance costs, administrative burdens	Farmer motivation, environmental awareness, advisory services effectiveness, market demand for sustainable products	Expanded variables to include motivation, environmental awareness, and advisory services
Relationships	Simple, linear cause-and-effect relationships (e.g., more subsidies lead to higher adoption rates)	Complex, interconnected relationships with explicit feedback loops	Transitioned from linear relationships to complex, interconnected feedback loops
Feedback Loops	No explicit feedback loops	Included loops like Financial Incentives Loop and Advisory Services Loop	Introduced feedback loops, enhancing understanding of the systemic dynamics
Analytical Rigor	No correlation or adjacency matrices to validate relationships	Incorporated data collected by case study coordinators and insights from CLD workshops to validate relationships, supported by correlation and adjacency matrices	Enhanced analytical rigor with data validation through correlation and Euclidean distance matrices
Strategic Recommendations	Broad, speculative suggestions	Targeted interventions based on feedback loops and identified leverage points	Shifted from speculative suggestions to specific, data-driven recommendations

Key advancements included the introduction of complex feedback mechanisms, such as the Financial Incentives Loop, and the integration of regulatory and cultural factors. These developments were informed by empirical data collected in Task 2.1. Moreover, insights from structural equivalence analysis further refined the relationships and feedback loops. Although the CSC was unable to attend the meeting, the CLD was validated by the CSC and further refined through feedback gathered during the workshop held in Novi Sad at the project's Spring 2024 General Assembly.

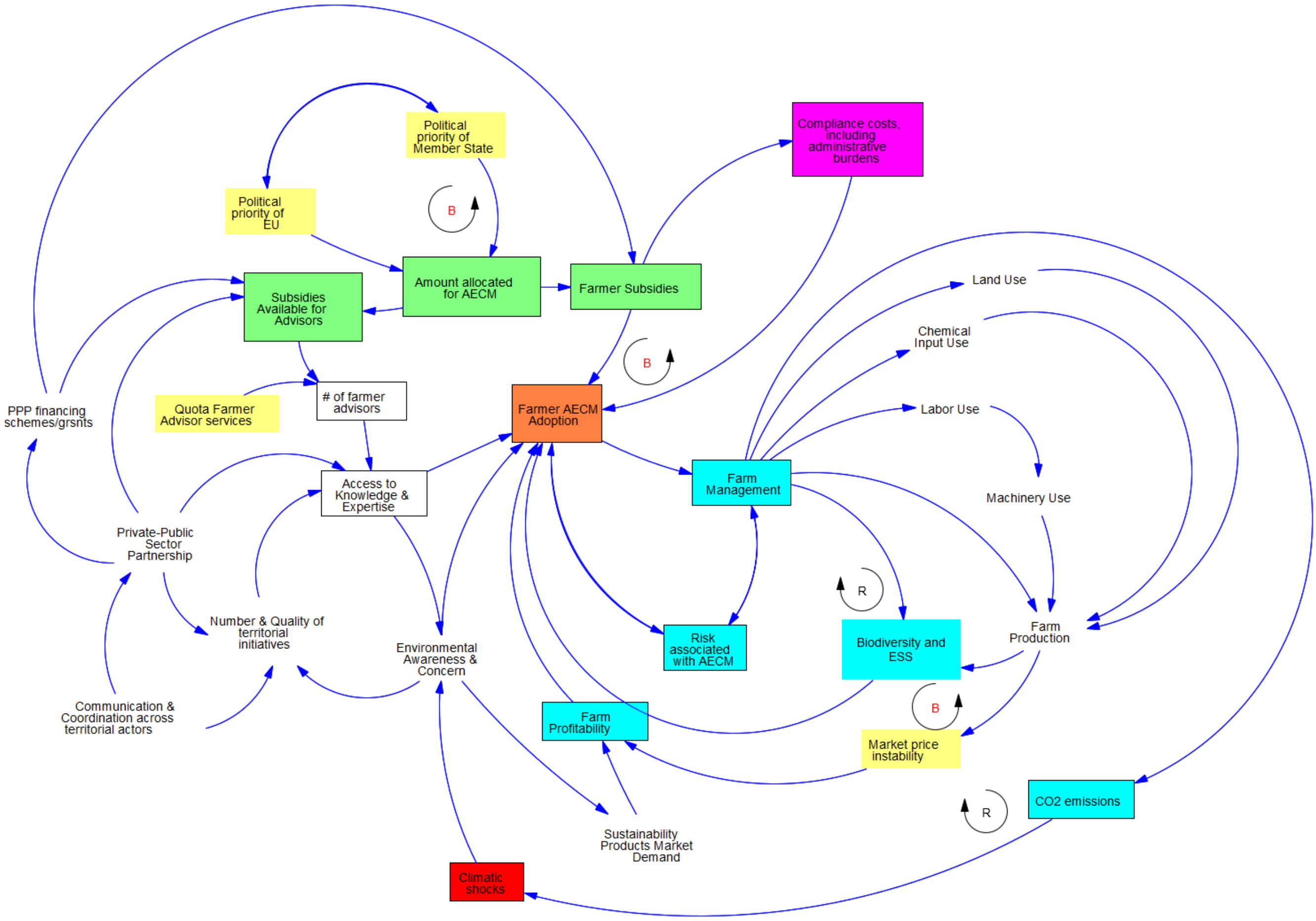


Figure 4 Initial CLD for AECM in France

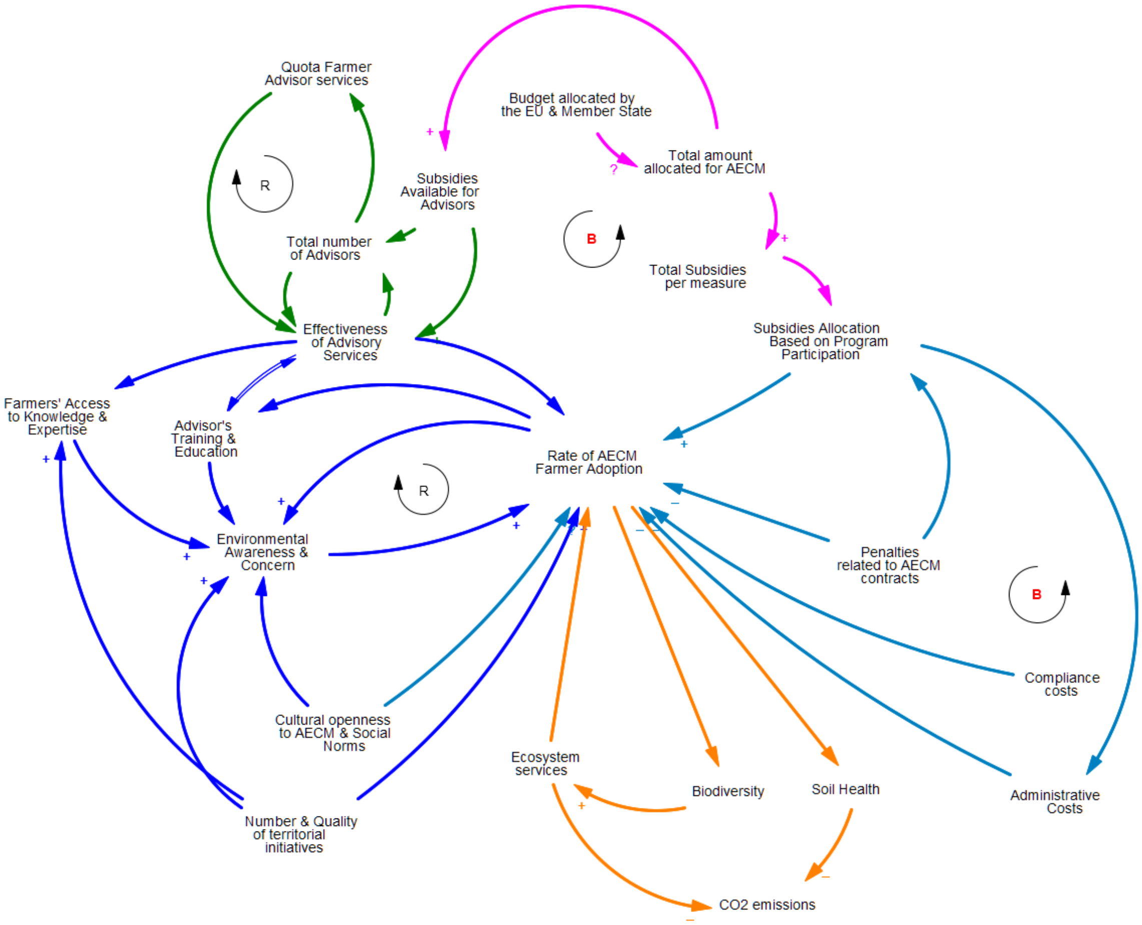


Figure 5 Final CLD for AECM in France

4.1.2 Feedback loops

In this section, we provide the details of feedback loops influencing AECM adoption in Hauts-de-France (B and R in the figure above). Based on the CLD depicted above, it becomes evident that various factors interact and interlink to drive the adoption and effectiveness of AECMs. By identifying both reinforcing and balancing loops, we shed light on the complex interactions between policy support (budget allocation), practical challenges (compliance, administrative costs), and the motivational factors (cultural factors) behind the adoption of sustainable agricultural practices in the region.

1. **Financial Incentives and Adoption Loop (Balancing)**: The loop functions as a balancing feedback mechanism. Subsidy allocation reduces the financial burden on farmers, encouraging AECM adoption. However, as the adoption rate increases and more farmers participate, the fixed total budget must be divided among a growing number of participants, thereby reducing the per-farmer subsidies. This reduction in financial support can discourage further adoption, balancing out the overall increase in the adoption rate. Compliance costs and administrative burdens also contribute to this balancing effect, limiting further growth in adoption despite initial financial incentives.

   Pathway: Subsidy Allocation Based on Program Participation → Compliance Costs for Adoption & Administrative Burden → Rate of AECM Adoption → (Feedback to) Subsidy Allocation

   Justification from the Structural Equivalence Analysis: The financial loop is supported by both the correlation and Euclidean distance matrices. The correlation matrix shows a positive relationship between subsidy allocation and the rate of AECM adoption, indicating that subsidies reduce financial barriers and drive adoption. However, there is also a negative correlation between compliance costs/administrative burden and adoption, suggesting these costs act as balancing forces that can slow adoption. The Euclidean distance matrix shows close proximity between these key variables, reinforcing their strong interconnectedness. As adoption rates increase, they feed back into the need for further subsidy allocation, completing the loop. Without continued financial support, rising compliance costs could limit further adoption, creating a balancing effect in the system.

2. **Advisory and Awareness Reinforcing Loop:** This loop is both a balancing and reinforcing mechanism. Increased funding for advisory services enhances their effectiveness that help farmers better understand and implement AECMs, thereby increasing adoption rates. However, given that the total AECM budget in France is fixed, higher adoption rates mean less funding per farmer for advisory services, which can then diminish the quality of these services and potentially hinder further/sustained adoption.

   Pathway: Advisor's Training & Education → Effectiveness of Advisory Services → Farmer's Access to Knowledge & Expertise →Environmental Awareness & Concern → Rate of AECM Adoption → (Increased) Demand for Advisory Services/More Advisory Training

   Justification from the Structural Equivalence Analysis: There is a strong relationship between advisor training and the effectiveness of advisory services, as demonstrated by the close proximity of these variables in the Euclidean distance matrix, indicating a strong connection. The correlation matrix also supports this, showing a positive correlation between advisor training and service effectiveness, which directly impacts AECM adoption rates. Enhanced advisor training improves the quality of advisory services, which in turn increases farmers' access to knowledge and expertise—both of which are closely linked in the results of the matrices. This heightened access to knowledge raises environmental awareness, as confirmed by their strong correlation, further lowering adoption barriers and driving higher AECM adoption rates. However, the correlation results also suggest that as more farmers adopt AECMs, the increased demand for advisory services may strain the available advisory capacity. This creates a balancing effect, as reflected in the correlation and Euclidean distances, potentially slowing further adoption unless additional resources are allocated to advisor training and support.

3. **Cultural-Environment Reinforcing Loop:** This is more of a reinforcing pathway where cultural openness influences environmental awareness, leading to greater AECM adoption, which in turn reinforces cultural shifts toward sustainability.

   Pathway: Cultural Openness → Environmental Concern & Awareness → Rate of AECM Adoption → Cultural Openness (Integration).

   Justification from the Structural Equivalence Analysis: The structural equivalence analysis shows that cultural openness and environmental awareness have similar patterns of influence on the rate of AECM adoption. This means both factors play equivalent roles in driving adoption. The correlation matrix further confirms that both are positively correlated with AECM adoption, indicating that increases in cultural openness led to greater environmental awareness, which in turn boosts adoption rates.

4.1.3 Lock-ins

The lock-ins reveal the complex system of interdependent challenges, empirically identified through data analysis, that farmers face when adopting AECMs.

1. **Economic Dependencies**: The correlation matrix shows a high correlation between subsidy allocation (from both EU and member states) and the rate of AECM adoption, indicating a strong reliance on these subsidies for adoption. The financial incentives and adoption loop reinforces this lock-ins: as more farmers adopt AECMs, the available subsidies must be divided among more participants, which reduces the per-farmer subsidy. This reduced financial support discourages further adoption, locking farmers into waiting for stable and predictable financial resources. Furthermore, the structural equivalence between EU and member state subsidies and their influence on adoption (seen in their similar positions in the adjacency matrix) confirms that financial uncertainty exacerbates this lock-in.

2. **Regulatory Barriers**: The structural equivalence between compliance costs and administrative burdens (demonstrated by their similar patterns in the adjacency matrix) indicates that these variables function similarly in reducing adoption. Both are structurally positioned to act as bottlenecks, despite the presence of financial incentives. Both are part of the financial incentive and adoption loop, where complex compliance requirements increase the administrative burden, making it harder for farmers to adopt AECMs, even when financial incentives are available. This similarity in structure, confirmed by similar distances in the Euclidean matrix, reinforces that addressing one could alleviate the effects of the other.

3. **Cultural Barriers**: The structural equivalence between cultural openness and environmental awareness (based on their comparable correlations with the rate of AECM adoption in the correlation matrix) suggests that both cultural and environmental factors act similarly in influencing farmer behavior. The cultural-environmental loop reveals that addressing both cultural resistance and environmental awareness together is essential for driving AECM adoption. Farmers who are culturally resistant to new practices may also lack environmental awareness, reinforcing the lock-in. Even with financial incentives, without cultural acceptance or awareness of environmental benefits, adoption rates will remain low. Their close proximity in the Euclidean distance matrix further supports this finding, showing that these factors function together as barriers, even when financial incentives are provided.

4. **Technological Lock-ins**: The structural equivalence between effectiveness of advisory services and access to knowledge and expertise (demonstrated by their similar connections in the adjacency matrix) shows that the lack of strong advisory support and knowledge dissemination hinders AECM adoption (Advisory-Compliance Loop). When advisory services are weak, farmers do not gain the necessary technical knowledge to adopt AECMs, and this increases compliance challenges. The advisory and awareness loop shows that improving advisory services not only fills the knowledge gap but also reduces compliance burdens by helping farmers understand and meet AECM standards more easily. This lock-in is reinforced by the correlation matrix, where both factors (advisory services and access to knowledge and expertise) have similar negative correlations with the compliance costs and administrative burdens that farmers face.

5. **Market Conditions**: While consumer demand for sustainable products is not explicitly included in the adjacency matrix, we can infer its influence through the analysis of financial dependencies and subsidies. The structural equivalence analysis shows a strong relationship between financial dependencies (such as reliance on subsidies) and the rate of AECM adoption, suggesting that farmers remain financially dependent on subsidies in the absence of strong market incentives for AECM-related products. This lock-in is driven by the financial incentives and adoption dependency loop, where subsidies are required to offset the costs of adopting AECMs. The correlation matrix reveals that even with financial support, adoption is limited by compliance costs and administrative burdens. Without stronger financial support mechanisms or alternative incentives (like market demand), farmers are locked into traditional systems, slowing AECM adoption. Although consumer demand was not directly analyzed, we can infer that creating stronger market incentives for sustainably produced goods could potentially reduce farmers' reliance on subsidies, helping to alleviate this lock-in over time.

6. **Knowledge gaps**: The structural equivalence between access to knowledge and cultural openness (seen in both the adjacency and correlation matrices) demonstrates that the lack of comprehensive information directly affects farmers' openness to adopting AECMs. The advisory-awareness loop reinforces this lock in as insufficient knowledge dissemination reduces both environmental concern and aareness and cultural openness, making it harder for farmers to adopt AECMs. The Euclidean distance matrix emphasizes that improving advisory services and access to knowledge/expertise could significantly reduce this lock-in by addressing cultural resistance and increasing environmental awareness simultaneously.

Despite the availability of financial support, these interlinked factors create a system of obstacles that collectively slow the adoption of sustainable farming practices.

4.1.4 Potential levers

Several potential levers can be employed to overcome these lock-ins and promote the adoption of AECMs:

1. **Policy interventions**: The structural equivalence analysis shows that both compliance costs and administrative burdens act as significant barriers by functioning in a similar way to slow down adoption. To address this, policy interventions should focus on streamlining the application processes and unifying administrative and budgetary management for public incentive policies. This will reduce the equivalent burdens of compliance and administration. Simplified processes will ease the adoption of AECMs by farmers who currently face these dual barriers.

   The structural analysis reveals that policy rigidity exacerbates these barriers, as policies that do not adapt to evolving conditions cannot address changing compliance requirements and farm-level diagnostics. Flexible policies, informed by harmonized data collection systems, would be more effective in responding to both farmers' needs and environmental shifts, reducing these barriers simultaneously.

2. **Financial incentives**: The structural equivalence analysis shows that economic dependency on subsidies and the financial risks associated with adoption are closely related. The barriers are amplified when subsidies fail to align with farmers' real financial needs. Addressing this lock-in requires subsidies that cover both the costs of AECM implementation and potential risks, which can be mitigated by offering crop insurance and tax breaks. This lever directly addresses the economic uncertainty barrier, ensuring financial support is consistent with the structural relationship between subsidies and risk mitigation.

   The analysis also shows that subsidy allocation and market demand are structurally equivalent, highlighting the need for responsive subsidies that adapt to market and financial conditions. Subsidies that adjust based on compliance costs and market dynamics would directly address both financial and market barriers, ensuring farmers have consistent financial motivation to adopt AECMs.

3. **Education and training**: The structural equivalence between effectiveness of advisory services and access to knowledge and expertise reveals a direct link between these two factors. When advisory services are ineffective, farmers lack access to the necessary knowledge for AECM adoption, effectively creating a knowledge gap. To overcome this barrier, it is essential to invest in expanding and improving advisory services. By doing so, farmers will receive timely, relevant, and localized support, which will address both the technological lock-in (through better technical guidance) and the lack of access to knowledge. Stronger advisory services will provide the tools and information farmers need to successfully integrate AECMs into their practices.

   The structural equivalence between cultural openness and environmental awareness indicates that both barriers must be addressed simultaneously through targeted training programs. Education initiatives should focus on aligning the environmental benefits of AECMs with local cultural values to overcome cultural resistance. By doing so, farmers will become more receptive to AECMs. Training programs that emphasize culturally relevant environmental benefits will help integrate sustainable practices more effectively into traditional farming systems, thus addressing the cultural barrier.

4. **Technological innovations**: The structural equivalence analysis shows that technological barriers and compliance challenges play similar roles in hindering AECM adoption. Since technological innovations were not discussed with stakeholders, focusing on advisory services is key. Advisory services can help farmers navigate compliance and technological issues using existing tools, offering practical support and guidance to meet AECM standards. Strengthening these services will address both barriers until innovations are explored further with stakeholder input.

5. **Market development**: Although consumer demand was not analysed directly, building market incentives for sustainably produced products can indirectly reduce reliance on subsidies. By raising consumer awareness, farmers can benefit from increased demand for their sustainable products, creating a market-based incentive for AECM adoption.

6. **Community engagement**: To address the cultural openness lock-in, leveraging local champions, i.e. farmers who have successfully adopted AECMs, can shift community perceptions. These champions can play a key role in demonstrating the practical and economic benefits of AECMs, encouraging other farmers to adopt more sustainable practices. This approach will align with increasing cultural openness and create a shift toward acceptance of new agricultural practices. Moreover, there is already a regional program focused on a

collective approach, where farmers share best practices. This collective knowledge-sharing approach enhances cultural openness by integrating AECMs into the community's shared agricultural values and practices, making adoption easier and more culturally acceptable.

Addressing these key six areas will provide an enabling environment for AECM adoption. These strategies are interlinked to remove obstacles, align incentives with farmers' realities, and trigger a shift in culture toward sustainability. These levers are intended to address the identified lock-ins. However, their impact would depend on how they are implemented and the specific context within which they are applied.

4.2 Case Study 2: Serbia - CAP-proofing Serbian Agriculture

Objective: CAP-proof Serbian agriculture through the Pioneer movement of regenerative farmers.

Local Stakeholders: Pioneer movement of regenerative farmers.

Geographic Scope: The case study is located in Vojvodina, a northern province of Serbia, within the Pannonian Plain, which is part of the larger Danube basin. The region's terrain is predominantly flat, with fertile plains rich in chernozem soils, making it ideal for arable farming. Vojvodina has a moderate continental climate, with warm summers, cold winters, and an average annual precipitation of 896 mm, with the highest rainfall in June. These biophysical conditions support intensive agricultural activities but have also led to environmental challenges, including soil degradation and biodiversity loss.

Description: This initiative aims to align Serbian agriculture with the EU's CAP by promoting regenerative farming practices. The project engages pioneer farmers who adopt and advocate for sustainable agricultural methods. Vojvodina has a population density of 81.34 citizens per square kilometre, with an average income of 535 EUR as of 2021. The region faces significant demographic challenges, including an aging population, high old-age dependency ratios, and low fertility rates. Rural areas are particularly affected by depopulation due to outmigration, especially among younger and female populations.

Agriculture remains a significant part of the local economy, primarily driven by small and medium-sized family farms, with an average farm size of 8 hectares. The sector is dominated by arable crop production, especially corn, wheat, sunflower, and soybeans. However, the sector faces challenges, including high input costs, improper application of agricultural techniques, and vulnerability to weather conditions. Conventional farming practices, characterized by heavy pesticide use, contribute to widespread soil erosion and declining soil health.

The case study promotes regenerative practices such as no-till farming, intercropping, and the use of cover crops. These methods aim to reduce environmental impacts by lowering pesticide use, improving water quality, increasing biodiversity, and enhancing soil health. In the long term, these practices are expected to contribute to climate neutrality and improve the economic viability of farms by reducing input costs and increasing productivity.

The adoption of regenerative practices in Vojvodina faces several lock-in conditions. The current farming system depends heavily on chemical inputs, and the value chain is integrated into global commodity markets, which prioritize short-term yields over long-term sustainability. Governance capacities are limited, and there is a lack of clear policy intentions regarding the promotion of sustainable practices. Economic challenges include the high costs of transitioning to regenerative practices and limited subsidies, aside from those available for organic farming.

To address these challenges, the case study proposes a mix of business, policy, and knowledge-sharing strategies. Economic optimization through cost-cutting measures is critical, while policy strategies include advocating for voluntary schemes, accessing IPARD support, and improving national policies and certification processes. Enhancing the Agricultural Knowledge and Innovation System (AKIS) is crucial for changing perceptions and increasing know-how among farmers and advisors. The project aims to produce several key outcomes, including better-informed farmers, practical manuals, demonstration fields, and increased farmer participation in regenerative practices.

The project faces potential risks, such as seasonal timing conflicts, fluctuating farmer motivation, and possible political or strategic changes. To mitigate these risks, the project will remain flexible, keep participants engaged, and align its objectives with national and EU policies.

Based on the analysis of the case study narrative and the dialogue with the case study coordinators the following variables were identified as relevant, and their relationship were outlines as in the table below:

Table 4 Regenerative Agriculture in Serbia: Key Variables

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Rate of Adoption of RA	RAA	Adoption rate percentage	Directly by SKE, AFS, YIF; indirectly by SQ through Y, then P	Directly reflects the uptake of RA practices by farmers.
Youth Interest in Farming	YIF	Engagement level, new entrants in farming	Directly affects RAA	Encourages adoption of new practices, influencing RAA.
Supply of Knowledge and Expertise of RA	SKE	Number of training programs, accessibility of expertise	Directly increases RAA	Increases ability to implement RA effectively.
Capacity of Public Extension and Advisory Services	CPEAS	Number of services/advisory sessions per advisor	Influences CFPA	Affects quality and reach of advisory services influencing RA adoption rates.
Consultation Fee of Private Advisors on RA	CFPA	Average cost of private consultation	Influences SKE; affected by CPEAS	Lower costs increase farmer access to private advisory services, boosting knowledge.
Research on RA at Farm-Level	RRA	Number of farm-level RA studies	Benefits SKE and CPEAS	Generates insights enhancing advisory capacity and knowledge supply.
Social Acceptance & Cultural Acceptance	SA/CA	Community support level, cultural alignment with RA practices	Directly impacts RAA	Affects willingness to adopt RA based on community and cultural values.
Total Input Cost	TIC	Costs of chemical inputs, labour, machinery, and organic fertilizers	Affects P and RAA indirectly	Higher costs reduce profitability, negatively impacting RA adoption.
Profit	P	Revenue minus costs	Directly affects RAA	Economic outcomes of RA can encourage or discourage adoption.
Yield	Y	Production output per hectare	Directly impacts P, indirectly RAA	Improved yields from healthier soils can encourage more farmers to adopt RA.
Soil Quality	SQ	Soil health indicators	Directly affects Y, indirectly RAA	Enhanced by RA practices leading to broader adoption.
Plant Diversity	PD	Variety of crops per hectare	Affects SQ, indirectly affects Y and RAA	Improves soil structure, reducing pest and disease

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
				pressure, enhancing resilience.
Chemical Input Use	CIE	Quantity of chemical inputs used	Directly affects SQ	Reduction leads to improved soil health and less dependence on chemicals.
Organic Fertilizer Use	OFU	Quantity of organic amendments used	Directly affects SQ	Enhances soil structure and fertility, promoting better crop growth.
Demand for Machinery	DM	Type and quantity of machinery needed	Affects P, RAA indirectly	High demand may increase costs and affect financial decisions regarding RA adoption.
Demand for Labor	DL	Labor hours required for RA practices	Similar to DM, affects P and RAA	Similar to machinery, high labor demand can affect costs and profitability.
Supply and Availability of Machinery for RA	SAMRA	Availability and cost of RA-relevant machinery	Affects RAA directly	Affects the ease and affordability of adopting RA practices.
Available Financial Subsidies	AFS	Financial assistance provided by government or organizations	Directly affects RAA	Mitigates costs associated with RA transition, encouraging adoption.
Market Access	MA	Ease of access to markets for RA products	Directly affects P, RAA indirectly	Ensures economic viability of RA products influencing farmer decisions to adopt RA.
Community Engagement and Education	CEE	Level of RA awareness programs	Affects YIF, which influences RAA	Increases community support and knowledge fostering a conducive environment for RA.
Cooperative	C	Number and activity level of agricultural cooperatives	Influences RAA	Facilitates knowledge exchange and support among farmers, promoting RA.
Demand for Seeds	DS	Types and quantity of seeds needed	Influences TIC, PD, and indirectly RAA	Reflects the need for diverse seed types as RA practices are adopted, influencing costs and biodiversity.

4.2.1 Final CLD for CAP-proofing Serbian Agriculture

Table 5 outlines the shift in the focus from the early concern with the general adoption of RA to an exploration of the factors that influence the adoption of Serbia (Figure 3). The insights evolved, particularly from simple linear relations to complex feedback around farmer motivation, financial incentives, and advisory service provisions. In developing this central argument, some key themes are brought into the foreground, such as cultural uptake, especially among younger farmers, and the longevity of RA. The table also presents an increasing focus on policy advocacy, technology support, and knowledge dissemination, translated into targeted, evidence-based recommendations to improve adoption rates, expand over regulatory barriers and enhance market outcomes.

Table 5 Evolution of CLD for Regenerative Agriculture in Serbia

Aspect	Initial CLD	Final CLD	Key Advancements
Focus	Broad focus on regenerative agriculture (RA) adoption	Specific focus on farmer motivation, youth involvement, and financial incentives	Narrowed to regional issues in Serbia with emphasis on youth interest and financial viability
Key Variables	Youth interest, financial support, knowledge gap, and compliance costs	Expanded to include social and cultural acceptance, advisory services, and market access	Added broader variables related to policy, culture, and market dynamics
Relationships	Linear relationships between financial support and RA adoption	Complex feedback loops integrating advisory services, financial incentives, and environmental awareness	Shifted from linear relationships to interconnected feedback loops focusing on knowledge and economic dynamics
Feedback Loops	No explicit feedback loops	Reinforcing loops like the Knowledge and Adoption Loop, and the Economic Incentives Loop	Introduced feedback loops highlighting the reinforcing effects of financial incentives and advisory services
Analytical Rigor	Lacked correlation or adjacency matrices for validation	Added correlation and adjacency matrices to validate relationships between financial incentives, knowledge, and RA adoption	Enhanced analytical rigor with data validation through correlation and Euclidean distance matrices
Strategic Recommendations	Broad recommendations for increasing financial support and simplifying administrative processes	Targeted interventions based on data analysis: focus on advisory services, financial incentives, and cultural integration	Shifted to specific, data-driven recommendations targeting youth involvement, subsidies, and policy support

Key advancements include the progression from simple linear relationships to more complex feedback loops, particularly around farmer motivation, financial incentives, and advisory service provisions. Over the course of seven iterations, the CLD now incorporates important themes such as cultural uptake among younger farmers and the long-term viability of RA practices (Figure 4). Moreover, the model has expanded to encompass policy advocacy, technology support, and knowledge dissemination. These developments have led to more targeted, evidence-based recommendations aimed at improving RA adoption rates, overcoming regulatory barriers, and enhancing market outcomes for RA products in Serbia. The CSC's active participation in the meeting and subsequent workshops ensured that these advancements accurately reflect the local context and challenges specific to Serbia's agricultural landscape.

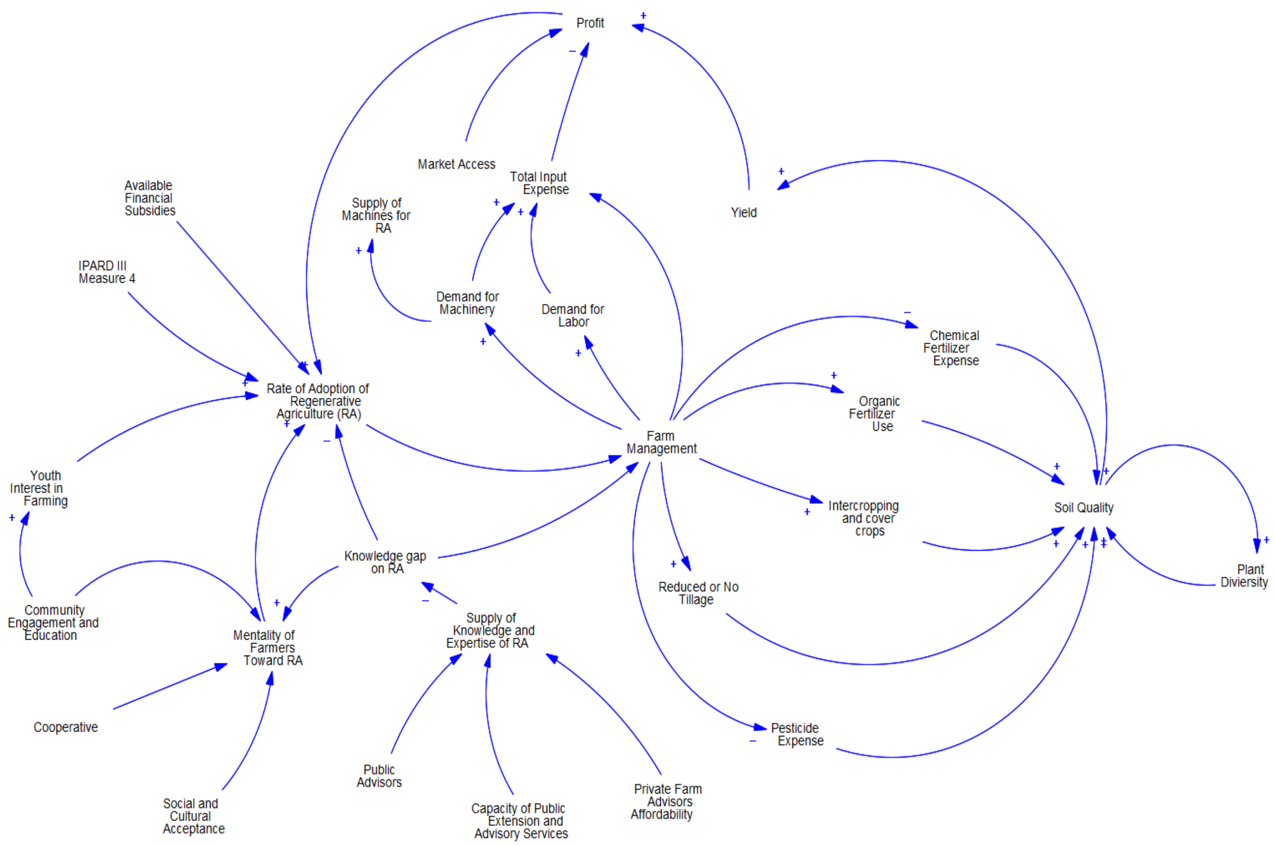


Figure 6 Initial Version of CLD for Regenerative Agriculture in Serbia

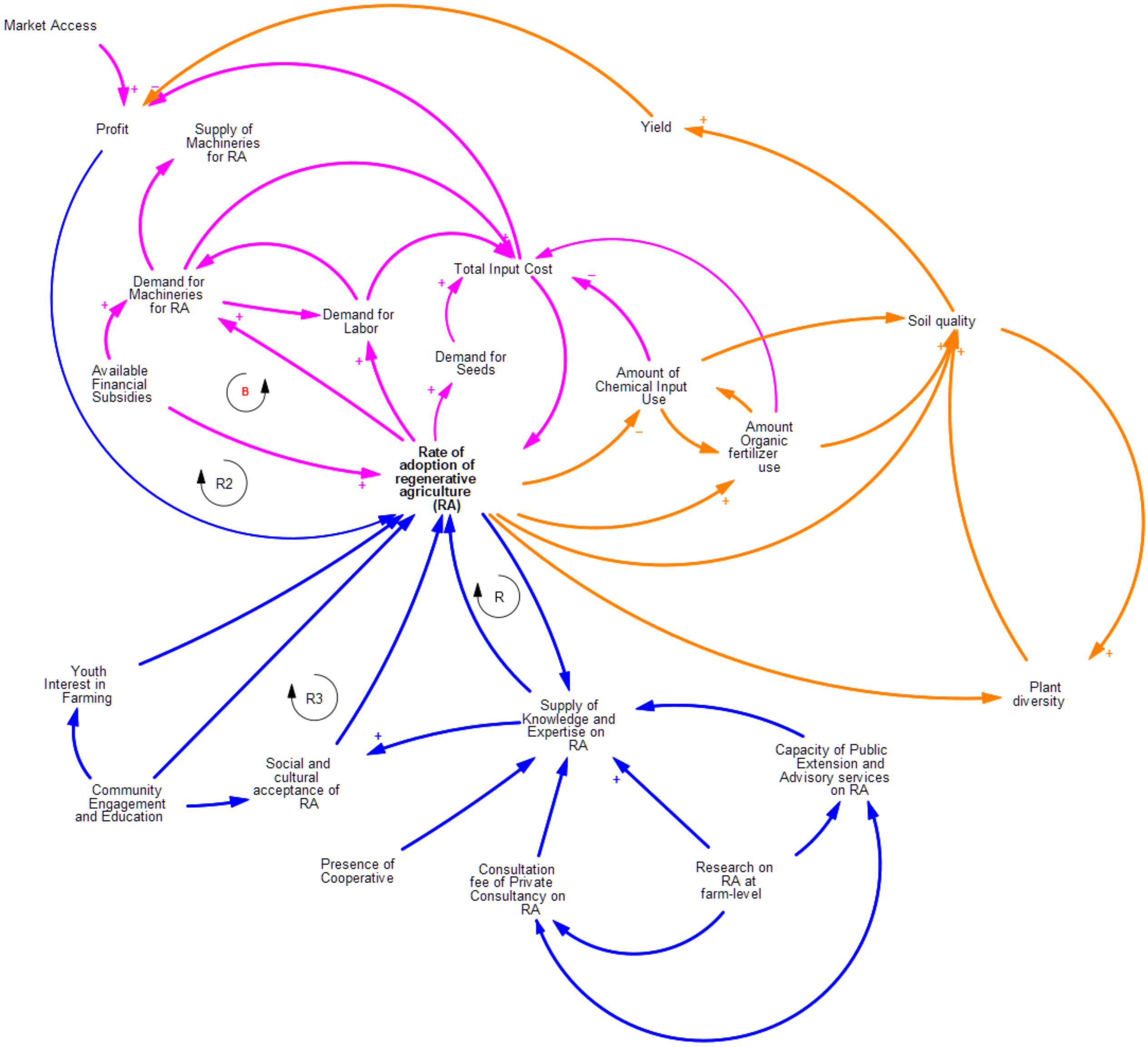


Figure 7 Final CLD for Regenerative Agriculture in Serbia

4.2.2 Feedback loops

Feedback loops are crucial in understanding the dynamics of RA adoption. They reveal how different factors interact to either promote or hinder the transition to sustainable farming practices. The four key feedback loops in this system include:

1. **Knowledge and Adoption Loop (Reinforcing):** This loop demonstrates a positive relationship between the Supply of Knowledge and Expertise of RA (SKE) and the Rate of Adoption of RA (RAA). This correlation suggests that as knowledge about regenerative agriculture increases, more farmers tend to adopt these practices, which in turn leads to greater demand for knowledge and expertise, creating a self-reinforcing cycle.

- Pathway: Supply of Knowledge & Expertise (SKE)→ Rate of Adoption of RA → SKE

- Justification from the Structural Equivalence Analysis: The Euclidean distance analysis reveals a strong linkage between knowledge and adoption underscores the reinforcing nature of the loop. As knowledge increases, adoption rates rise, which in turn drives demand for more knowledge, creating a self-reinforcing cycle. This statistical evidence highlights the critical role of education and information dissemination in promoting the uptake of regenerative agriculture practices. It suggests that investing in knowledge transfer and expertise development could be a powerful lever for increasing the adoption of regenerative agriculture among farmers.

2. **Economic Incentives Loop (Reinforcing):** This loop acts as a reinforcing feedback mechanism where financial subsidies (AFS) make it financially viable for farmers to adopt RA practices. Adoption results to improved soil quality, increased plant diversity, and improved crop yields and profits, which in turn justify further financial support.

   Pathway: Available Financial Subsidies (AFS) → RAA → Soil Quality/Plant Diversity → Yield → Profit→ (feedback to increase) AFS

   Justification from the Structural Equivalence Analysis: The correlation matrix shows a positive relationship between financial subsidies and the adoption of RA. This suggests that subsidies can effectively lower financial barriers, hence encouraging adoption. As adoption increases, the environmental and economic benefits create a positive feedback loop that further reinforces the provision of subsidies. While the impact of increased RAA on Yield and Profit, and subsequently back to AFS, is not directly observable in the Euclidean distance analysis, it can be inferred from the financial dynamics where subsidies enhance profitability through improved yields. This sequence outlines the economic incentive created by subsidies, highlighting how financial support can drive a positive cycle of adoption and improved agricultural outcomes. However, it's important to note that this loop doesn't automatically feed back to increase AFS. For the loop to be fully reinforcing, there would need to be a policy mechanism in place that adjusts subsidies based on the increased profits resulting from RA adoption. Without such a mechanism, the loop remains open-ended, relying on external policy decisions to maintain or increase subsidy levels. This underscores the importance of adaptive policy frameworks in sustaining the transition to regenerative agriculture practices.

3. **Financial and Technical Constraints Loop (Balancing):** This loop, acts as a balancing feedback mechanism as the demand for machinery influences the adoption of RA. The high costs of specialized machinery needed for RA increase total input costs, thereby reducing profitability and potentially lowering the adoption rate. As adoption decreases, the demand for such machinery also declines, either by reducing the scale of operations or by influencing decisions on investing in RA-specific machinery, hence balancing effect on the system.

   Pathway: Demand for Machinery (DM) → Total Input Cost → P→ RAA → DM

   Justification from the Structural Equivalence Analysis: The Euclidean distance analysis provides further insight into this loop. It shows that changes in profits have a direct and immediate impact on RA adoption rates. However, the influence of adoption rates on machinery demand is weaker and less direct. This loop acts as a balancing mechanism in the system: high initial costs associated with RA adoption (particularly machinery costs) can discourage widespread uptake. Conversely, as RA practices are adopted, they may lead to adaptations in machinery needs and costs, which can dynamically adjust the demand for machinery. This balance between costs, profits, and adoption rates plays a crucial role in the transition to regenerative agriculture practices.

4. **Cultural Resistance Loop (Reinforcing):** This loop highlights the role of cultural and social acceptance (CA/SA) in influencing the adoption of RA. Cultural resistance to change, especially among older farmers accustomed to traditional practices, can slow down the rate of adoption. As RA practices are adopted and demonstrate their benefits, cultural and social acceptance may gradually improve, creating a reinforcing loop that supports wider adoption over time. However, the initial resistance suggests that changing cultural perceptions requires sustained effort and time.

   Pathway: Cultural Acceptance/Social Acceptance (CA/SA) → RAA → (feedback to improve) CA/SA

   Justification from the Structural Equivalence Analysis: The Euclidean distance between Cultural and Social Acceptance (CA/SA) and Rate of Adoption of RA (RAA) is relatively large distance. This suggests that the impact of CA/SA on the RAA is not very direct or immediate, and the influence of adoption rates back on cultural and social acceptance similarly involves a weaker or more indirect connection. This reinforces the CA/SA role as initial barriers. However, as RA demonstrates benefits and these distances shrink over time, it can suggest a gradual cultural shift that facilitates RA adoption.

4.2.3 Lock-ins

Several barriers hinder the widespread adoption of RA practices in Serbia as identified by stakeholders and CSC. These barriers are multifaceted and include the following:

1. **Economic Dependencies:** The correlation matrix shows a high correlation between Available Financial Subsidies and the Rate of Adoption of RA (RAA), indicating that farmers rely heavily on subsidies to transition to RA. The Financial Incentives Loop reinforces this lock-in: as more farmers adopt RA, available subsidies must be divided among more participants, reducing the per-farmer subsidy. This reduced financial support discourages further adoption. The structural equivalence between subsidies and profitability (shown in the adjacency matrix) confirms that economic uncertainty exacerbates this lock-in.

2. **Regulatory Barriers:** The structural equivalence between Total Input Costs and administrative burdens indicates that these variables function similarly in slowing adoption, as demonstrated by their positions in the adjacency matrix. Both are part of the Financial and Technical Constraints Loop, where the high costs associated with RA, combined with complex regulations, increase administrative burdens for farmers. This similarity, confirmed by distances in the Euclidean matrix, highlights that reducing input costs and simplifying regulations could alleviate both barriers.

3. **Cultural Practices:** The correlation matrix indicates a similar relationship between Social/Cultural Acceptance and RAA, suggesting that cultural factors play a role in adoption. Resistance to change from traditional practices, especially old farmers, significantly slows the adoption of RA practices. The cultural resistance loop, although reinforcing, suggests that changing cultural perceptions is a slow process. The resistance to change is often driven by scepticism about the effectiveness of RA and a reluctance to move away from familiar practices. The Euclidean distance matrix shows that these factors function together as barriers, further limiting adoption.

4. **Technological Lock-ins:** The structural equivalence between Demand for Machinery and Supply of Knowledge and Expertise (seen in both the adjacency and correlation matrices) suggests that the lack of appropriate machinery and expertise is a key barrier to RA adoption. When farmers do not have access to the necessary machinery or advisory services, they struggle to implement RA. The Financial and Technical Constraints Loop shows that without strong advisory support and technological availability, farmers face significant challenges.

5. **Market Conditions:** The correlation matrix highlights the financial dependency of farmers on subsidies, and although consumer demand for RA-produced goods is not explicitly included in the adjacency matrix, we can infer its influence. Without a strong market for RA products, farmers remain dependent on subsidies to cover the high costs of adoption. This lock-in is reinforced by the Financial Incentives Loop, where subsidies are necessary to offset input costs, but market development could reduce this dependency over time.

6. **Knowledge Gaps:** The structural equivalence between Supply of Knowledge & Expertise and Cultural/Social Acceptance demonstrates that a lack of knowledge contributes to cultural resistance and slows adoption. The Knowledge and Adoption Loop emphasizes that insufficient knowledge dissemination limits both cultural openness and the implementation of RA. The Euclidean matrix underscores that improving advisory services and providing localized knowledge could help address this lock-in.

4.2.4 Potential levers

Identifying and implementing potential levers to overcome these barriers is crucial for facilitating the adoption of RA practices in Serbia.

1. **Policy Interventions**: Official recognition of regenerative agriculture by the Ministry of Agriculture and Ministry of Environmental Protection, and the establishment of stronger links between them, is critical for aligning policies with sustainability goals. The structural equivalence analysis shows that high Total Input Costs and administrative burdens act as significant barriers to RA adoption. Policy interventions should focus

on reducing these burdens by simplifying regulatory processes and unifying administrative and budgetary management for public incentive policies. Simplified processes will ease the adoption of RA by farmers who currently face economic and administrative barriers.

2. **Financial Incentives**: The correlation matrix reveals that financial dependencies on subsidies are closely tied to adoption rates. Increasing subsidies and financial incentives will mitigate financial risks and offset the high upfront costs of RA. These incentives should be aligned with farmers' financial realities and should include subsidies for machinery, crop insurance, and tax breaks to cover the costs of transitioning to RA practices. Moreover, coordination with local, regional, and national institutions is essential to ensure that farmers receive comprehensive support for administrative, financial, and operational needs.

3. **Education and training**: The structural equivalence between advisory services and access to knowledge shows that expanding and improving the National Agricultural Advisory Service (NAAS) is essential for overcoming knowledge and technological barriers. Advisors must be educated, trained, and prepared to provide farmers with regenerative consulting services. The Knowledge and Adoption Loop reinforces that improving advisory capacity and knowledge dissemination is a powerful lever. Collaboration between agricultural institutes, universities, NAAS, and farmers' organizations will strengthen the link between science, practice, and farmers, ensuring that farmers receive timely, localized guidance on RA practices.

4. **Technological Innovations**: Access to appropriate machinery and technologies remains a key technological lock-in. Investments in RA-specific machinery and innovations are essential, but in the short term, strengthening advisory services will help farmers navigate compliance and technological issues using existing tools. This will provide practical support until further innovations are developed and introduced to the market. Pedo-climatic zoning and preparing specific guidelines for farmers and consultants based on local conditions will ensure that regenerative practices are adapted to Serbia's diverse agricultural environments, enhancing the effectiveness of technological innovations.

5. **Market Development**: Developing a market for RA-specific machinery is critical to addressing the technological lock-ins that currently hinder widespread adoption. By promoting investment in RA-specific machinery and fostering partnerships with machinery producers, the market can provide farmers with the tools they need to implement RA practices effectively.

   Subsidies and financial incentives should be aligned with market developments to help farmers purchase or lease appropriate equipment. Encouraging public-private partnerships between machinery manufacturers, agricultural institutes, and government bodies could drive innovation and make RA machinery more accessible and affordable.

   Educating consumers, industry, and the market about the benefits of RA for the environment, economy, and sustainability will boost demand for sustainably produced goods. Certification programs and marketing campaigns can differentiate RA products, adding value and ensuring that farmers benefit from market-based incentives.

6. **Community Engagement**: The Cultural Resistance Loop emphasizes the importance of addressing cultural barriers to RA adoption. Promoting regenerative agriculture and its benefits, along with the services offered by the NAAS, will help shift community perceptions. To address the cultural and social acceptance barriers to adopt and sustain RA practices, it is critical to implement community-based programs and outreach focused on demonstrating the monetary and non-monetary benefits/value of RA. These programs should highlight how RA improves farm profitability, soil health, and long-term sustainability. Strengthening cooperatives and networks to facilitate knowledge sharing and mutual support among farmers. Cooperatives can provide a platform for farmers to exchange best practices, access shared resources, and collaborate on implementing RA. These networks can also serve as a conduit for spreading innovations and fostering a community-driven approach to RA adoption.

4.3 Case Study 3: Switzerland - Biodiversity Promotion Using Locally Adapted Practices

Objective: Promote biodiversity using locally adapted practices.

Local Stakeholders: 30 farmers, biodiversity advisors, Cantonal administration, agricultural school, farmers' association; BLW (national agricultural administration).

Description: This case study aims to enhance biodiversity on farms by implementing locally adapted agricultural practices. It involves a collaborative effort between farmers, biodiversity advisors, and local administrations to promote sustainable farming that supports biodiversity. In Switzerland, the promotion of biodiversity on farmland is influenced by a number of complex factors, many of which needs further exploration and understanding. It is assumed that e.g. education, financial incentives, or access to technology will drive change but it is important to examine the broader set of factors influencing biodiversity in agricultural systems. The case study is situated in the Alpine North region, within the Swiss midland, covering parts of the Canton of Zurich characterized by the pre-Alps and the Jura. The region features a diverse pedo-climatic zone with average annual precipitation of 1,133 mm and a mean temperature of 9.3°C. Elevation in the canton ranges from 330 meters to 1,291 meters above sea level, with most farms in the study located around 500 meters above sea level. The soils in this area are well-suited for arable crops, primarily consisting of lessivé and para-brown earth, with some areas of regosols, calcisols, gleysols, and histosols. The agricultural sector in the Canton of Zurich is diverse, with intensive vegetable, arable, and cattle farming in the lowlands and extensive livestock farming in the uplands. The region also hosts valuable natural ecosystems, including lakes, peatlands, and mountain formations that contribute to local biodiversity. Despite these natural advantages, the current system of biodiversity management in Switzerland has been criticized for its one-size-fits-all approach, which does not always fit the specific needs of different farms and locations. The Canton of Zurich has a mix of conventional and organic farms, with 14% of farms managed organically. However, the region faces several challenges in promoting biodiversity. These include the inflexibility of current regulations, the administrative burden on farmers, and the need for improved knowledge and skills in biodiversity promotion. Additionally, there is a concern that biodiversity-promoting areas are sometimes seen as untidy by the public, and there is a lack of long-term planning due to frequently changing agricultural policies. The case study aims to scale up locally adapted biodiversity promotion practices that are tailored to each farm's specific conditions. The focus is on result-oriented rather than process-oriented biodiversity management, allowing farmers to choose appropriate measures and set their own goals. This approach is expected to enhance the effectiveness of biodiversity promotion, increase farmers' motivation and responsibility, and ultimately lead to more sustainable and resilient farming systems. There are several risks associated with the implementation of this case study, including the possibility that farmers may not significantly change their practices or that the canton and federal offices may decide not to continue funding if the results are not satisfactory. To mitigate these risks, careful communication between all stakeholders is essential, ensuring that expectations are managed and that no false promises are made. By the end of the project, it is anticipated that farmers and cantonal offices will receive valuable feedback on the effectiveness of result-oriented biodiversity promotion. This feedback will be crucial for informing future regulations on national biodiversity promotion. Additionally, the project aims to study whether result-oriented measures are a more effective way to promote biodiversity and could potentially serve as a model for broader implementation across Switzerland.

Based on the analysis of the case study narrative and the dialogue with the case study coordinators the following variables were identified as relevant, and their relationship were outlines as in the table below:

Table 6 Biodiversity Promotion Using Locally Adapted Practices Key variables

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Knowledge and Skills in Biodiversity Management	KSBM	Number of farmers receiving biodiversity advice; Number of students attending biodiversity classes in basic agricultural training	Uptake of Biodiversity Measures, Biodiversity Quality, Stakeholder collaboration	Increased knowledge and skills lead to improved biodiversity management practices and greater uptake of biodiversity measures.
Advisory Service	AS	Number of biodiversity-focused advisory sessions conducted; Number of advisors trained in biodiversity	Number of farmers receiving personalized biodiversity advice	Improved advisory service coverage leads to more informed farmers adopting biodiversity measures.
Uptake of biodiversity measures by farmers	UBMF	Number of farmers applying site specific measures for biodiversity Or Number of farmers engaging in biodiversity programmes (doesn't not really answer the question, but could be an approximation)	Biodiversity Quality, Stakeholder collaboration, Food and Feed Production	Greater uptake of measures leads to improved biodiversity and sustained food/feed production.
Biodiversity Quality on farmland	BQF	Soil health indicators, species diversity	Other Environmental Benefits, food and Feed production and policy adjustment	Enhanced biodiversity quality contributes to greater environmental benefits and policy adjustments.
Financial Incentives	FI	Amount of subsidies, financial assistance	Uptake of Biodiversity Measures, Biodiversity Friendly Policy Adjustments	Financial incentives drive the adoption of biodiversity practices.
Stakeholder Collaboration	SC	Number of collaborative projects, stakeholder interactions	Knowledge and Skills, Uptake of Biodiversity Measures	Collaboration among stakeholders fosters innovation and improved biodiversity management practices.
Biodiversity Friendly Policy Adjustments	BFPA	Number of biodiversity friendly policy adjustments within 4 years	Financial Incentives, Uptake of Biodiversity Measures, Other environmental benefits, Advisory Services	Adjusting policies to ensure that incentives lead to genuine biodiversity improvements and greater uptake of biodiversity measures.
Food and Feed Production	FFP	Agricultural production	Biodiversity Quality, Policy Adjustments	Supports biodiversity quality and influences policy adjustments.

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Other environmental Benefits	OEB	CO_2 reduction	Biodiversity Quality, Policy Adjustments	Reduction in CO_2 contributes to enhanced biodiversity quality and supports policy adjustments.

4.3.1 Final CLD for Biodiversity Promotion Using Locally Adapted Practices

The process of building the CLD began with the identification of key variables influencing biodiversity management, which included Knowledge and Skills in Biodiversity Management, Financial Incentives, Stakeholder Collaboration, and Biodiversity Quality. These variables were derived from detailed data collection, including interviews with local farmers, biodiversity advisors, and representatives from the Cantonal administration. The initial draft of the CLD was constructed using these variables, focusing on the relationships that influence biodiversity outcomes on Swiss farms (Figure 5).

The relationships were mapped to illustrate what factors enable farmers to implement effective biodiversity practices. These practices, in turn, would enhance the quality of biodiversity areas, generating significant environmental benefits. Financial incentives were identified as a crucial driver for adopting these practices, while stakeholder collaboration was seen as a facilitator of innovation and continuous improvement in biodiversity management. After the initial CLD was drafted, it underwent a series of bilateral meetings with key stakeholders, including representatives from the Research Institute of Organic Agriculture (FiBL), local biodiversity advisors, and members of the farmers' association. These meetings were essential for discussing the relationships depicted in the CLD and for identifying any missing variables or feedback loops that might influence the system.

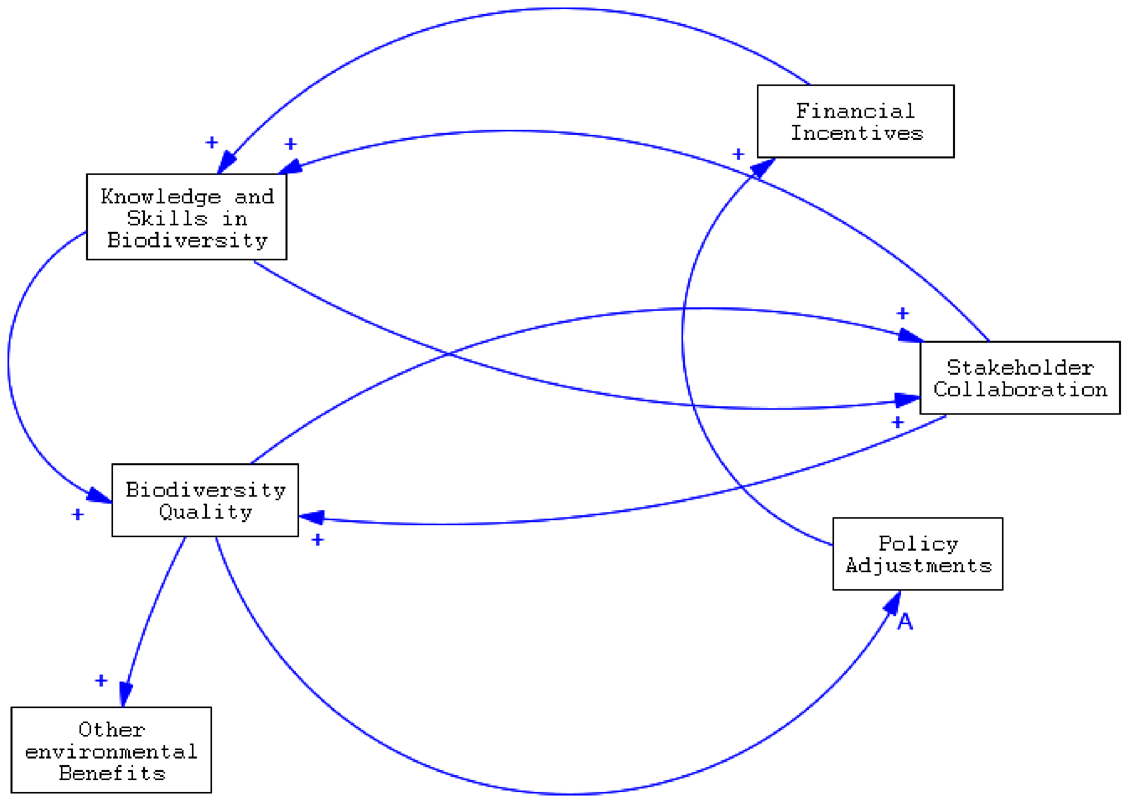


Figure 8 Initial CLD for Biodiversity Promotion Using Locally Adapted Practices

Table 7 Evolution of CLD for Biodiversity Promotion Using Locally Adapted Practices

Aspect	Initial CLD	Final CLD	Key Advancements
Focus	Focus on advancing biodiversity in general	Specific focus at farmland level	Increased specificity and narrowed focus to the farmland level
Key Variables	Too few variables not reflecting the case complexity. Initial variables: Knowledge and Skills in Biodiversity; Biodiversity Quality; Financial incentives; Stakeholder collaboration; Policy adjustment; Other environmental benefits	Inclusion of additional variables and renaming of some of the existing ones. Final variables: Knowledge and Skills in Biodiversity; Uptake of biodiversity measures by farmers; Biodiversity Quality on farmland; Financial Incentives; Stakeholder collaboration; Biodiversity friendly policy adjustment; Food and feed production; Other environmental benefits; Food sovereignty; Advisory service. Two suggested variables by the CSC were not included in the final version: i.e. i) policy implementation and ii) Farmers' perception on the role/value of biodiversity. The first was not included because it was redundant (policy adjustment), the second because was not measurable; the use of proxies will be explored	Variable pool improved and expanded
Relationships	Simple linear relations	Added complexity in line with the increased number of variables	Feedback loops were added providing a more articulated picture
Feedback Loops	No feedback loops	Three feedback loops were identified	Introduced feedback loops, enhancing understanding of the systemic dynamics
Strategic Recommendations	Very genera suggestions	Targeted recommendations based on specific farm level relations ad feedback loops	The CD evolved from very general suggestions to specific recommendations founded on data-based variables

Through the discussions summarised in Table 7, the CLD was refined to include more detailed feedback loops. For instance, a reinforcing loop was added to show how improved Biodiversity Quality could further justify and enhance biodiversity management efforts, creating a positive cycle of continuous improvement. Additionally, a balancing loop was introduced to capture the potential policy adjustments needed when financial incentives did not lead to genuine biodiversity improvements, highlighting the need for adaptive policies that could evolve with changing environmental conditions.

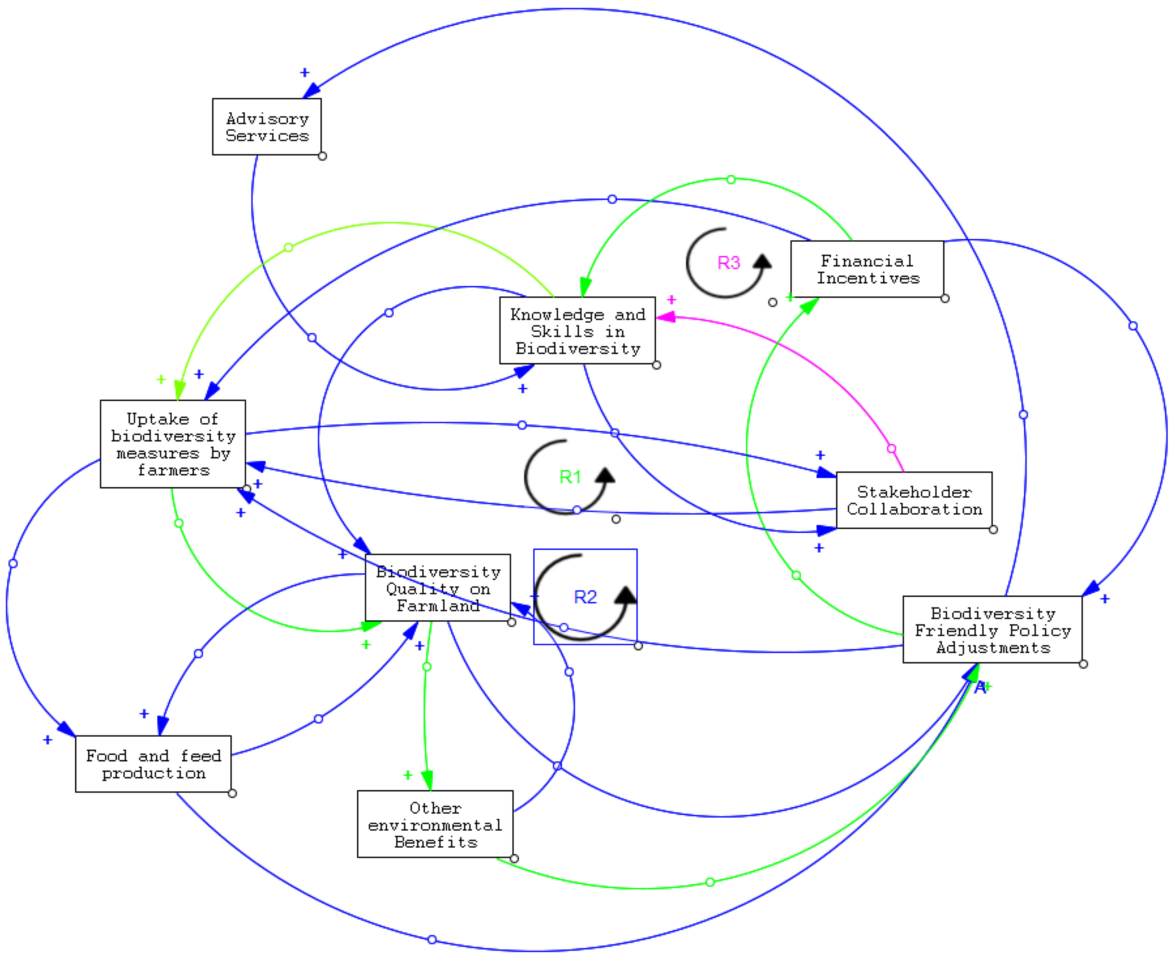


Figure 9 Final CLD for Biodiversity Promotion Using Locally Adapted Practices

4.3.2 Feedback loops

In the context of biodiversity promotion in Switzerland, three key reinforcing loops have been identified, each playing a crucial role in how biodiversity measures are adopted and sustained.

1. **Knowledge and Skills Loop (R1):** The first loop, Knowledge and Skills Loop (R1), highlights the importance of knowledge and skills in biodiversity management. As farmers' knowledge and skills improve, they are more likely to adopt biodiversity measures, which in turn enhances the quality of biodiversity on their farms. This improvement brings broader environmental benefits, prompting policy adjustments that lead to increased financial incentives. These incentives further support the development of knowledge and skills, creating a strong reinforcing cycle. This loop is supported by the results of the structural equivalence analysis, showing the strong interdependence between training availability and adoption rates. By standardizing training availability across various regions, the adoption of biodiversity measures can become more consistent, as demonstrated in adjacency matrices from other case studies.

   Pathway: Knowledge and Skills in Biodiversity Management (KSBM) → Uptake of Biodiversity Measures (UBM) → Biodiversity Quality (BQ) → Environmental Benefits (EB) → Policy Adjustments (PA) → Financial Incentives (FI) → Knowledge and Skills in Biodiversity Management (KSBM)

   Justification from the Structural Equivalence Analysis: The Euclidean distance between these variables suggests a strong and direct linkage, reinforcing this loop.

2. **Financial Incentives Loop (R2):** The second loop, Financial Incentives Loop (R2), emphasizes the role of financial support in encouraging the uptake of biodiversity measures. Financial incentives lead to greater adoption of these measures, which improves biodiversity quality. Enhanced biodiversity quality then influences policy adjustments that ensure continued or increased financial support, thus sustaining the loop. This cycle underscores the critical role that economic mechanisms play in promoting biodiversity-friendly practices.

   Pathway: Financial Incentives (FI) → Uptake of Biodiversity Measures (UBM) → Biodiversity Quality (BQ) → Policy Adjustments (PA) → Financial Incentives (FI)

   Justification from the Structural Equivalence Analysis: The positive correlation among these variables indicates that financial mechanisms play a crucial role in sustaining biodiversity management efforts.

3. **Stakeholder Collaboration Loop (R3):** The third loop, Stakeholder Collaboration Loop (R3), underscores the value of collaboration among farmers, advisors, and administrators. Effective collaboration enhances knowledge and skills in biodiversity management, leading to higher adoption rates of biodiversity measures and improved environmental outcomes. These outcomes drive policy changes that provide further financial incentives, which in turn promote even greater collaboration among stakeholders. This loop highlights the interconnected nature of knowledge, policy, and collaboration in fostering sustainable agricultural practices.
   Pathway: Stakeholder Collaboration (SC) → Knowledge and Skills in Biodiversity Management (KSBM) → Uptake of Biodiversity Measures (UBM) → Biodiversity Quality (BQ) → Environmental Benefits (EB) → Policy Adjustments (PA) → Financial Incentives (FI) → Stakeholder Collaboration (SC)

   Justification from the Structural Equivalence Analysis: The analysis conducted shows that collaborative interactions significantly strengthen the link between knowledge acquisition and policy-driven incentives, supporting the sustainable uptake of biodiversity practices across various regions. The close Euclidean distance among these variables underlines the influential role of stakeholder engagement in sustaining and expanding biodiversity measures.

4.3.3 Lock-ins

The case study aims at promoting locally adapted biodiversity practices with a public policy scheme that is based on the achievement of biodiversity results and not of the fulfilment of predefined biodiversity measures. It can be defined as a specific type of a results-based scheme. In the context of promoting biodiversity in agricultural practices with the help of such a results-based scheme, a comprehensive analysis of barriers was done in the framework of task 2.1 revealing a complex array of challenges to be addressed to ensure successful implementation of results-based schemes. The identified barriers are multifaceted, spanning technical, financial, market-related, organizational, cultural, and knowledge-related domains. Technical barriers included the time-intensive processes of implementing and monitoring biodiversity measures, alongside the inherent risks of not achieving desired outcomes, which may discourage farmer participation. Financial barriers were significant, with uncertainties surrounding the potential costs and financial rewards of goal-oriented biodiversity measures, particularly given the need for additional consultancy services and the risk of sanctions for unmet goals. Market-related barriers further complicated the situation, as farmers face difficulties in making biodiversity-promoting products visible to consumers, compounded by the time constraints imposed by daily farm operations. Organizational barriers highlighted the challenges in agreeing on new objectives, developing suitable indicators, and managing the increased administrative workload associated with these measures. Cultural barriers revealed a resistance to change, with farmers expressing scepticism towards new systems and the accompanying administrative burdens. Finally, knowledge-related barriers underscored the varied levels of understanding and expertise in biodiversity management among farmers, necessitating targeted training and support. Additionally, the heterogeneity of Swiss farms, the impact of external shocks, and the creative demands of developing site-specific biodiversity measures represent further obstacles.

Based on these barriers and on the results of the structural equivalence analysis, a series of lock-ins were elaborated and identified as relevant in context with the selected variables and on the basis of the results of the structural equivalence analysis. Those lock-ins included economic dependencies, where the reliance on financial incentives can create vulnerability if funding becomes inconsistent or inefficient. The high initial costs and perceived economic risks associated with transitioning to biodiversity-focused practices can further deter farmers from adopting these measures without adequate financial support. Regulatory barriers also play a significant role, particularly when a one-size-fits-all approach does not account for the diverse needs of different regions and farming systems, leading to resistance and challenges in policy implementation. Additionally, cultural practices, such as public perceptions of biodiversity areas as untidy or a lack of education on the benefits of these practices, can reduce social acceptance and hinder adoption. These lock-ins illustrate the complex challenges that must be addressed to foster the successful integration of biodiversity measures into agricultural practices, additional details are provided below.

1. **Economic Dependencies**: The reliance on financial incentives to drive biodiversity practices creates an economic lock-in. The structural equivalence analysis reveals a strong correlation between financial dependency and uptake of biodiversity measures, where farmers are hesitant to implement practices without stable funding. As financial resources become scarcer, the competition for subsidies intensifies, reducing the financial support per farmer, which discourages wider adoption of biodiversity-friendly practices.
2. **Regulatory Barriers**: The one-size-fits-all approach in policymaking presents a significant regulatory lock-in. The correlation matrix shows that high administrative and compliance burdens disproportionately affect smaller farms, leading to slower adoption of biodiversity practices. The structural equivalence of compliance costs and administrative hurdles highlights their joint role as bottlenecks in this feedback loop, reinforcing the lock-in through a lack of flexibility in regulatory frameworks tailored to local biodiversity needs.
3. **Cultural Practices**: The public perception of biodiversity areas as unproductive or untidy represents a cultural lock-in. The correlation matrix demonstrates that cultural resistance correlates closely with the rate of adoption of biodiversity practices. Structural equivalence analysis supports this by showing a close relationship between cultural acceptance and environmental awareness, both of which are necessary to foster a transition toward sustainable farming.

4.3.4 Potential levers

To overcome these lock-ins and promote the adoption of biodiversity practices, several strategic levers were identified through dialogue. Policy interventions are crucial, particularly in enhancing public extension services and adapting regulations to be more region-specific and flexible, thereby encouraging local adoption. Financial incentives remain a key lever, with an emphasis on paying for the delivery of ecosystem services including public policies for effective biodiversity promotion or business strategies involving market actors paying farmers higher prices for biodiversity-friendly products. Education and training are essential for building the necessary knowledge and skills among farmers, with targeted, farm-specific programs and collaborations with agricultural schools to enhance practical knowledge dissemination. Community engagement is another powerful lever, focusing on implementing programs that demonstrate the tangible benefits of biodiversity practices and strengthening networks among farmers to facilitate knowledge sharing and mutual support.

1. **Policy Interventions:** Enhance public extension services to provide better support and education on biodiversity practices. Adapt and enforce policies to be more region-specific and flexible to encourage local adoption.
2. **Financial Incentives:** Increase and ensure the efficient use of financial resources to develop and sustain advisory services that support biodiversity practices. In this scheme, the state covers the costs of developing and paying for advisory services, lowering the burden on farmers and promoting biodiversity management. Develop business opportunities such as labels and communication strategies to promote biodiversity-friendly products.
3. **Education and Training:** Implement farm-specific training programs to build knowledge and skills in biodiversity management. Collaborate with agricultural schools and local stakeholders to enhance practical knowledge dissemination.
4. **Community Engagement:** Implement community-based programs to demonstrate the benefits of biodiversity practices. Strengthen networks among farmers to facilitate knowledge sharing and mutual support.

4.4 Case Study 4: France - Promoting Protein Autonomy in French Livestock Farms

Objective: Improve protein autonomy at dairy farm level to decrease importation of oilseed cakes while evaluating and disseminating new varieties of legumes, increasing competitiveness and sustainability of oilseed and protein production, and responding to the food transition with local products.

Local Stakeholders: Technical institutes, advisors, support organizations, agricultural education, dairy farmers, seed producers.

Description: The focus is on promoting protein autonomy in French livestock farms by evaluating and disseminating a wide set of practices i) at farm level (better use of grasslands and grazing, legumes implementation, oil seed production ...), ii)in the feed industry, through a national or EU sourcing rather than a foreign and GMO sourcing iii) in the dairy sector with the implementation of quality scheme promoting autonomous farms or non GMO feed. The project aims to drastically reduce the dependency on soja import to feed dairy cows. The case study is situated in the Atlantic pedo-climatic zone of France, which includes a diverse range of dairy basins such as the west, north, Franche-Comté, and Auvergne regions. The climate in these areas varies from temperate to oceanic and continental, with lowland and mountainous terrains. This diversity in geography and climate provides a broad representation of the challenges and opportunities for promoting protein autonomy in different farming conditions. France has a well-established dairy farming sector, with approximately 54,000 dairy farms operating across the country. The average farm size is 118 hectares, with an average of 68 dairy cows per farm. These farms vary widely in terms of scale, ranging from small to semi-large operations, and include both conventional and organic practices. However, current farming practices often rely on imported soybean meal for cattle feed, which presents significant environmental and economic challenges. Several issues impede the progress toward protein autonomy in French dairy farms. These include the environmental impacts of soybean imports, such as deforestation and greenhouse gas emissions, and the lack of a robust legume supply chain, particularly in processing. Social and human capital challenges also exist, such as the influence of large food sellers, the need for better support networks, and a general lack of knowledge and research on legume cultivation and grassland optimization. Financially, growing cereals and importing soybean meal remains more profitable for many farmers, creating a dependency on global markets and exposing farms to price volatility. The case study aims to increase the adoption of practices that enhance protein autonomy in dairy farms. Key practices include optimizing grazing by extending its duration and implementing dynamic grazing systems, improving grass and meadow cultivation through grass-legume mixtures, and promoting the cultivation of forage legumes. These practices are expected to reduce dependency on imported soy, enhance biodiversity, improve carbon storage, and increase the overall resilience of farms by making them less reliant on volatile global markets. In the long term, the project aspires to achieve full protein self-sufficiency for French dairy farms. This ambitious goal involves multiple stages and collaborative projects aimed at establishing a sustainable and locally sourced protein supply chain. Achieving this will significantly contribute to the sustainability and competitiveness of the French dairy sector, aligning with broader goals of climate neutrality and biodiversity enhancement. The successful implementation of this case study faces several potential risks, including difficulties in engaging with various stakeholders and the willingness of farmers to adopt new practices. To mitigate these risks, the project will leverage trusted intermediaries to facilitate communication and ensure that the unique issues and contexts of each stakeholder group are understood and addressed effectively.

Based on the analysis of the case study narrative and the dialogue with the case study coordinators the following variables were identified as relevant, and their relationship were outlines as in the table below:

Table 8 Promoting Protein Autonomy in French Dairy Livestock Farms Key variables

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Local Feed Sources	LFS	Hectares under legume cultivation	Enhanced Pasture Management, Economic Incentives	Shifting to local feed sources fosters biodiversity, improves soil health, and reduces soy dependency.
Economic Incentives	EI	Amount of subsidies, financial assistance	Local Feed Sources, Market Stabilization Tools	Economic incentives support the transition to sustainable practices.
Market Stabilization Tools	MST	Use of futures contracts, price stability metrics	Local Feed Sources, Economic Incentives	Stabilizes income for farmers, encouraging sustainable practices.
Infrastructure Development	ID	Infrastructure spending, number of new facilities	Local Feed Sources, Sustainable Agriculture Policies	Supports the transition to sustainable practices by improving infrastructure.
Sustainable Agriculture Policies	SAP	Number of policies passed, impact assessments	Local Feed Sources, Enhanced Pasture Management	Policies support sustainable farming methods and reduce environmental impact.
Enhanced Pasture Management	EPM	Soil quality indicators, pasture yield	Local Feed Sources, Market Dependency Reduction	Improved pasture management practices enhance soil health and biodiversity, reducing market dependency
Market Dependency Reduction	MDR	Percentage of local consumption, import statistics	Local Feed Sources, Economic Incentives	Reduces dependency on global markets, supporting local production and sustainability.
Indicator-Based Monitoring	IBM	Monitoring data on agricultural practices, specific indicators (e.g., protein autonomy, percentage of pasture usage, legume cultivation areas)	Sustainable Agriculture Policies, Infrastructure Development	Monitors effectiveness and impact of policies and practices over time
Extension Services	ES	Number of training sessions, farmer outreach metrics	Skills Enhancement for Legume Cultivation, Education & Community Engagement	Provides education and support for farmers to adopt sustainable practices

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Skills Enhancement for Legume Cultivation	SELC	raining completion rates, practice adoption rates	Extension Services, Sustainable Agriculture Policies	Specialized training for legume cultivation supports sustainable agriculture
Education & Community Engagement	ECE	Community workshop attendance, survey results	Local Feed Sources, Extension Services	Builds community support for sustainable practices through education and engagement
Resilience Building	RB	Resilience metrics, recovery rates after disturbances	Infrastructure Development, Sustainable Agriculture Policies	Improves agricultural systems' resilience through infrastructure and diversified practices

4.4.1 Final CLD for Promoting Protein Autonomy in French Livestock Farms

To gain additional insights and validate the initial CLD (Figure 7) , the CSC and NIBIO arranged a discussion and explored the various factors influencing the country's capacity to achieve self-sufficiency in protein production. The conversation aimed to identify the current barriers to protein autonomy and understand how resources are distributed among key actors involved in the protein production network. The discussion highlighted several critical factors that influence protein autonomy, including agronomic practices, research and innovation, policy support, and market dynamics. Both environmental and economic motivations were recognized as driving forces behind the push for greater protein self-sufficiency. However, significant challenges were identified, particularly in terms of knowledge gaps and the reluctance among farmers to adopt new practices, such as the increased production of legumes.

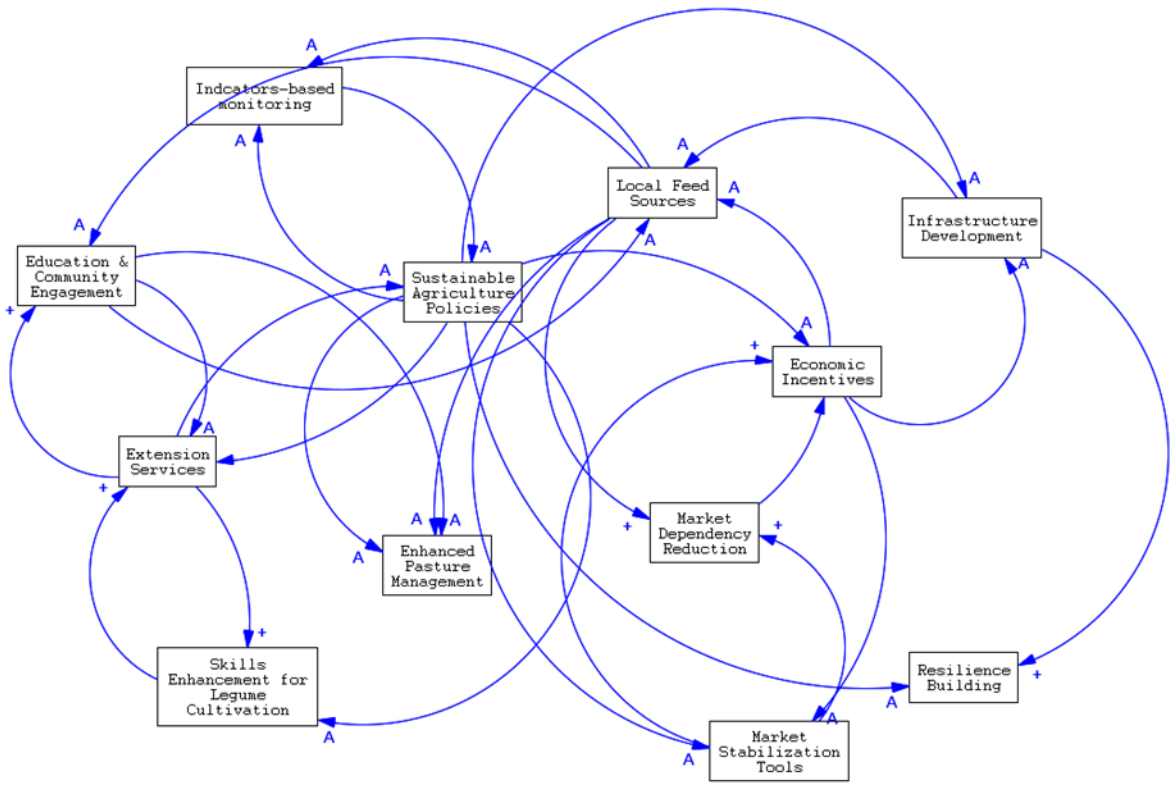


Figure 10 Initial CLD for Promoting Protein Autonomy in French Livestock Farms

Barriers to achieving protein autonomy were extensively discussed. A key issue was the lack of sufficient skills among farmers and advisors in legume production, which is essential for enhancing protein self-sufficiency. Additionally, the difficulty in changing entrenched agricultural practices posed a significant challenge. The discussion also revealed that the current rotation practices are inadequate to meet the growing demand for locally produced protein. The dairy industry, a significant consumer of protein crops, often prioritizes other concerns, thereby reducing the focus on paying a premium for self-sufficient milk production. The group identified several key actors within the protein production ecosystem, including farmers, advisors, industry stakeholders, research institutions, and import/export companies. Despite identifying these actors, the distribution network for locally produced protein remains unclear, presenting a major challenge. Understanding this network is crucial for pinpointing intervention opportunities that could shift economic incentives and promote greater self-sufficiency. The discussion also generated ideas for potential interventions to address the identified barriers. One significant bottleneck is the inadequate transfer of knowledge between ongoing projects and the lack of industrial initiatives to support protein autonomy. To overcome these challenges, the group proposed organizing validation workshops that would bring together a mix of stakeholders. The main points used to improve the initial CLD are summarised in Table 9.

Table 9 CLD evolution for Promoting Protein Autonomy in French Livestock Farms

Aspect	Initial CLD	Final CLD	Key Advancements
Focus	Regional focus	National level, all dairy area not only west	The focus was expanded to increase the use of grasslands and pasture in animal feeding at national level. The CSC pointed out that they wanted to unpack the complexity of optimal grassland management compared to maize and soil based feeding
Key Variables	The initial key variables included: Local Feed Sources; Enhanced Pasture Management; Economic Incentives; Infrastructure development; Market Stabilization Tools; Market Dependency Reduction; Sustainable Agriculture Policies; Indicator-Based Monitoring; Extension Services; Skills Enhancement for Legume Cultivation; Education & Community Engagement; Resilience Building	The list of variables remained the same but additional details were given, and adjustments were done for their definitions influencing the relations e.g. for enhanced pasture management, the CSC pointed out that he idea was not only to improve soil health but to increase the part of grass and grassland legumes in dairy cows feed because grass is richer in proteins than maize. Furthermore, for Economic incentives they should be linked not only to infrastructure but also to pasture management (incentives to enhance grazing like pathways …).	Additional details were provided, and definitions of variables were adjusted to better capture relationships, especially for pasture management and economic incentives.
Relationships	Linear relations	Complex, more numerous and interconnected relationships with explicit feedback loops	The CLD evolved into a more complex representation incorporating multiple interconnected relationships and providing a more accurate depiction of the system.
Feedback Loops	No explicit feedback loops	Eight feedback loops were identified and added to the CLD providing additional complexity	Introduced feedback loops, enhancing the understanding of the systemic dynamics within the agricultural system
Strategic Recommendations	General suggestions for improvement	Specific data-driven recommendations focusing on policy support, economic incentives and infrastructure development	The recommendations shifted to specific applicable strategies such as enhancing policy support, providing economic incentives, and investing in infrastructure to support sustainable practices.

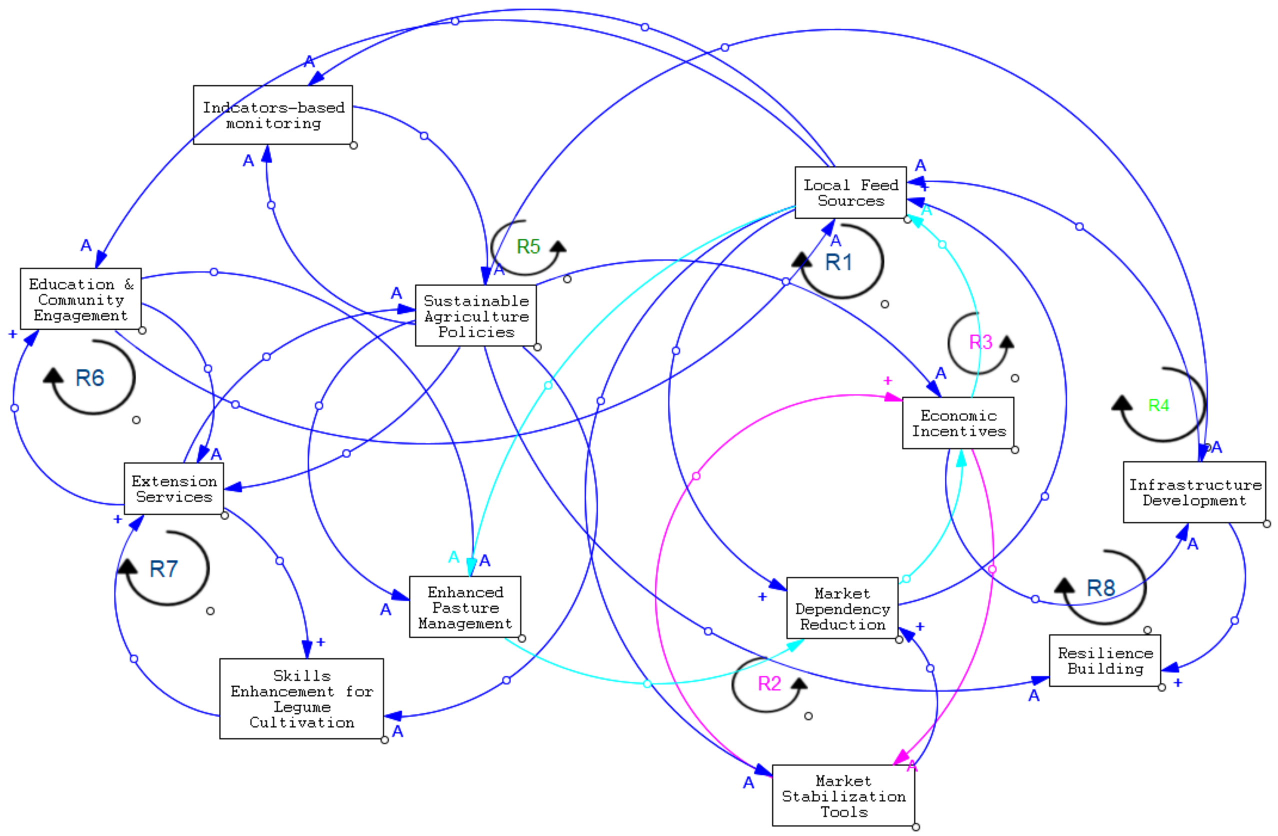


Figure 11 Final CLD for Promoting Protein Autonomy in French Livestock Farms

4.4.2 Feedback loops

The identified loops illustrate how various factors interact dynamically within the agricultural system, reinforcing or balancing each other's effects. In this case study, several reinforcing feedback loops are identified, each playing a crucial role in promoting local feed sources, improving pasture management, and reducing dependency on global markets.

1. **Local Feed Sources Loop (R1):** emphasizes how shifting to local feed sources can enhance pasture management, which in turn reduces market dependency and encourages further adoption of local feed sources.

   Pathway: Local Feed Sources (LFS) → Enhanced Pasture Management (EPM) → Market Dependency Reduction (MDR) → Local Feed Sources (LFS).

   Justification from the Structural Equivalence Analysis: The structural equivalence analysis reveals a strong direct relationship between local feed sources and pasture management improvements. By prioritizing local feed sources, farms enhance soil health and support biodiversity. The low Euclidean distance between Local Feed Sources (LFS) and Enhanced Pasture Management (EPM) variables indicates a mutual reinforcement that strengthens autonomy from market dependencies, further encouraging local sourcing.

2. **Economic Incentives Loop (R2):** shows how financial incentives can catalyse the adoption of local feed sources, leading to improved pasture management and a more stable market, which then justifies the continuation of these incentives.

   Pathway: Economic Incentives (EI) → Local Feed Sources (LFS) → Enhanced Pasture Management (EPM) → Market Dependency Reduction (MDR) → Economic Incentives (EI)

Justification from the Structural Equivalence Analysis: The close Euclidean distance between these variables shows that financial incentives strongly influence the adoption of local feed sources, as demonstrated by. Financial support not only aids the transition to sustainable practices but also enables farmers to maintain pasture quality, which contributes to stable incomes and reduces reliance on volatile markets.

3. **Market Stabilization Tools Loop (R3):** highlights the importance of supportive policies and infrastructure in fostering sustainable practices.

   Pathway: Market Stabilization Tools (MST) → Local Feed Sources (LFS) → Economic Incentives (EI) → MST

   Justification from the Structural Equivalence Analysis: The structural equivalence analysis underscores the importance of market stabilization tools in fostering sustainable practices by providing income predictability for farmers. The proximity of Market Stabilization Tools (MST) to Local Feed Sources (LFS) and Economic Incentives (EI) illustrates how such tools create a supportive environment for adopting local feed sources, thus encouraging consistency and sustainability in farming practices.

4. **Infrastructure Development Loop (R4):** highlights the importance of supportive policies and infrastructure in fostering sustainable practices.

   Pathway: Infrastructure Development (ID) → Local Feed Sources (LFS) → Sustainable Agriculture Policies (SAP) → Infrastructure Development (ID)

   Justification from the Structural Equivalence Analysis: Infrastructure development is closely aligned with the establishment of local feed sources, as shown by the analysis. The structural proximity between Infrastructure Development (ID) and Sustainable Agriculture Policies (SAP) suggests that improved infrastructure enhances the feasibility and appeal of sustainable practices, making the transition more accessible and resilient to market changes.

5. **Sustainable Agriculture Policies Loop (R5):** improve pasture management practices, which further encourages the use of local feed sources.

   Pathway: Sustainable Agriculture Policies (SAP) → Enhanced Pasture Management (EPM) → Local Feed Sources (LFS) → Sustainable Agriculture Policies (SAP)

   Justification from the Structural Equivalence Analysis: Structural analysis highlights the reinforcing effect of policies on pasture management, shown by the low Euclidean distance between Sustainable Agriculture Policies (SAP) and Enhanced Pasture Management (EPM). By embedding these policies into the agricultural framework, farms are encouraged to integrate local feed sources, creating a sustainable cycle of policy-driven support and ecological improvement.

6. **Education and Extension Services Loop (R6):** provide education and support for farmers to adopt sustainable practices. Specialized training for legume cultivation supports sustainable agriculture.

   Pathway: Extension Services (ES) → Skills Enhancement for Legume Cultivation (SELC) → Sustainable Agriculture Policies (SAP) → Extension Services (ES)

   Justification from the Structural Equivalence Analysis: The analysis conducted shows that education services significantly influence skills development in legume cultivation. The close alignment between Extension Services (ES) and Sustainable Agriculture Policies (SAP) variables indicates that outreach and education are crucial for enhancing sustainable practices, bridging knowledge gaps, and supporting the transition to sustainable local feed sources.:

7. **Community Engagement Loop (R7):** underscore the importance of knowledge dissemination and community involvement. By enhancing skills and engaging the community, these loops help to build a more resilient and sustainable agricultural system.

Pathway: Education & Community Engagement (ECE) → Local Feed Sources (LFS) → Extension Services (ES) → Education & Community Engagement (ECE)

Justification from the Structural Equivalence Analysis: Structural equivalence analysis demonstrates the importance of community engagement in sustaining local feed sources and extension services. The minimal Euclidean distance between Education & Community Engagement (ECE) and Local Feed Sources (LFS) indicates that community involvement amplifies the effectiveness of local sourcing initiatives by fostering a knowledgeable and supportive base of farmers and stakeholders.

8. **Resilience Building Loop (R8):** focuses on improving infrastructure and diversifying practices to enhance overall resilience.

   Pathway: Resilience Building (RB) → Infrastructure Development (ID) → Sustainable Agriculture Policies (SAP) → Resilience Building (RB)

   Justification from the Structural Equivalence Analysis: The analysis confirms that resilience building, through infrastructure and diversified practices, has a positive influence on sustainable agricultural policies. The close relationship between Resilience Building (RB) and Infrastructure Development (ID) underscores the role of resilient practices in creating a stable agricultural environment, adaptable to external changes while supporting protein autonomy.

4.4.3 Lock-ins

Despite the potential benefits of transitioning to sustainable agricultural practices, several lock-ins present significant barriers to change. French livestock farms' reliance on imported protein sources, such as soy, is a major economic dependency that hinders the shift to locally sourced alternatives. This dependency is exacerbated by regulatory barriers, where inconsistent and short-term protein plans fail to provide sustained support for local legume production. Additionally, cultural practices influenced by large food sellers and established conventional farming methods further entrench resistance to change.

Technological lock-ins also play a role, as the current agricultural infrastructure is better suited to conventional farming methods, making the transition to sustainable practices more challenging. Knowledge gaps about the benefits of sustainable practices and local feed sources further limit the willingness and ability of farmers to adopt these new approaches.

1. **Economic Dependencies:** The profitability of cereal cultivation and soy imports compared to domestic legume production can deter shifts to local crops. Vulnerability to global market fluctuations affects income stability and farmer decision-making.
2. **Regulatory Barriers:** Regularly implemented but inconsistent protein plans lack sustained momentum. External factors like European market dynamics and geopolitical crises impact the stability of farming practices.
3. **Cultural Practices:** Influence of large food sellers over farming practices reduces farmer autonomy. Lack of support for legume-based production hinders local supply chain development.
4. **Lack of infrastructures**: The current agricultural infrastructure is better suited to conventional farming method, there are no processing plants for alternative protein sources.
5. **Conventional farming practices:** Established conventional farming methods resistant to change towards sustainable practices.
6. **Knowledge gaps:** Limited awareness and understanding of the benefits of sustainable practices and local feed sources.

4.4.4 Potential levers

To overcome these lock-ins, several potential levers have been identified to facilitate the transition to sustainable agricultural practices. Policy interventions are critical, with a focus on establishing a comprehensive framework that promotes crop diversification and aligns national policies with long-term strategic goals. Financial incentives are also crucial, including subsidies for growing and processing legumes to make them competitive with imported soy and cereals, and the development of financial instruments to stabilize income.

Education and training play a vital role in equipping farmers with the knowledge and skills needed to adopt sustainable practices. Expanding extension services and building educational programs within local cooperatives can help reduce environmental impacts and increase the adoption of local feed sources. Market development strategies, such as promoting local protein crops and supporting these with financial incentives and marketing campaigns, are essential for reducing dependency on imports.
Finally, community engagement and infrastructure development are key levers in building support for sustainable practices and ensuring that the necessary infrastructure is in place to support the transition.

1. **Policy Interventions:** Establish a comprehensive policy framework promoting sustainable farming and crop diversification. Align national policies with long-term strategic planning to ensure resilience against external impacts.
2. **Financial Incentives:** Provide subsidies for growing and processing legumes to make them competitive with cereals and imported soy. Develop financial instruments like futures contracts to stabilize income for local crop practices.
3. **Education and Training:** Expand extension services to support the transition to sustainable practices. Build educational programs within local cooperatives focusing on techniques that reduce environmental impact, on techniques to improve grazing rates and grasslands' Management, and on legumes and oil seeds cultivation.
4. **Market Development:** Promote local protein crop alternatives to reduce dependency on imported soybeans. Implement financial incentives and marketing campaigns to support local products.
5. **Community Engagement:** Building community support for sustainable practices through education and outreach programs.
6. **Infrastructure Development:** Investing in infrastructure to support the transition to sustainable agricultural practices and improve resilience.

4.5 Case Study 5: Germany - Creating Regional Production-Consumption Cycles/Sustainable pig farming

Objective: Create regional value chains for pig meat and enhance sustainability in farming systems via guaranteed remuneration through new value chains and political funding instruments.

Local Stakeholders: Regional farmers' association (Landesbauernverband Brandenburg).

Description: This case study aims to establish regional production-consumption cycles for pig meat. The initiative seeks to enhance farming sustainability by ensuring fair remuneration for farmers through regional value chains and supporting political funding instruments. The current pig farming system in Brandenburg is heavily specialized and reliant on external inputs, particularly imported feed. This specialization creates challenges in achieving sustainable farming practices and integrating regional value chains. Key problems include the need for increased regional feed production, the adaptation of animal husbandry systems to meet higher welfare standards, and the development of a regional pig product value chain that includes primary and secondary processing, retail, gastronomy, and logistics. Brandenburg is characterized by a diverse range of soil productivity, from nutrient-poor sandy soils to very fertile areas, with a continental climate that poses challenges such as irregular weather patterns, frost events, and increased production risks due to extreme weather events. Approximately 80% of Brandenburg's agricultural area is considered disadvantaged, with limited irrigation infrastructure available to mitigate these challenges.

The region of Brandenburg has a total agricultural area of approximately 1.3 million hectares, managed by around 5,413 farms, with an average farm size of 242 hectares. This average farm size is significantly above the national average, reflecting the dominance of large corporate and medium-sized farms in the region. However, the pig farming sector is relatively small, with only 405 farms and a declining pig population, which stood at approximately 597,500 pigs in 2022. The region’s farming practices are heavily influenced by the legacy of the DDR (East Germany), with many farms operating old stables that present significant challenges related to animal welfare and emissions. The specialized nature of these farms, which often separate breeding and rearing processes, further complicates efforts to integrate more sustainable and natural farming practices. Additional challenges include a high dependency on imported feed and the impact of African Swine Fever (ASF) on production practices, all of which have contributed to the decline in livestock numbers. The overarching goal is to create a closed regional food system circuit, where pig farming is part of a sustainable, self-sufficient cycle that reduces reliance on external inputs and enhances environmental and economic resilience. Brandenburg is characterized by a continental climate with significant variations in soil productivity, ranging from nutrient-poor sandy soils to more fertile areas. The region faces challenges from irregular weather patterns, including frost events, summer droughts, and increased extreme weather occurrences, which exacerbate production risks. Around 80% of Brandenburg's agricultural area is classified as disadvantaged, with limited irrigation capacity, further complicating agricultural productivity.

The case study aims to promote several key farming practices that align with the goals of enhancing sustainability and animal welfare. These practices include:

- Stable Adaptations: Implementing stables that allow for natural animal behaviours, such as free farrowing and providing stimuli for rooting and defecating. Modular systems that can be retrofitted to improve animal welfare are encouraged.
- Fodder-Manure Exchange: Promoting cooperation between pig farms and crop farms to facilitate the exchange of fodder and manure, thus creating more closed nutrient cycles and reducing the reliance on imported feed.
- Reduction of Livestock Density: Limiting the number of livestock units per hectare to improve animal welfare and reduce environmental impacts.
- Abandoning Harmful Practices: Phasing out practices such as tail-docking and castration, with plans to adopt alternative methods such as boar fattening.
- Regional Quality Scheme: Establishing a regional quality label to incentivize farmers and consumers to support sustainable and animal-friendly pig farming practices.

The case study aims to establish mechanisms that incentivize farmers to adopt sustainable practices, such as improved animal welfare and regional fodder production, despite the challenges posed by ASF and financial constraints. A key component of the case study is the development of a regional quality label (Brandenburger Qualitätszeichen) that certifies pig products based on stringent animal welfare and environmental standards. This label aims to differentiate regional products in the market, fostering consumer willingness to pay a premium for sustainably produced pork. Additionally, the study highlights the importance of addressing the decreasing trend in home slaughtering and the challenges posed by new EU legislation on mobile slaughtering. By improving the value chain and marketing strategies, the case study seeks to enhance the economic viability of sustainable pig farming in Brandenburg.

The ultimate goal is to identify levers within political, economic, and societal contexts that can be adjusted to support a more sustainable regional pig production system. By fostering collaboration between farmers, policymakers, and other stakeholders, the case study seeks to create a more resilient and self-sufficient pig farming system in Brandenburg that aligns with broader sustainability goals.

Based on the analysis of the case study narrative and the dialogue with the case study coordinators the following variables were identified as relevant and their relationship were outlines as in the table below:

Table 10 Creating Regional Production-Consumption Cycles Key Variables

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Policy Requirements	PR	Number of policies enacted per year, pig farming compliance rate percentage	Farmer Proposals and Adoption Practices (FP+ARSP), Government Funding Support (GFS)	Sets the regulatory framework that farmers need to comply with, influencing their proposals and practices.
Farmer Proposals and Adoption Practices	FP+ARSP	Number of sustainable practices proposed and adopted by farmers	Animal Welfare Systems (AWS), Regional Feed Production (RFP), Environmental	Drives the adoption of sustainable methods and practices, impacting multiple areas.

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
			Impact (EI), Profit (P)	
Regional Feed Production	RFP	Tons of feed produced locally per year, percentage of feed consumption that is regionally sourced	Animal Husbandry System (AHS)	Indicates the shift towards using local feed resources, reducing reliance on imported feeds.
Animal Welfare Systems	AWS	Number of farms achieving certain animal welfare standards, amount invested in welfare improvements	Consumer Willingness to Pay (CWTP)	Enhances animal welfare standards, appealing to consumer preferences for ethically produced goods.
Value Chain Development	VCD	Number of stakeholders involved, efficiency index of the value chain	Actor Influence (AI), Regional Feed Production (RFP)	Assesses the development of a robust and sustainable regional value chain from production to retail.
Actor Influence	AI	Number of key actors supporting or obstructing sustainable practices, influence rating (scale of 1-10)	Farmer Proposals and Adoption Practices (FP+ARSP), Value Chain Development (VCD)	Evaluates how different stakeholders affect the adoption of sustainable practices.
External Market Factors	EMF	Index of market price fluctuations for pork and feed, number of farms affected by external crises	Regional Feed Production (RFP), Value Chain Development (VCD)	Captures external economic pressures impacting economic stability and decision-making of farmers.
Consumer Willingness to Pay	CWTP	Degree to which consumers are willing to pay more for sustainably produced pork products	Profit (P)	Drives market demand for sustainably produced products.
Government Funding Support (GFS)		Financial support provided by government bodies	Farmer Proposals and Adoption Practices (FP+ARSP)	Provides financial resources to support sustainable practices.
Environmental Impact	EI	Reduction in greenhouse gas emissions, changes in land use efficiency	Certification, Value Chain Development (VCD)	Evaluates the environmental outcomes of adopting sustainable practices.
Profit	P	Financial gain or loss from pig farming operations	Farmer Proposals and Adoption Practices (FP+ARSP)	Provides financial incentives for adopting sustainable practices.

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Arable Production System	APS	Cultivation of crops used for animal feed	Regional Feed Production (RFP)	Determines the availability and sustainability of local feed resources.
Animal Husbandry System	AHS	Management and care practices for livestock	Animal Welfare Systems (AWS)	Enhances the welfare and productivity of livestock.
Certification	CERT	Process and standards required for sustainable farming practices	Consumer Willingness to Pay (CWTP), Profit (P)	Provides market differentiation and potentially higher market prices for certified products.
System Trust	ST	Level of trust in the system by various stakeholders	Farmer Proposals and Adoption Practices (FP+ARSP), Policy Requirements (PR)	Facilitates the adoption of sustainable practices by enhancing cooperation and compliance.
Constantly Changing Regulations	CCR	Frequency and impact of changes in regulations	Farmer Proposals and Adoption Practices (FP+ARSP), System Trust	Creates an unstable regulatory environment, affecting long-term planning for sustainability.
Perceived Regulatory Risk	PRR	Risk perceived by stakeholders regarding regulatory changes	Farmer Proposals and Adoption Practices (FP+ARSP), Policy Requirements (PR)	Impacts the willingness of stakeholders to invest in sustainability.
Policy Dialogue	PD	Communication and negotiation between policymakers and stakeholders	Policy Requirements (PR), Government Funding Support (GFS)	Shapes the development of policies and funding mechanisms.
Regional Quality Label	RQL	Label awarded to farms/products meeting regional standards	Consumer Willingness to Pay (CWTP), Profit (P)	Enhances market differentiation and consumer trust.

4.5.1 Final CLD for Creating Regional Production-Consumption Cycles/Sustainable pig farming

Table 11 shows the evolution of the CLD for sustainable pig farming in Germany. The development process involved at least three iterations of the CLD, each refining and adding complexity until the final version was reached. The preliminary CLD (see Figure 9) had simple and linear relationships, such as the interplay of animal welfare practices and market demand. By contrast, the final CLD (see Figure 10) consisted of complex feedback loops, which comprised certification systems, consumer willingness to pay, and market dynamics. Important extensions are the use of matrices, especially adjacency, correlation, and Euclidean distance, to substantiate and narrow down the relationships, hence making the analysis more robust. The final version was thoroughly validated and further refined through CSC feedback and expert input until the narrative was expanded to include technological advances and policy support as means of overcoming the identified challenges toward sustainable adoption.

Table 11 Evolution of the CLD for Sustainable Pig Farming in Germany

Aspect	Initial CLD	Final CLD	Key Advancements
Focus	General focus on sustainable pig farming in Germany	Specific focus on animal welfare, local feed production, and market dynamics	Narrowed to regional sustainability practices with emphasis on animal welfare and feed production
Key Variables	Animal welfare practices, feed composition, technical requirements	Expanded to include certification systems, consumer willingness to pay, and market access	Broader variables related to certification, market dynamics, and environmental sustainability
Relationships	Linear cause-and-effect relationships between welfare practices and market demand	Complex feedback loops integrating policy support, market demand, and certification systems	Shifted from linear to systemic relationships with multiple reinforcing feedback loops
Feedback Loops	No explicit feedback loops	Reinforcing loops like the Certification and Value Chain Enhancement Loop, and Integrated Sustainable Practices Loop	Introduced complex feedback loops that reinforce the connection between certification and market development
Analytical Rigor	Lacked correlation or adjacency matrices to validate relationships	Added matrices to validate relationships between market dynamics, certification, and profitability	Enhanced analytical rigor through correlation and adjacency matrices for validation
Strategic Recommendations	Broad suggestions for improving animal welfare and local feed production	Targeted interventions based on data analysis: focus on certification systems, policy support, and sustainable market development	Shifted to specific, data-driven recommendations targeting certification and consumer market development

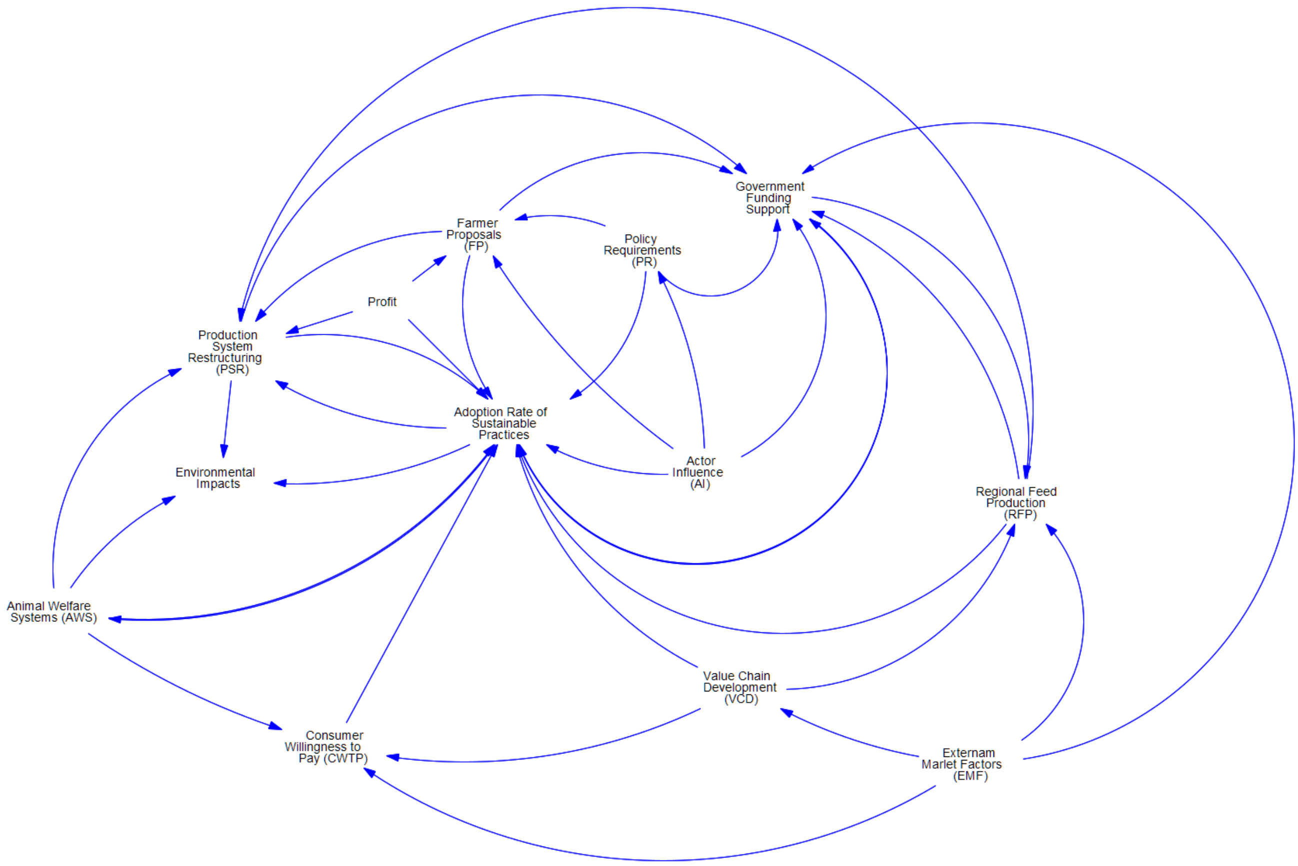


Figure 12 Initial CLD for Sustainable Pig Farming in Germany

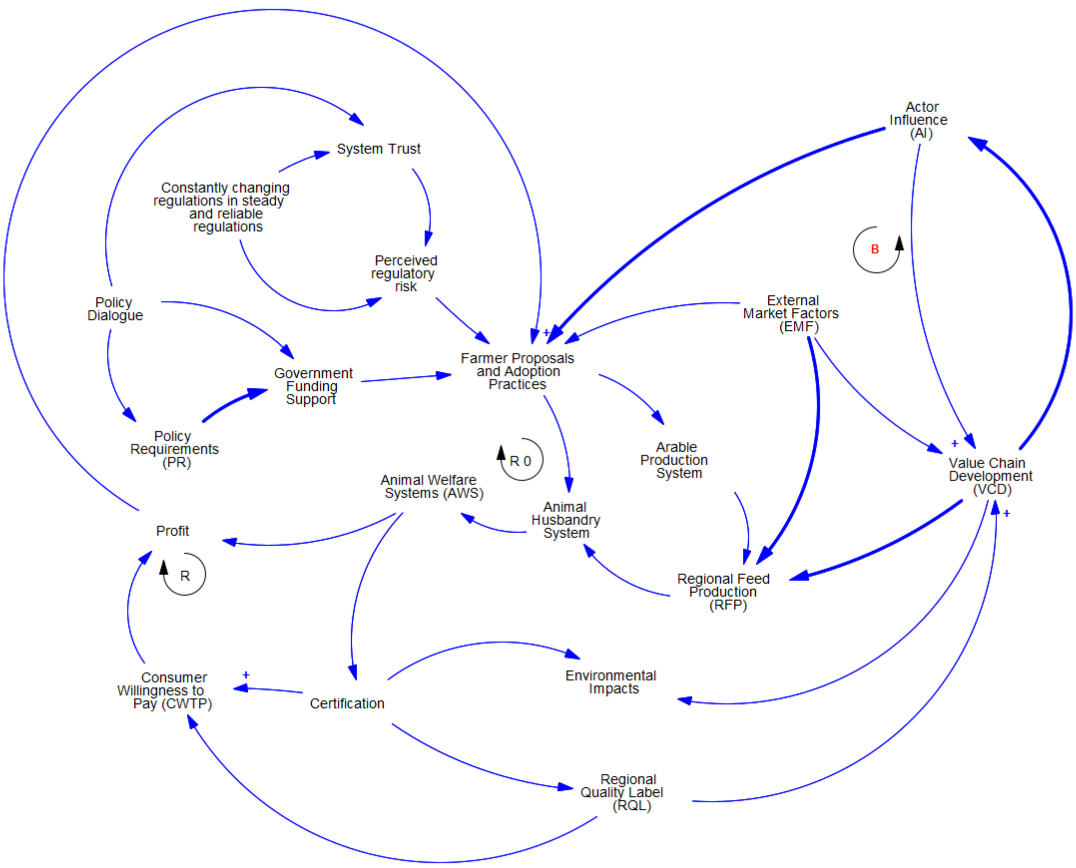


Figure 13 Final CLD for Sustainable Pig Farming in Germany

4.5.2 Feedback Loops

The feedback loops identified in the study highlight the complex interactions within the pig farming system, where initial changes can either reinforce further adoption of sustainable practices or create barriers that need to be addressed.

1. **Certification and Value Chain Enhancement Loop (Reinforcing):** demonstrates how investments in sustainable practices, such as improved animal husbandry and welfare systems, can lead to certification and the development of a regional quality label. This, in turn, enhances the value chain and increases the influence of key actors, creating a cycle that encourages further adoption of sustainable practices.

- Pathway: Farmer Proposals and Adoption Practices (FP+ARSP) → Animal Husbandry System (AHS) → Animal Welfare Systems (AWS) → Certification → Regional Quality Label (RQL) → Value Chain Development (VCD) → Actor Influence (AI) → FP+ARSP
- Evidence: The strong correlations and short Euclidean distances between these elements suggest that as more farmers adopt sustainable pig farming practices, the system supports and increases this adoption through better market recognition and stakeholder influence.

2. **Integrated Sustainable Practices and Profitability Loop (Reinforcing):** shows how sustainable arable production can improve local feed production, which supports better animal welfare practices. The resulting certifications and quality labels drive consumer demand, increasing profitability and enabling further investments in sustainability.

- Pathway: Farmer Proposals and Adoption Practices (FP+ARSP) → Arable Production System (APS) → Regional Feed Production (RFP) → Animal Husbandry System (AHS) → Animal Welfare Systems (AWS) → Certification → Regional Quality Label (RQL) → Consumer Willingness to Pay (CWTP) → Profit (P) → FP+ARSP
- Evidence: The loop links sustainable farming practices with increased profitability through improved consumer demand for certified products. The correlation and adjacency matrices demonstrate how these interconnectedness factors reinforce each other. This means that better/sustainable practices increase profits, which then encourage further adoption of sustainable methods.

3. **Market Adjustment Loop (Balancing):** illustrates how external market factors can moderate the rate of adoption by influencing profitability. Fluctuations in market conditions can prompt adjustments in farming practices, which may stabilize the system but also slow down the adoption of sustainable methods depending on market pressures.

- Pathway: External Market Factors (EMF) → Value Chain Development (VCD) → Actor Influence (AI) → Farmer Proposals and Adoption Practices (FP+ARSP) → Profit (P) → External Market Factors (EMF).
- Evidence: The analysis shows that market conditions (e.g., price changes or economic pressures) directly affect farmer's profits. This balances the system in such a way that when profits are low, farmers might not be able to afford to invest in sustainable practices that can impede adoption.

4.5.3 Lock-ins

From the data collection the transition towards more sustainable pig farming in Brandenburg is hindered by several significant challenges such as:

1. **Economic Dependencies:** Transition to sustainable pig farming might be difficult to do as farmers rely on established, non-sustainable practices that currently ensure profitability and are perceived less risky. Moreover, farmers would be reluctant to change their current practices as transitioning to sustainable practices require new financial investments in the face of unstable market conditions.
2. **Regulatory Barriers:** The Certification and Value Chain Enhancement Loop suggests a lock-in because it involves strict rules that farmers must follow to get certified, which can be expensive and complex. This disincentive the farmers to try new methods, which can be difficult and costly.
3. **Cultural Practices:** Cultural norms and traditional practices are often upheld or challenged by key stakeholders such as feed suppliers, local leaders, or regulatory bodies. Actor Influence (AI) is closely linked to other variables such as Farmer Proposals or Government Funding Support. This suggests that AI is a

critical factor in maintaining current practices. If these actors are resistant to change, they can create a lock-in by influencing others within the community to adhere to established practices.

4. **Technological Lock-ins:** The feedback loops emphasizing technological requirements for certification and quality labelling suggest a lock-in where current technology and infrastructure may not support or be adaptable to newer, more sustainable practices without significant overhaul.
5. **Market Conditions:** The Market Adjustment Loop, which shows adjustments in practices due to market pressures, indicates that external market factors and consumer willingness to pay create lock-ins by influencing profitability and thus the adoption of sustainable practices.
6. **Knowledge Gaps:** Loops involving education and training (implicitly through the need for technological updates and market development) suggest that lack of knowledge or training on sustainable practices is a significant lock-in, preventing stakeholders from understanding or implementing new methods.

4.5.4 Potential levers

To overcome these lock-ins, several strategic levers have been identified.

1. **Policy Interventions:** Policy interventions could potentially impact the Certification and Value Chain Enhancement Loop and the Integrated Sustainable Practices and Profitability Loop by shaping the regulatory context in which certifications are granted and by influencing the availability of government funding support. If there are supportive policies that could simplify obtaining certifications or increase economic incentives for adapting sustainable practices, then there will be higher rate of adoption of sustainable pig faming practices.
2. **Financial Incentives:** To mitigate the financial burden associated with transitioning to sustainable practices, enhanced government funding support is critical. This can take the form of subsidies and grants specifically aimed at covering initial investments needed for upgrading facilities or purchasing eco-friendly feed and equipment. Also, offering financial assistance to cover certification costs can make it easier for farmers to attain and maintain necessary sustainability standards. Market development efforts (e.g., premium pricing agreements and government-backed marketing campaigns) can ensure stable and profitable markets for sustainably produced pork. Furthermore, risk mitigation tools (e.g., investment risk-sharing programs) can help farmers manage the financial risks associated with the adoption of sustainable pig farming practices.
3. **Education and Training:** Regular training sessions to educate farmers about the benefits and techniques of sustainable farming can bridge knowledge gaps. In addition, enhancing agricultural extension services to provide hands-on assistance and advice can facilitate the transition to sustainable practices.
4. **Technological Innovations:** Investing in research to develop new, more efficient, and cost-effective sustainable farming technologies can make these options more attractive while ensuring that new technologies are accessible and affordable through government or cooperative programs can accelerate their adoption.
5. **Market Development:** Developing robust certification systems that are recognized by consumers can increase market demand for sustainably produced goods. Educating consumers about the benefits of sustainably produced pork can drive market demand, incentivizing farmers to adopt sustainable practices.
6. **Community Engagement:** Facilitating collaboration between farmers, consumers, NGOs, and government agencies can create a shared vision and collective action towards sustainability. Empowering local leaders to champion sustainable practices can foster community support and more widespread change.

4.6 Case Study 6: Greece - Shifting to Sustainable Practices Across the EU Through Consumer Brands

Objective: Shift to sustainable practices across the EU through consumer brands.

Local Stakeholders: Poios Einai to Afentiko, partners of the C'est Qui le Patron initiative.

Description: This case study focuses on the transition to sustainable agricultural practices in the European Union, particularly through the influence of consumer brands. The initiative, supported by the partner organization GAIA, is active in various regions, including West Macedonia in Greece, and Vojvodina in Serbia. The objective is to promote and scale up sustainable practices that reduce the use of drinkable water, pesticides, and energy while improving animal welfare and ensuring fair economic returns for farmers. The project engages local stakeholders, including the initiative "Poios Einai to Afentiko" in Greece, which partners with the "C'est Qui le Patron" initiative, and a pioneer movement of regenerative farmers in Serbia. These stakeholders aim to shift practices in small to medium-sized family-owned farms, particularly in sectors such as orchards, vegetables, and livestock. The focus is on regions characterized by a Mediterranean Southern climate in Greece and a Panonian climate in Serbia. The Macedonian region is known for its continental-mediterranean microclimate, which presents unique challenges such as high rainfall, frost, droughts during summer, and the need for sustainable management of natural resources. The current farming practices in these regions face several challenges, including reliance on chemical inputs, globalized commodity markets, and limited governance capacities despite high intentions. The farming sector in West Macedonia, for instance, is characterized by a predominance of small-scale farms with an average size of 12.2 hectares, producing a variety of agricultural commodities across approximately 187,780 hectares of agricultural land. The project aims to address significant issues such as nitrogen deposition, biodiversity loss, and the use of pesticides, which pose risks to both the environment and the economic viability of farms. The ambition of this case study is to achieve a robust uptake of sustainable practices, which include reducing the use of pesticides and natural resources, thereby lowering production costs and improving product quality. The project also emphasizes shortening supply chains and adopting environmentally friendly packaging solutions. However, there are several risks that could jeopardize the implementation of these goals, such as the aging farming population, land abandonment, and difficulties in accessing financial resources. To mitigate these risks, the project aims to motivate and engage more actors, including producers, cooperatives, consumers, and markets, to create a broader impact.

Based on the analysis of the case study narrative and the dialogue with the case study coordinators the following variables were identified as relevant and their relationship were outlines as in the table below:

Table 12 Shifting to Sustainable Practices Across the EU Through Consumer Brands Key Variables

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Practices to Reduce Fertilizers	PRF	Fertilizer application rates per hectare	Market Stability	Reducing chemical fertilizers improves water quality and promotes crop diversification.
Market Stability	MS	Market stability indices	-	Improved farming practices lead to more stable productivity, influencing market relationships.
Transportation and Logistics Challenges	TLC	Transportation costs, delivery times, number of cooperative initiatives	Cooperation Among Small Producers	Addressing transportation issues is critical where producers need to cooperate for effective logistics.
Cooperation Among Small Producers	CSP	Number of cooperative initiatives, collaboration rates	Transportation and Logistics Challenges, Entry of Organic Products, Distribution of Organic Products	Cooperative efforts among producers improve logistics and market access for organic products.
Investment in Digital Agriculture Technologies	IDAT	Investment rates, ROI on technologies	Knowledge and Training in Sustainable Practices	Financial investments in technology should be accompanied by training programs to maximize efficiency.
Knowledge and Training in Sustainable Practices	KTSP	Training completion rates, practice adoption rates	Investment in Digital Agriculture Technologies	Enhancing knowledge and training maximizes technology use and efficiency.
Consumer Education	CE	Consumer awareness programs	Market-Related Barriers, Willingness to Pay	Enhancing consumer awareness can mitigate market barriers and improve product distribution.

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Willingness to Pay	WTP	Willingness to pay surveys	Market Access for Organic Products	Higher willingness to pay increases market demand for organic products.
Market-Related Barriers	MRB	Number of barriers identified, successful mitigation strategies	Consumer Education and Willingness to Pay	Reducing market barriers improves market access for organic products.
Entry of Organic/Biological Products	EOP	Number of new organic products in the market, market share	Cooperation Among Small Producers, Distribution of Organic Products	Entry of organic products boosts market diversity and consumer choices.
Distribution of Organic/Biological Products	DOP	Distribution channels, market penetration rates	Market Access for Organic Products, Entry of Organic/Biological Products	Effective distribution ensures organic products reach a wider market, supporting market access.
Market Access for Organic Products	MAOP	Market entry rates, distribution channels	Consumer Education, Investment in Digital Technologies	Improved market access drives demand for organic products.

4.6.1 Final CLD for Shifting to Sustainable Practices Across the EU Through Consumer Brands

To gain a deeper understanding of the business model employed by this brand and to identify the challenges encountered in the implementation of sustainable agricultural practices within the CLD (Figure 11) initially drafted, NIBIO arranged a discussion with the CSC. The initial part of the discussion focused on the mechanics of the brand's business model, particularly how consumer requirements for specific products are communicated to farmers, who then produce these goods. A key point of debate was whether the terms of production and product specifications are dictated more by consumer demands or by the brand itself. This disagreement highlighted the complexity of the supply chain, where the balance of influence between consumers and the brand can significantly impact how products are produced and marketed. As the discussion progressed, the group identified significant market lock-ins that pose barriers to the adoption of sustainable practices by farmers. The most critical lock-in identified was market access. Farmers expressed a lack of incentive to adopt sustainable practices due to the uncertainty surrounding the sale of their produce. This uncertainty is compounded by unclear and underdeveloped distribution channels, which further diminish the motivation for farmers to commit to sustainable methods. Further analysis revealed several specific barriers that farmers face in implementing sustainable agricultural practices. These include a lack of productivity assurances and secure contracts, which are essential for farmers to invest in and maintain sustainable practices. Moreover, there is a noticeable gap in market recognition of the added value that sustainable practices bring. This gap is exacerbated by challenges related to labelling, which hinders effective communication of the environmental benefits associated with sustainably produced goods. Consequently, consumers may not be fully aware of the sustainable attributes of the products they purchase, reducing the potential market demand for such products. Traditional farming practices and technological lock-ins contribute to soil erosion, water scarcity, and biodiversity loss. Providing access to advanced sustainable technologies can help farmers transition to more sustainable practices. Promoting consumer awareness and demand for sustainable products will enhance market access, while education and training programs will build knowledge about sustainable farming, leading to environmental and economic benefits.

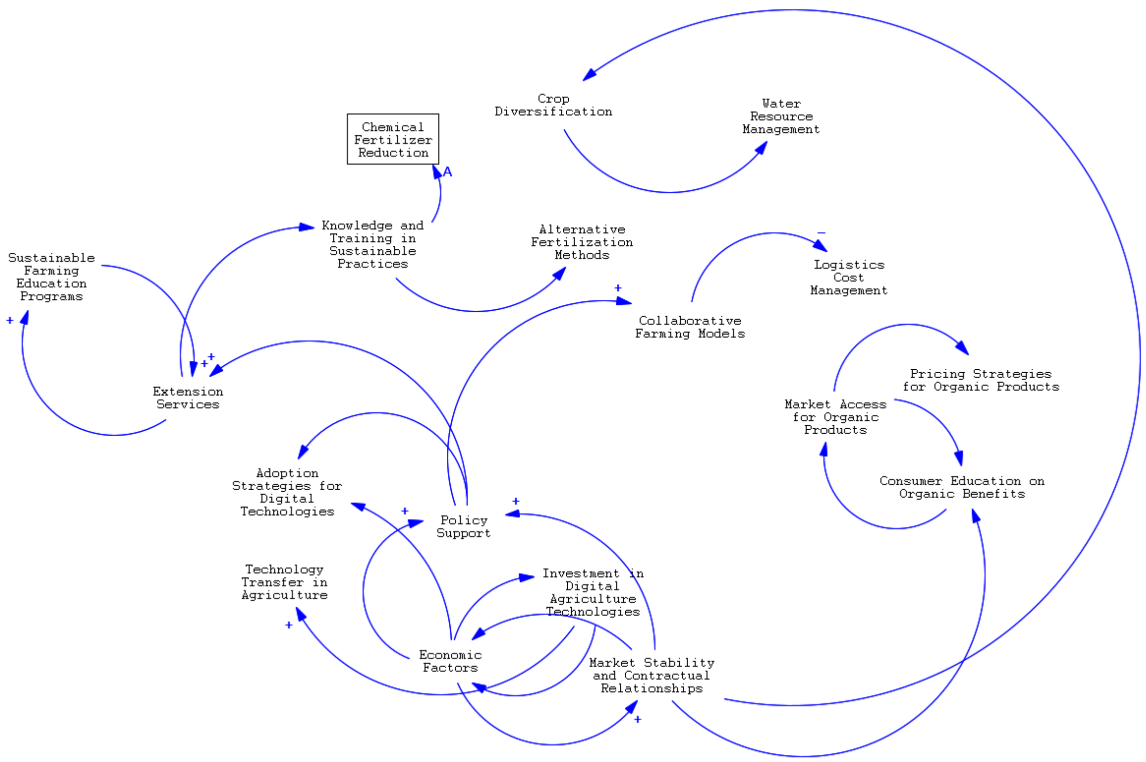


Figure 14 Initial CLD for Shifting to Sustainable Practices Across the EU Through Consumer Brands

The case study highlighted significant challenges in aligning the goals of sustainable agriculture with the realities of market dynamics in Greece. The complexities of the supply chain, market access issues, and the barriers faced by farmers all point to the need for a more coordinated effort among stakeholders. Based on the CSC feedback the drafting of the CLD progressed and its evolution is highlighted in the table below.

Table 13 CLD evolution for Sustainable Practices Across the EU Through Consumer Brands

Aspect	Initial CLD	Final CLD	Key Advancements
Focus	Promoting sustainable agricultural practices in specific regions of the EU, with a focus on small to medium-sized farms.	Expanding sustainable practices across the EU through consumer brands, focusing on regions with Mediterranean and Pannonian climates.	The focus was broadened from regional initiatives to a more comprehensive EU-wide approach, leveraging consumer brands to drive sustainability across diverse climates.
Key Variables	Initial focus on reducing fertilizers, improving market stability, and enhancing logistics for sustainable farming, further elaboration and inclusion of variables like consumer education, market access for organic products, and digital agriculture technologies	Additional relations were suggested by the CSC in the adjacency matrix and specificities for the definition of some of the variables.	Expanded the scope to include a deeper relation between consumer-driven factors and advanced technologies, enhancing the systemic understanding of the transition to sustainable practices.
Relationships	Primarily linear relationships	Complex, interconnected relationships with feedback loops	Relationships evolved to reflect the dynamic interactions between various stakeholders, incorporating

Aspect	Initial CLD	Final CLD	Key Advancements
			more detailed and systemic interconnections across the value chain.
Feedback Loops	No explicit feedback loops identified.	Five feedback loops identified, emphasizing the role of knowledge, consumer demand, market access, sustainable practices, and logistics in driving change.	The introduction of feedback loops provided a deeper understanding of how different elements reinforce or balance each other in the transition to sustainable agricultural practices.
Strategic Recommendations	General recommendations focused on improving farming practices and logistics	Specific recommendations on policy support, financial incentives, education and training, and market development strategies.	Strategic recommendations were refined to target critical areas such as policy frameworks, financial support, consumer awareness, and infrastructure improvements to support sustainable transitions.

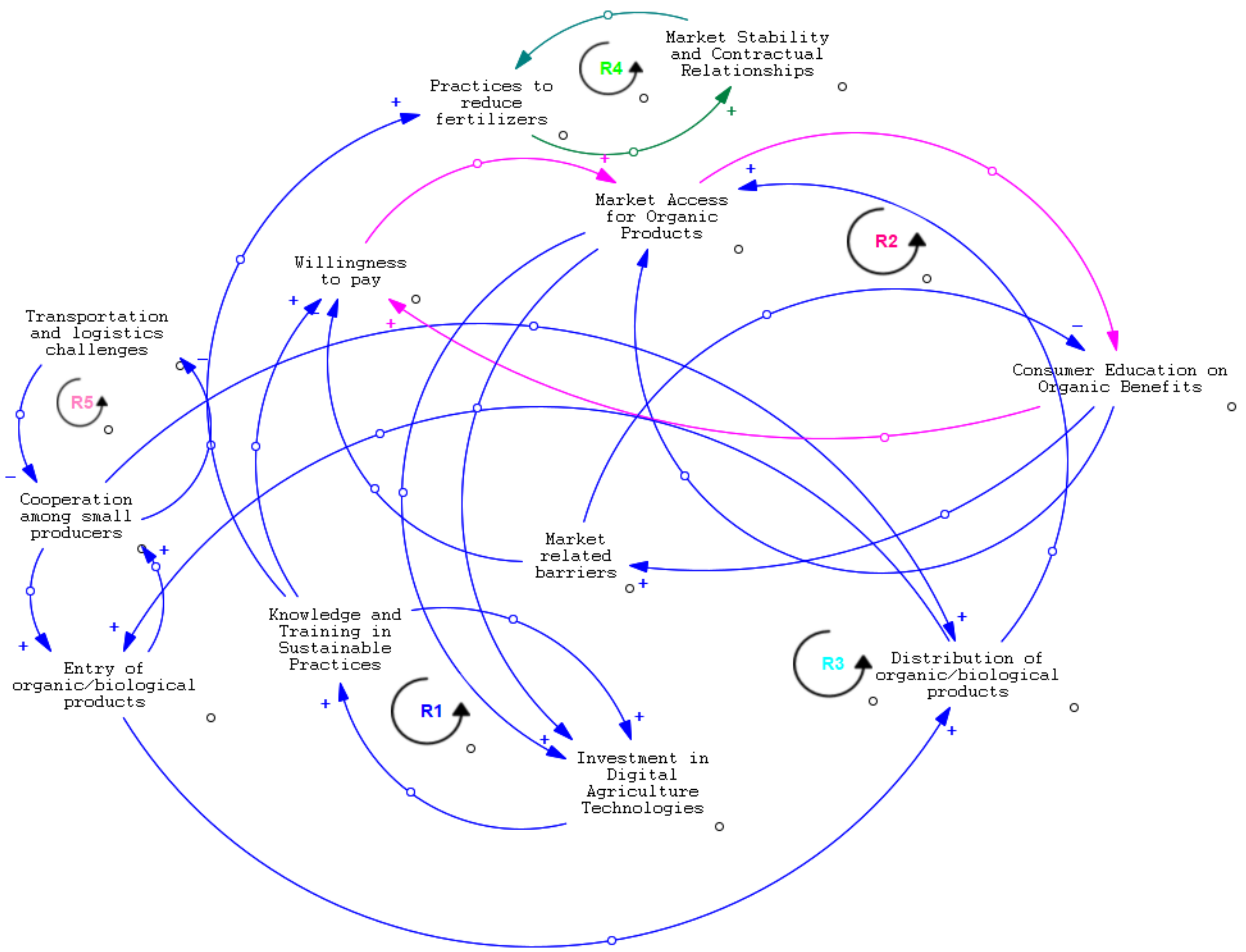


Figure 15 Final CLD for Shifting to Sustainable Practices Across the EU Through Consumer Brands

4.6.2 Feedback loops

In the context of transitioning to sustainable agricultural practices, several reinforcing feedback loops have been identified that can either propel or hinder progress.

1. **Knowledge and Training Loop (Reinforcing):** Enhanced knowledge and training in sustainable practices lead to better utilization of digital agricultural technologies (Knowledge and Training in Sustainable Practices KTSP → Investment in Digital Agriculture Technologies IDAT). This, in turn, fosters further learning and training, creating a positive cycle where increased knowledge enhances technology use, which further promotes learning and adoption of sustainable practices.

   Pathway: KTSP → IDAT → KTSP

   Explanation: Enhanced knowledge and training lead to better use of digital technologies, which in turn promotes further knowledge and training.

2. **Consumer Demand Loop (Reinforcing):** Consumer education (CE) plays a critical role in increasing the willingness to pay (WTP) for sustainable and organic products. As consumers become more educated, their demand grows, which improves market access (MAOP) for these products. Enhanced market access then reinforces the need for further consumer education, strengthening the overall market for sustainable goods.

   Pathway: CE → WTP → MAOP → CE
   Explanation: Increased consumer education boosts willingness to pay, which enhances market access and further supports consumer education.

3. **Market Access Loop (Reinforcing):** Improved market access (MAOP) facilitates the distribution (DOP) of organic products, encouraging more producers to enter the market. This expansion fosters greater cooperation among producers (CSP), which further improves market access, creating a reinforcing loop that supports the growth of the organic sector.

   Pathway: MAOP → DOP → EOP → CSP → MAOP

   - Improved market access facilitates distribution, which encourages entry of new organic products, boosting cooperation among producers and further enhancing market access.

4. **Sustainable Practices Loop (Reinforcing):** Reducing the use of fertilizers (PRF) contributes to market stability (MS) by ensuring the long-term viability of sustainable farming practices. Market stability, in turn, supports continued reductions in fertilizer use, promoting a sustainable agricultural environment.

   Pathway: PRF → MS → PRF

   - Reducing fertilizers enhances market stability, which in turn supports further reduction of fertilizers.

5. **Logistics and Cooperation Loop (Reinforcing):** Addressing logistical challenges (TLC) enhances cooperation among small producers (CSP). This cooperation improves logistics further, creating a cycle that strengthens the ability of small producers to distribute organic products efficiently and sustainably.

   Pathway: TLC → CSP → TLC

   - Addressing logistics challenges enhances cooperation among small producers, which further improves logistics.

4.6.3 Lock-ins

Lock-ins were developed through the analysis of the barriers done by the CSC in the framework of task 2.1. In the examination of the systemic barriers within the case study, a comprehensive identification process revealed a range of obstacles across various stages of the agricultural value chain. These barriers, categorized into technical, financial, market-related, organizational, cultural, and knowledge-related types, highlight the complexities faced by stakeholders in transitioning to sustainable agricultural practices. At the farm level, key technical barriers were identified, including the need to reduce fertilizer usage, lack of crop variety, and challenges in irrigation management. These issues are further compounded during the transportation stage, where difficulties in logistics, particularly the poor connectivity between rural farming areas and industrial processing zones, lead to high transportation costs. Additionally, the distribution of organic and conventional products is hindered by logistical challenges, making it difficult to enter new markets. Finally, at the consumer stage, the lack of clear traceability, labelling of nutritional content, and transparency in the distribution of costs along the value chain further complicate market penetration for sustainably produced goods. Financial barriers are prevalent across the value chain. Farmers face high initial costs when investing in digital agriculture technologies, with these investments not being immediately balanced by future efficiencies. The instability of costs related to agricultural inputs and energy adds another layer of financial risk. Access to financial resources is also a challenge, with difficulties in securing loans from banks or national and EU investment programs. At the consumer level, there is a reluctance to pay premium prices for products produced under sustainable practices, largely due to a lack of recognition of their added value. Market-related barriers primarily stem from uncertain and unstable productivity at the farm level, which creates challenges in securing contracts with distributors and markets. This uncertainty extends to the processing stage, where the lack of stable productivity affects the consistent supply of products. At the distribution stage, the inability of distributors to recognize and disseminate the added value of sustainably produced products limits their market visibility. Furthermore, consumers face difficulties in finding specific products that meet sustainable and organic standards, which hinders market growth. Organizational barriers are particularly evident at the farm stage, where the small-scale productivity of numerous producers necessitates cooperation to achieve economies of scale. The adoption of innovative management practices is also limited by these organizational challenges. In the transportation stage, difficulties in collecting products from different sites add another layer of complexity, further hindering efficient market operations. Cultural barriers, though less explicitly identified in the data, are implicitly linked to the reluctance to adopt new practices and the challenges in changing established farming behaviours. Knowledge-related barriers are significant, with a clear lack of understanding of sustainable agricultural practices, insufficient training programs on innovative farming methods, and limited knowledge on the use of available agricultural technology. These knowledge gaps extend to consumers, who are often unaware of the environmental benefits of sustainably produced agricultural goods, further complicating the market's ability to support sustainable transitions. Based on this information the following lock-ins were identified:

1. **Fragmented Transportation and Logistics:**

- The transportation and logistics infrastructure is fragmented, making it difficult for small producers to effectively collaborate and distribute organic products. This fragmentation leads to higher costs and inefficiencies that hinder the adoption of sustainable practices.

2. **Limited Access to Digital Technologies:**

- There is limited access to digital agriculture technologies and the necessary training to use them effectively. Without significant investment and education, farmers are unable to maximize the benefits of these technologies, slowing down the transition to sustainable practices.

3. **Consumer Mistrust and Lack of Awareness:**

- Many consumers are unaware of the benefits of organic products or do not trust their quality. This lack of consumer awareness and trust creates a significant barrier to increasing market demand for sustainably produced goods.

4. **High Market-Related Barriers:**

- There are significant market-related barriers such as regulatory hurdles, market entry costs, and competitive pressures from conventional agricultural products. These barriers prevent small producers from entering and competing in the market for organic products.

5. **Insufficient Cooperative Efforts:**
- There is a lack of strong cooperative efforts among small producers. Without collaboration, it is challenging to overcome logistical challenges and achieve economies of scale necessary for competitive organic production and distribution.

4.6.4 Potential levers

To effectively address the identified lock-ins, several strategic levers have been proposed to support the transition to sustainable agricultural practices. Policy interventions are essential in establishing a strong foundation for sustainable farming. These should focus on implementing policies that not only support sustainable agricultural practices but also actively reduce environmental impacts. Additionally, providing legislative support to ensure clear and stable requirements for sustainable agriculture will help create a consistent regulatory environment that encourages long-term investments in sustainable practices. Financial incentives are crucial for facilitating farmers' transition to sustainable methods. There is a need to improve access to financial resources, particularly for younger farmers, to address the aging population in agriculture. By developing targeted financial programs that offer incentives and subsidies for sustainable practices, the transition can be made more economically feasible for farmers, ensuring their long-term success and resilience. Education and training are vital in empowering farmers with the knowledge and skills necessary to adopt sustainable practices and new technologies. Promoting the use of advanced farming solutions like the Gaia-sense Smart Farming platform can provide valuable support to Greek farmers. Moreover, enhancing training programs on sustainable practices and technology adoption will be instrumental in increasing the uptake of innovative and environmentally friendly agricultural methods. Market development strategies are also key in supporting the broader adoption of sustainable products. This includes backing consumer brand initiatives that highlight the benefits of sustainably produced goods, which can drive consumer demand and market growth. Additionally, strengthening the infrastructure to improve market access for organic products is essential. This involves not only supporting the distribution networks but also ensuring that supply chains are well-integrated and capable of meeting the demands of a growing market for sustainable agriculture.

1. **Policy Interventions:**
- Implement policies that support sustainable farming practices and reduce environmental impacts.
- Provide legislative support to ensure clear and stable requirements for sustainable agriculture.

2. **Financial Incentives:**
- Facilitate access to financial resources to help farmers transition to sustainable practices.
- Develop financial programs that target younger farmers to address the aging population issue.

3. **Education and Training:**
- Promote the use of the Gaia-sense Smart Farming solution to support Greek farmers.
- Enhance training and educational programs on sustainable practices and technology adoption.

4. **Market Development:**
- Support consumer brand initiatives to promote sustainable products.
- Strengthen infrastructure to support market access for organic products.
- Strengthening policy frameworks and integrating supply chains.

4.7 Case Study 7: Slovenia - Boosting Direct Selling in Slovenia

Objective: Boost direct selling in Slovenia.

Local Stakeholders: Young Farmers of Slovenia.

Geographic Scope: Predominantly small and medium-sized farms across Slovenia

Description: This case study is part of a broader initiative aimed at enhancing the sustainability and economic viability of agricultural practices across Europe. Specifically, this case study focuses on boosting direct selling among farmers in Slovenia, a strategy that aligns with the growing demand for short food supply chains and aims to improve the profitability and resilience of small and medium-sized farms in the country. The primary objective of this case study is to promote the adoption and scaling of direct selling practices among Slovenian farmers. Direct selling, which involves the sale of agricultural products directly from the producer to the consumer, bypasses traditional intermediaries, thereby offering farmers the opportunity to retain a larger share of the revenue generated from their products. This approach is particularly relevant in Slovenia, where small and medium-sized farms dominate the agricultural landscape, and where the development of short food supply chains could play a crucial role in ensuring the economic sustainability of these farms.

The case study is conducted in partnership with CEJA, the European Council of Young Farmers, which is working closely with the Young Farmers of Slovenia to implement the project. The involvement of local stakeholders is critical to the success of this initiative, as the Young Farmers of Slovenia are at the forefront of advocating for the adoption of direct selling practices. Their deep understanding of the local agricultural context and their commitment to fostering a new generation of farmers are invaluable assets in driving this transition. Slovenia's agricultural sector is shaped by the Panonian pedo-climatic zone, characterized by diverse soil types, including Chromic Cambisol, Rendzina, Dystric Cambisol, and Eutric Cambisol.

The region's agricultural potential is further influenced by its geography, with 36% of the land being agricultural and 61% covered by forests. However, the sector faces significant challenges due to climate variability, including frequent floods, droughts, and other extreme weather events. These conditions underscore the importance of developing resilient agricultural practices that can withstand environmental fluctuations. The agricultural sector in Slovenia is predominantly composed of small and medium-sized family farms, with an average farm size of 7.0 hectares and an average of 6.0 livestock units per holding. Despite the small scale of these operations, direct selling has gained popularity, particularly among organic farmers, as a way to enhance profitability and sustainability. However, the sector faces several economic challenges, including inflation, low competition, and issues related to territorial connectivity. Additionally, rigid labour contracts in the public sector are hindering the hiring of skilled ICT professionals, which is critical for advancing digital marketing and other modern agricultural practices.

The case study identifies several key challenges that need to be addressed to promote the broader adoption of direct selling practices in Slovenia. These challenges include:

- Natural Capital: The sector's vulnerability to climate variability and extreme weather events, which can significantly impact agricultural productivity.
- Social Capital: Historical trust issues stemming from Slovenia's Yugoslavian past, which hinder cooperation among direct-selling farmers. Additionally, the Chamber of Agriculture's limited resources have resulted in a focus on subsidy-related services at the expense of technical development and digital marketing skills.
- Human Capital: A lack of digital marketing skills and difficulties in hiring skilled labour, coupled with generational transmission issues and the burden of multitasking on small farms.
- Financial Capital: Investment challenges and the difficulty of balancing investment with workforce availability, which limit the capacity of farms to adopt more sustainable and profitable practices.

The case study aims to encourage the sustainability of short food supply chains by promoting direct selling as a viable and profitable practice for Slovenian farmers. This includes improving the balance between workload and income, as well as enhancing the infrastructure necessary for direct selling, such as labelling machines, storage facilities, and delivery vehicles. By the end of the project, the goal is for Slovenian farmers engaged in direct selling to achieve a higher profitability-to-income ratio, thus ensuring the long-term viability of their operations. Two major risks have been identified that could jeopardize the implementation of the ENFASYS case study methodology in Slovenia. First, the case study coordinator, CEJA, is not based in the country and operates through a member organization in Slovenia, which has no contractual link with the project. Second, a language barrier complicates communication and coordination efforts. To mitigate these risks, CEJA will employ an interpretation service to facilitate the case study's progress and ensure effective collaboration with local stakeholders. The current value chain in Slovenia's agricultural sector is dominated by long food supply chains, which offer low added value to farmers. Intermediaries often fail to provide fair prices, making it difficult for farmers to achieve sustainable incomes. In contrast, direct selling offers a more equitable distribution of value, allowing farmers to capture a larger share of the revenue generated from their products. However, traditional marketing practices associated with direct selling are time-consuming, highlighting the need for modern, efficient marketing strategies. This case study on boosting direct selling in Slovenia represents a significant step towards enhancing the sustainability and economic viability of the country's agricultural sector. By addressing the challenges related to natural, social, human, and financial capital, and by promoting the adoption of direct selling practices, the project aims to create a more resilient and profitable agricultural system.

Based on the analysis of the case study narrative and the dialogue with the case study coordinators the following variables were identified as relevant and their relationship were outlines as in the table below:

Table 14 Boosting Direct Selling in Slovenia Key Variables

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Farmers' Revenue from Direct Selling	FRDS	Total income generated by farmers from direct selling	Farmer's Profit (FP)	Higher revenue from direct selling increases farmers' profit.
Investment in Direct Selling Infrastructure	IDS	Capital invested in facilities and digital platforms for direct selling	Farmers' Revenue from Direct Selling (FRDS), Market Accessibility (MA)	Improves the infrastructure for direct selling, enhancing revenue and market access.
Farmer Training and Capacity Building		Number of training programs, participation rates	Rate of Adoption of Farmers Practicing Direct Selling (RAFDS), Farmer's Profit (FP)	Enhances farmers' skills and knowledge, increasing adoption of direct selling practices and profitability.
Short Supply Chain Development and Local Economy Enhancement	SSCD	Number of initiatives, impact on local economy	Market Accessibility (MA), Consumer Demand for Locally-Sourced and Organic Products (CDLSOP)	Develops short supply chains, improving market access and increasing consumer demand for local products.
Number of Farmers Using Digital Marketing Tools	DFMT	Adoption rate of digital marketing strategies by farmers	Farmers' Revenue from Direct Selling (FRDS), Consumer Engagement (CE)	Increases the adoption of digital marketing, enhancing revenue and consumer engagement.
Consumer Demand for Locally-Sourced and Organic Products	CDLSOP	Preference and purchase volume of local and organic products	Farmers' Revenue from Direct Selling (FRDS), Market Prices of Directly Sold Products (MPDSP)	Higher demand for local and organic products increases revenue and market prices.
Cost of Production and Distribution	CPD	Total costs associated with production and distribution	Farmer's Profit (FP)	Higher costs reduce farmers' profit.
Market Prices of Directly Sold Products	MPDSP	Valuation of directly sold products	Farmers' Revenue from Direct Selling (FRDS)	Higher market prices increase revenue from direct selling.
Market Accessibility	MA	Ease of accessing markets, diversity of product range	Farmers' Revenue from Direct Selling (FRDS), Rate of Adoption of Farmers Practicing Direct Selling (RAFDS)	Improved market access increases revenue and adoption of direct selling practices.
Labor Hours Dedicated to Direct Selling	LDS	Total labour investment in direct selling activities	Cost of Production and Distribution (CPD), Farmer's Profit (FP)	Higher labour investment increases costs but can also enhance profitability through better sales practices.

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Consumer Engagement	CE	Level of consumer interaction and application usage	Consumer Demand for Locally-Sourced and Organic Products (CDLSOP)	Higher consumer engagement increases demand for local and organic products.
Consumer Awareness and Trust Levels	CATL	Level of consumer awareness and trust in direct selling products	Consumer Demand for Locally-Sourced and Organic Products (CDLSOP)	Increased awareness and trust boost demand for local and organic products.
Rate of Adoption of Organic Certification and Labelling	RAOCL	Number of farmers with organic certifications and labelling	Consumer Demand for Locally-Sourced and Organic Products (CDLSOP), Market Prices of Directly Sold Products (MPDSP)	More certifications and labelling increase consumer demand and market prices.
Farmer's Profit	FP	Net financial gain from direct selling activities	Rate of Adoption of Farmers Practicing Direct Selling (RAFDS)	Higher profit motivates more farmers to adopt direct selling practices.
Rate of Adoption of Farmers Practicing Direct Selling	RAFDS	Percentage or number of farmers practicing direct selling	Farmers' Revenue from Direct Selling (FRDS)	Higher adoption rates increase revenue from direct selling.
Technical Support and Quality Assurance	TSQA	Support services provided to farmers	Farmer Training and Capacity Building (FTCB), Legislative Compliance (LC)	Enhances training and ensures compliance with production standards.
Policy and Regulatory Support with Chamber Advocacy	PRCA	Influence of policy and regulations shaped by advocacy efforts	Legislative Compliance (LC), Investment in Direct Selling Infrastructure (IDS)	Advocacy influences regulatory support and infrastructure investment.
Legislative Compliance	LC	Adherence to regulations	Farmers' Revenue from Direct Selling (FRDS), Environmental Impact Score (EIS)	Compliance ensures sustainable practices, affecting revenue and environmental impact.
Generational Dynamics	GD	Changes due to generational shifts	Farmer Training and Capacity Building (FTCB), Rate of Adoption of Farmers Practicing Direct Selling (RAFDS)	Generational changes influence training needs and adoption rates of direct selling practices.
Environmental Impact Score	EIS	Measure of environmental impact	Consumer Demand for Locally-Sourced and Organic Products (CDLSOP)	Lower environmental impact enhances consumer demand for sustainable products.

4.7.1 Final CLD for Boosting Direct Selling in Slovenia

Table 15 shows how the CLD for Slovenia has evolved from a simple overview to a more detailed and complex analysis of the direct selling system. Initially, the CLD focused on overall benefit links of direct selling, namely the increase in farmer income and investment in infrastructure. However, as the CLD evolved, it became more sophisticated by incorporating feedback loops that better capture the interactions between market demand, revenue generation, and the use of direct selling strategies.

Key advancements included the introduction of specific feedback loops, such as the **Training and Digital Tool Application Loop** and the **Direct Selling Loop**. These loops, identified through detailed data analysis, show how different factors work together to influence outcomes in the direct selling system. The final version also included the Market Equilibrium Feedback Loop, which helps to prevent the market from having more supply than demand when more farmers are engaged in direct selling.

Table 15 CLD evolution in Boosting Direct Selling in Slovenia

Aspect	Initial CLD	Final CLD	Key Advancements
Focus	General focus on direct selling and short food supply chain	Specific focus on digital marketing, consumer engagement, and market dynamics in Slovenia	Narrowed focus to address market dynamics, digital transformation, and consumer behaviour
Key Variables	Farmers' revenue, investment in infrastructure, consumer demand	Expanded to include organic certification, technical support, digital marketing, and consumer awareness	Broader set of variables including market access, consumer trust, and environmental impact
Relationships	Simple cause-and-effect relationships between revenue, market demand, and infrastructure	Complex relationships with feedback loops linking training, digital marketing, and consumer engagement	Developed complex feedback loops demonstrating the interplay of market, training, and digital adoption
Feedback Loops	No explicit feedback loops	Included loops like the Training and Digital Tool Application Loop and Direct Selling Loop	Introduced complex feedback loops highlighting the reinforcing effects of digital marketing and investment in infrastructure
Analytical Rigor	Lacked correlation or adjacency matrices to validate relationships	Added matrices to validate relationships between digital marketing, consumer behaviour, and market access	Improved analytical rigor by incorporating data-supported validation through correlation matrices
Strategic Recommendations	Broad suggestions to improve market access and consumer engagement	Targeted interventions focused on digital transformation, training, and policy support for sustainable practices	Shifted to specific, data-driven recommendations targeting digital tools and market expansion

Figures 13 and 14 illustrate the progression from a simple focus on the benefits of direct selling to a more detailed analysis that also looks at digital marketing, how consumers are involved, and how the local market works.

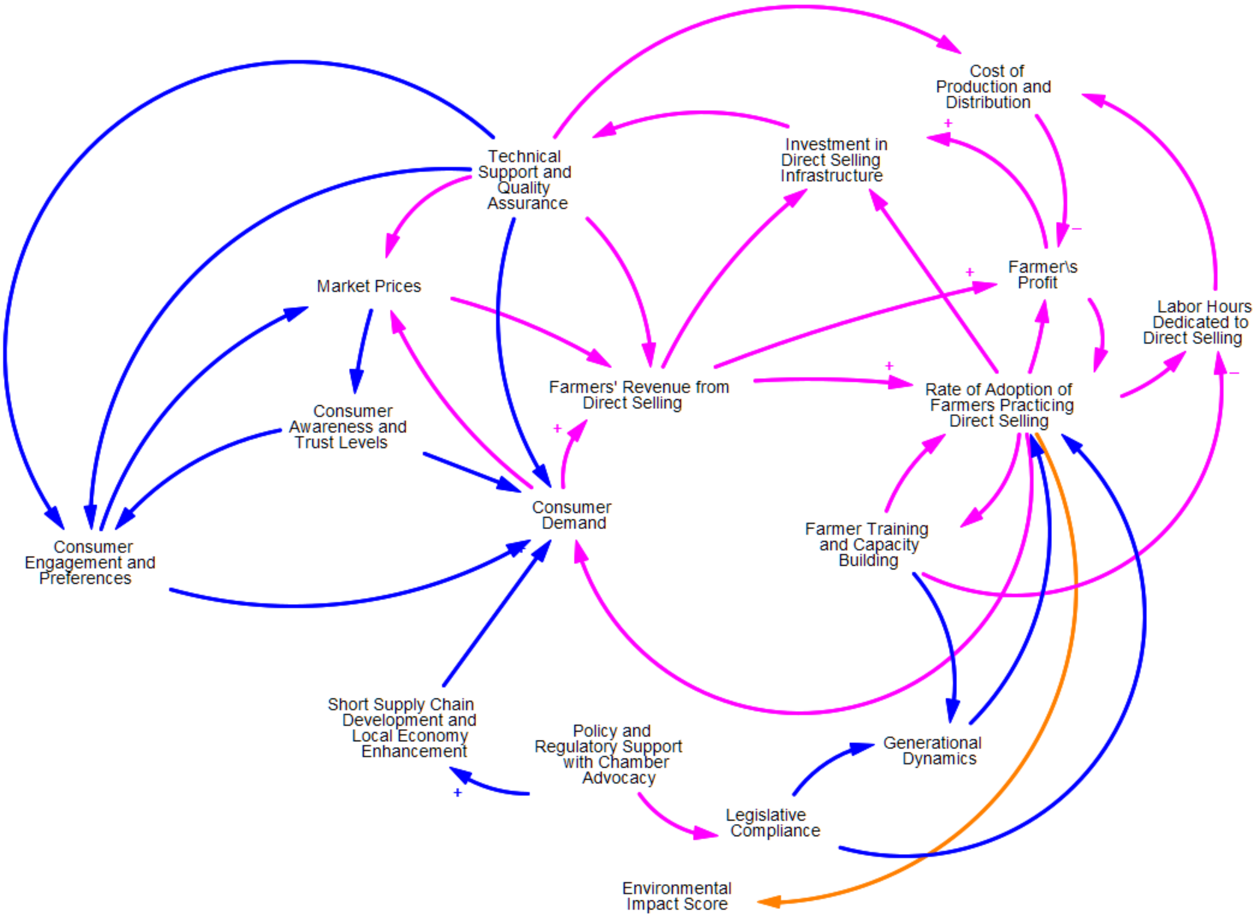


Figure 16 Initial Version of the CLD for Direct Selling in Slovenia

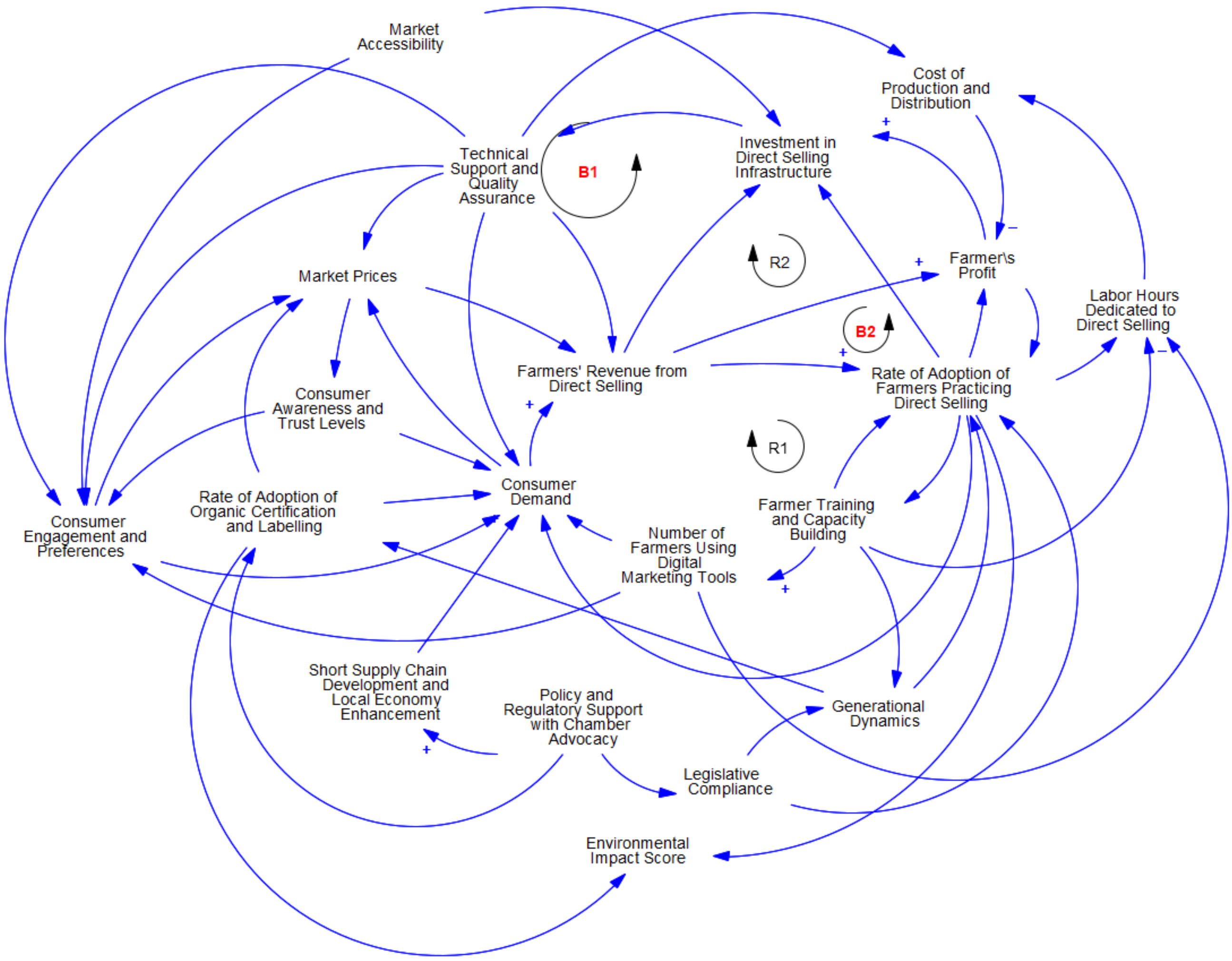


Figure 17 Final Version of the CLD for Direct Selling in Slovenia

4.7.2 Feedback loops

In our analysis of direct selling practices in agriculture, we identified several key feedback loops that play crucial roles in the system's dynamics. These loops can be categorized into two types: reinforcing loops and balancing loops.

1. **Training and Digital Tool Application Loop (Reinforcing):** highlights the importance of continuous improvement in training and capacity building as a foundation for driving adoption rates and expanding the direct selling model.

   Pathway: Farmer Training and Capacity Building → Number of Farmers Using Digital Marketing Tools → Consumer Demand for Locally-sourced and Organic Products → Farmers' Revenue from Direct Selling → Rate of Adoption of Farmers Practicing Direct Selling → Farmer Training and Capacity Building

   Justification from the Structural Analysis: The Adjacency Matrix shows direct relationships linking training to the use of digital tools, consumer demand, and the rate of farmers adopting direct selling. High positive correlations between these factors indicate that improvements in one area positively affect the others, thereby reinforcing the entire cycle. Close distances between these factors indicate strong interconnections, suggesting that changes in one are likely to affect the others closely. This reinforcing loop highlights the importance of continuous improvement in training and capacity building as a foundation for driving adoption rates and expanding the direct selling model.

2. **Direct Selling and Infrastructure Loop (Reinforcing):** supports the economic foundation of direct selling, making it a more attractive and sustainable option for farmers. Increased profits and reinvestments lead to better support systems and infrastructure, enhancing the overall effectiveness and appeal of direct selling.

   Pathway: Farmer's Profit → Investment in Direct Selling Infrastructure → Technical Support and Quality Assurance → Farmer's Revenue from Direct Selling → Farmer's Profit

   Justification from the Structural Analysis: The Adjacency Matrix shows a direct relationship between farmer's profit and investments, and between infrastructure improvements and farmer's revenue. Likely shows positive correlations among these elements, reinforcing their mutual influence. Closer distances among these elements indicate a strong relationship and interdependence. This loop supports the economic foundation of direct selling, making it a more attractive and sustainable option for farmers. Increased profits and reinvestments lead to better support systems and infrastructure, enhancing the overall effectiveness and appeal of direct selling.

3. **Local and Organic Direct Selling Loop (Balancing):** ensures the system does not grow beyond its sustainable capacity. It helps maintain a stable market for direct selling products, preventing over-expansion and ensuring long-term viability.

   Pathway: Consumer Demand for Locally-sourced and Organic Products → Farmers' Revenue from Direct Selling → Investment in Direct Selling Infrastructure → Technical Support and Quality Assurance → Consumer Demand for Locally-sourced and Organic Products

   Justification from the Structural Analysis: The Adjacency Matrix indicates direct links between revenue, investment, and technical support which ultimately influence consumer demand. The Correlation Matrix shows diminishing returns in correlations between consumer demand and infrastructure investment as the system matures. Longer distances between later stages of investment and initial consumer demand may reflect the complex interactions that stabilize growth. The balancing loop ensures the system does not grow beyond its sustainable capacity. It helps maintain a stable market for direct selling products, preventing over-expansion and ensuring long-term viability.

4. **Market Equilibrium Feedback Loop in Direct Selling Adoption (Balancing):** acts as a natural regulator, ensuring that the growth in direct selling does not exceed the market's capacity to absorb new entrants sustainably. It helps maintain equilibrium between supply and demand.

   Pathway: Rate of Adoption of Farmers Practicing Direct Selling → Consumer Demand for Locally-sourced and Organic Products → Farmers' Revenue from Direct Selling → Rate of Adoption of Farmers Practicing Direct Selling

   Justification from the Structural Analysis: The adjacency Matrix shows indirect influences from the relationships between adoption rates, consumer demand, and revenue. Correlation Matrix shows negative correlations between market saturation and consumer demand, reflecting their inverse relationship. Greater distances between adoption rates and consumer demand could indicate the complexity and delayed impact of market dynamics. This balancing loop acts as a natural regulator, ensuring that the growth in direct selling does not exceed the market's capacity to absorb new entrants sustainably. It helps maintain equilibrium between supply and demand, preventing boom-and-bust cycles.

4.7.3 Lock-ins

Our analysis reveals five major lock-ins hindering the adoption of direct selling practices among Slovenian farmers:

1. **Economic Dependencies:** Consumer demand directly impacts farmer's profits and the necessity of continued investment in infrastructure to sustain direct selling practices. This is connected to the Direct Selling and Infrastructure Loop (Reinforcing), where profits lead to infrastructure investments, improving technical support and quality assurance, which in turn boosts revenues. However, while the connections between profits and investment are strong, financial outcomes might be constrained by the limitations in available resources. The adjacency matrix highlights strong links between these factors, but the distances in

the Euclidean matrix indicate challenges in managing financial sustainability over time. These constraints limit farmers' ability to consistently invest in infrastructure improvements, making it difficult to scale or innovate beyond current operations. This lock-in reinforces itself, as farmers must continue reinvesting profits just to maintain operations, without the flexibility to innovate or grow.

2. **Regulatory Barriers:** Farmers may find it difficult to implement quality control on small quantities. The adjacency matrix shows weak or absent links between technical support, quality assurance, and small-scale operations, which hinders farmer's ability to maintain quality and comply with regulations. This is particularly evident in the Local and Organic Direct Selling Loop, where investments in infrastructure and technical support are necessary to ensure compliance with quality standards. However, small farmers often lack access to adequate advisory services, which creates a bottleneck that restricts their ability to participate fully in direct selling. As compliance costs rise, farmers struggle to meet the necessary standards, reinforcing this regulatory lock-in. The correlation matrix highlights weak links between compliance and small-scale farmers, making it clear that addressing one side of the barrier, such as increasing access to technical support, could help alleviate the regulatory pressures on farmers.

3. **Cultural Practices:** The correlation matrix reveals that farmer training and capacity building have a positive relationship with the rate of adoption of direct selling, but the strength of this relationship weakens, suggesting slower adoption of modern selling practices among certain farmers. This aligns with the Training and Digital Tool Application Loop, where training is designed to increase the adoption of digital marketing tools and direct selling practices. However, some farmers may be slower to engage with these innovations, indicating possible cultural resistance to adopting new practices. The adjacency matrix confirms strong connections between farmer training, consumer demand, and adoption rates, but weaker links between training and actual adoption imply that some farmers may resist changing their methods, potentially due to established cultural practices. The Euclidean distance matrix highlights a gap between training uptake and the full adoption of direct selling methods, reinforcing the idea that certain habits or preferences may be slowing adoption.

4. **Technological Lock-ins and Knowledge gap:** As mentioned in #2, there is a weak link between technical support and small-scale operations, indicating limited access to the tools and infrastructure needed for quality assurance and efficient production. Farmer advisory services might be more focused or more responsive to the needs of larger or more commercial operations. In this case, small-scale farmers do not receive specialized advice or support in terms of, for example, production methods and compliance with quality standards. This is closely tied to the Direct Selling and Infrastructure Loop, where investments in infrastructure improve technical support and overall selling capacity. However, small-scale farmers often struggle to afford or access this technology, as shown by the Euclidean distance matrix, which highlights the gap between small-scale operations and available technological resources. This lack of access creates a self-reinforcing barrier, as without the necessary technology, these farmers are unable to meet the required quality standards for market participation, further limiting their capacity to invest in technology in the future.

5. **Market Conditions:** The correlation matrix highlights weak connections between market accessibility and farmers' revenue from direct selling, indicating that farmers struggle to access broader markets, especially those practicing direct selling. This is directly linked to the Market Equilibrium Feedback Loop in Direct Selling Adoption, where the rate of adoption must align with consumer demand. Farmers who are geographically disadvantaged or lack sufficient market access face additional burdens in reaching consumers, as reflected in the Euclidean distance matrix, which shows significant distances between market access and revenue. This lock-in is self-reinforcing, as logistical challenges and limited market exposure reduce farmer participation in direct selling.

6. **Knowledge Gaps**: The structural equivalence between farmer training and the rate of adoption of direct selling reveals that knowledge gaps, especially in areas like digital marketing and quality assurance, limit the adoption of direct selling practices. This lock-in is part of the Training and Digital Tool Application Loop, where increased training is supposed to boost adoption rates. However, the correlation matrix shows weaker links between training and adoption for smaller, less-resourced farmers, and the Euclidean distance matrix reinforces this by highlighting a gap in knowledge transfer. Without adequate advisory services and targeted training, these knowledge gaps create a self-reinforcing barrier that slows adoption.

4.7.4 Potential levers

To overcome the identified lock-ins and facilitate the adoption of direct selling practices, strategic interventions or levers must be applied. These levers are designed to disrupt the entrenched barriers and create a more conducive environment for the growth of direct selling in Slovenia.
To overcome the lock-ins identified in Slovenia's direct selling system, strategic interventions must be applied. These levers aim to address specific barriers and unlock the potential for more sustainable and profitable direct selling practices.

1. **Policy Interventions:** Simplifying regulatory frameworks and fiscal processes can help reduce the administrative burdens that hinder farmers from fully engaging in direct selling. This lever addresses the Regulatory Barriers lock-in, where weak links between compliance and small-scale farmers restrict their ability to participate in direct selling. By improving the links between Legislative Compliance (LC) and Investment in Direct Selling Infrastructure (IDS), policy reforms would enhance regulatory support, making it easier for small-scale farmers to comply with quality standards. Reinstating legislative acts that support direct selling practices, such as policies on cooperative shop registration, can help create a more farmer-friendly regulatory environment and improve market participation.

2. **Financial Incentives:** Offering financial support, such as subsidies for infrastructure development and digital marketing tools, can address the Economic Dependencies lock-in. Farmers currently face difficulties balancing investment with workforce availability, limiting their ability to adopt sustainable direct selling practices. Subsidies targeting Investment in Direct Selling Infrastructure (IDS) and Farmers' Revenue from Direct Selling (FRDS) would alleviate financial strain, allowing farmers to reinvest in technology and expand their market presence. This lever would improve the overall economic foundation of direct selling, increasing profitability and making it a more attractive option for Slovenian farmers.

3. **Education and Training:** Expanding training programs to focus on digital marketing, legislative compliance, and pricing strategies is crucial for overcoming Knowledge Gaps and the Cultural Practices lock-ins. Tailored training would enable farmers to adopt new selling methods and improve their business acumen, which is essential for direct selling success. By enhancing Farmer Training and Capacity Building (FTCB) in the Training and Digital Tool Application Loop, this lever would increase the number of farmers using digital marketing tools, improving consumer engagement and revenue generation. Offering specialized training in both traditional and modern selling techniques would help farmers overcome resistance to change and fully integrate direct selling into their business models.

4. **Technological Innovations**: Improving access to digital marketing tools and e-commerce platforms can address the Technological Lock-ins faced by smaller farmers. Many small-scale farmers lack the infrastructure needed to efficiently engage in direct selling, limiting their participation in broader markets. Investing in Technical Support and Quality Assurance (TSQA) and Digital Marketing Tools (DFMT) would reduce these barriers by providing farmers with the resources and guidance needed to succeed. Collaborative initiatives, such as co-funding digital platforms and centralizing product information, would allow farmers to reduce costs and increase their market visibility.

5. **Market Development**: Reducing logistical barriers and improving access to markets can help address the Market Conditions lock-in. Smaller farmers, especially those in remote areas, face challenges in reaching consumers and competing with larger producers. By improving Market Accessibility (MA) and Consumer Demand for Locally-Sourced and Organic Products (CDLSOP), this lever would help farmers capture a larger share of the local market. Promoting local procurement through educational campaigns and creating flexible public procurement processes would enhance market access for small-scale farmers, stabilizing their revenue from direct selling.

6. **Community Engagement**: Strengthening cooperation among farmers and fostering a culture of collaboration can help address the Social Capital lock-in, where historical trust issues hinder collective direct selling efforts. Initiatives aimed at building trust and cooperation among farmers will encourage stronger collective action and improve direct selling outcomes. By leveraging the Rate of Adoption of Farmers Practicing Direct Selling (RAFDS) in the Training and Digital Tool Application Loop, farmers can work together to increase consumer demand for locally sourced products and share best practices. Community

engagement programs, such as trust-building workshops or cooperative marketing efforts along with training Chamber of Agriculture advisors, would create a stronger sense of collective responsibility and enhance the overall success of direct selling in Slovenia.

4.8 Case Study 8: Italy - Community-supported Agriculture

Objective: Enhance community-supported agriculture (CSA) to foster a sustainable agricultural model focused on environmental stewardship, social equity, and economic viability. The goal is to support a community of citizens in producing their own food directly, using organic and agroecological practices that ensure fair pay for farmers, responsible consumption, and healthy, affordable food.

Local Stakeholders: CSA - Community Supported Agriculture cooperative.

Geographic Scope: Emilia-Romagna, Italy

Description: The project prioritizes proximity farming, reducing the environmental impact of food production by focusing on local production and consumption. It also seeks to enhance consumer awareness about sustainable food systems. UNIBO provides academic and technical support to Arvaia, a cooperative based on a non-hierarchical, solidarity model where users and growers are equals. This structure, inspired by CSA models from Northern Europe, fosters community participation and shared responsibility.

Emilia-Romagna, with its fertile Po Valley plains and Apennine mountains, is well-suited for agricultural innovation. The region's silty soils and temperate climate support a wide variety of crops, including vegetables, cereals, and legumes—the primary commodities produced by Arvaia. The cooperative practices organic farming with a strong focus on agroecology and regenerative agriculture, integrating horticultural production with crop rotations, green manure, and minimal pesticide use to promote biodiversity.

Emilia-Romagna's population is approximately 4.5 million, with a high population density and an average income of €36,200 per year. The economy is strong, with high employment rates and significant agricultural exports. However, a shrinking younger population presents challenges for the long-term sustainability of farming practices. Arvaia recognizes the need to attract younger members, as the cooperative's average membership age is relatively high.

Arvaia operates on 35 hectares of land, with 11 hectares dedicated to horticulture in rotation with green manure and cereals. It produces about 16,000 kilograms of vegetables annually, tailored to meet the needs of its members. The cooperative consists of five active members, seasonal workers, labour members focused on transportation and communication, and volunteer members. While the cooperative's annual turnover is between €230,000 and €250,000, most of this revenue is reinvested into the organization.

Arvaia's long-term goal is stability rather than growth. The cooperative seeks to consolidate its operations, support the establishment of new CSAs, and ensure stable employment for its members. It also aims to scale up practices like agroecology and regenerative farming while adopting new technologies, such as automated irrigation systems, photovoltaic energy, and agrivoltaic technologies. Specific progress indicators are yet to be established, but the cooperative continues to explore innovative ways to enhance sustainability.

The cooperative's marketing strategy relies on word-of-mouth and direct engagement with local associations and consumers, which has built a strong community but limits scalability. Arvaia recognizes the potential benefits of professional communication strategies but currently lacks the resources to implement them.

Arvaia's cooperative model, centred on sustainable agriculture and community engagement, provides a valuable blueprint for creating resilient, community-supported food systems. Ongoing monitoring and adaptive management will be essential to ensure the initiative's long-term success.

Based on the analysis of the case study narrative and the dialogue with the case study coordinators the following variables were identified as relevant and their relationship were outlines as in the table below:

Table 16 Community-supported Agriculture Key Variables

Key Variable	Acronym	Quantitative Indicator	Influences What Variables	Nature of Effect
Rate of CSA Adoption	RCSAA	Number of new members per year	Organic Certification Status, Market Demand for Organic Products	Positive influence on community engagement, financial stability, and CSA growth
Cultivated Land Area	CLA	Total hectares used for agriculture	Annual Land Rent Cost	Larger areas may require increased labour and machinery, influencing costs
Annual Land Rent Cost	ALRC	Annual cost in Euro	Cultivated Land Area, Total Annual Revenue from Membership Fees	Higher costs may necessitate adjustments in membership fees and cultivated area
Land Tenure Security		Length of current land lease	Cultivated Land Area	Stability in land access impacts long-term planning and sustainable practices
Organic Certification Status	OCS	Certification status (Yes/No)	Rate of CSA Adoption, Environmental Impact Score	Enhances appeal to eco-conscious consumers, influences market demand
Production and Biodiversity Index		Number of different crops cultivated		Supports ecosystem health and member choice, influences environmental impact
Total Number of Volunteers and Staff Hours	TNVSH	Hours per week		Critical for managing operations, affects efficiency and costs
Worker Training Levels	WTL	Training sessions attended per year		Improves skill levels, operational efficiency, and crop yield quality
Availability of Training Courses	ATC	Accessibility and frequency of training		Affects worker training levels and overall skill development
Volunteer Engagement Rate	VER	Percentage of members who volunteer	Number of Community Events	Higher engagement supports operational capacity and community events
Number of Community Events	NCE	Events per year	Volunteer Engagement Rate	Enhances community cohesion and engagement, supports volunteer participation
Participation Rate in Community Events	PRCE	Participants per event	Volunteer Engagement Rate	Indicates community engagement and effectiveness of outreach
Machinery and Infrastructure Availability	MIA	Number of key machinery items	Land Tenure Security	Direct impact on farming capacity and operational efficiency
Annual Machinery Maintenance Costs	AMMS	Euro per year	Total Annual Revenue from Membership Fees	Affects operational efficiency and cost-effectiveness
Membership Fees	MF	Euro per member per year	Rate of CSA Adoption	Direct impact on revenue and member affordability, influences membership levels
Total Annual Revenue from Membership Fees	TARMF	Euro per year	Membership Fees	Crucial for covering operational costs and planning future activities
Market Demand for Organic Products	MDOP	Annual sales volume	Rate of CSA Adoption	Affects production decisions and membership fees

Key Variable	Acronym	Quantitative Indicator	Influences What Variables	Nature of Effect
Environmental Impact Score	EIS	Composite score		Reflects commitment to sustainable practices, influences adoption rates
Policy and External Funding Support	PEFS	Level of policy support and funding	Rate of CSA Adoption	Supports operational stability and sustainable practice adoption

4.8.1 Final CLD for Community-supported Agriculture

Table 17 illustrates the development of the CLD on CSA in Italy. The CLD evolved from a broad focus on sustainability and community participation to a more detailed framework that models the interrelated dynamics of volunteer participation, external funding, and environmental impact.

Table 17 Evolution of CLD for CSA in Italy

Aspect	Initial CLD	Final CLD	Key Advancements
Focus	Broad focus on CSA adoption and organic practices	Specific focus on land tenure, volunteer management, and financial sustainability	Narrowed focus to emphasize land security, volunteer engagement, and CSA adoption
Key Variables	CSA adoption, membership fees, land rent costs	Expanded to include community events, organic certification, and machinery costs	Broadened to capture the role of community involvement, land tenure, and training
Relationships	Linear relationships between land rent costs, fees, and adoption	Complex feedback loops involving volunteer engagement, external funding, and sustainability	Introduced reinforcing and balancing feedback loops related to CSA operations
Feedback Loops	No explicit feedback loops	Reinforcing loops like Volunteer Engagement and Community Event Loop and External Funding and Environmental Impact Loop	Introduced loops that demonstrate the interplay of community events, volunteerism, and funding
External Funding & Support	Limited focus on funding beyond membership fees	Integrated external funding and policy support as crucial for operational sustainability	Identified policy advocacy and diversified funding as key levers for CSA expansion
Environmental Impact & Sustainability	Environmental benefits seen as a general outcome of organic practices	Focused on specific metrics for environmental impact, linked to funding opportunities and member satisfaction	Reinforced sustainability as a driver for funding and membership growth
Analytical Rigor	Lacked correlation and adjacency matrices to validate relationships	Introduced matrices to validate connections between land rent, community involvement, and CSA adoption	Improved rigor with data validation through correlation matrices and system dynamics
Strategic Recommendations	General recommendations for improving land tenure and community engagement	Targeted interventions for improving land lease terms, volunteer management, and community events	Shifted to specific strategies focused on land agreements, volunteer engagement, and funding
Land Tenure Security	General focus on land rent costs and operational expenses	Specific focus on securing long-term lease contracts and reducing land rent volatility	Emphasized the importance of stable land access for sustainable practices and planning
Volunteer Engagement	Highlighted the challenge of maintaining a reliable volunteer workforce	Focused on enhancing volunteer participation through community events and training	Developed strategies for improving volunteer retention and engagement
Organic Certification	Viewed as a secondary factor in driving membership growth	Highlighted as a critical component for market demand and consumer trust	Strengthened the role of certification in promoting CSA and ensuring sustainability

Initially, the CLD (see Figure 15) captured basic outcomes such as the diffusion rate of CSA and the balance between operating costs and members' contributions. As the CLD developed (see Figure 16), it incorporated more specific feedback loops that are informed by relationships derived from adjacency, correlation, and Euclidean distance matrices.

Highlights include reinforcing mechanisms, such as the Volunteer Engagement and Community Event Loop, which demonstrates how increasing community participation supports CSA operations by increasing volunteer hours and engagement, and, in turn, leads to an increase in CSA adoption.

Similarly, the External Funding and Environmental Impact Loop shows that, in turn, better environmental performance would encourage more external funding to contribute toward growth and sustainability initiatives within CSA operations. These refinements draw from empirical work with matrix analyses and insights by the stakeholders to better understand systemic interactions within the operations of CSA.

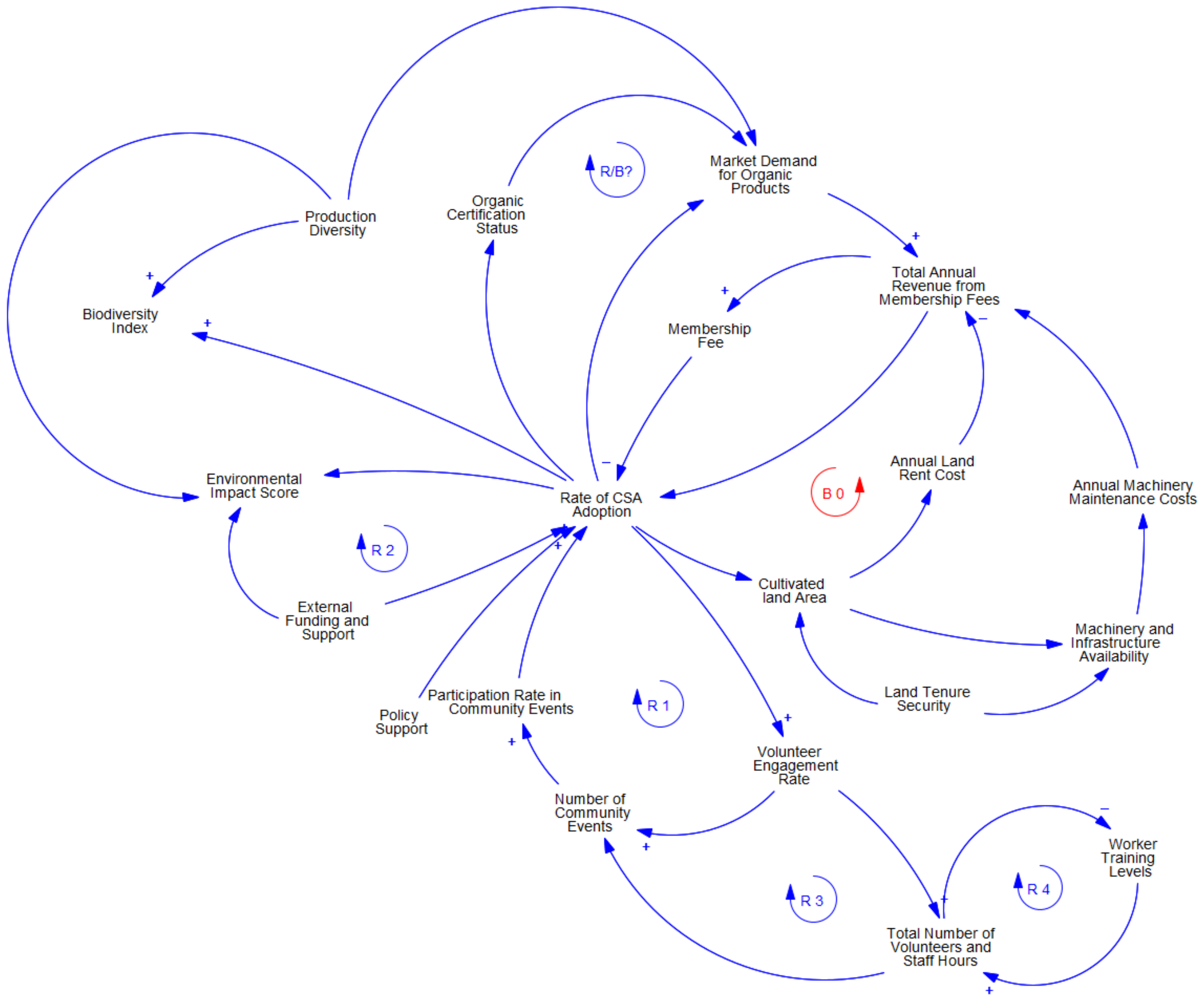


Figure 18 Initial CLD for CSA in Italy

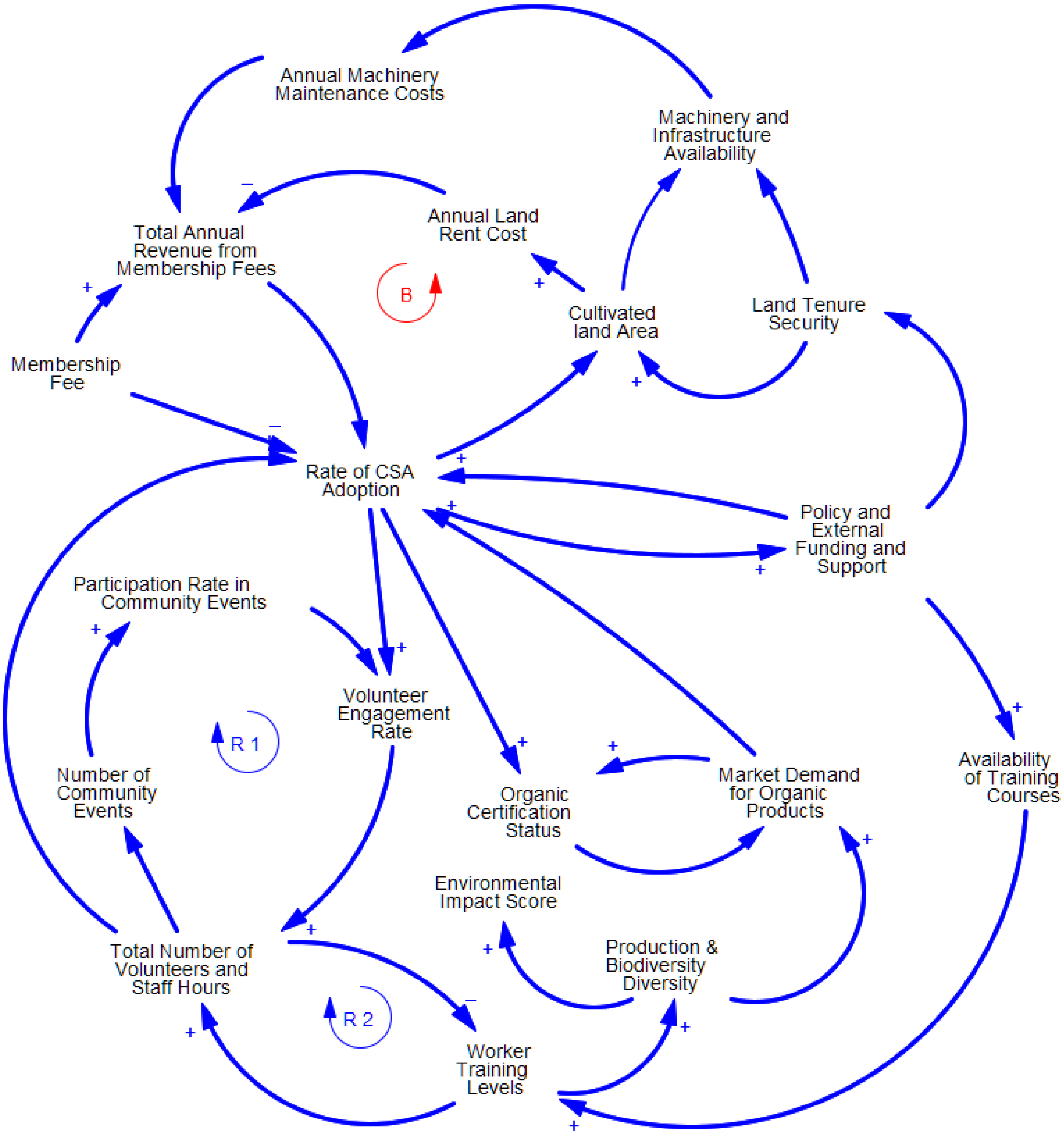


Figure 19 Final CLD for CSA in Italy

4.8.2 Feedback Loops

In the context of Arvaia, a community-supported agriculture (CSA) initiative in Emilia-Romagna, understanding the dynamics of reinforcing and balancing feedback loops is essential for improving operational efficiency and ensuring the sustainability of the cooperative. These loops are pivotal in driving key aspects of Arvaia's functioning, including volunteer engagement, training, land rent management, and organic certification.

1. **Volunteer Engagement and Community Event Loop (Reinforcing).** Increased volunteer engagement happens when more community events lead to higher participation. As more people volunteer, the cooperative has more resources (volunteer hours) to organize even more events that further increases adoption of the CSA.

   Pathway: Number of Community Events (NCE) → Participation Rate in Community Events (PRCE) → Volunteer Engagement Rate (VER) → Total Number of Volunteers and Staff Hours (TNVSH) → Rate of CSA Adoption (RCSAA) → Number of Community Events (NCE).

   Justification from the Structural Analysis: Both correlation and Euclidean distance data confirm strong relationships, showing that volunteer engagement and community events closely influence each other. As participation increases, it exposes more people to the CSA's values, leading to higher adoption rates and a stronger volunteer base, which sustains this reinforcing loop.

2. **Training and Efficiency Loop (Reinforcing):** Worker's efficiency and productivity increases with training. More efficient operations in the farm can justify further investment in worker's training.

   Pathway: Worker Training Levels (WTL) → Total Volunteer and Staff Hours (TNVSH) → Worker Training Levels (WTL).

   Justification from the Structural Analysis: Correlation matrix shows strong positive relationships between worker training levels and total volunteer and staff hours, suggesting that increased training leads to higher efficiency and engagement. Euclidean distances are small, confirming that these variables are closely related. This loop indicates that better training improves staff efficiency, leading to more effective CSA operations, which in turn justifies further investment in training.

3. **Land Rent Cost and Membership Fees Loop (Balancing):** This loop is balancing because higher land rent costs can lead to increased membership fees, which might reduce the rate of CSA adoption. As the CSA grows and more land is cultivated, the rent increases, which in turn requires careful financial management to keep membership fees affordable.

   Pathway: Annual Land Rent Cost (ALRC) → Total Annual Revenue from Membership Fees (TARMF) → Rate of CSA Adoption (RCSAA) → Cultivated Land Area → Annual Land Rent Cost (ALRC).

   Justification from the Structural Analysis: The adjacency matrix indicates influences among these variables, and correlation data shows mixed relationships, suggesting a balancing dynamic. Higher land rent costs could strain finances, leading to adjustments in membership fees and cultivated land area, potentially affecting CSA adoption rates. Euclidean distances are moderate, indicating that while relationships exist, they are not very close. This loop suggests a balancing dynamic where increases in land rent costs could potentially strain the CSA's finances, leading to adjustments in membership fees and operational strategies to maintain or boost CSA adoption rates. The positive correlation between land rent costs and total revenue is counterintuitive and could indicate that the CSA is effectively passing on costs to members without reducing membership levels. However, the negative impacts on membership fees and adoption rates highlight potential risks to long-term sustainability.

4. **Organic Certification and Member Satisfaction Loop (Balancing):** Achieving and maintaining organic certification increases member satisfaction, which in turn increases CSA adoption rates. However, as the cooperative grows, maintaining high standards can become more challenging that might affect member satisfaction if not managed well.

   Pathway: Organic Certification Status (OCS) → Member Satisfaction (MS) → Rate of CSA Adoption (RCSAA) → Organic Certification Status (OCS).

   Justification from the Structural Analysis: The correlation matrix shows a complex relationship where organic certification may enhance member satisfaction, leading to higher adoption rates. Euclidean distances are moderate, suggesting that while connections exist, they need to be strengthened for better outcomes. The feedback loop outlined suggests that while there are connections between these elements, they do not necessarily lead to the expected outcomes in a straightforward manner. The correlations and distances imply a complex relationship where organic certification does not directly enhance market demand or revenue but does encourage more robust organic practices as CSA adoption increases. Furthermore, this loop highlights the need for better communication strategies to leverage organic certification, improve member satisfaction, and enhance adoption rates. The focus here is on how organic certification affects the members' perception and satisfaction, thereby influencing their commitment to the CSA.

4.8.3 Lock-ins

Despite its successes, Arvaia faces several lock-in conditions that hinder its ability to scale up its operations.

1. **Economic Dependencies:** The CSA operates on land leased from the municipality; hence it is very vulnerable to rental increases. Moreover, high land rent costs can limit CSA's financial capacity to make further investments. Also, membership fees are the primary source of income for CSA, which might not be stable or sufficient to cover all operational costs, including labour and land rent. This dependency is tied to the Land Rent and Membership Fees Loop, where rising land rent require higher membership fees, potentially reducing the rate of CSA adoption and the cultivated land area, creating a financial strain that hinders long-term sustainability. The correlation matrix shows a strong positive relationship between land rent costs and total revenue from membership fees, indicating that rent pressures directly impact financial health. However, higher fees can lower adoption rates, creating a financial lock-in where fluctuating membership limits growth potential.

2. **Regulatory Barriers:** The CSA's long-term planning and investments in sustainable practices is dependent on the length of land lease agreements with the municipality as the stability of access to agricultural land is critical. In addition, as income from membership fees may not be stable or sufficient, CSA needs supportive policies or incentives to support its operation. The Land Rent and Membership Fees Loop is again central to this lock-in. The correlation matrix highlights a strong link between land tenure security and cultivated land area, with Euclidean distances showing that fluctuations in land access disrupt long-term planning, locking the CSA into short-term decisions.

3. **Cultural Practices:** The CSA model relies heavily on volunteer labour, creating a lock-in linked to the Volunteer Engagement and Community Event Loop. If there are no regular volunteers or fluctuations in volunteer engagement and commitment levels, then this can disrupt CSA operation and sustainability. Correlation data shows strong relationships between community events and volunteer engagement, but moderate Euclidean distances indicate that fluctuations in participation levels create operational instability, limiting the CSA's ability to grow.

4. **Technological Lock-ins:** The CSA's operations are dependent on existing farming machinery and infrastructure, which can be costly to maintain and may not be optimized for sustainable practices. Annual machinery maintenance costs can be significant that can affect the operational efficiency and financial sustainability of the CSA. The Training and Efficiency Loop further exacerbates this lock-in. In this loop, inadequate worker training (Worker Training Levels) reduces the effectiveness of staff and volunteers (Total Volunteer and Staff Hours, which in turn limits opportunities for skill improvement and operational efficiency. Correlation data shows a positive relationship between training and volunteer/staff hours, but the Euclidean distance matrix reveals that without adequate training, workers remain under-skilled, leading to inefficiencies that make it difficult to manage maintenance costs. Policy and External Funding Support also influence Availability of Training Courses, and reduced funding constrains training availability, reinforcing this technological lock-in.

5. **Market Conditions:** Market demand for organic products is closely tied to the rate of CSA adoption and financial stability. However, demand is unpredictable, which creates a lock-in where the CSA's financial health is highly dependent on external market forces that it cannot control. If there is low market demand, then CSA's revenue and financial stability will suffer. If there is low market demand for organic products, membership levels can also decrease, affecting the predictability of income from membership fees. This is connected to the Organic Certification and Member Satisfaction Loop, where the appeal of organic certification (Organic Certification Status - OCS) enhances member satisfaction (MS) and drives adoption, but fluctuating demand for organic products can undermine this loop. The correlation matrix shows a strong relationship between market demand and adoption rates, but fluctuations in demand can directly affect membership levels and total revenue (TARMF). When market demand decreases, the structural equivalence analysis indicates that membership fees may not be sufficient to cover operational costs, creating a financial lock-in. The Euclidean distance matrix shows moderate proximity between market demand and revenue, suggesting that while there is a relationship, the unpredictability of external market forces the CSA into a reactive financial position, hindering its long-term planning and stability.

6. **Knowledge Gaps:** Inaccessibility of training courses for CSA members and workers creates a knowledge gap that limits operational efficiency. Policy and External Funding Support heavily influence training availability. Although Availability of Training Courses (ATC) is linked to Worker Training Levels (WTL), this connection is dependent on external funding, creating a lock-in. The correlation matrix shows a strong

positive relationship between WTL and Total Number of Volunteers and Staff Hours (TNVSH). However, the Euclidean distance matrix reveals that without consistent funding for training, workers cannot improve their skills, exacerbating inefficiencies and reinforcing this knowledge gap lock-in.

4.8.4 Potential levers

To address the identified challenges, the case study explores various strategies.

1. **Policy Interventions**: Securing long-term land lease agreements with the municipality can address the Economic Dependencies and Regulatory Barriers lock-ins. Stable land tenure would reduce financial uncertainty, enabling the CSA to make long-term investments in infrastructure and sustainable farming practices. By stabilizing Land Tenure Security in the Land Rent and Membership Fees Loop, the CSA can mitigate the impact of fluctuating rent costs and reduce the pressure to increase membership fees. This would improve financial sustainability and adoption rates. To allow for greater operational stability, advocate for policy support or external funding to secure long-term leases and reduce rent volatility.

2. **Financial Incentives**: Offering subsidies or financial incentives to reduce Annual Land Rent Costs (ALRC) and Machinery Maintenance Costs (AMMC) can address the Economic Dependencies and Technological Lock-ins. Subsidies would alleviate financial strain, reducing the dependency on increasing membership fees to cover operational costs. In the Land Rent and Membership Fees Loop, this would prevent the financial burden from negatively impacting CSA adoption rates. Negotiate better land lease terms with the municipality or seek financial support for machinery maintenance to decrease operational costs. Moreover, developing flexible financial strategies that account for fluctuations in demand and rent costs to avoid reactive decision-making. A proactive approach to financial planning can mitigate the effects of Economic Dependencies and Market Conditions, ensuring the CSA is less vulnerable to external forces. This can be done by implementing budgeting practices that build reserves during high-demand periods to offset revenue shortfalls during demand slumps, helping smooth out the impact of market fluctuations.

3. **Education and Training**: Increasing the availability of training programs for CSA members and workers is crucial to overcoming Knowledge Gaps and Technological Lock-ins. Expanded training opportunities would improve worker efficiency and reduce the maintenance burden on outdated machinery. By improving Worker Training Levels (WTL) in the Training and Efficiency Loop, the CSA can enhance operational efficiency, allowing for more effective use of volunteer and staff hours. This would address the lack of skills that contributes to inefficiencies and high maintenance costs. Invest in expanding training opportunities through partnerships or external funding, ensuring that workers can improve their skills to enhance productivity and reduce inefficiencies.

4. **Technological Innovations**: Investing in modern, sustainable farming equipment would address the Technological Lock-ins related to high machinery maintenance costs and inefficiencies. Reducing Annual Machinery Maintenance Costs (AMMC) through better technology would improve operational efficiency. By enhancing Machinery and Infrastructure Availability (MIA), the CSA can decrease its dependency on outdated, high-maintenance equipment. Explore collaborative models for sharing high-cost equipment among CSA networks to reduce financial burden, or seek external funding to invest in newer, more efficient machinery.

5. **Market Development**: Creating stronger demand for organic products through marketing and educational campaigns can help stabilize revenues, addressing the Market Conditions lock-in. In the Organic Certification and Member Satisfaction Loop, increasing demand for organic products would enhance member satisfaction (MS) and strengthen CSA adoption rates (RCSAA). This would reduce the vulnerability of the CSA to fluctuating market demand. Moreover, promoting the environmental and health benefits of organic products to build a loyal customer base can stabilize demand and ensure more predictable revenues.

6. **Community Engagement**: Strengthening community involvement by organizing more events can boost volunteer engagement and improve the stability of the CSA, addressing the Cultural Practices lock-in. The Volunteer Engagement and Community Event Loop is crucial for maintaining a steady volunteer base. Increasing the number of community events (NCE) and enhancing participation rates (PRCE) can build a stronger sense of community and improve volunteer retention. For example, organize regular community

events that emphasize the benefits of CSA participation, fostering a sense of ownership among members and encouraging higher volunteer engagement.

4.9 Case Study 9: Ireland - Growing the Organic Dairy Farming Sector

Objective: Grow the organic dairy farming sector in Ireland.

Local Stakeholders: Teagasc Organic Farm Advisors, National Organic Training Skillnet, Department of Agriculture, Food and the Marine (DAFM) Organic Unit, Organic Trust, Irish Organic Association, The Organic College, individual organic dairy producers.

Description: This case study focuses on the expansion and development of the organic dairy farming sector in Ireland, a strategic initiative driven by the Irish government's goal to increase organic production from 2% to 7.5% of the utilisable agricultural area by 2027. The project, spearheaded by TEAGASC (the Agriculture and Food Development Authority of Ireland) in collaboration with a network of stakeholders including organic farm advisors, educational institutions, and various organic certification bodies, aims to facilitate a significant transition within Ireland's dairy sector. The core objective is to grow the organic dairy farming sector by supporting the conversion of conventional farms to organic practices, thereby enhancing environmental sustainability, improving animal welfare, and ensuring economic viability for farmers. The initiative also seeks to address the underdeveloped state of organic dairy farming in Ireland, where the sector currently accounts for less than 1% of the total milk volume produced. Ireland's organic dairy sector operates within the Atlantic climatic zone, characterized by a temperate climate ideal for grass-based farming systems. This natural advantage supports the cultivation of grass, clover, and multi-species sward crops, which are integral to organic dairy farming. Despite these favourable conditions, the organic dairy sector remains underdeveloped, with only about 70 fully organic dairy farmers managing a combined herd of 5,000 cows, supplemented by an additional 30 farmers currently undergoing the organic conversion process. Ireland's organic dairy sector currently represents a small fraction of the national dairy production, accounting for less than 1% of the total milk volume. Despite the country's ideal conditions for organic dairy farming—such as its Atlantic climatic zone, which supports grass growth and multi-species sward crops—organic dairy farming has been slow to expand. This is partly due to the high profitability of conventional dairy farming, which has traditionally overshadowed the economic incentives for conversion to organic practices. The Irish government's Organic Strategy aims to increase organic production from 2% to 7.5% of the utilisable agricultural area by 2027. However, this target faces significant challenges, including the need for more robust policy support, increased capital investment in processing facilities, and enhanced market development for organic dairy products. Understanding the factors that have impeded the growth of the organic dairy sector and identifying effective levers for change are crucial for achieving these targets.

Table 18 Growing the Organic Dairy Farming Sector Key Variables

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Organic Certification		Number of farms certified organic	Conversion Practices	Certification encourages adherence to organic practices.
Conversion Practices		Adoption rates of organic farming practices	Environmental Impact, Organic Certification	Adoption of organic practices improves environmental health and supports certification.
Environmental Impact		Soil health, biodiversity indices	Policy Support, Market Demand, Farmer Motivation	Improved environmental health can lead to increased policy support, market demand, and farmer motivation.
Economic Returns		Profit margins, market prices	Farmer Motivation, Market Demand	Higher economic returns motivate farmers and increase market demand.
Policy Support		Number of policies, amount of subsidies	Conversion Practices,	Policies and subsidies reduce financial burden and support sustainable practices.

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
			Environmental Impact	
Training and Advisory Services		Number of training sessions, farmer participation rates	Farmer Motivation, Conversion Practices	Training increases knowledge and confidence in adopting organic practices.
Infrastructure and Processing Facilities		Investment in facilities, number of processing units	Market Demand	Investment supports the supply chain, meeting market demand.
Farmer Motivation		Survey results on farmer willingness to convert	Economic Returns, Environmental Impact	Motivation drives adoption of organic practices and improves economic returns.
Marketing and Branding		Marketing campaigns, consumer awareness metrics	Market Demand	Effective marketing increases consumer awareness and demand for organic products.
Supply Chain Efficiency		Cost of logistics, delivery times	Economic Returns	Efficient supply chains reduce costs and improve profitability.
Market Demand		Sales volumes, consumer preference data	Economic Returns, Environmental Impact	Higher market demand supports higher economic returns for organic products and encourages sustainable practices.

4.9.1 Final CLD for Growing the Organic Dairy Farming Sector in Ireland

The process began by identifying the key variables that impact the organic dairy sector, including Economic Returns, Market Demand, Policy Support, Conversion Practices, and Farmer Motivation. These variables were identified through extensive data collection, including interviews with organic dairy producers, advisors from Teagasc, and policymakers from the Department of Agriculture, Food and the Marine (DAFM).

The initial CLD (Figure 17) was drafted to map out the causal relationships between these variables. For example, it illustrated how Market Demand for organic dairy products drives Economic Returns for farmers, which in turn motivates more farmers to convert to organic practices. Policy Support was shown to influence both the economic viability of organic farming and the success of conversion practices, highlighting the importance of government subsidies and incentives in the transition to organic dairy farming. Following the initial draft, the CLD underwent a series of refinements through bilateral meetings with stakeholders, including organic farming advisors, and policymakers. These meetings were critical for validating the initial relationships and for identifying additional variables and feedback loops that were not initially considered.

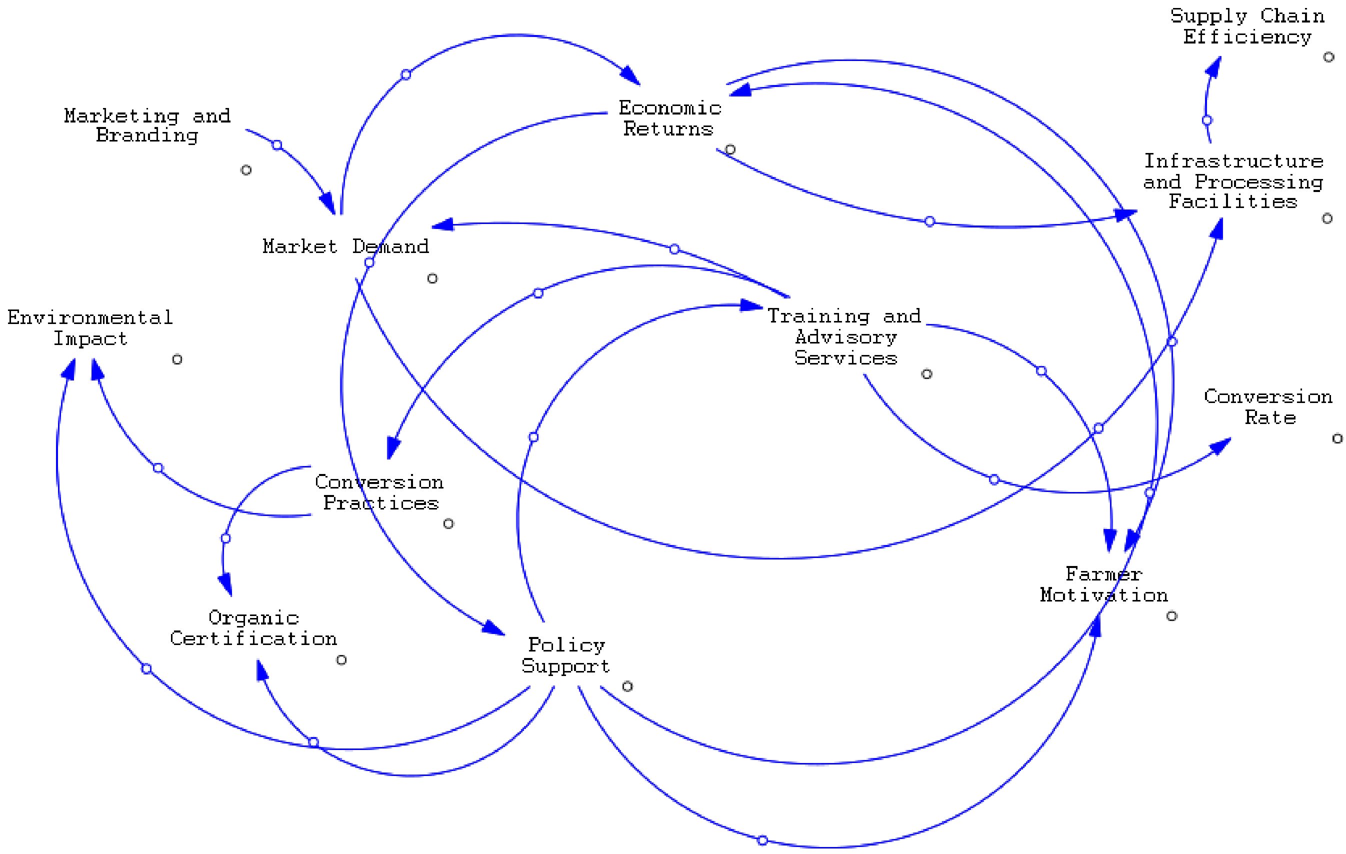


Figure 20 Initial CLD for Growing the Organic Dairy Farming Sector in Ireland

One significant refinement involved the inclusion of a feedback loop that linked Farmer Motivation and Economic Returns. This loop highlighted how higher economic returns from organic farming practices could further motivate farmers to adopt these practices, creating a reinforcing cycle that supports the growth of the organic dairy sector. Additionally, a balancing loop was added to represent the challenges posed by Environmental Impact and Policy Support. This loop emphasized the need for continuous monitoring and adjustment of policies to ensure they effectively mitigate environmental impacts while promoting organic farming.

The main takeaways from the whole process highlighted that Ireland's dairy farming sector faces significant challenges due to dependence on conventional practices, high transition costs, and knowledge gaps. Providing access to sustainable dairy farming technologies and financial incentives can support the transition to organic practices. Education and training programs will build knowledge about organic dairy farming, contributing to environmental and economic sustainability.

Table 19 CLD evolution for Growing the Organic Dairy Farming Sector in Ireland

Aspect	Initial CLD	Final CLD	Key Advancements
Focus	Increase organic dairy farming through targeted support in specific areas.	Expand organic dairy farming sector nationwide in Ireland, aiming for 7.5% of the agricultural area by 2027	The focus was expanded from localized support to a national strategic initiative with clear targets for organic dairy farming expansion across Ireland
Key Variables	The first variables included were targeting the narrative aspect related to Economic returns, Policy support and Farmer motivation. This	Through iteration and dialogue the final list of variables included also variables accounting for different aspects such as Market Demand, Training	Expanded the scope to include market dynamics, training, and infrastructure, providing a more holistic view of factors influencing organic dairy farming.

Aspect	Initial CLD	Final CLD	Key Advancements
	was based also on the initial discussion with the CSC	and Advisory Services, and Infrastructure Development	
Relationships	Linear relationships mainly between Policy Support, Economic Returns, and Farmer Motivation	More complex relationships with feedback loops connecting market demand, economic returns, and policy support	Relationships evolved to show the interconnectedness of policy, market demand, and economic returns, highlighting the cyclical nature of support and motivation for organic farming
Feedback Loops	No explicit feedback loops identified	Six feedback loops identified, emphasizing the role of policy support, market dynamics, training, and infrastructure in driving the organic dairy sector	Introduction of feedback loops provided a deeper understanding of how these factors reinforce or balance each other, crucial for the growth of the organic dairy farming sector
Strategic Recommendations	General recommendations focused on improving farming practices and economic returns	Specific recommendations on policy support, financial incentives, education and training, market development, and infrastructure investment	Strategic recommendations were refined to target critical areas such as policy frameworks, financial support, training, and infrastructure improvements to support the expansion of organic dairy farming.

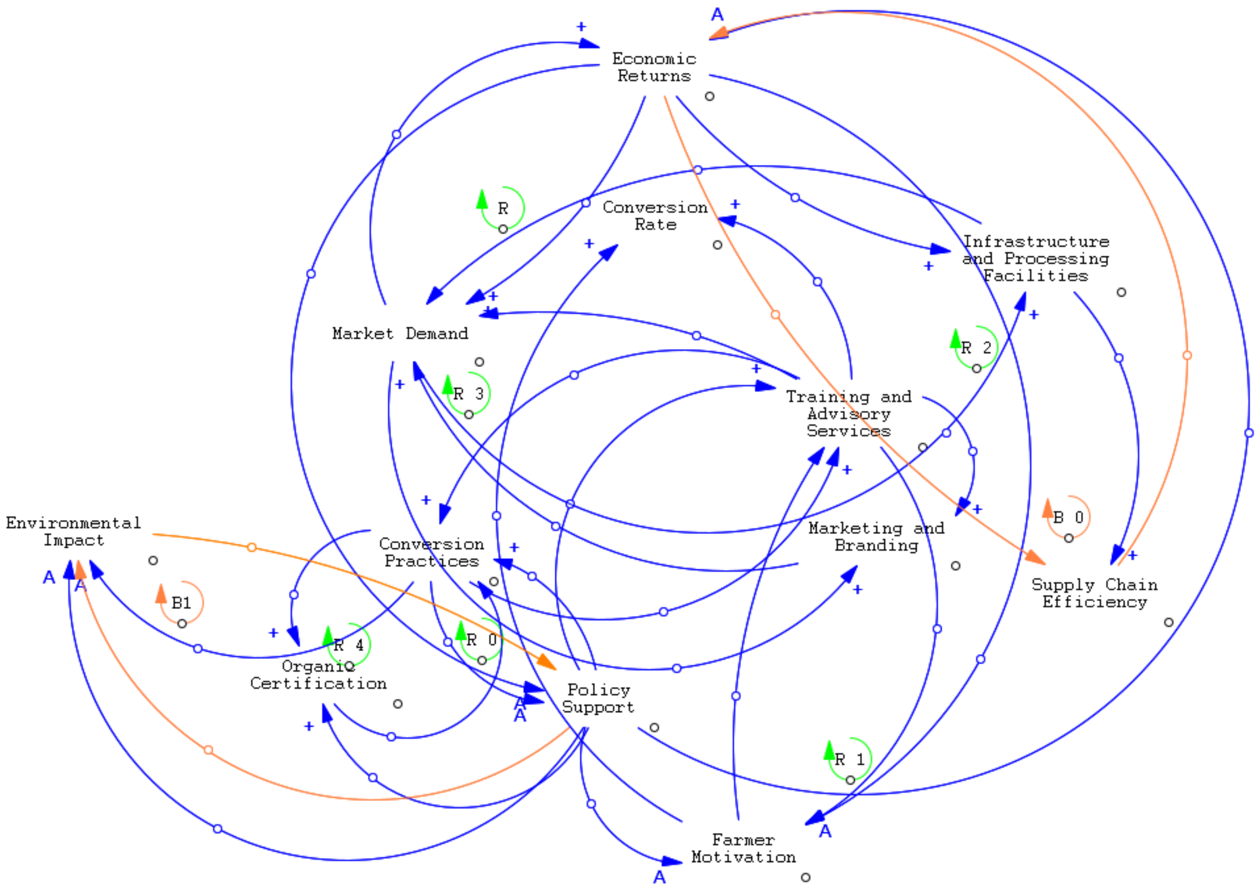


Figure 21 Final CLD for Growing the Organic Dairy Farming Sector in Ireland

4.9.2 Feedback loops

1. **Economic Return Loop (Reinforcing):** Higher market demand for organic products increases economic returns. Better economic returns motivate farmers to convert to organic farming. Increased conversion rates lead to more organic products, further boosting market demand. This reinforcing loop highlights the economic incentives driving organic farming adoption.

   Pathway: Market Demand (MD) → Economic Returns (ER) → Farmer Motivation (FM) → Conversion Practices (CP) → MD

2. **Policy Support Loop (Reinforcing):** Policy support enhances economic returns by providing subsidies. Improved economic returns motivate more farmers to convert. Higher conversion rates justify further policy support.

   Pathway: Policy Support (PS) → Economic Returns (ER) → Farmer Motivation (FM) → Conversion Rate (CR) → Policy Support (PS)

3. **Training and Advisory Services Loop (Reinforcing):** Training services improve conversion practices. Better practices lead to more organic certifications. Increased certifications motivate more farmers, boosting conversion rates and demand for more training. This loop highlights the role of education in sustaining organic farming transitions.

   Pathway: Training and Advisory Services (TAS) → Conversion Practices (CP) → Organic Certification (OC) → Farmer Motivation (FM) → Conversion Rate (CR) → Training and Advisory Services (TAS)

4. **Marketing and Branding Loop (Reinforcing):** Effective marketing increases market demand. Higher demand improves economic returns, enabling further investment in marketing.

   Pathway: Marketing and Branding (MB) → Market Demand (MD) → Economic Returns (ER) → Marketing and Branding (MB)

5. **Infrastructure and Processing Facilities Loop (Reinforcing):** Better infrastructure improves supply chain efficiency, increasing market demand. Higher demand enhances economic returns, justifying further investment in infrastructure.

   Pathway: Infrastructure and Processing Facilities (IPF) → Supply Chain Efficiency (SCE) → Market Demand (MD) → Economic Returns (ER) → Infrastructure and Processing Facilities (IPF)

6. **Environmental Impact Loop (Reinforcing):** Improved conversion practices reduce environmental impact. Positive environmental outcomes enhance policy support, encouraging further adoption of better practices.

   Pathway: Conversion Practices (CP) → Environmental Impact (EI) → Policy Support (PS) → Conversion Practices (CP)

7. **Environmental Policy Balancing Loop (Balancing):** Reduced environmental impact leads to increased policy support for sustainable practices. If the environmental impact becomes too positive, the urgency for further policy support may decrease, balancing the loop.

   Pathway: Environmental Impact (EI) → Policy Support (PS) → Conversion Rate (CR) → Environmental Impact (EI)

8. **Supply Chain and Economic Returns Balancing Loop (B1):** Improved supply chain efficiency increases market demand, leading to better economic returns. If economic returns get too high, the focus may shift away from further improving supply chain efficiency, balancing the loop.

   Pathway: Supply Chain Efficiency (SCE) → Market Demand (MD) → Economic Returns (ER) → Supply Chain Efficiency (SCE)

9. **Organic Certification and Conversion Loop (Reinforcing):** The loop emphasizes the direct relationship between certification and sustainable farming.

   Pathway: Organic Certification (OC) → Farmer Conversion Practices (FCP) → Environmental Impact Reduction (EIR) → OC

4.9.3 Lock-ins

Through the interviews and the consequent data collection several lock-in conditions have been identified that hinder the expansion of organic dairy farming in Ireland:
Economic Dependencies: The economic structure of the conventional dairy industry presents significant challenges for organic conversion. With Ireland's dairy sector being highly profitable, especially after the removal of dairy quotas in 2015, many farmers are hesitant to switch to organic practices. For many conventional farmers with a high stocking rate, converting to organic farming would lead to a reduction in their income. Additionally, higher costs are driven by organic land rent, limited access to organic feed, and increased transportation expenses due to the wide distribution of organic dairy farms.
Regulatory Barriers: The stability of access to agricultural land is a critical issue, with long-term planning and investments in organic farming practices often dependent on the length and security of land lease agreements with municipalities. Furthermore, the lack of sufficient policy and external funding support makes it difficult for farmers to sustain the transition to organic farming.
Cultural Practices: Farmer attitudes towards organic farming have historically been low but this is starting to change as organic farming is becoming more popular in Ireland. The idea of maximising production on farms is still often

perceived as a measure of a successful farmer. This however conflicts with organic farming regulations which restrict farmers to 2 livestock units per hectare.
Technological Lock-ins: The high costs of maintaining existing farming machinery and infrastructure, coupled with the need for more sustainable and modern equipment, pose significant financial burdens on organic farmers. This technological dependency further complicates the transition to more sustainable practices.
Market Conditions: The organic dairy market in Ireland is still relatively small, with demand for organic products being unpredictable. This volatility in market demand can impact the financial stability of organic dairy farms, making it difficult to plan and invest for the future.
Knowledge Gaps: There is a lack of accessible training and development opportunities for organic farmers, which hinders the growth and efficiency of the sector. Without proper education and skills development, farmers may struggle to implement organic practices effectively, limiting the potential for expansion.

1. **Economic Dependencies:**
    - High initial costs for organic certification and conversion practices.
    - Financial challenges and insufficient investment in organic farming infrastructure.
2. **Regulatory Barriers:**
    - Need for greater policy research and advisory support to incentivize organic conversion.
    - Dependence on government policies and subsidies to support organic farming practices.
3. **Cultural Practices:**
    - Slow promotion of organic products.
    - Need for increased market demand to drive organic dairy sector growth.
4. **Technological Lock-ins:**
    - Limited availability of organic processing facilities.
    - Dependence on conventional dairy infrastructure that may not support organic products.

4.9.4 Potential levers

To overcome the abovementioned challenges and accelerate the growth of the organic dairy sector, the case study identifies several strategic levers:

1. **Policy Interventions:** Enhance government support and subsidies for organic conversion. Implement policies that support the development of organic processing facilities.
2. **Financial Incentives:** Increase financial subsidies and grants for organic farming. Encourage investment in organic infrastructure and processing capabilities.
3. **Education and Training:** Expand training and advisory services to support organic practices. Develop educational programs highlighting the economic and environmental benefits of organic farming.
4. **Market Development:** Promote Irish organic dairy products through marketing and branding campaigns. Develop local and international markets for organic products to ensure fair pricing.
5. **Community Engagement:** Implement programs to build community support for organic farming. Strengthen networks among organic farmers to facilitate knowledge sharing and mutual support.

4.10 Case Study 10: Belgium - Increasing Organic Certified Vegetable Production

Objective: Increase organic certified vegetable production while maintaining environmental and social benefits.

Local Stakeholders: Bioforum

Description: This case study focuses on the organic vegetable farming sector in Flanders, Belgium, and aims to address the challenges and opportunities associated with increasing organic vegetable production while maintaining the environmental and social benefits that define organic farming practices. Conducted in collaboration with the Research Institute for Agriculture, Fisheries, and Food (EV-ILVO) and local stakeholders such as Bioforum, this study seeks to understand the dynamics of the organic farming sector and to develop strategies for overcoming existing barriers to growth. The primary objective of this case study is to enable a robust shift in the organic vegetable sector in Flanders by increasing the production of organic-certified vegetables. This goal is aligned with the broader ambition of promoting sustainable agricultural practices that ensure biodiversity conservation, efficient resource use, climate mitigation, and fair economic returns for farmers. The study particularly emphasizes the need to scale up practices that support the conservation of natural enemies of pests, minimize the use of biopesticides, and adopt organic robust varieties that are better suited to organic farming systems. Flanders, situated in the Atlantic pedo-climatic zone, is characterized by its highly suitable sandy to sandy-loamy soils, which are ideal for vegetable production. The region is densely populated, with a significant portion of its land dedicated to agriculture. The vegetable sector in Flanders, particularly in Western Flanders, is a vital part of the region's agricultural economy, contributing significantly to both local and international markets. However, the region faces several challenges, including soil degradation, water pollution, and a decline in agrobiodiversity, all of which are linked to intensive conventional farming practices. In this context, organic farming presents a viable alternative that can address these environmental concerns while also providing economic benefits to farmers. The organic farming sector in Flanders is small but growing, with a strong focus on vegetable production. The region has 4724 farms specializing in open-air vegetable production, contributing significantly to both the national and European markets. However, the organic sector covers only 1.6% of the Utilized Agricultural Area (UAA), despite its rapid growth in recent years. Organic farms in Flanders typically vary in size, with some reaching up to 270 hectares. However, most organic farms are small to medium-sized, family-owned enterprises that rely heavily on seasonal labour.

The ultimate goal of this case study is to implement an action plan that significantly increases the area under organic vegetable production in Flanders while safeguarding the core social and environmental principles of organic farming. The study aims to create a more sustainable, productive, and resilient organic vegetable sector that can serve as a model for other regions. By addressing the identified lock-ins and implementing the proposed strategies, the study seeks to ensure that the growth of the organic sector aligns with its foundational principles of sustainability, biodiversity conservation, and fair economic returns.

The organic vegetable sector faces several challenges, including high land prices, competition with conventional farming, and a lack of infrastructure and support for small organic farmers. Additionally, the sector is characterized by a significant disparity in farm sizes, with larger farms occupying a substantial portion of the land, while smaller farms struggle with limited resources. Despite its potential, the sector faces significant barriers to growth, including high land prices, competition with conventional farming, and a lack of infrastructure and support for small organic farmers.

Based on the analysis of the case study narrative and the dialogue with the case study coordinators the following variables were identified as relevant, and their relationship were outlines as in the table below:

Table 20 Increasing Organic Certified Vegetable Production Key Variables

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Organic Farming Area	OFA	Hectares under organic farming	Market Demand, Governance	Expansion of organic farming area is driven by consumer interest and policy incentives.
Market Demand	MD	Consumer preferences, sales volumes	Social Dynamics, Value Chain	Increasing demand for organic products is influenced by social trends and impacts the value chain.
Environmental Impact	EI	Soil health, water quality, biodiversity indices	Farming Practices, Governance, Economic Factors	Environmental outcomes are shaped by sustainable practices, regulations, and economic factors.
Farming Practices	FP	Adoption rates of sustainable techniques	Environmental Impact, AKIS, Governance	Sustainable farming practices improve environmental health and are guided by knowledge and regulations.
Governance	G	Number of policies, amount of subsidies	Environmental Impact, Organic Farming Area, Farming Practices, AKIS	Governance supports sustainable practices through policies and incentives.

Key Variable	Acronym	Quantitative Indicators	Influences What Variables	Nature of Effect
Economic Factors	EF	Profit margins, market prices, land prices	Environmental Impact, Social Dynamics, Demographics	Economic conditions affect environmental health, social dynamics, and demographic patterns.
Social Dynamics	SD	Rural-urban divide, social attitudes, market access	Market Demand, Economic Factors	Social trends influence consumer demand and are impacted by economic conditions.
Demographics	D	Age distribution of farmers, labour availability	Economic Factors, Social Dynamics	Demographic patterns affect labour availability and economic conditions.
Value Chain	VC	Efficiency metrics, cost of logistics	Market Demand, Governance	Efficiency in the value chain is influenced by consumer demand and regulatory environment.
AKIS (Agricultural Knowledge & Innovation Systems)	AKIS	Number of training sessions, farmer participation rates	Governance, Farming Practices	Knowledge dissemination supports sustainable farming practices and is guided by governance.

To refine the variables, deepen the understanding of their interplay and address the challenges and opportunities surrounding organic vegetable production in Flanders, two meetings were arranged with CSC. The discussion focused on the various obstacles that small organic vegetable farmers face, particularly in balancing local supply and demand amidst the diversity of products and land use. It was highlighted that while larger farms are responsible for the majority of organic output, many smaller farms depend heavily on direct sales to sustain their operations.

A significant portion of these meetings was dedicated to strategies for increasing the area of land dedicated to organic farming in Flanders. Two primary approaches were discussed: diversifying crop rotations on existing organic farms and converting conventional farms to organic practices. The latter, however, presents challenges, as the conversion process can take up to two years and requires a long-term commitment that may be complicated by current land tenure laws.

Converting conventional farmland to organic was identified as a crucial strategy for expansion. However, it was noted that landowners often have limited influence over the farming practices on their land, particularly under current legislation. This creates a barrier to conversion, as landowners may be hesitant to support such a transition without clear incentives or legal support.

The discussion also touched on the various stakeholders involved in the conversion process. These include organizations within the organic sector, retailers, processors, and government departments focused on agriculture. While these stakeholders generally support the expansion of organic farming, there is concern among current organic farmers that an increase in organic land could potentially impact their income negatively, creating resistance to expansion efforts. One of the critical barriers identified in the meeting was the issue of land tenure, particularly the uncertainty associated with short-term leases. It was suggested that policymakers could play a key role in overcoming this barrier by introducing incentives for landowners to support the conversion to organic farming. This could involve contract requirements that encourage or even mandate sustainable practices, provided that such measures are permitted under existing laws.

Overall, these meetings highlighted the complex interplay of factors that influence organic vegetable production in Flanders. Addressing these challenges will require coordinated efforts among all stakeholders, with particular attention to policy changes that can support long-term commitments to sustainable farming practices.

The CSC provided extensive feedback by mail in the course of May and April on the draft CLD. The CSC suggested that the draft CLD did not cover crucial barriers identified in the analysis. Based on a list of 13 barriers, that was later on validated by a diverse group of local stakeholders in the policy workshop conducted in the framework of task 6.1, the CSC proposed including a set of variables and relations in next version. The CSC considered certain variables vaguely defined (e.g. 'Social Dynamics', 'Economic Factors', 'Farming Practices') or underspecified ('AKIS', 'Governance', …). To render the CLD more meaningful to local stakeholders, the CSC made suggestions to rename these variables. The variable 'Infrastructure' was deemed less relevant to the system of interest and was therefore removed.

Below is the list of final variables and the suggested additional variables, nested under the one considered in the final version. Those nested will be used to identify the relevant equations during the transition from conceptual model to stock and flow model in the activities foreseen in Task 2.3.

Final variables	CSC suggested variables
Organic Farming Area (OFA)	Organic Vegetable Area in Flanders
Market Demand	Overall local demand for OF products
	Excess supply organic vegetables from abroad
Governance	Policy support for agroecological transition
	Environmental regulation
Farming Practices	Uptake of agroecological practices by vegetable farmers
	Input-substitution & mechanisation options
	Need for external farm labour
AKIS	Research and extension services supporting agroecological transition
Environmental Impact	Environmental Impact
	Intensive agricultural activities
Economic Factors	Expected farm income to converting/upscaling Organic Vegetable farming
	Competitiveness of local supply
	Land leases & prices
Demographics	Generational renewal & entree of new farmers
Value Chain	Development of local processing channels for wholesale
	Establishment of alternative food networks
Social Dynamics	Farmer attitudes towards Organic farming
	Affordable, skilled and motivated seasonal labour
	Purchasing power & employment
	Credibility organic label & Willingness to Pay for (local) organic products
	Consumer expectations regarding convenience & cosmetic quality

For project purposes, in close dialogue with the WP4 leader and Task 2.3 leader it was decided to maintain the structure as simple as possible and to use “SMART” variables, the CLD developed for task 2.2 are meant to grasp the overall current situation, not the detailed micro-environment of each case. The feedback provided by the CSC have always been adding more complexity rather than simplifying the picture, and therefore the simplest version has been considered while a more complete description could be taken up in a publication together with the corresponding CLD (Figure 22).

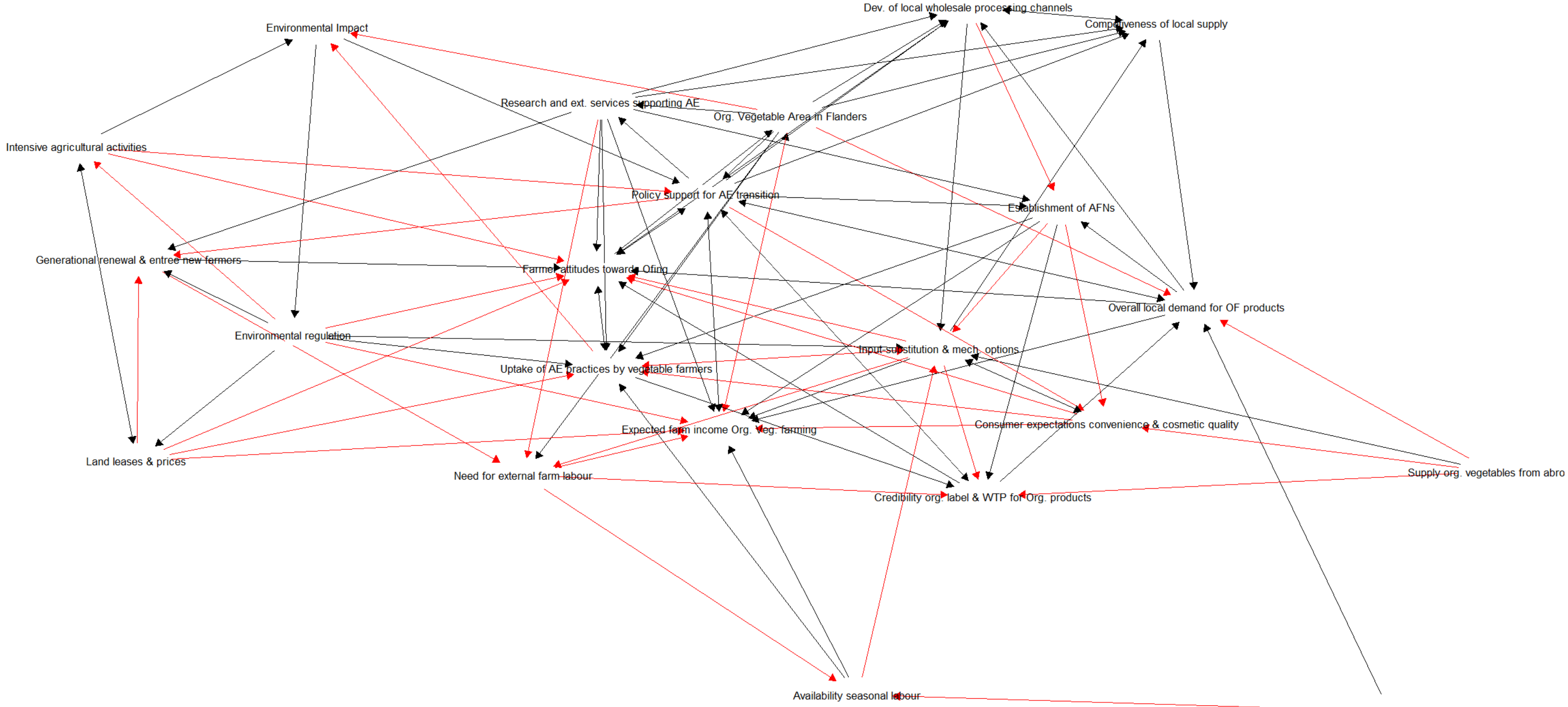


Figure 22 Detailed causal map developed by CSC for CS10

4.10.1 Final CLD for Increasing Organic Certified Vegetable Production in Flanders

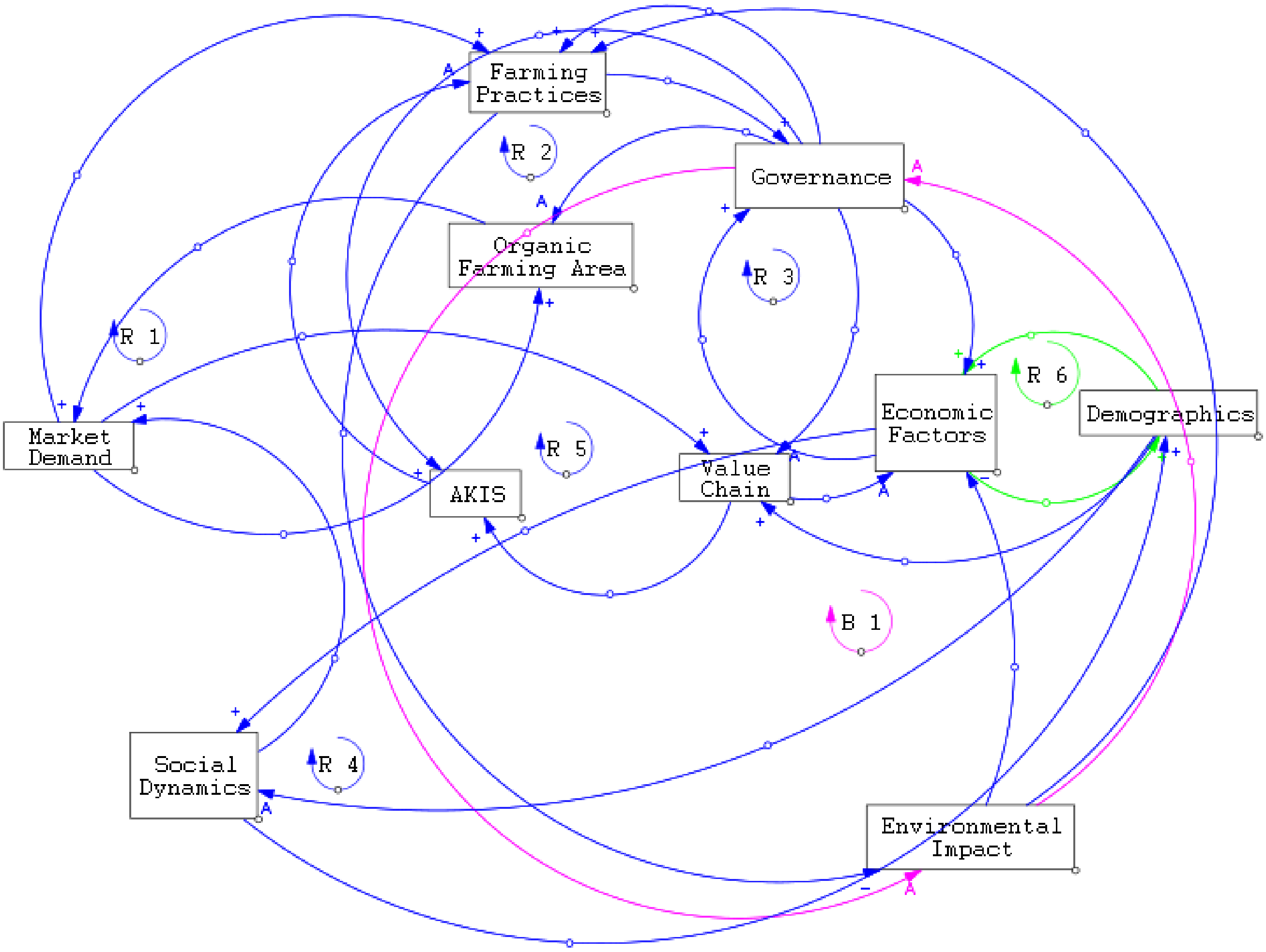


Figure 23 Final CLD for Increasing Organic Certified Vegetable Production in Belgium

4.10.2 Feedback loops

The organic vegetable sector in Flanders, though growing, faces significant challenges that require a deep understanding of these feedback loops to design effective strategies for overcoming barriers to growth. The case study aims to expand the area under organic vegetable farming, a goal that hinges on reinforcing positive feedback loops and mitigating the effects of balancing loops that could constrain progress.

The feedback loops identified in this case study highlight how various factors - ranging from market demand to governance policies - interact to influence the sector's development. For example, reinforcing loops such as the Market Demand Loop (R1) demonstrate how increased consumer interest in organic products can drive the expansion of organic farming, which in turn generates more market demand. Similarly, the Environmental Impact Loop (R2) underscores the relationship between sustainable farming practices and environmental health, creating a virtuous cycle that promotes further adoption of these practices.

On the other hand, balancing loops, such as the Governance and Environmental Impact Balancing Loop (B1), show how negative environmental outcomes can trigger stronger governance responses that eventually stabilize the system by reducing adverse impacts. These loops are essential for understanding how the sector can maintain its core principles while scaling up production.

Reinforcing loops (R):

1. **Market Demand Loop (R1):** Increased market demand for organic products leads to an expansion in the organic farming area, which further boosts market demand as more organic products become available.
   Pathway: Market Demand (MD) → Organic Farming Area (OFA) → Market Demand (MD)

2. **Environmental Impact Loop (R2):** Sustainable farming practices improve environmental outcomes. Improved environmental outcomes encourage the adoption of more sustainable farming practices. This reinforcing loop highlights the positive feedback between farming practices and environmental health.
   Pathway: Environmental Impact (EI) → Farming Practices (FP) → Environmental Impact (EI)

3. **Governance and Economic Factors Loop (R3):** Effective governance improves economic factors by creating favourable conditions for profitability and investment, which in turn supports further policy development.
   Pathway: Governance (GOV) → Economic Factors (EF) → Governance (GOV)

4. **Demographics and Social Dynamics Loop (R4):** Positive social dynamics attract younger farmers and improve the demographic composition, which in turn strengthens the social networks within the farming community**.**
   Pathway: Social Dynamics (SD) → Demographics (DEM) → Social Dynamics (SD)

5. **AKIS, Farming Practices, and Governance Loop (R5):** Advancements in AKIS improve farming practices, which influence governance to support sustainable practices. This, in turn, enhances the value chain, creating a reinforcing cycle that supports further advancements in AKIS.
   Pathway: AKIS → Farming Practices (FP) → Governance (GOV) → Value Chain (VC) → AKIS

6. **Economic Factors and Demographics Loop (R6):** Improved economic conditions attract more people to farming, positively affecting demographics, which in turn further improves economic factors.
   Pathway: Economic Factors (EF) → Demographics (DEM) → Economic Factors (EF)

7. **Governance and Environmental Impact Balancing Loop (B1):** Negative environmental impacts lead to stronger governance and policies, which reduce environmental impacts over time.
   Pathway: Environmental Impact (EI) → Governance (GOV) → Environmental Impact (EI)

8. **Economic Factors and Social Dynamics Balancing Loop (B2):** Economic stability and improved social dynamics attract more people to farming, but if economic conditions worsen, it can lead to a decline in social dynamics, balancing the loop.
   Pathway: Economic Factors (EF) → Social Dynamics (SD) → Economic Factors (EF)

4.10.3 Lock-ins

In Belgium, the adoption of organic vegetable production is constrained by both economic and governance-related lock-ins. The correlation matrix shows a strong dependency between financial barriers, such as the high cost of organic certification, and farmers' willingness to transition to organic methods. The structural equivalence analysis confirms that financial and regulatory burdens are strongly linked, where bureaucratic challenges in obtaining certification mirror the financial strain of adapting to organic standards, creating a significant lock-in.
Additionally, market access for organic vegetables remains limited, with the correlation matrix indicating that farmers who invest in organic practices struggle to access markets that offer fair prices. This market-related lock-in is reinforced by weak value chain infrastructure, as revealed in the adjacency matrix. Furthermore, the structural equivalence analysis shows that governance support for organic farming is weak, with limited policy interventions that effectively address these challenges. This governance lock-in manifests in a reluctance to invest in organic production due to the high risks and low immediate rewards, further deterring large-scale adoption.

The correlation matrix highlights the strong relationship between regulatory complexity and market access, confirming that reducing the regulatory burden could significantly ease entry into organic production. The Euclidean distance analysis shows that both financial and market-related variables are closely aligned, reinforcing the argument for integrated policy measures that address both the economic and governance aspects of these lock-ins simultaneously.

The case study identifies several lock-in conditions that hinder the growth and development of the organic vegetable sector in Flanders:

1. **Farming System Lock-ins:** The organic vegetable sector in Flanders is characterized by a biological input and biodiversity-based farming system. However, the reliance on biological inputs and the need for biodiversity conservation can limit the scalability of organic farming practices. The adoption of practices such as minimal tillage, organic robust varieties, and the conservation of natural enemies of pests is essential, but these practices require significant changes to current farming systems, which can be challenging for farmers accustomed to conventional methods.

2. **Value Chain Lock-ins:** The organic vegetable sector is primarily integrated into regional retail value chains and alternative food networks. However, these value chains are less developed than conventional commodity chains, which limits the market access and economic viability of organic vegetable producers. The lack of transparency in pricing and the strong influence of retailers on quality standards pose additional challenges to organic farmers.

3. **Governance Lock-ins:** The governance structures in the organic vegetable sector are characterized by low intentions and moderate capacity for change. This is reflected in the limited support for organic farming from both policymakers and agricultural organizations. The current policy environment, while supportive of organic farming in principle, often lacks the specific measures needed to incentivize organic vegetable production at a significant scale.

4. **Economic and Financial Lock-ins:** High land prices and competition for land use present significant financial barriers to organic vegetable farmers, particularly small and medium-sized enterprises. The lack of access to credit and financial resources further exacerbates these challenges, making it difficult for organic farmers to invest in the necessary infrastructure and technologies to expand their operations.

5. **Traditional/conventional Farming Practices:**
   Existing practices that resist change towards more sustainable methods. Farmers may be hesitant to adopt new organic practices due to familiarity and perceived reliability of conventional methods

6. **Individualistic Attitudes Among Farmers:**
   Social dynamics that discourage cooperation and collective action

7. **Regulatory Barriers:**
   Policies that hinder the adoption of organic practices due to complexity and costs associated with certification. Bureaucratic challenges and the cost of compliance with regulations can make the transition to organic farming less attractive.

8. **Economic Dependencies:**
   High costs of organic certification and production that deter farmers from adopting organic practices. Farmers' reliance on current market structures and subsidies hinders the shift to organic farming.

9. **Knowledge Gaps:**
   Limited awareness and understanding of the benefits of organic farming, which prevents farmers from transitioning to organic practices. A lack of knowledge about the benefits and techniques of organic farming can hinder its adoption.

4.10.4 Potential levers

To overcome the challenges identified above and unlock the potential of the organic vegetable sector in Flanders, the case study proposes several strategic interventions:

Business Strategies: The study suggests the formation of farmer cooperatives to enhance bargaining power and improve access to markets. By negotiating with retailers on quality standards and forming collective marketing strategies, organic farmers can improve their market position and increase their economic returns.

Policy Strategies: The case study emphasizes the importance of national strategic plans, such as the Common Agricultural Policy (CAP) and organic farming regulations, in supporting the growth of the organic vegetable sector. These policies should focus on providing financial incentives, reducing administrative burdens, and promoting research and development in organic farming practices.

Educational and Peer-Learning Strategies: The study highlights the need for increased communication of economic risks and benefits to farmers. Peer-learning initiatives, where farmers can share knowledge and experiences, are also critical for promoting the adoption of organic farming practices. These strategies can help build a more resilient and informed farming community that is better equipped to navigate the challenges of organic farming.

Infrastructure and Technological Innovations: To support the transition to organic farming, the development of cost-effective and environmentally friendly alternatives to certain inputs is essential. Investments in infrastructure, such as modern irrigation systems and precision agriculture technologies, can also help reduce the environmental impact of farming practices and improve the productivity of organic farms.

By elaborating on these data the following levers were identified:

1. **Policy Support and interventions:**

- Governance lever that can provide incentives and reduce financial burdens for adopting sustainable practices.
- Financial incentives to encourage the adoption of sustainable practices and technologies.

2. **Training (Education) and Advisory Services (AKIS):**

- Knowledge dissemination that can enhance farmer motivation and adoption of sustainable practices. Offering training programs to enhance farmers' skills in sustainable practices and digital technologies.

3. **Market Development:**

- Efforts to increase consumer awareness and demand for organic products. Utilizing market stabilization tools to ensure price stability and support for organic products.

4. **Value Chain Efficiency:**

- Improvements in the value chain to reduce costs and increase profitability for organic farmers.

5 Cross case analysis

5.1 The analysis of the variables

The variables that were found to be identical across multiple case studies based on a cosine similarity threshold of 0.8 are highlighted in Table 21. This high threshold was chosen to ensure that only variables with strong semantic and functional equivalence were grouped together. The identification of these identical variables is crucial because it allows us to streamline the CLD by merging conceptually similar variables from different case studies into single nodes. This not only reduces complexity but also enhances the clarity of the CLD, making it easier to identify systemic patterns and interactions. For example, the variable "Environmental Impact" appears consistently across several case studies, sometimes under slightly different names, such as "Environmental Impact Score." By treating these as identical, we ensure that the analysis captures a unified view of environmental concerns across different contexts, which is critical for understanding how environmental factors influence and are influenced by other system components. Similarly, the merging of variables like "Community Engagement" and "Education & Community Engagement" reflects a broader understanding of the role of societal involvement in driving sustainable practices.

Table 21 Identical variables across all cases

Variable 1	Case number	Variable 2	Case number	Cosine similarity
Community Engagement	2	**Education & Community Engagement**	4	0.8660254
Consumer Willingness to Pay	5	**Willingness to Pay**	6	0.8660254
Environmental Impact	9	**Environmental Impact Score**	7	0.8164966
Environmental Impact	5	**Environmental Impact Score**	7	0.8164966
Organic Certification Status	8	**Organic Certification**	9	0.8164966
Environmental Impact	5	**Environmental Impact**	9	1
Environmental Impact Score	7	**Environmental Impact**	10	0.8164966
Environmental Impact Score	7	**Environmental Impact**	9	0.8164966
Environmental Impact	9	**Environmental Impact**	10	1
Environmental Impact Score	7	**Environmental Impact**	5	0.8164966
Environmental Impact	10	**Environmental Impact**	5	1
Value Chain Development	5	**Value Chain**	10	0.8164966

In Table 22 are reported variables that, while not identical, exhibit significant overlap across case studies, as indicated by a cosine similarity threshold ranging from 0.5 to 0.79. These overlapping variables were clustered into generalized categories to reflect broader themes that recur across the different cases. The clustering process is essential for two reasons. First, it allows the integration of diverse terminologies and perspectives into a cohesive framework, ensuring that the final CLD is both comprehensive and representative of the variety of contexts studied. Second, by identifying and grouping these overlapping variables, we can uncover underlying systemic themes that are not immediately apparent when looking at individual case studies in isolation. For instance, the cluster "Subsidies and Financial Support" combines variables related to budget allocations for agri-environmental climate measures (AECM) at both the EU and Member State levels. This aggregation highlights the importance of financial mechanisms in driving agricultural sustainability and allows for a more nuanced analysis of how these mechanisms operate across different regions. Similarly, the cluster "Environmental and Agricultural Practices" brings together various rates of adoption for different sustainable practices, illustrating a common trend across case studies where adoption rates are influenced by a complex interplay of policy support, market dynamics, and community engagement. This clustering provides deeper insights into the factors that drive or hinder the adoption of sustainable practices, which is crucial for designing effective interventions.

Table 22 Overlapping variables based on cosine similarity across all cases by cluster

Cluster	Variable 1	Case number	Variable 2	Case number	Cosine similarity
Subsidies and financial support	EU Budget Allocation for AECM	1	Member State Budget Allocation for AECM	1	0.7302967
	EU Budget Allocation for AECM	1	Total Allocated Budget for AECM	1	0.6
	Member State Budget Allocation for AECM	1	Total Allocated Budget for AECM	1	0.5477226
	Profit	2	Farmer's Profit	7	0.7071068
	Profit	2	Economic returns	9	0.7991597
	Government Funding Support	5	Policy Support and External Funding Support	9	0.5163978
Training and education	Access to Knowledge and Expertise	1	Knowledge and Skills	3	0.5163978
	Access to Knowledge and Expertise	1	Knowledge and Skills	10	0.5163978
Consumers awareness and engagement	Market Access for Organic Products	6	Market Demand for Organic Products	8	0.7984562
	Consumer Demand for Locally-sourced and Organic Products	7	Market Demand for Organic Products	8	0.6761234
Environmental and Agricultural Practices	Rate of AECM Adoption	1	Rate of Adoption of RA	2	0.75
	Rate of AECM Adoption	1	Rate of Adoption of Organic Certification and Labelling	7	0.5669467
	Rate of AECM Adoption	1	Rate of Adoption of Farmers Practicing Direct Selling	7	0.5669467
	Rate of AECM Adoption	1	Rate of CSA Adoption	8	0.75
	Rate of Adoption of RA	2	Rate of Adoption of Organic Certification and Labelling	7	0.5669467
	Rate of Adoption of RA	2	Rate of Adoption of Farmers Practicing Direct Selling	7	0.5669467
	Rate of Adoption of RA	2	Rate of CSA Adoption	8	0.75
Market Dynamics	Demand for Machinery	2	Demand for Labor	2	0.6666667
	Demand for Machinery	2	Demand for Seeds	2	0.6666667
	Demand for Machinery	2	Market Demand for Organic Products	8	0.5163978

Cluster	Variable 1	Case number	Variable 2	Case number	Cosine similarity
	Demand for Labor	2	Demand for Seeds	2	0.6666667
	Demand for Labor	2	Market Demand for Organic Products	8	0.5163978
	Demand for Seeds	2	Market Demand for Organic Products	8	0.5163978
	Market Access	2	Market Access for Organic Products	6	0.6324555
	Market Demand for Organic Products	8	Market Demand	9	0.6324555
Certification and Regulation	Certification	5	Organic Certification Status	8	0.5773503
	Certification	5	Organic Certification	9	0.7071068
	Rate of Adoption of Organic Certification and Labelling	7	Organic Certification	9	0.5345225
	Policy and Regulatory Support with Chamber Advocacy	7	Policy Support and External Funding Support	9	0.5070926
Supply Chain Management	Value Chain Development	5	Short Supply Chain Development	7	0.5773503
	Short Supply Chain Development	7	Supply Chain Efficiency	9	0.5773503

The list of variables after the merging is available in Annex 2.

5.2 Identified Common Lock-ins

The analysis of the ENFASYS project's 10 case studies uncovered a range of barriers, each deeply tied to its specific context. These barriers, categorized in the data collection phase (Task 2.1) as economic dependencies (or financial barriers), regulatory/organizational barriers, cultural practices, technological lock-ins, market conditions, and knowledge gaps, were thoroughly assessed to identify common patterns. However, the diversity among the case studies made it challenging to group these barriers together, as many were unique to their particular environments. This highlights the complexity of moving toward sustainable farming across different regions in Europe. Table 23 summarises the specific lock-ins for each case study clustered in the categories defined by task 2.1.

Table 23 Context specific Lock-ins

Case Study	Economic Dependencies	Regulatory Barriers	Cultural Practices	Technological Lock-ins	Market Conditions	Knowledge Gaps
France & Belgium	Strong reliance on EU and state subsidies, with reduced support per farmer as adoption increases.	High compliance and administrative costs deter adoption despite subsidies.	Resistance to changing traditional farming methods; cultural openness and environmental awareness are critical.	Limited advisory services and knowledge dissemination hinder adoption	Weak market demand for eco-scheme products limits growth beyond subsidies.	insufficient knowledge and training on AECMs, exacerbated by lack of effective advisory support. Insufficient knowledge and training on AECMs, exacerbated by

Case Study	Economic Dependencies	Regulatory Barriers	Cultural Practices	Technological Lock-ins	Market Conditions	Knowledge Gaps
						lack of effective advisory support.
Serbia	Dependency on subsidies for CAP compliance	Inconsistent regulations; lack of supportive policies	Cultural attachment to traditional practices; low social acceptance	Demand for specialized machinery not locally available.	Limited market access for regenerative farming products	Insufficient knowledge and expertise about regenerative practices
Switzerland	Financial incentives drive biodiversity practices but create economic dependencies	Cultural resistance to biodiversity-friendly practices	Knowledge and skills gaps in biodiversity management hinder adoption	Limited access to biodiversity-specific technologies	Market development for biodiversity-friendly products is slow	Lack of specific knowledge and skills in biodiversity management
France	Dependency on global soy markets due to the higher profitability of cereal cultivation over domestic legume production	Inconsistent and irregularly implemented protein plans, external factors like European market dynamics and geopolitical crises impacting farming stability	Influence of large food sellers reducing farmer autonomy; resistance to legume-based production due to cultural preferences	Reliance on established conventional farming methods, resistance to adopting new sustainable practices	Vulnerability to global market fluctuations affecting income stability; lack of local supply chain support for legumes	Limited awareness and understanding of the benefits of sustainable practices and local feed sources.
Germany	Strong reliance on subsidies and external funding mechanisms; fragmented value chains limit profitability.	Certification and regulatory complexities, including stringent animal welfare and environmental standards, increase costs and slow adoption.	Resistance to adopting sustainable practices due to conventional methods and long-standing farming traditions.	Lack of technological infrastructure for sustainable practices, such as regional feed production and updated stables.	Market volatility and pricing pressures from large retailers reduce the incentive for sustainable production.	Limited awareness and advisory services on the benefits and costs of regional production and sustainable practices
Greece	Dependence on subsidies for shifting to sustainable practices	Fragmented regulatory frameworks across the EU	Traditional practices contributing to soil erosion and water scarcity	Limited access to sustainable technologies	Market access challenges due to consumer mistrust and high costs	Gaps in training and knowledge dissemination about sustainable practices
Slovenia	Financial risks in small-scale direct selling operations; investment in infrastructure	Weak regulatory support for small-scale operations	Reluctance to cooperate in small-scale farming models; generational shifts	Weak technological support for direct selling; limited access to modern selling technologies	Geographical limitations in market access	Knowledge gaps in direct selling methods
Italy	High rent costs limiting	Land tenure issues with	Low/fluctuations in community	Outdated and expensive	Volatile demand for	Insufficient training and

Case Study	Economic Dependencies	Regulatory Barriers	Cultural Practices	Technological Lock-ins	Market Conditions	Knowledge Gaps
	financial flexibility; membership fee dependency	municipal leases; inadequate policy support	engagement in CSA practices; heavy reliance on community	machinery; high maintenance costs	organic CSA products; membership volatility	development opportunities for CSA members
Ireland	High dependency on subsidies for organic farming conversion	Regulatory barriers to organic certification	Slow adoption of organic practices within traditional farming communities	Conventional dairy infrastructure not aligned with organic farming needs	Market demand volatility for organic dairy products	Insufficient knowledge and advisory services on organic practices
Belgium	High costs of certification for organic farming	Regulatory complexities in organic certification	Resistance to shift from conventional to organic farming	Dependence on conventional farming technologies	Limited market access for organic vegetables	Gaps in knowledge about organic farming techniques

The initial step in the analysis involved aggregating all lock-ins from the ten case studies into a single list. This aggregation was used to identify unique lock-ins across the entire dataset. By unifying these lock-ins, we established a comprehensive set of variables representing the diverse barriers within the food systems under study. A presence-absence matrix was constructed to determine the occurrence of each unique lock-in across the ten case studies. In this matrix, each row represented a unique lock-in, and each column corresponded to a case study. A binary value was assigned to each cell, indicating the presence (1) or absence (0) of a specific lock-in in each case. This matrix served as the foundation for subsequent frequency analysis. The frequency of each lock-in across the case studies was calculated by summing the presence values across all cases. This step allowed us to quantify how widespread each lock-in was across the different case studies. The frequency data provided insight into which lock-ins were common across multiple contexts, revealing systemic issues that may be prevalent across various agricultural and food systems. To identify the most significant lock-ins, a threshold was established, defining a "common" lock-in as one that appeared in at least five out of the ten case studies. Lock-ins meeting this threshold were considered to represent systemic barriers that are likely to affect multiple regions or contexts. These common lock-ins were highlighted as critical areas for targeted interventions aimed at breaking systemic barriers to sustainable transitions. The frequency data were visualized using bar plots, which provided a clear depiction of the prevalence of each lock-in across the case studies. Separate visualizations were created for all lock-ins and specifically for those deemed common based on the established threshold. These visualizations facilitated the interpretation of the data, allowing for a more intuitive understanding of the distribution and impact of various lock-ins (Figure 21).

The analysis revealed that certain lock-ins, such as "Market Demand," "Subsidies," and "PolicySupport," were consistently present across multiple case studies, indicating their widespread influence on the sustainability of food systems. These common lock-ins highlight systemic issues that transcend individual contexts and suggest areas where coordinated policy interventions could be particularly effective.

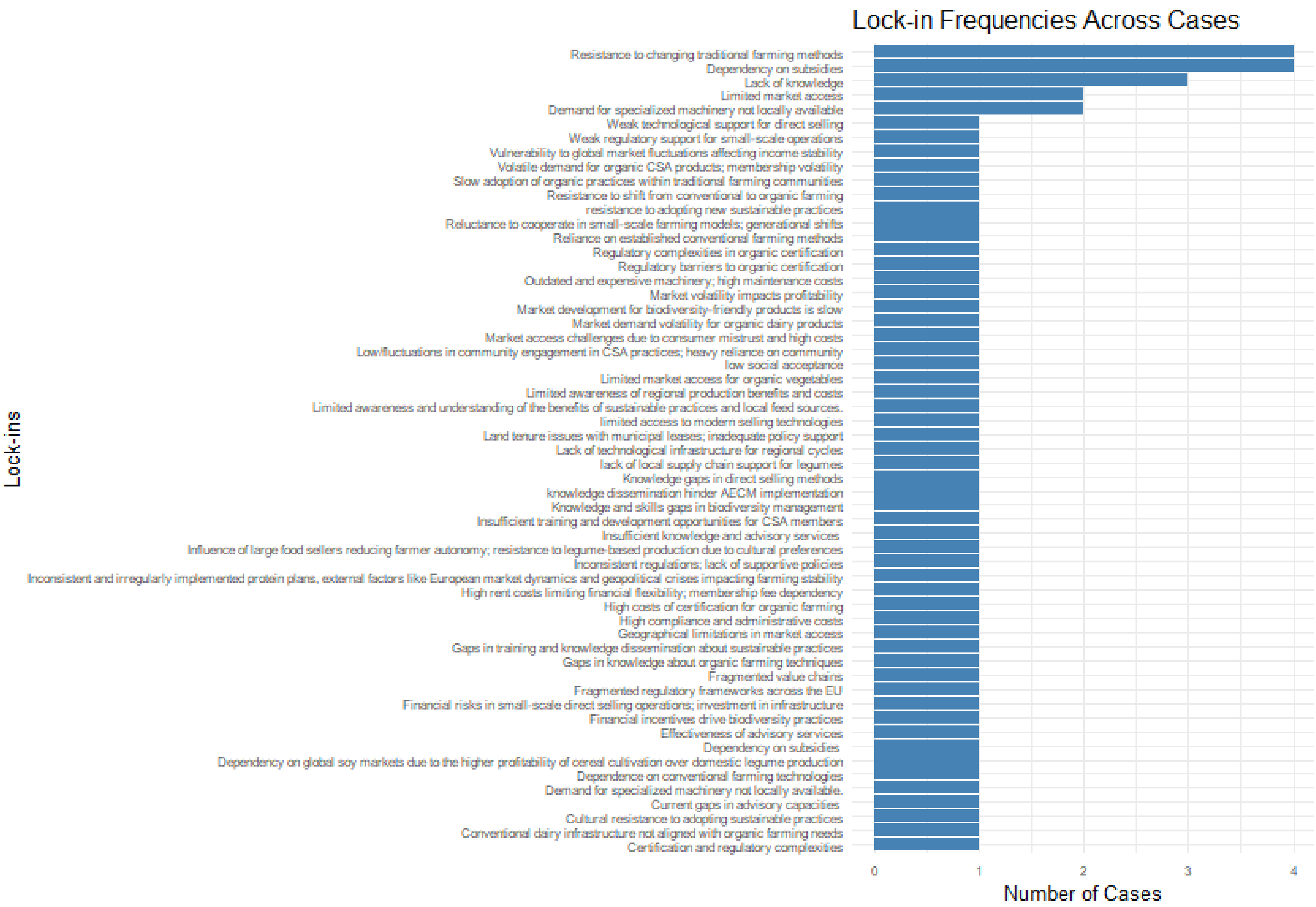


Figure 24 Frequency of lock-ins across cases

1. **Economic Dependencies**

The reliance on financial subsidies is a critical factor for sustaining eco-schemes, organic farming, and regenerative agriculture across various regions, as observed in France, Belgium, Serbia, and Ireland. These subsidies are essential for maintaining sustainable agricultural practices, and without them, it would be exceedingly difficult for farmers to continue such efforts. Additionally, the high costs associated with certification or conversion to sustainable practices present a significant barrier, particularly in organic farming and biodiversity adoption. This issue is prominently seen in Belgium, Ireland, and Switzerland, where the financial burden of certification deters broader adoption of sustainable methods.

2. **Regulatory Barriers**

The complexity and expense of certification processes, especially in organic farming, have been identified as major obstacles to the widespread adoption of sustainable practices. This challenge is evident in regions such as Belgium, Ireland, and Serbia, where complicated regulatory frameworks hinder progress. In Serbia, compliance with the Common Agricultural Policy (CAP) further exacerbates these challenges. Moreover, issues related to land tenure and security, as seen in Italy's Community Supported Agriculture (CSA) sector, create uncertainty and impede long-term sustainability planning. The inability to secure long-term land leases restricts the capacity of CSAs to invest in sustainable practices, leading to instability in agricultural planning.

3. **Cultural Practices**

Cultural factors significantly influence the adoption of sustainable agricultural practices. In France, Belgium, Germany, and Serbia, a deep-rooted attachment to traditional farming methods creates resistance to change, slowing the transition to more sustainable practices. This cultural inertia is further compounded by perception issues, particularly in Switzerland, where biodiversity-friendly practices are often viewed as untidy or less productive. Such perceptions contribute to the reluctance among farmers and the public to embrace sustainable methods, despite their long-term benefits.

4. **Technological Lock-ins**

Technological barriers also play a crucial role in hindering the adoption of sustainable practices. In regions like Serbia, Greece, and France, limited access to modern, sustainable technologies prevents farmers from optimizing their agricultural methods. This technological gap is further exacerbated by outdated infrastructure, particularly in Italy and Belgium, where the lack of modern facilities hampers the processing and implementation of sustainable practices. These technological lock-ins create significant challenges for regions striving to adopt and maintain sustainable agricultural systems.

5. **Market Conditions**

Market conditions present another set of challenges for sustainable agriculture. In countries such as Slovenia, Italy, and France, limited market access for sustainable products, including those from eco-schemes and Community Supported Agriculture (CSA), makes it difficult for these practices to be economically viable. The underdevelopment of markets for regenerative and sustainable products creates financial uncertainty for farmers. Additionally, market volatility, as observed in Germany and Ireland, further undermines the profitability and appeal of adopting sustainable practices. The instability of markets creates a risk-averse environment where farmers are hesitant to invest in sustainability due to uncertain returns.

6. **Knowledge Gaps**

Finally, knowledge gaps significantly impede the transition to sustainable agriculture. In Switzerland, Ireland, and Belgium, the lack of sufficient training and education on sustainable practices, such as organic farming and biodiversity management, slows down the adoption of these methods. The absence of comprehensive educational programs and resources means that many farmers are not equipped with the necessary skills and knowledge to implement sustainable practices effectively. Addressing these knowledge gaps is crucial for enabling a broader and more successful transition to sustainability in agriculture.

5.3 Potential levers for transformation

During the analysis of the potential levers for transforming agricultural practices towards sustainability, it became clear that these levers were deeply rooted in the unique challenges and conditions of each region. This means that what works well in one area might not be as effective in another, making it difficult to find common solutions across the different case studies we examined. The result of the mathematical analysis corroborated this initial assessment.

It would have been possible to harmonise the text of the levers but doing so would have resulted in a total loss of their specific traits.

The agricultural systems within the ENFASYS project are shaped by a mix of local factors, including economic conditions, regulatory frameworks, cultural practices, technological access, market dynamics, and community involvement. These factors were suggested in the data collection phase of task 2.1 and were used here to cluster the different actions fostering transformation. As a result, these broader categories are used to make the data (i.e. the list of interventions) more "SMART" without losing their individuality as strategies that might work well in one place might not be as relevant or effective elsewhere. E.g., in France and Belgium, simplifying the application and compliance processes for eco-schemes is crucial because the current high administrative burden is a major roadblock to sustainability while in Serbia, the focus is on improving advisory support and aligning regulatory frameworks to better support regenerative agriculture. This difference highlights how important it is to tailor interventions to the specific needs and challenges of each region.

Financial incentives also vary widely depending on the local context. In Switzerland, offering financial incentives for biodiversity measures is key to promoting locally adapted biodiversity-friendly practices while in France's push for protein autonomy, subsidies for local feed sources are essential to reduce reliance on imported feed. These examples show how financial strategies need to be carefully crafted to address the specific economic dependencies and market conditions of each region.

Education and training needs are also diverse, for example in Slovenia there's a strong need to train farmers in digital marketing to help them connect with consumers, while in Switzerland, the focus is on training farmers and advisors in biodiversity management to overcome cultural resistance. These differences reflect the various knowledge gaps and cultural barriers that exist in different agricultural systems, requiring customized educational approaches.

Technological innovation is another area where local context is crucial. For example, in Greece, developing technological solutions that reduce the need for fertilizers is particularly important given the country's specific agricultural practices and environmental challenges. In Italy, however, investing in modern machinery for Community Supported Agriculture (CSA) is necessary to address outdated infrastructure that stands in the way of sustainable practices. Market development and community engagement are also heavily influenced by regional dynamics. In Slovenia, developing short food supply chains is essential to improve market access for direct-selling farmers, while in Italy, fostering greater community involvement in CSA initiatives is key to stabilizing and growing these sustainable models. These differences highlight the need for market and community strategies that resonate with local conditions and values.

Table 24 Context specific levers for transformation

Case Study	Policy Interventions	Financial incentives	Education & Training	Technological innovations	Market Development	Community Engagement
France& Belgium	Streamline application and compliance processes	Align financial incentives with the actual needs of farmers, cover costs and risks	Invest in expanding the capacity and capability of advisory services	Support technological adaptations that comply with AECM standards	Raise environmental awareness about the benefits of AECM practices	Integrate AECM benefits with local cultural values, utilize local champions.
Serbia	Improve advisory support, align regulatory frameworks	Increase financial subsidies and grants to lower initial adoption costs	Provide necessary skills for RA, enhance availability of training programs	Support the development of RA-specific machinery and technologies.	By raising consumer awareness, enhance the market demand for RA products.	Develop programs integrating RA benefits with local cultural values.
Switzerland	Promote locally adapted biodiversity-friendly practices	Provide financial incentives for biodiversity measures	Train farmers and advisors on biodiversity management	Support adoption of site-specific biodiversity technologies	Develop markets for biodiversity-friendly products	Engage local stakeholders, including farmers and biodiversity advisors

Case Study	Policy Interventions	Financial incentives	Education & Training	Technological innovations	Market Development	Community Engagement
France (protein autonomy)	Support policies promoting protein autonomy in livestock farms	Provide subsidies for local feed sources and market stabilization tools	Enhance training on legume cultivation and sustainable agriculture practices	Invest in infrastructure for local feed production	Promote local protein sources, reduce dependency on imported feed	Build community support through education and local engagement initiatives
Germany	Simplify regulations for animal welfare and environmental certifications, streamline approval processes for modular stables	Increase subsidies, grants, financial support for upgrading to sustainable infrastructure, including modular system-based stables and regional feed production.	Provide regular training and advisory services on sustainable practices, including animal welfare and feed production benefits	Invest in regional technologies for regional feed production, modern stables, and sustainable faming systems: research sustainable feed alternatives like local legumes.	Develop a regional quality label for sustainably produced pork, create commercial agreements with retailers for long-term price guarantees.	Strengthen collaboration among key stakeholders to foster collective action; promote consumer awareness campaigns about sustainable faming benefits.
Hellas	Encourage adoption of sustainable practices via consumer brands	Offer financial incentives through consumer brand collaborations	Provide training on sustainable practices for farmers	Support technological solutions that reduce the need for fertilizers	Leverage consumer demand for sustainable products	Engage consumers and local communities in promoting sustainable agriculture
Slovenia	Simplify direct selling regulations	Provide financial incentives for infrastructure development.	Train farmers in digital marketing	Adopt digital marketing tools to increase consumer engagement.	Develop short food supply chains to boost market access. Improve infrastructure (e.g., labelling, storage, delivery).	Foster trust-building initiatives among farmers. Strengthen advisory services for collaboration
Italy	Support long-term land leases	Negotiate lower land rents Diversify income sources beyond membership fees.	Increase access to training for CSA members Educate the community on CSA benefits.	Invest in modern CSA machinery	Promote health and environmental benefits of CSA organic products to increase demand.	Organize community events to boost engagement and volunteer support
Ireland	Enhance government support and subsidies for organic conversion	Increase financial subsidies and grants for organic farming	Expand training and advisory services to support organic practices	Invest in organic processing facilities and infrastructure	Promote Irish organic dairy products through marketing and branding campaigns	Strengthen networks among organic farmers to facilitate knowledge sharing
Belgium	Reform policies to support organic farming	Provide financial incentives for organic	Increase training and education on sustainable	Support technological solutions for sustainable farming	Develop markets for organic vegetables by leveraging	Engage local communities and farmers in organic

Case Study	Policy Interventions	Financial incentives	Education & Training	Technological innovations	Market Development	Community Engagement
		certification and production	farming techniques		consumer demand	production practices

Policy Interventions:

Introducing supportive regulations and incentives for sustainable practices is fundamental for driving change in the agricultural sector. Reforming existing agricultural policies to align with sustainability goals can create an enabling environment where sustainable practices become the norm rather than the exception. By setting clear regulations and offering incentives, policymakers can encourage farmers to adopt practices that are environmentally friendly, economically viable, and socially responsible. This alignment is essential for achieving national and EU-wide sustainability targets. For example, reducing the bureaucratic complexity of accessing CAP benefits could help farmers in Serbia more easily transition to regenerative practices.

Financial Incentives:

Subsidies and financial support are critical for helping farmers transition to sustainable technologies and practices. The high initial costs of adopting sustainable methods can be a significant barrier for many farmers. Financial incentives can lower these barriers, making it economically feasible for farmers to invest in sustainability. In France and Belgium, aligning financial incentives with eco-schemes could encourage farmers to shift away from high-input cereal farming. Additionally, developing new business models that promote economic viability for sustainable farming ensures that farmers can maintain profitability while implementing environmentally friendly practices. These financial measures are crucial for fostering long-term adoption and success.

Education and Training:

Education and training programs play a pivotal role in transforming agricultural practices. Farmers and stakeholders need to understand the benefits of sustainable practices and how to implement them effectively. Community-based workshops and extension services are excellent tools for disseminating this knowledge. By providing hands-on training and continuous support, these programs can empower farmers to make informed decisions that benefit both their livelihoods and the environment. Building a knowledgeable and skilled farming community is essential for sustained transformation. In Switzerland, training programs that focus on biodiversity management could help overcome cultural resistance to adopting sustainable practices.

Technological Innovations:

Access to advanced, sustainable agricultural technologies can significantly enhance productivity and environmental performance. Investing in research and development for sustainable farming solutions ensures that farmers have the tools and technologies needed to practice sustainable agriculture. Innovations such as precision farming, renewable energy applications, and sustainable irrigation systems can reduce resource use and increase efficiency. By adopting these technologies, farmers can achieve higher yields with lower environmental impacts. In Greece, for example, supporting the development and distribution of technologies that reduce fertilizer dependency could help farmers transition to more sustainable practices.

Market Development:

Creating local and regional markets for sustainably produced goods is vital for supporting sustainable agriculture. These markets provide farmers with reliable outlets for their products, ensuring fair prices and stable incomes. Promoting consumer awareness and demand for sustainable products is also crucial. When consumers understand the benefits of sustainably produced goods and are willing to pay a premium for them, it creates a strong market pull that encourages more farmers to adopt sustainable practices. This market development is essential for building a robust and resilient food system. In Slovenia, developing infrastructure for short food supply chains could enhance the economic viability of direct-selling farmers.

Community Engagement:

Encouraging community-supported agriculture (CSA) and cooperative models can strengthen local food systems and promote sustainability. In Italy, for example, fostering greater community engagement in CSA initiatives could help stabilize and grow these sustainable models. Engaging local communities in sustainable farming initiatives fosters a sense of ownership and responsibility towards the environment. CSAs and cooperatives can also provide mutual support and resources, helping farmers overcome individual challenges. Community engagement is key to creating sustainable food systems that are rooted in local needs and values.

6 Synthesis of findings and Conclusions

6.1 Synthesis of Findings on Lock-ins and Levers

The analysis of the case studies has revealed a complex web of systemic lock-ins hindering the transition to sustainable farming systems across Europe. These lock-ins include economic dependencies, regulatory barriers, cultural practices, technological constraints, and market access issues. The identified common lock-ins underscore the deep rooting of conventional farming practices within the current agricultural framework, creating significant barriers to the adoption of sustainable methods.

The distinction between "barriers" and "lock-ins" was emphasized during the analysis. Barriers refer to specific, concrete aspects that directly impede innovation, such as high costs, lack of infrastructure, or regulatory challenges. In contrast, lock-ins are situations where multiple interconnected barriers create a more complex and difficult environment for change, effectively trapping stakeholders within the existing system.

The aggregated data from the ten case studies revealed over 400 identified barriers, which were fairly evenly distributed across the different categories. These barriers were predominantly found at the farm level, indicating that the primary challenges to innovation often originate at the very foundation of agricultural systems. For instance, the German pork sector is currently facing significant challenges, primarily due to high investment costs coupled with low returns. The barriers identified in this sector include the constantly evolving legal requirements, which add uncertainty and compliance costs for farmers, and a lack of consumer willingness to pay premium prices for higher-quality pork. Additionally, the sector suffers from inadequate regional slaughtering capacity and the long-term nature of the conversion process, which further complicates efforts to implement more sustainable practices.

Similarly, in the case of implementing biodiversity objectives and environmental schemes in France and Belgium, several critical barriers were highlighted. These include limited flexibility for regional actors due to the constraints imposed by national policy frameworks, a lack of sufficient financial resources to design and implement sustainable farming practices, and inadequate advisory support and skills related to agri-environmental practices. These barriers collectively hinder the effective realization of biodiversity goals in these regions.

In the case of the organic dairy sector in Ireland, its growth is impeded by a range of barriers, most notably the high perceived risks and switching costs for conventional dairy farmers considering conversion to organic practices. This sector also faces a lack of critical processing and distribution infrastructure, which is essential for supporting organic dairy production. Additionally, there is a deficiency in advisory support and knowledge about organic dairy farming, making it difficult for farmers to transition smoothly.

In Flanders, Belgium, the sustainable growth of organic vegetable farming is instead challenged by high land prices and a dependence on short-term leases, which create instability for farmers. Additional barriers include the perceived high switching costs and production risks, an aging farmer population, and a shortage of affordable labour. The market for organic vegetables is also characterized by tight margins and a lack of transparency, further exacerbating the challenges. There is also insufficient investment in ecological innovation, which is necessary to drive long-term sustainability in this sector.

The findings from tasks 2.1 and 2.2 underscore the significant systemic lock-ins that impede the transition toward sustainable agricultural practices across various regions. Economic dependencies, such as the reliance on high-input, conventional farming methods supported by subsidies, present a formidable barrier to adopting regenerative practices. In Serbia, the fear of financial losses from abandoning chemical inputs makes the shift to sustainable farming particularly challenging. Regulatory and political barriers also play a critical role in hindering progress. In countries like France and Belgium, the cumbersome procedures and high compliance costs associated with eco-schemes deter farmers from adopting biodiversity-friendly practices. Similarly, deep-rooted cultural practices and knowledge gaps contribute to resistance to change, as seen in Switzerland, where traditional farming methods dominate despite governmental efforts to promote more sustainable practices.

Technological constraints exacerbate the situation, particularly for smallholder farmers who lack access to modern, sustainable technologies and extension services. This is evident in Slovenia, where direct-selling farmers struggle with outdated infrastructure and limited digital tools, impacting their ability to expand their markets. Market constraints also pose significant challenges, as farmers often face difficulties in accessing markets for sustainably produced goods, as illustrated by the struggles of CSA farmers in Italy.

A key observation is that these systemic lock-ins while pervasive, manifest differently depending on the regional context and the specific agricultural practices involved. For instance, economic dependencies on high-input, conventional farming methods, supported by subsidies, are particularly challenging in regions like Serbia, where farmers heavily rely on chemical inputs. The fear of financial losses if these inputs are abandoned makes the shift to regenerative farming difficult. Similarly, regulatory frameworks often favour large-scale industrial agriculture, imposing significant administrative burdens on farmers. This is evident in France and Belgium, where the cumbersome procedures and high compliance costs associated with eco-schemes slow the adoption of biodiversity-friendly practices. Cultural and knowledge barriers further complicate the transition. In Switzerland, for instance, deeply rooted traditional farming practices dominate, and despite government efforts to promote biodiversity-friendly practices, the strong attachment to tradition results in lower-than-expected uptake. Technological constraints also play a significant role, particularly for smallholder farmers who lack access to sustainable technologies and extension services. In Slovenia, direct-selling farmers struggle with outdated infrastructure and limited access to digital marketing tools, which hinders their ability to expand their reach and profitability. Market constraints add another layer of difficulty, as farmers often face significant challenges in accessing markets for sustainably produced goods. In Italy, for example, farmers involved in Community Supported Agriculture (CSA) struggle to expand their clientele due to limited public awareness of organic products and difficulties in securing long-term land leases.

This interlinked nature of lock-ins suggests that isolated interventions may be insufficient for driving systemic change. Instead, a holistic approach that addresses multiple lock-ins simultaneously is necessary to facilitate the transition to sustainable farming systems in line with the ENFASYS overall scope.

Beyond these common lock-ins, the analysis also highlights context-specific challenges shaped by local conditions. For instance, in Serbia, the focus is on mitigating soil degradation caused by intensive agriculture, while in Ireland, the challenge lies in growing the organic dairy sector despite the dominance of conventional dairy production. In Germany, efforts to create sustainable pig farming systems are hampered by limited regional market cycles, which restrict the development of more sustainable practices. Despite these challenges, the study identifies several potential levers that could drive the transition toward sustainability. Policy reform is a key lever, with a need to reorient agricultural subsidies toward sustainability goals. For instance, policy adjustments in Belgium to simplify access to organic certification and provide more accessible financial incentives have proven effective in increasing the rate of organic vegetable production. Financial incentives are also critical, as they can encourage farmers to adopt sustainable land management practices. In Serbia, for example, farmers transitioning to regenerative agriculture require European Union and national subsidies to cushion the high costs of moving away from conventional practices.

Education and extension services are vital tools for promoting sustainable practices. In Switzerland, expanded extension services focused on biodiversity management have helped increase the adoption of locally adapted, biodiversity-friendly practices among farmers. Technological innovation is another crucial lever; in Greece, new technological solutions are being sought to reduce the carbon footprint of agriculture as part of broader efforts to meet EU sustainability goals. Market development is essential for consolidating local and regional markets for sustainably produced goods. In Slovenia, the promotion of direct sales has been supported by an enhanced infrastructure for short food supply chains, thereby boosting the market for local produce. Finally, community engagement and stakeholder collaboration are pivotal for ensuring the successful delivery of sustainable products. In Italy, the success of CSAs is largely attributed to strong community involvement, which provides a stable customer base for organic products through high volunteer support. Market development is another key area, with the need to strengthen local and regional markets for sustainably produced goods. Community engagement and stakeholder collaboration are essential for ensuring the successful delivery of these products. In Italy, for example, the success of CSAs is largely due to strong community involvement, which provides a stable customer base for organic products.

Policy reform emerges as a crucial lever, with the need to reorient subsidies toward sustainability goals. Financial incentives are also critical, as they can make sustainable practices more appealing to farmers. Education and extension services play a vital role in spreading knowledge and promoting sustainable practices, while technological innovation offers new solutions to reduce the carbon footprint of agriculture.

6.2 Strategic approach for transitioning and conclusions

Given the interconnected nature of the lock-ins identified, several strategic approaches can support the transition to sustainable farming systems. In line with the findings on the common levers, identifying policy reform as pivotal, a key focus is on comprehensive policy reform that aligns agricultural practices more closely with sustainability goals. This may involve revising subsidy structures to favour sustainable methods, simplifying regulatory frameworks to ease the administrative burden on farmers, and fostering innovation through the development of supportive frameworks. Addressing economic dependencies is crucial, and targeted financial strategies could play a significant role. These might include financial support to cover the initial costs of transitioning to sustainable practices, along with continued assistance to ensure long-term viability.

Bridging knowledge gaps is another critical area, which could be achieved through comprehensive education and training initiatives for farmers. These programs would ideally highlight the benefits of sustainable farming practices and provide practical guidance tailored to specific regional contexts to maximize their effectiveness. Investment in the research and development of sustainable agricultural technologies is also essential. Supporting initiatives that make these technologies accessible and affordable could encourage the adoption of precision farming, renewable energy applications, and sustainable irrigation systems, all of which have the potential to enhance productivity while reducing environmental impacts. Developing local and regional markets for sustainably produced goods is vital to ensuring the economic viability of sustainable practices. Strategies could focus on raising consumer awareness about the benefits of these products, creating demand through marketing efforts, certification schemes, and infrastructure that supports direct selling and shorter supply chains. Finally, fostering community engagement is critical for the success of sustainable farming initiatives. Supporting community-based agriculture models, such as Community Supported Agriculture (CSA) and cooperatives, can help build a sense of ownership and responsibility among local communities, which is key to achieving long-term sustainability.

The transition to sustainable farming systems is a complex and multifaceted challenge that requires coordinated efforts across multiple levels of governance, from local communities to the European Union. The findings of this report highlight the deeply entrenched nature of conventional farming practices and the systemic lock-ins that prevent change. However, by adopting a holistic approach that addresses these lock-ins in a coordinated manner, significant progress can be made towards achieving sustainable agricultural systems.

The analysis of the case studies has provided valuable insights into the specific barriers and lock-ins that hinder the advancement of sustainable agriculture practices across different regions and sectors. The findings underscore the need for targeted interventions that address both the immediate barriers and the more complex lock-ins that entrench existing practices. Moving forward, the project will focus on developing strategies to influence behaviour, business practices, and policy frameworks in ways that can overcome these obstacles. The next phases will involve continued collaboration with stakeholders to refine these strategies and implement solutions that can foster innovation and sustainability in agriculture.

Ultimately, the transition to sustainable farming is not just an environmental necessity but also an economic and social imperative. By addressing the systemic barriers identified in this report, we can build a food system that is capable of meeting the challenges of the 21st century, ensuring food security, environmental sustainability, and economic viability for future generations.

7 Annex 1

WP2 template for reporting and relevant outputs

ENFASYS WP2 - Reporting and outputs from data collection

WP2 template for reporting and outputs

Case study number: CS coordinator name: Country:

Introduction: How to use this file

This template is provided to CS coordinators for reporting actions, gathering the relevant data and elaborating outputs. The outputs requested in the context of WP2 can be useful for the Case Studies themselves since they will allow characterize their situation; for WP2 partners who are in charge of the cross-case study analysis; as well as for other WPs (WP3, WP4).

The CS coordinators are invited to gather the data and reporting actions all along the WP2 data collection in this reporting template. The document should be stored in the Teams WP2 folder 'CS data collection for WP2' link to folder below: this way one can review it at any time and be inspired by other CSs.

>> Link to the WP2 data collection folder.

Table of contents

Part 1. Reporting of data collection efforts

R1. Effective actions you have done for collecting data

Please list here the effective actions you have done for collecting data

Data collection step	Actions	Number / details	Comments
Step 1	Number of experts interviewed*:		
Step 2	Number of in-depth interviews:		
Step 3	Number of focus groups:		
	number of participants:		
Step 4	Online survey modalities of distribution:		
	Number of respondents:		

*(please provide details in the list below).

R2. List the grey literature references that you have used

List the grey literature references that you have used for Step 1/can be useful for further data collection.

Add lines as much as necessary

Authors	Title	Date	Topic

R3. List of actors engaged in the survey

List of actors engaged in the survey

Add lines as much as necessary

Step of the survey (Step 1 to Step 4)	Name	Last name	Email	Consent to use data was checked (Yes/no)	Organization	Category of the actor*

*Categories: Inputs providers; Financial institutions: Banks or; insurance & risk management services; Farmers, farmworkers and farmers unions/organizations; agribusinesses (Collectors, Logistics, food Processing industry; distribution/retail and marketing actors; Consumers, citizens and voters; Public sector/government institutions; research/scientific organizations and education; Civil society organizations or NGOs.

Output A1. Case Study description/framing

Update the table if necessary, and further describe each aspect.

Table A1. Overview of your Case Study (here Case Study 1 as an example).

		CASE 1	update for your CS
Objective		facilitating uptake eco-schemes by cereal farmers in France	
Partner		UCL	ABE
local stakeholders taking initiative		Intercereales cooperative	Pioneer movement of regenerative farmers
Pedo-climatic zone		Atlantic	Panonian
Region, Country		FR	Vojvodina, Serbia
Type of commodity/sector		cereals	arable crops
Farm size		large industrial farms	family small and medium farms
Practices to be scaled up/maintained		greening measures on arable land	
Benefits		climate, biodiversity, resource use, ghg	
Lock-in Cond,	**Farming system**	chemical input based	
	value chain	global commodity markets	
	governance	high capacities, moderate/hight intensions	
Lock-in Solutions	**business side strategies**	increase sustainability of weat value-chain at national level	
	policy side strategies	national policies, certification and lobbying on CAP	
	Other strategies		
Stage in transition		initiated to medium	

Provide complementary information on the following topics.

Table A2. Detailed description of the Case Study

		Complementary information about your CS
biophysical and social geography of the CS territory.		
	Relevant information such as climate, elevation, soil types, naturally occuring ecosystems, spread of agricultural sectors	
	population densitiy, average income, main employment opportunities, main demographic trends	
	Economic trends	
	Other key information	
Current farming sector		
	Number of farmers	
	What agricultural commodities do they produce conventional/organic/transitioning to organic/agroecological?	
	Size of farms:	
	average per farm?	
	Variability among farms?	
	small-scale/large-scale	
	size of land in ha / number of animals in the herd:	
	total within the CS region?	
	average per farm?	
	Variability among farms?	
	volume of production (with unit)	
	total within the CS region?	
	average per farm?	
	Variability among farms?	
	Other key information	

What are the problems with the current farming practices in relation to the four capitals:		
	Current practices?	
	Problems related to the Natural Capital (e.g. soil health, water availability, pest and disease control, biodiversity)?	
	Problems related to the Social Capital (I.e. networks, relationships, and institutions that support agricultural production, such as farmer organizations, extension services, and local markets.)	
	Problems related to the human Capital (I.e. related to the skills, knowledge, and health of the people involved in agricultural production)	
	Problems related to the Financial Capital (I.e. financial resources available to support agricultural production, such as savings, loans, and investments.	
	Other key information	
What are the farming practices that the CS aims at having a higher and more robust uptake of among farmers:		
	Desired practices to be encouraged through the CS?	
	indicator to measure progress (e.g. average use of Pesticide per ha)	
	Specific infrastructure, buildings and machinery used or needed	
	How would the increased uptake of these practices be part of a just and robust transition to sustainable, productive, climate-neutral, biodiversity friendly and resilient farming systems?	
	What are the ambition levels or expectations for the case study? I.e. where do CS actors want to stand at the end of the project?	
	What are potential risks that could jeopardize the implementation of the ENFASYS CS methodology in this CS?	
	What can be done to mitigate these risks?	
	Other key information	
Value chain		
	Turnover / added value of the sector	
	Value repartition within the value chain	
	Specific marketing strategy	
	Other key information	

Output A2. Description of the policy space and governance environment

List relevant policies that apply in the context of your CS, and describe the related policy goals, policy bodies and specific governance schemes.

Add lines as much as necessary

Table A2. Description of the policy design space and governance environment

Name of the policy	***Type of policy instrument****	Level**	***Policy bodies that roll out or monitor this policy***	***If there are multi-stakeholders' arenas for governance, mention actors involved and type of governance****	***Aim of the policy***	***How does it influence your CS?***
Policy 1:						
Policy 2:						

*Types of Policy instruments: choose in the list below

Admin-based instruments:

- Public procurement
- Regulation
- Others (Tradable permits, etc.)

Market-based:

- Tax and charges
- Subsidy, subsidy reforms, support schemes and incentives
- Food stamps
- Certification and labelling instruments
- Others

Other instruments

** Level: (inter-) municipal, province, regional, national, eu-level

***consultation / co-construction / review, etc.

Optional: Feel free to add open text below if you would like to provide more descriptive, detailed information.

Output B1. Actors List

Please fill the table.
Add lines as much as necessary
(This is the same table as provided in Questionnaire for Step 1 and Step 2).

Table B1. Table for listing and describing the actors

Categories of actors	Detailed categories	List here the relevant actors (name of the person/organisation)	Describe their role in the value chain / sector	If relevant, forms of internal organisation within the category of actor (ex: farmers to farmers networks)	How might they further influence the CS context? What are their interests in a potential change of the CS context?
Upstream	Includes both inputs providers (such as seeds, machinery and chemical input providers) and transversal service providers (ex: banking, insurance & risk management services)				
Farming and support to farming	farmers and farmer organization; advisory services/consultants; Veterinarians				
Collectors, Logistics					
Processors					
Distribution and marketing	Ex: retailers				
consumers', citizens' and voters'	Individually or as an organisation				
public sector/government institutions	Includes administration & policy makers (From the regional to the national level)				
research/scientific organizations	Include social and economic sciences and natural sciences/e.g. agronomic research				
civil society organizations or NGOs					
Education	agricultural education institutes				

Optional: Feel free to add open text below if you would like to provide more descriptive, detailed information.

Output B2. Value network map

1. Visualization of the network of actors:

Design a "Value Network map" showing the actors involved and the types of relationships they are connected through.
You can find an example of a Value Network Map below.
Indications:

Indicate each actor in a circle, with their name and category. There can be several groups of each category of actors (specific sub groups of farmers, several local government institutions, etc.).

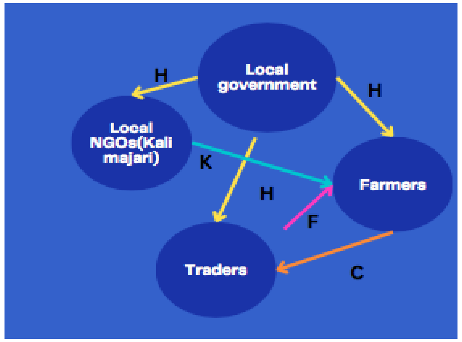
Characterize the types of relationships <u>between actors</u> using the following coding: H= Hierarchy lines; F= Financial capital; C= Commodities (products and services); K=knowledge.

There might also be relationships to describe <u>within a group of actors</u> (ex commodities exchange between farmers, knowledge sharing within farmers networks).

WP2 partners can help you design the map, feel free to contact us. We recommend you start drafting your Value Network Map early in the data collection, and to update it progressively.

Your map:

Example of a Value Network Map:



(Source: Systems Thinking, Mapping and Change in Food and Agriculture Paper submitted to Bio-Based and Applied economics, Dentoni D. et al, 2023).

2. Provide a description of social relations in which actors are embedded:

The objective of this part is to further describe the social relationships that are the most significant for the Case Study .
Please select max. 10 relationships: Focus on relationships that most significantly contribute to maintaining the current system, hinder/encourage changes and adoption of sustainable innovations relevant to your CS.
In other words, as you have indicated a relationship with an H / C / F / K above in the value network map, here you have the opportunity to describe it more in depth and highlight how it participates in framing the system.
There are various complementary information you can provide:
(1) What **type of social relation** *(various types of buyer-seller, buyer-buyer, seller-seller relationships, creditor-debtor relationships, employer-employee relationships, administrative or political-juridical hierarchies/role divisions, ...)?*
(2) What **resources** are mobilized by the involved actors (goods, services, knowledge, money, access to natural resources/means of production, legitimacy, access to third parties)
(3) What are the **aims** of the relationship (to exchange existing resources, to reinforce existing institutions, to develop new resources/technologies, to develop new institutions,…)?
(4) Who is **empowered or constrained** by the relationship?

Does the relationship provide either one power over the other (dependence-mutual dependence-independence)

- *Does the relationship provide either one more or less power than the other to pursue their goals (cooperation, competition, co-existence)*
- *Does the relationship provide either one the power to hamper/ enable the other to pursue their goals? (synergy, antagonism, neutrality)*

(Scientific reference if you need background about this classification: cfr. Avelino, F., & Wittmayer, J. M. (2016). Shifting power relations in sustainability transitions: a multi-actor perspective. Journal of Environmental Policy & Planning, 18(5), 628-649.)

Significant actor-pair (name of the actors and type /role)	Type of social relation (1)	(2) Resources	(3) Aims of the relationship	(4) Impacts on agency
Example: Actor-pair: organic dairy farmers within the biomilk.be cooperative	*Producer-owned cooperative between sellers of the same commodity*	*capital and labor to negotiate and organize organic milk collection and sale, exchange market information and know-how on organic dairy farming, access to large buyers.*	*improve farmer income by improved bargaining power with buyers, cutting of processing and transportation costs, expand demand for Belgian organic milk by gaining access to larger buyers, and exchange knowledge.*	*Empowerment:* - *independence/mutual dependence (benefits from the cooperative depend on production volume and therefore participation of farmers) but participation is voluntary* - *cooperation: benefits are spread progressively (smaller farmers have equal say)* - *synergistic in terms of bargaining position vis-à-vis potential buyers, softening potential antagonisms between dairy farmers who would otherwise be competitors particularly when organic milk demand is too low.*

add lines as much as you need

Optional: Feel free to add open text if you would like to provide more descriptive, detailed information.

Output C1. Systemic identification of Barriers

Compile the barriers that were identified in your CS, from previous literature or actors engaged in the survey (fill in the table).

Add lines as much as necessary

	... at the farm stage?	from farms to processors (i.e. collection, transportation, storage)?	at the processing stage?	at the distribution stage?	at the consumers' stage?	for stakeholders outside of the value chain?	other
Technical barriers	Barrier 1: …. Barrier 2: …						
Financial barriers							
Market-related barriers							
Organizational barriers							
Cultural barriers							
Knowledge-related barriers							
Other barriers'							
I cannot answer because…							

Output C2. Detailed interpretation and concrete facts about each barrier

For each of the barrier that was identified through the survey, compile the different ways to describe the barrier and possible divergence of interpretation among actors. You may add verbatims from the detailed interviews and focus group.

Barrier	Actor	How they describe the barrier (verbatims, summarized description, indicators, etc)
Barrier 1:	....	
Barrier 2:	....	
Barrier 3:	....	
Barrier 4:	....	
Barrier 5:	....	
Barrier 6:	....	
Barrier 7:	....	
Barrier 8:	....	
Barrier 9:	....	
Barrier 10:	....	

	Short name of the lever	Description	Category of levers (1)	Value chain stages	Which scale?	Actors to be involved (2)	Expected impact (3)	Excepted timeframe (4)
Lever 1								
Lever 2								
Lever 3								
Lever 4								
Lever 5								
Lever 6								
Lever 7								
Lever 8								
Lever 9								
Lever 10								

Data sources

This list of levers should be created based on the interviews and focus groups. It will be further used to make the Causal Loop Diagram.

(1) Categories of levers are defined below:

CATEGORY	DESCRIPTION	EXAMPLES
Material and Technical levers	Change in the physical amount of inputs, production, infrastructures and change of practices/techniques at the farm, processing or other stages of value chains.	Change of material resources such as machinery, allowing new practices to be implemented. Change of farming practices resulting in a reconfiguration of the farming system. Technical changes at the processing stages, allowing to process new crops, etc.
Financial / Funding levers	Change in financial flows (amount and actors involved).	Example of levers include lowering investment costs at the farm level; establishing new funding schemes for sustainability transition, etc.
Economic levers	Change in the economic variables of the value chain.	Examples of levers include securing sufficient market outcomes; fair price schemes; setting insurance mechanisms to overcome low/variable yield situations.
Organizational levers	Change in the organization of production and all related activities. Organizational changes can be implemented at the farm, value chain, regional, or policy level.	Examples of levers include: changing the work organization at the farm level; managing complexity by developing management tools; reorganizing the crop collection process.
Education / Information / knowledge	Change in terms of the information conveyed or change of the information channels. Can be technical knowledge, economical, market related, impact related, etc.	Examples : developing further knowledge through experimentation; strengthening access to, or distribution of, knowledge to actors (diversification of knowledge networks, provision of trainings, etc.).
Cultural / Cognitive levers	Change in the mindset or paradigm out of which the system arises.	Supporting change in farmers' habits (emphasizing a cost-benefits approach on the long term, supporting farmers in reshaping their routines and farming systems); integrating alternative farming systems in training and education; reducing the misinterpretation of risks associated with alternative practices.
Other levers		

Actors to be involved (2)

actors to be involved in funding, design and implementation

Expected impact (3)

Hierarchy of the levers according to their expected impact vs the CS goal

Excepted timeframe (4)

To rank levers' feasibility, we suggest you to assess the expected timeframe within which the necessary resources to implement this lever could become available.

8 Annex 2

Causal Loop Validation Checklist

1. Completeness
   - ✓ Are all relevant variables included? (Sterman, 2000)
   - ✓ Is there any missing element that could impact the system understanding? (Senge, 1990)

2. Consistency
   - ✓ Are the causal relationships logically consistent? (Sterman, 2000; Richardson, 1996)
   - ✓ Are the polarity (positive/negative) of relationships correctly identified?

3. Loops
   - ✓ Have all feedback loops (both reinforcing and balancing) been identified?
   - ✓ Are the feedback loops correctly labelled and make logical sense?

4. Clarity
   - ✓ Are all variables clearly labelled and easy to understand? (Sterman, 2000)
   - ✓ Are the causal links clearly drawn and easy to follow? (Senge, 1990)
   - ✓ Do the links avoid excessive overlap, making the diagram hard to read?

5. Connections
   - ✓ Are all nodes connected, ensuring there are no isolated components? (Sterman, 2000)
   - ✓ Does the overall structure make sense and flow logically? (Senge, 1990)

6. Assumptions and Justifications
   - ✓ Are the assumptions behind each causal link explicitly stated?
   - ✓ Is there a clear and logical justification for why each causal relationship exists?

7. Redundancies and Simplifications
   - ✓ Have any redundant variables or links that do not add value been identified and removed?
   - ✓ Have complex sections of the CLD been simplified where possible without losing critical information?

8. Stakeholder Review
   - ✓ Has the CLD been reviewed by relevant stakeholders for accuracy and completeness? (Senge, 1990)
   - ✓ Has feedback from stakeholders been integrated into the CLD? (Sterman, 2000)

9 Annex 3

Cross case analysis: detailed methodological approach for Task 2.3

The ENFASYS project seeks to promote a transition to sustainable, productive, climate-neutral, biodiversity-friendly, and resilient farming systems. Central to this task is the development of a cross-case Causal Loop Diagram (CLD), which aims to identify systemic lock-ins and potential levers for change across different case studies. This section details the methodology for constructing a cross-case CLD, emphasizing the importance of selecting relevant and measurable variables to ensure the efficacy of subsequent system dynamics analysis.

The methodological approach for creating a cross-case CLD integrates comprehensive data collection and rigorous analysis. The process began with extensive data gathering through interviews, surveys, and literature reviews, ensuring a robust and diverse data set. This approach aligns with the work of Forrester (1961) on the importance of empirical data in system dynamics and is further supported by Sterman (2002), who emphasizes the need for detailed and accurate data in modelling complex systems.

According to (Ryan et al., 2021) there are different methods for aggregating multiple Causal Loop Diagrams (CLDs) to achieve a comprehensive and coherent model that adequately represents a system. The aggregation of CLDs is essential when multiple perspectives or data sets are involved in system dynamics studies. The three primary approaches for aggregating CLDs are:

- **Triangulation**: This method involves including all data from various sources to create a comprehensive model. It aims to encompass every variable and causal link from all the CLDs, ensuring that no information is left out. However, this can lead to overly complex models that are difficult to analyse.
- **Grounded Theory**: This approach focuses on the frequency of occurrence, including only the variables and links that appear most frequently across the CLDs. It helps simplify the model but might omit critical variables that are less common but still important.
- **Synthesis**: Synthesis extends beyond frequency and considers the magnitude of occurrence, ensuring that even less frequent but highly significant variables are included. This method seeks to create a balanced and holistic representation of the system.

No single aggregation method is universally optimal; the choice of method should be guided by the specific complexity, variety, and number of CLDs involved in the study. (Ryan et al., 2021) also highlights the concepts of equifinality - achieving the same outcome through different pathways - and multifinality - where similar starting conditions lead to different outcomes - in the context of CLD aggregation. The methodology for creating a merged CLD in this study incorporates structural equivalence analysis to identify common variables and relationships across different case studies. This approach facilitates a more thorough understanding of the dynamics underpinning agricultural transitions in various regions, thereby enhancing the development of targeted and effective strategic interventions.

Data collection was carried out from March 2023 to January 2024, guided by a structured protocol developed by the WP2 partners. This protocol facilitated the aggregation and comparison of data across case studies. Key areas of focus included the policy space, governance environments, actors' networks, and barriers to transition towards sustainable farming systems. Each case study identified relevant policies, examined governance structures, and mapped stakeholder interactions to understand the complex dynamics influencing their agricultural systems. The selection of variables for the CLD was guided by the principles outlined by Richardson (1991) and Morecroft (2015), which stress the importance of relevance and measurability in system dynamics modelling. Variables were chosen based on their significance to the system's behaviour and their ability to be quantified in close collaboration with the partners involved in WP4. This ensured that the CLD could be effectively used for dynamic simulations and policy analysis. The construction of the initial CLD for each case study involved synthesizing primary and secondary data. Primary data were collected through key informant interviews and focused group sessions, providing insights into the causal relationships within the system. This approach is supported by Peck (Peck, 1998), who highlights the value of stakeholder engagement in building accurate and comprehensive system models.

Secondary data, including published literature, grey literature reports, and policy documents, were selectively reviewed to support and contextualize the cause-and-effect linkages. This targeted review was crucial for validating the relationships within CLDs and for ensuring the models were grounded in relevant empirical and theoretical frameworks. The importance of integrating multiple data streams, as noted by Rouwette et al. (2002), guided our approach, enhancing the validity and robustness of our models by providing a broader perspective on the dynamics influencing agricultural systems. Merging Individual CLDs into a Comprehensive Cross-Case CLD

The process of merging individual Causal Loop Diagrams (CLDs) from various case studies into a comprehensive cross-case CLD is essential for capturing systemic complexity and identifying shared lock-ins and levers across different contexts. This section details the methodological steps undertaken to synthesize the individual CLDs into a single, integrated diagram that reflects the multifaceted nature of agricultural systems under study.

1. Standardization of Variables and Relationships

The first step in merging individual CLDs involves standardizing the variables and relationships across the case studies. Given the diversity in terminologies and frameworks used by each case study, harmonizing these elements is critical to ensuring consistency. This standardization process begins with identifying common variables by reviewing each CLD to pinpoint variables that are conceptually similar or serve the same function. For example, variables such as “Knowledge and Skills in Biodiversity Management” and “Financial Incentives” may appear in various forms and thus need to be standardized. Following this, the types of relationships (causal links) between variables are defined consistently across all diagrams, specifying the nature of the influence—whether positive or negative.

2. Structural Equivalence Analysis

To identify similar patterns and relationships among the individual CLDs, structural equivalence analysis is employed. This involves constructing adjacency matrices for each CLD, where rows and columns represent variables, and entries indicate the presence (1) or absence (0) of a causal relationship. Weighted values can also be used to denote the strength of these relationships. Similarity scores are then calculated using metrics such as Euclidean distance, correlation, or Jaccard similarity to identify structurally equivalent variables and relationships. Hierarchical clustering is utilized to group similar variables and relationships, facilitating the identification of common patterns and their integration into a single framework. This approach is supported by the works of Lorrain and White (1971) and Sailer (1978), who emphasize the importance of structural equivalence in network analysis.

3. Integrating Feedback Loops

Feedback loops are a critical in representing the dynamic nature of systems within CLDs. During the integration process, common feedback loops are identified by examining each CLD for reinforcing and balancing loops that are prevalent across multiple case studies. These loops are then mapped to ensure they are represented in the integrated CLD. By using the identified feedback loops, the integrated CLD is developed to highlight both reinforcing and balancing dynamics present across various agricultural systems. This step aligns with Lane and Husemann (2008) insights into the importance of feedback loops in system dynamics.

4. Aggregation and Synthesis

Once common variables and feedback loops are identified, the next phase will be done in Task 2.3 and involves aggregating and synthesizing the individual CLDs into a single, comprehensive diagram. This process includes merging variables from each CLD into single nodes within the integrated CLD and incorporating unique variables that provide additional insights to capture the full complexity of the system. Causal relationships from the individual CLDs are combined to create a comprehensive map of how variables influence each other across different case studies. While commonalities are emphasized, it is also crucial to incorporate unique insights from individual case studies to ensure that the integrated CLD accurately reflects the diversity and complexity of the different agricultural systems.

5. Iterative Validation and Refinement

In Task 2.3 he integrated CLD undergoes several rounds of validation and refinement to ensure its accuracy and relevance. This iterative process begins with case study coordinator validation, where the integrated CLD is presented to case study coordinators from each case study for feedback. This step is vital for ensuring that the diagram accurately reflects the real-world complexities and nuances of the agricultural systems. Feedback from stakeholders is incorporated into the CLD, refining the relationships and variables to enhance the diagram's robustness and validity.

6. Finalizing the Cross-Case CLD

The final integrated CLD represents a static representation of the farming systems across different agricultural contexts. It highlights both common lock-ins and potential levers for change, providing a valuable tool for system dynamics analysis and policy development. For instance, when merging the CLDs from two case studies, variables such as "Financial Incentives" and "Adoption of Sustainable Practices" may be combined to reflect a reinforcing loop showing that increased incentives lead to higher adoption rates, which in turn justify further incentives. Additional factors such as "Stakeholder Collaboration" and "Policy Adjustments" from other case studies can be integrated to enrich the overall CLD, demonstrating the impact of policy changes on sustainable practices.

This integrated approach ensures that the final CLD is not only comprehensive but also reflective of the diverse dynamics and challenges faced by different agricultural systems. By following these methodological steps, the ENFASYS project can create a robust cross-case CLD that identifies systemic lock-ins and levers, providing a foundation for informed policy-making and strategic interventions to promote sustainable farming systems.

The methodological rigor applied in merging CLDs from various case studies into a comprehensive cross-case CLD is supported by literature emphasizing the importance of detailed and accurate data in system dynamics. For instance, Forrester (1994) and Sterman (2002)stress the significance of empirical data in modelling complex systems, while Richardson (1994) and Morecroft and Robinson (2014) highlight the need for relevance and measurability in variable selection. The integration of feedback loops and structural equivalence analysis further aligns with the work of Lane and Husemann (2008), (Schoenberg et al., 2020); Schoenberg (2020) and Schoenberg (2020), ensuring a robust and comprehensive understanding of the systemic dynamics at play.

Similarly for the creation of the case study level CLDs we have been preparing the adjacency matrices, representing the relationships between variables in each individual CLD. Each matrix was constructed based on data from the respective case studies, indicating the presence (1) or absence (0) of direct relationships between variables. The adjacency matrices were then converted into graph objects using the *igraph* package in R (Csardi, 2013). This step facilitated the structural equivalence analysis by enabling graph-based operations. Then the structural equivalence analysis was performed identifying nodes (variables) with similar patterns of connections. This was done by calculating the Euclidean distance between rows of the adjacency matrix, which quantifies the similarity between the nodes. In order to further identify common variables and their relationships across different cases, the distance matrices from the structural equivalence analysis were compared. Variables with low Euclidean distances were considered structurally equivalent and thus potential candidates for merging. Once this was done the common variables identified from the structural equivalence analysis were integrated into a unified set of nodes for the merged CLD. In the same way, the relationships from each individual CLD were combined into the merged CLD, ensuring that relationships between common variables were accurately represented.

To build the merged CLD, variables across all cases were compared and those identical in terms of names and functions were highlighted. First, variables from each case study within the provided dataset were extracted and reviewed (the list of original variables is in annex 1). Then the variables' names were standardised and harmonised to ensure that different terminologies that refer to the same concept were aligned. For example, "Market Access" and "Access to Markets" were treated as identical since they refer to the same concept. Variables across all cases were compared, focusing on identifying variables that are named identically or have the same functional role in different contexts. We checked for exact matches in the names of variables as well as for synonymous terms used in different cases. After identifying these variables, they were clustered to see which ones appeared across multiple cases and to count the frequency of their appearance, identical variables were then aggregated, and those appearing in more than one case were highlighted.

The practical analysis process was executed in R involving several steps: data preparation, tokenisation, vectorisation, calculation of the distance between every pair of variables across the causes using again the distance matrix (cosine similarity) (Huang, 2008).

10 Annex 4

Adjacency Matrix, Correlation Coefficient Matrix and Euclidian Distance Matrix for each Case

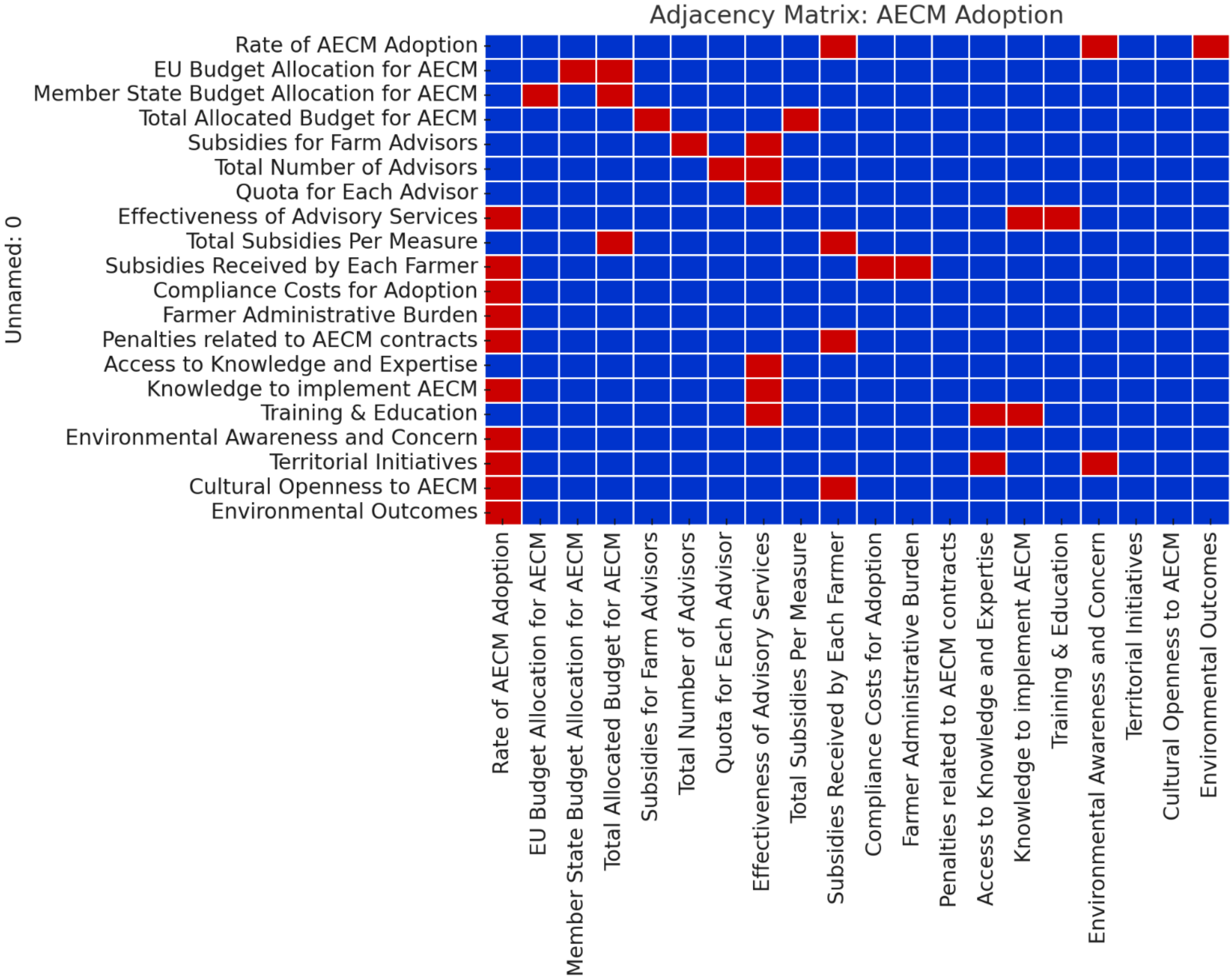


Figure 25 Adjacency Matrix case 1

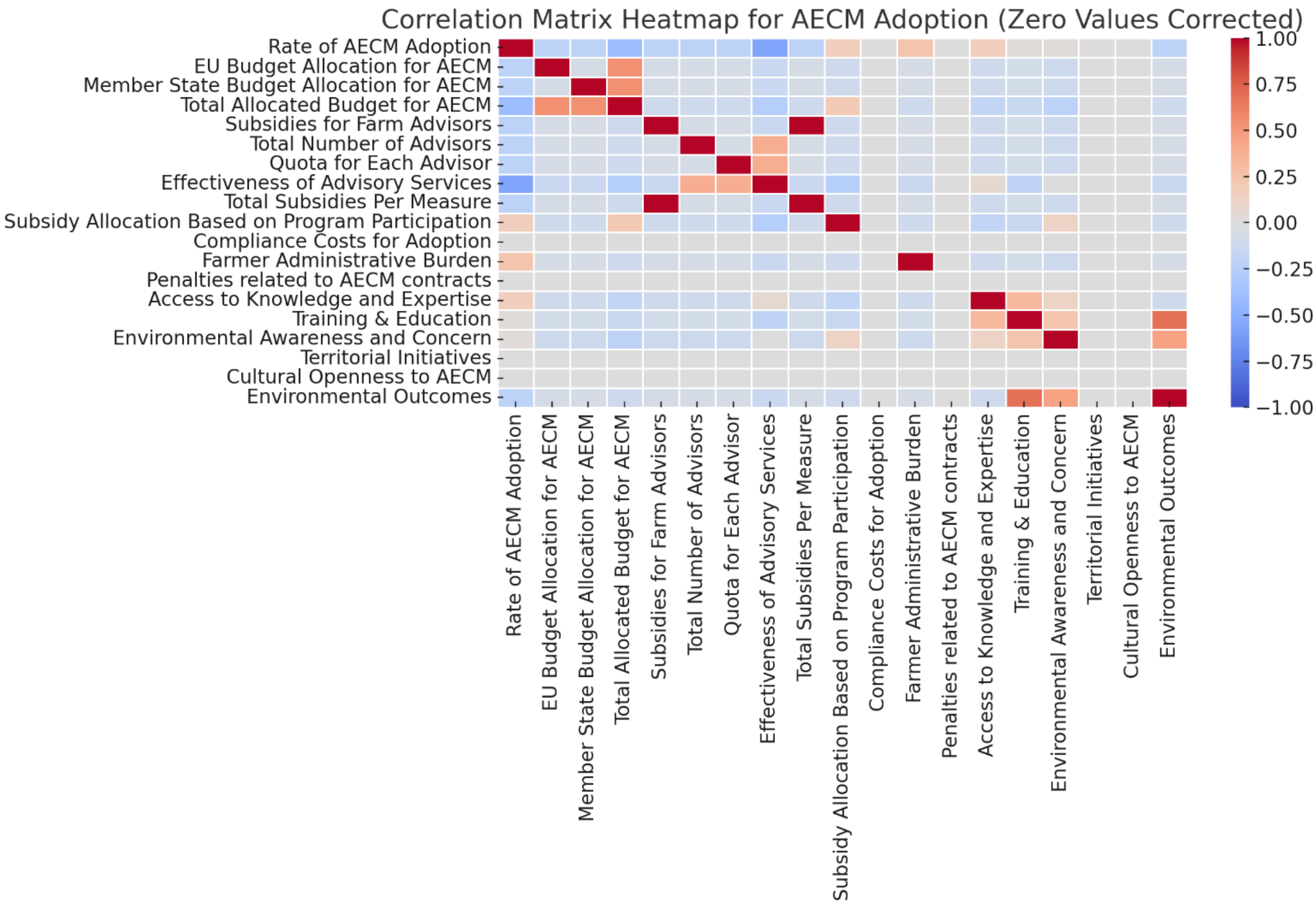


Figure 26 Correlation matrix case 1

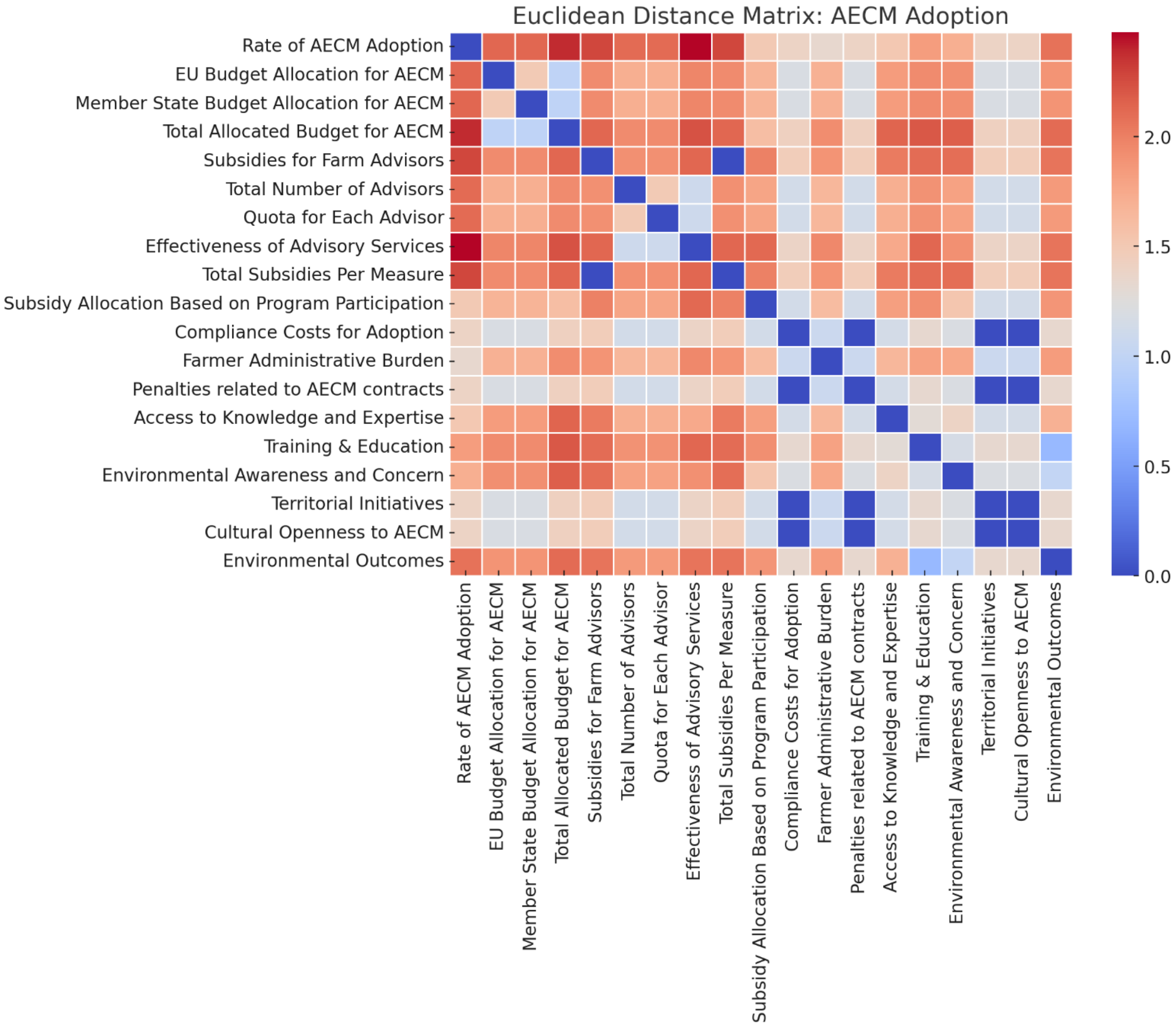


Figure 27 Euclidean Distance matrix case 1

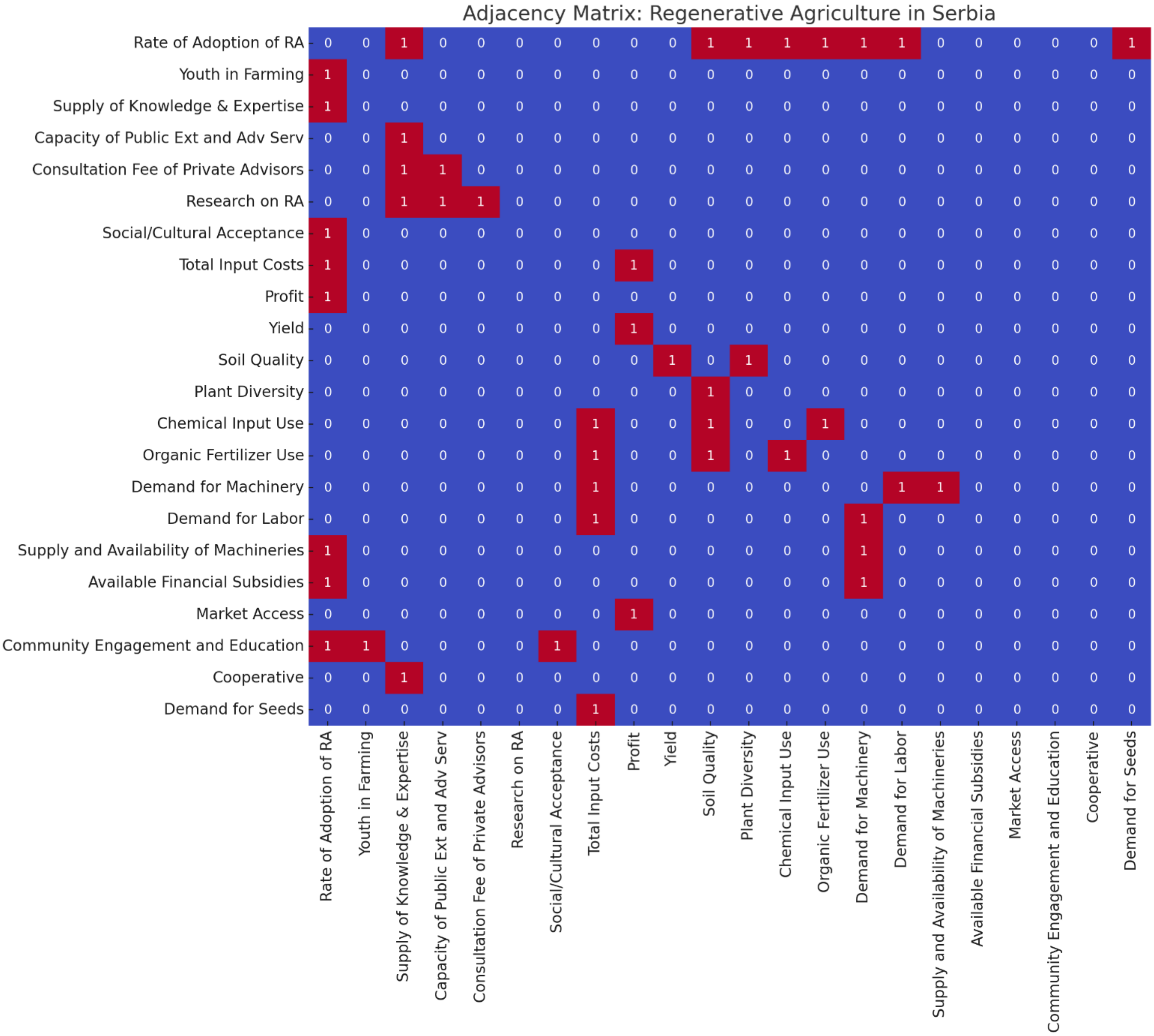


Figure 28 Adjacency Matrix case 2

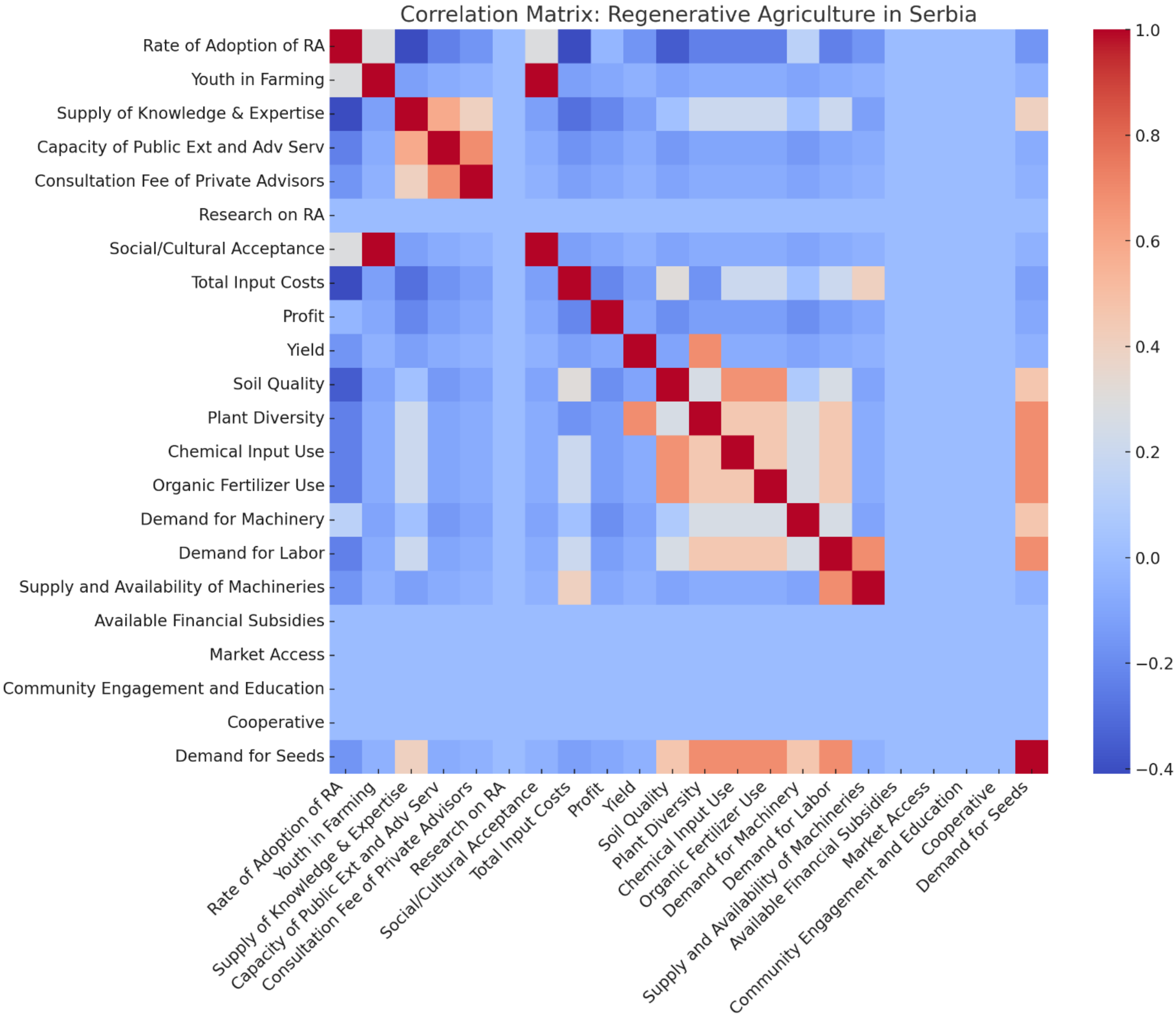


Figure 29 Correlation matrix case 2

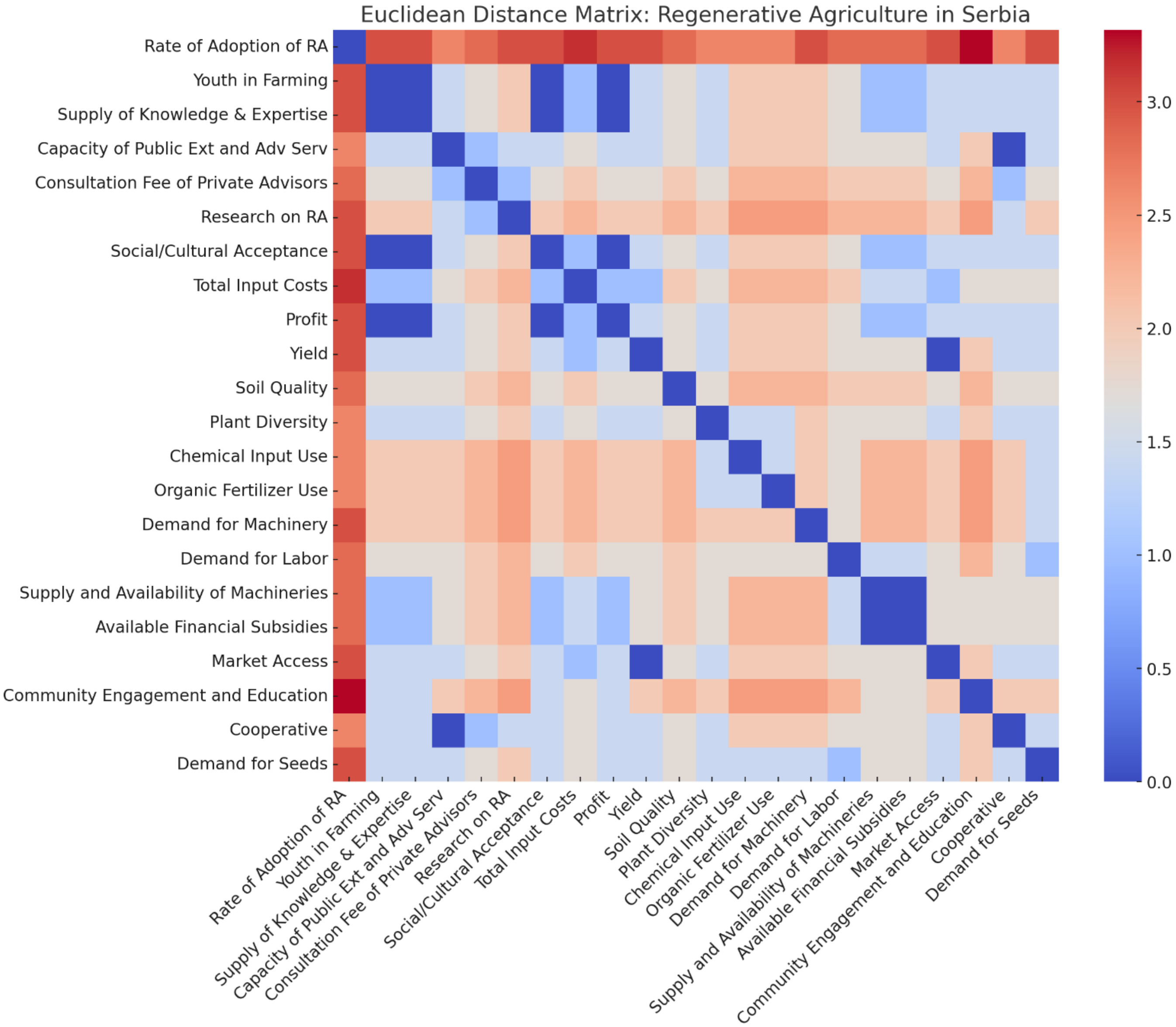


Figure 30 Euclidean Distance matrix case 2

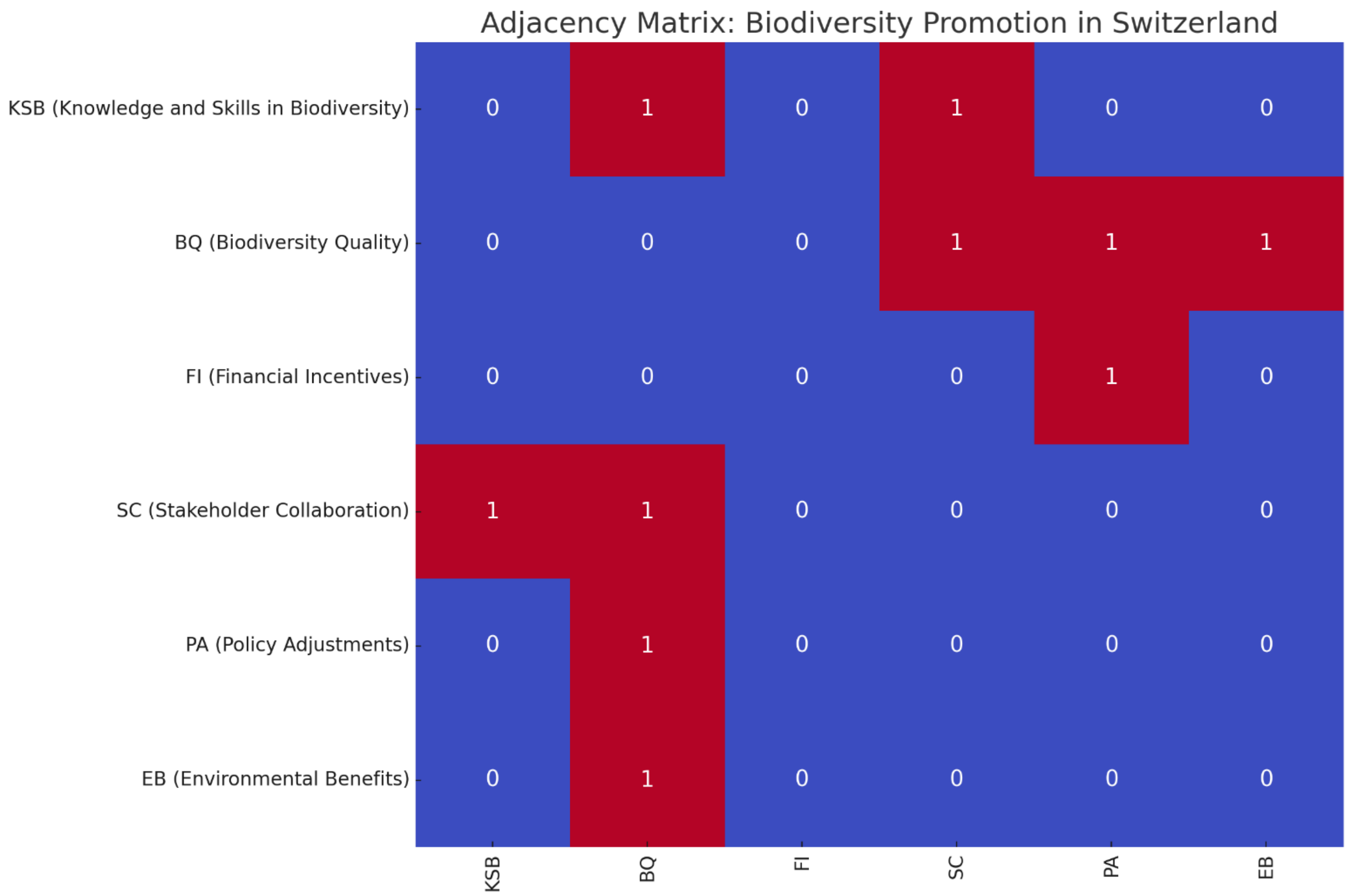


Figure 31 Adjacency Matrix case 3

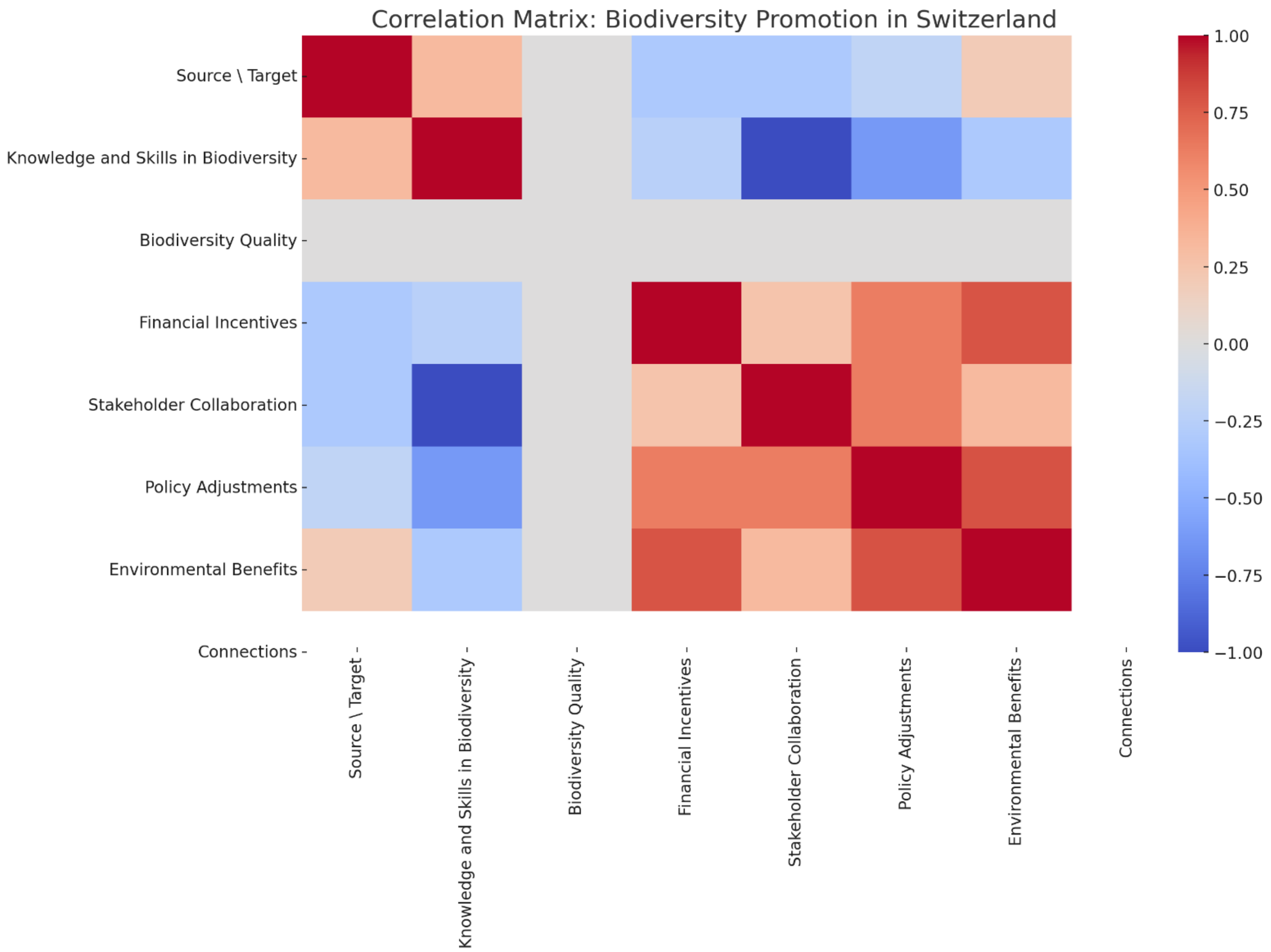


Figure 32 Correlation matrix case 3

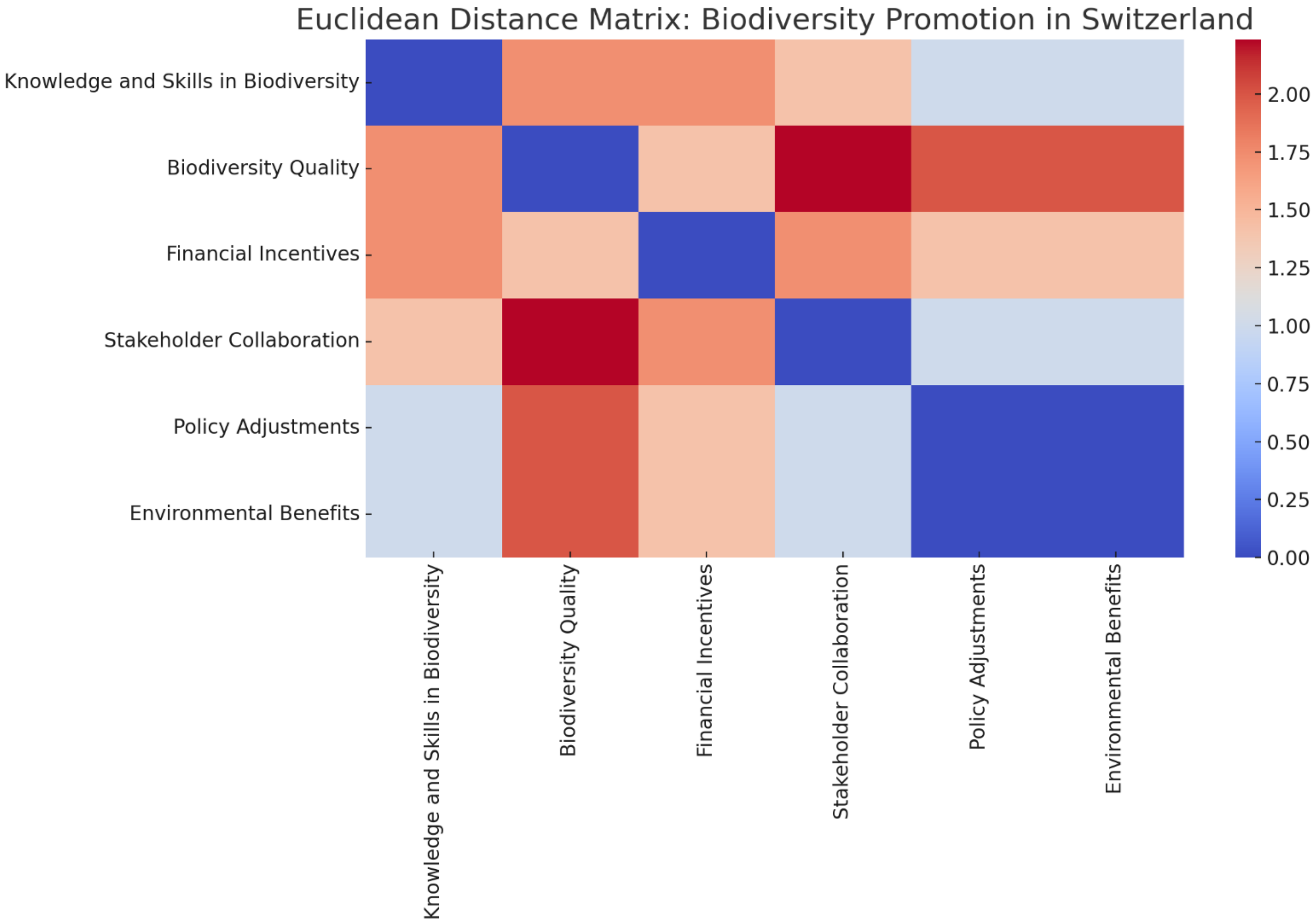


Figure 33 Euclidean Distance matrix case 3

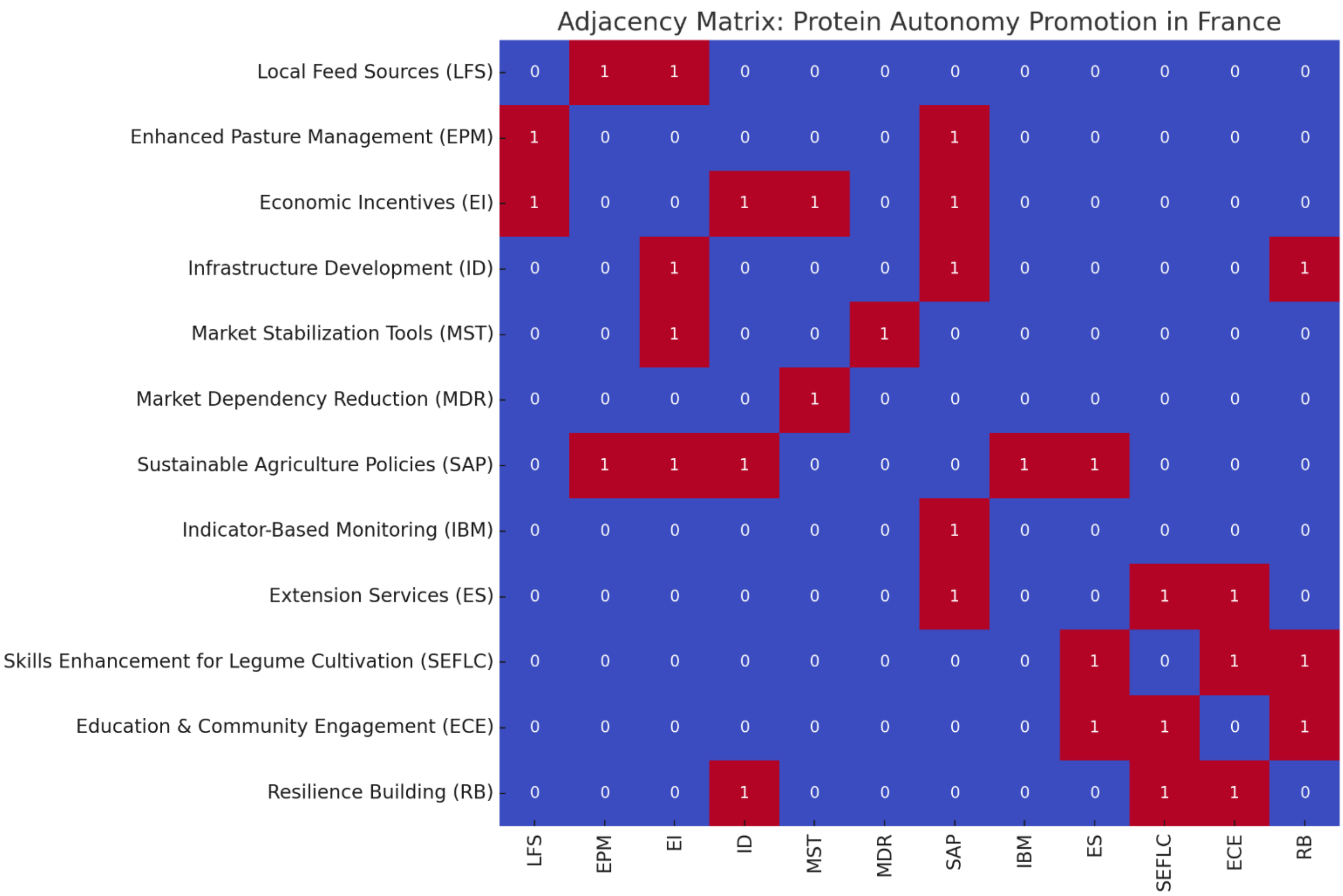


Figure 34 Adjacency Matrix case 4

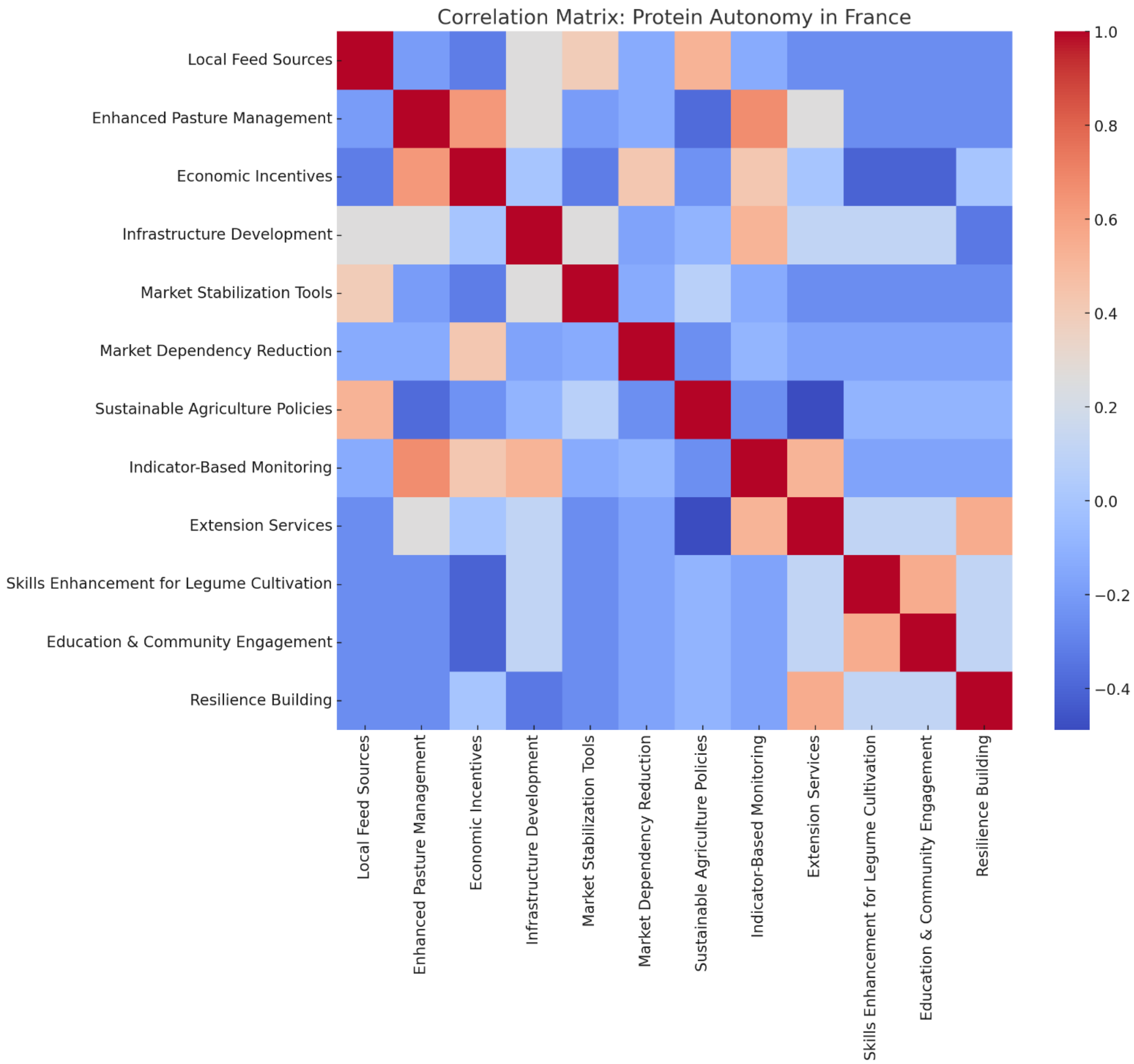


Figure 35 Correlation matrix case 4

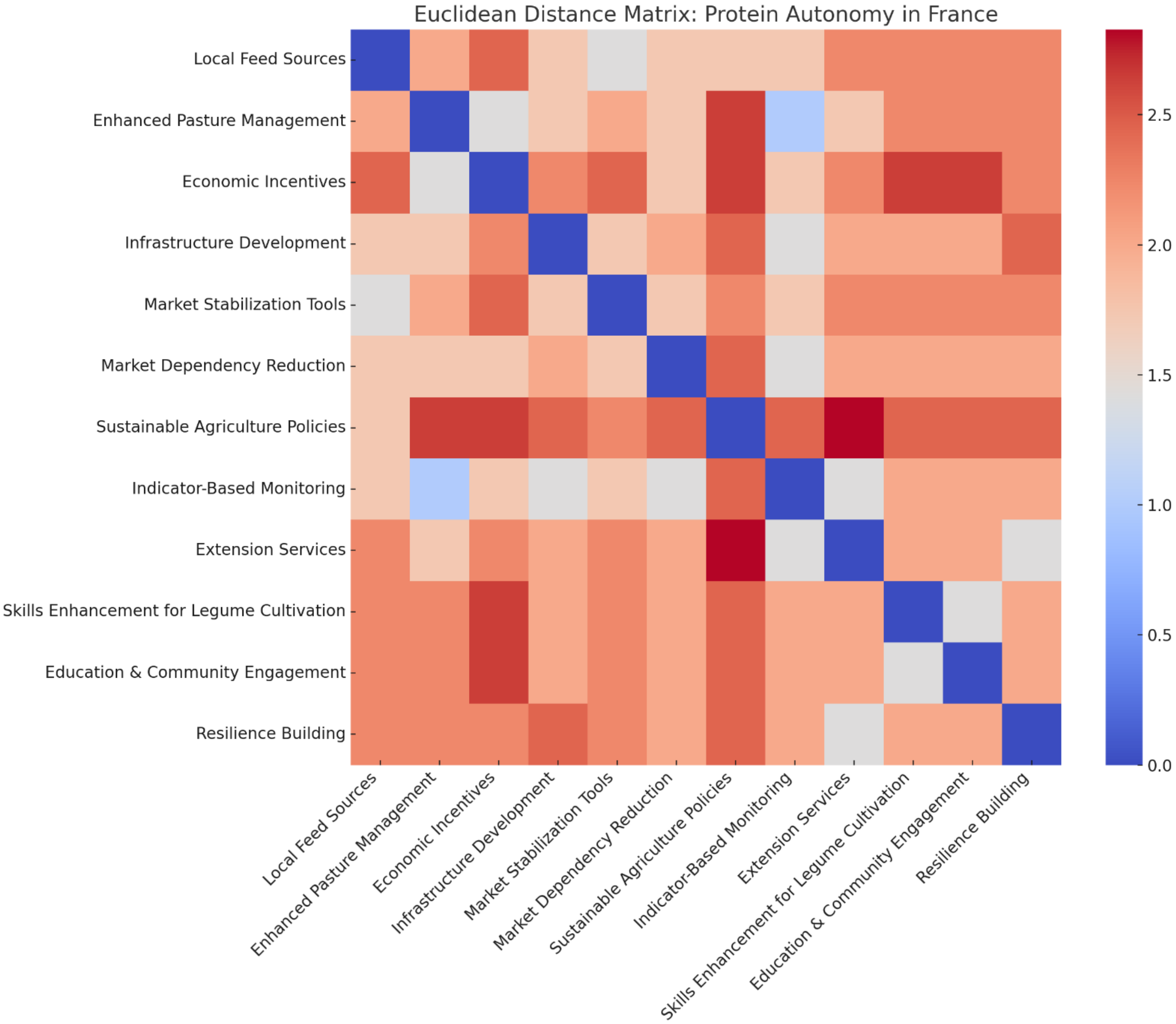


Figure 36 Euclidean Distance matrix case 4

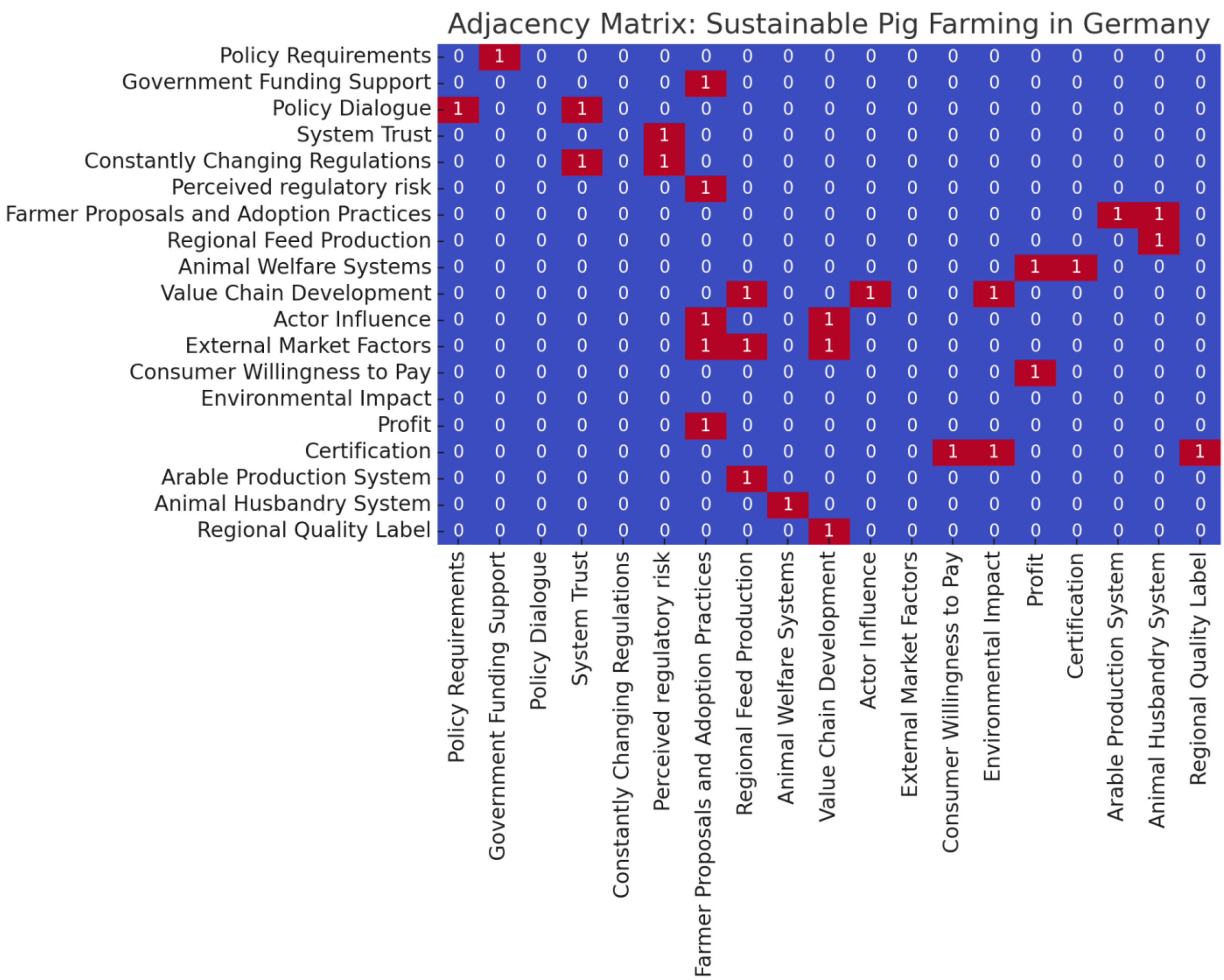


Figure 37 Adjacency Matrix case 5

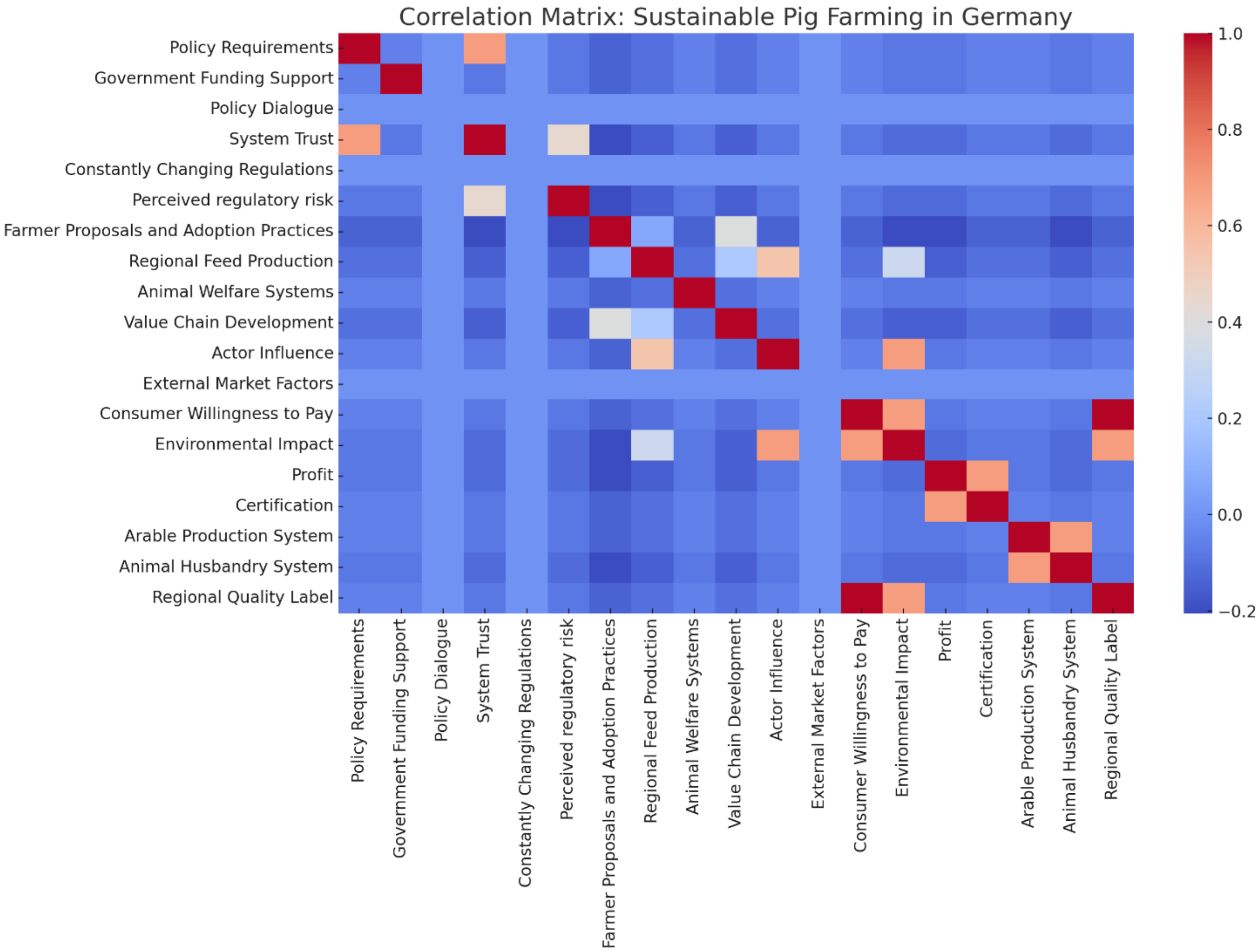


Figure 38 Correlation matrix case 5

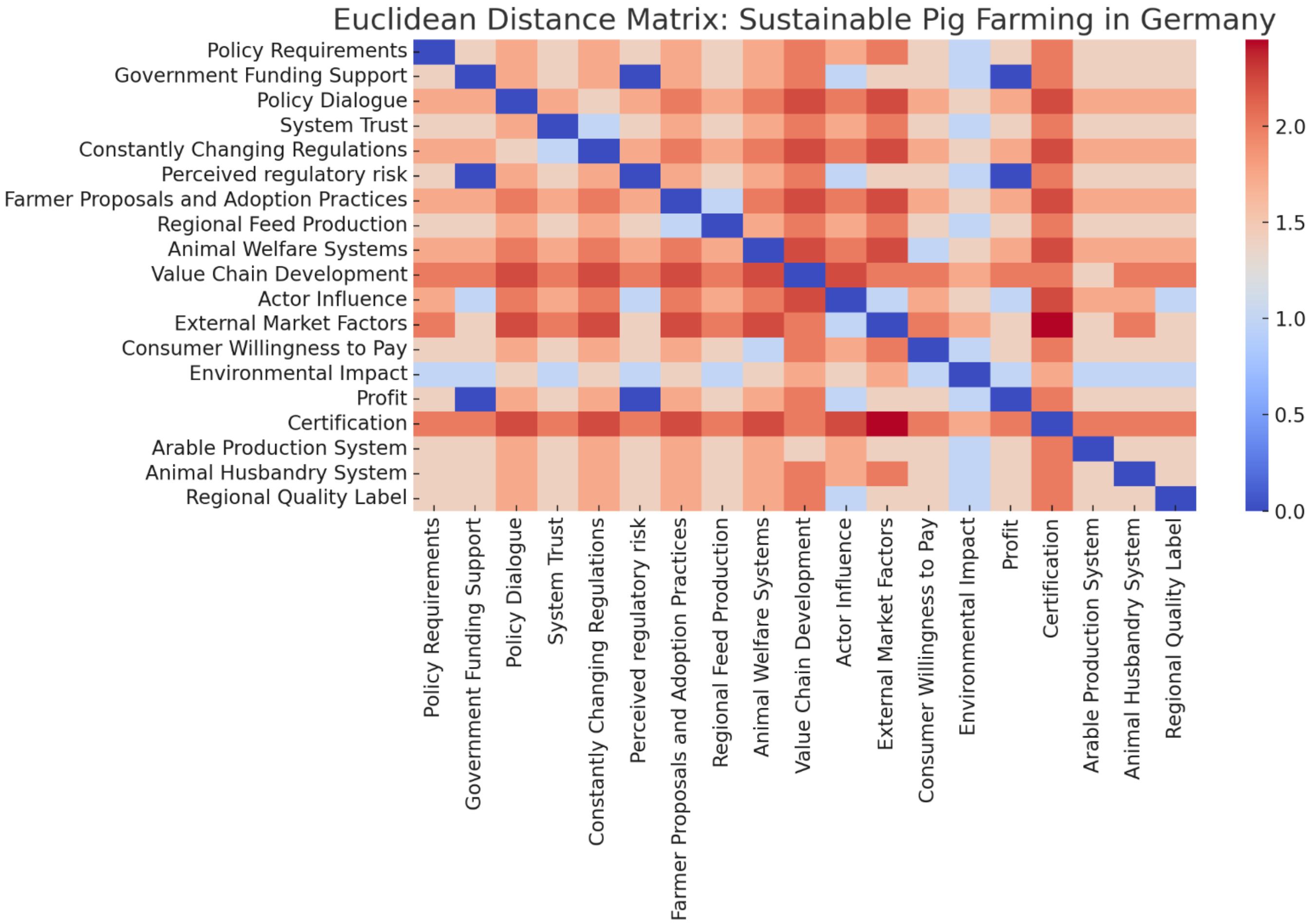


Figure 39 Euclidean Distance Matrix case 5

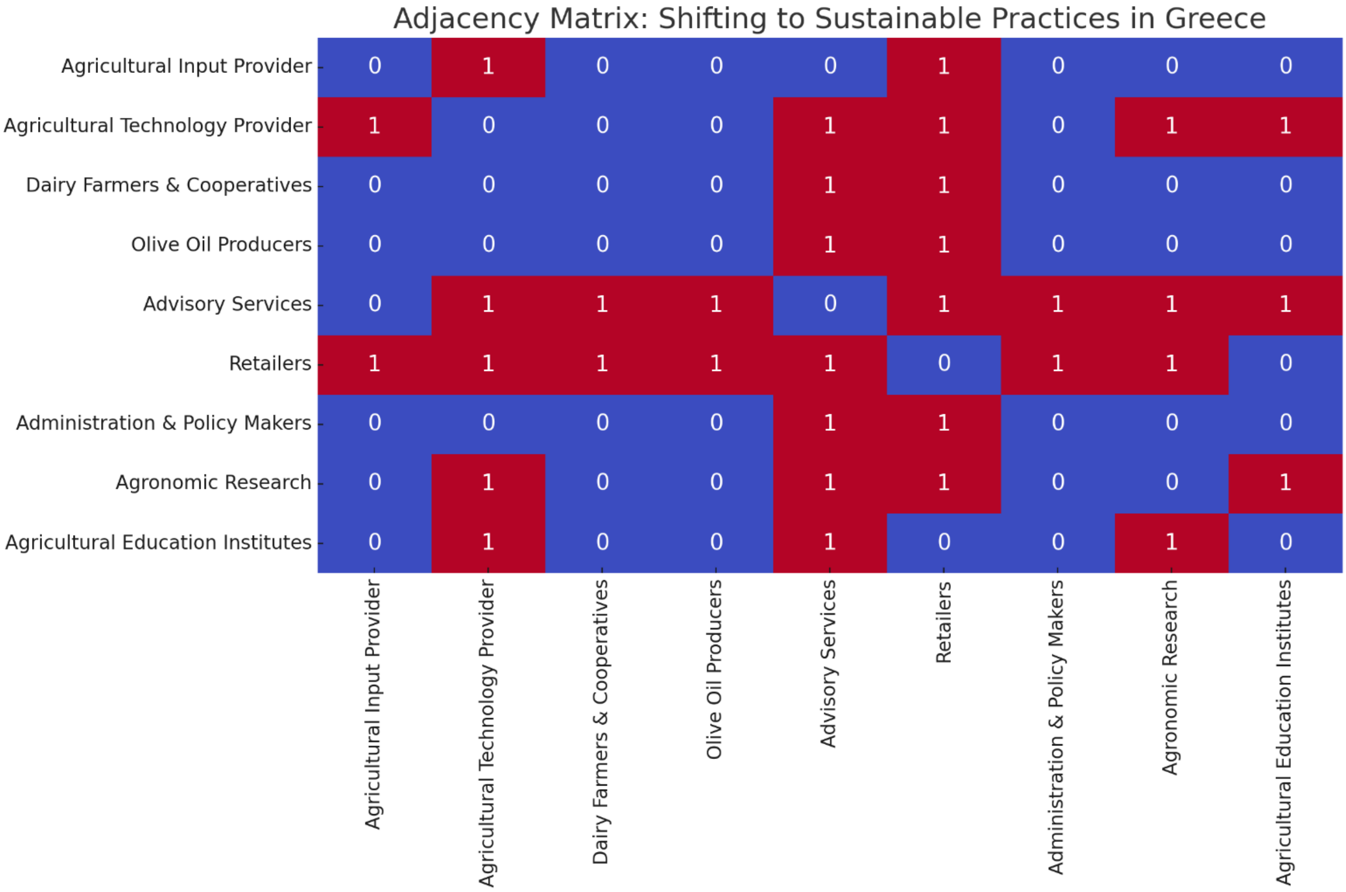


Figure 40 Adjacency Matrix case 6

Figure 41 Correlation matrix case 6

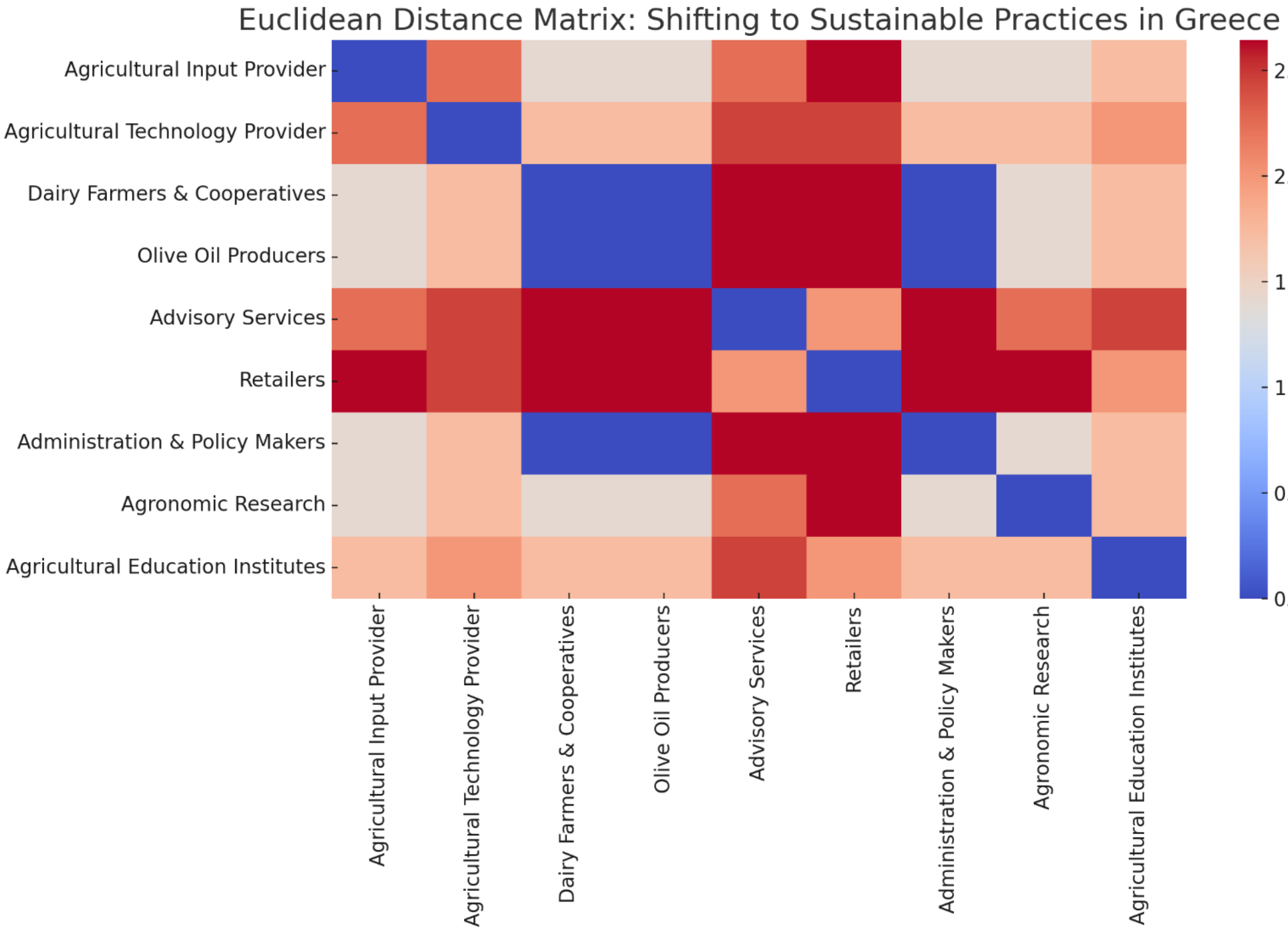


Figure 42 Euclidean Distance matrix case 6

Adjacency Matrix: Sustainable Direct Selling - Slovenia

	Farmer's Revenue from Direct Selling	Investment in DS Infrastructure	Farmer Training and Capacity Building	Short Supply Chain Development	Number of Farmers Using Digital Marketing Tools	Consumer Demand for Locally-sourced and organic products	Cost of Production and Distribution	Market Prices of Directly Sold Products	Market Accessibility	Labor Hours Dedicated to DS	Consumer Engagement	Consumer Awareness and Trust Levels	Rate of Adoption of Organic Certification and Labeling	Farmer's Profit	Rate of Adoption of Farmers Practicing Direct Selling	Technical Support and Quality Assurance	Policy and Regulatory Support with Chamber Advocacy	Legislative Compliance	Generational Dynamics	Environmental Impact Score
Farmer's Revenue from Direct Selling	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Investment in DS Infrastructure	0	0	1	0	1	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0
Farmer Training and Capacity Building	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0
Short Supply Chain Development	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Farmers Using Digital Marketing Tools	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Consumer Demand for Locally-sourced and organic products	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Cost of Production and Distribution	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Market Prices of Directly Sold Products	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Market Accessibility	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Labor Hours Dedicated to DS	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Consumer Engagement	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Consumer Awareness and Trust Levels	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Rate of Adoption of Organic Certification and Labeling	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Farmer's Profit	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Rate of Adoption of Farmers Practicing Direct Selling	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1
Technical Support and Quality Assurance	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	1	0	0
Policy and Regulatory Support with Chamber Advocacy	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0
Legislative Compliance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0
Generational Dynamics	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Environmental Impact Score	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0

Figure 43 Adjacency Matrix case 7

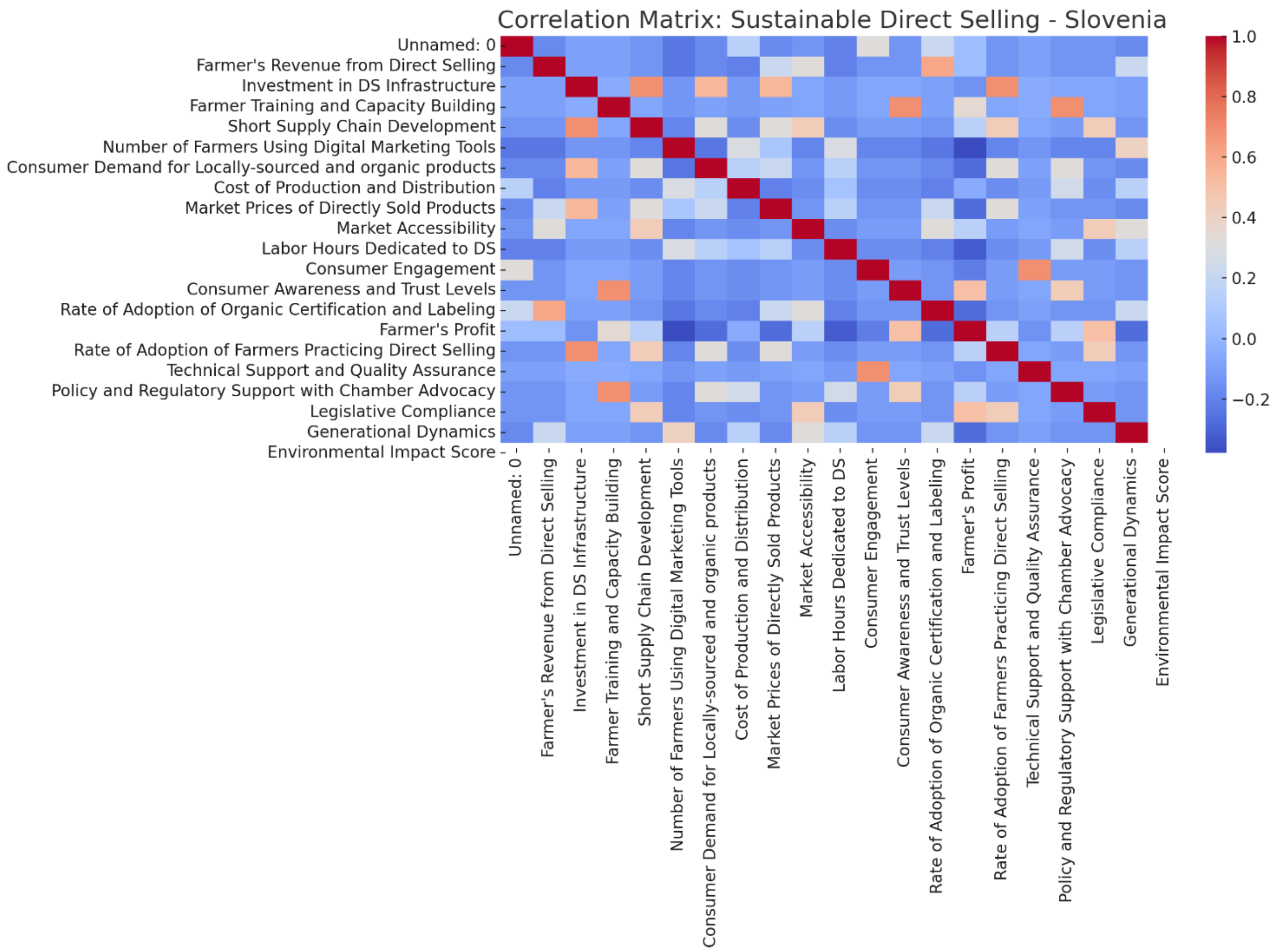


Figure 44 Correlation matrix case 7

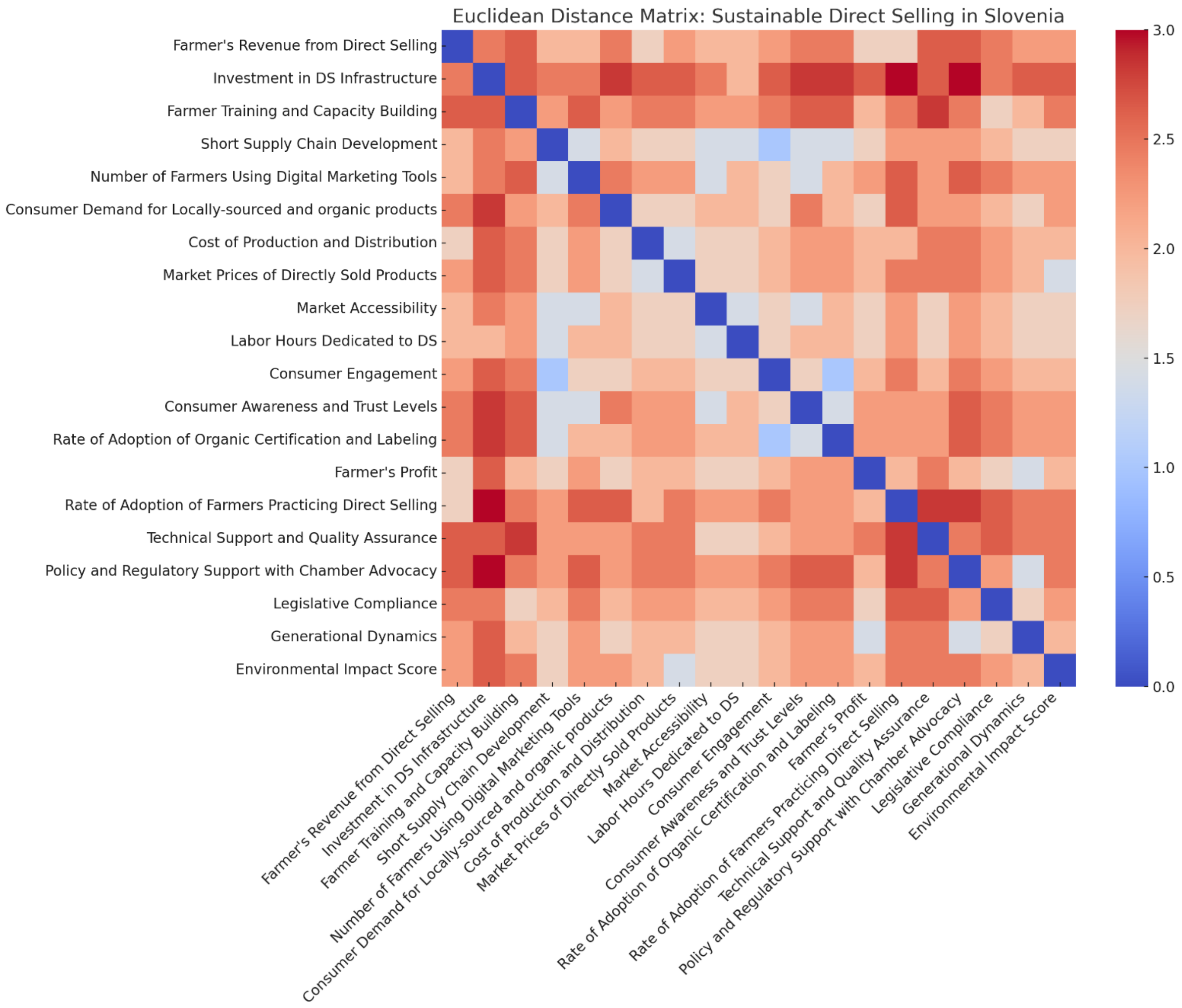


Figure 45 Euclidean Distance matrix case 7

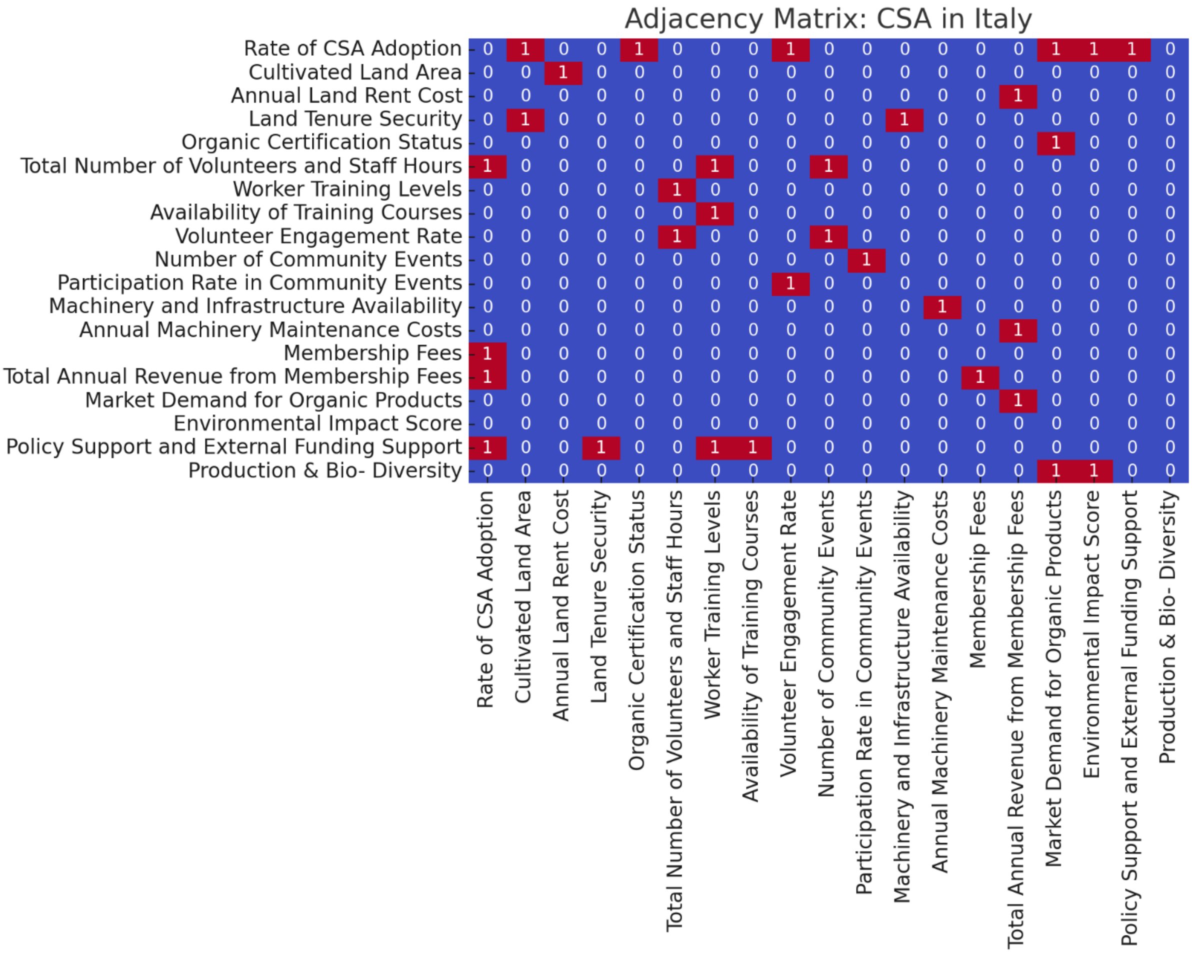


Figure 46 Adjacency Matrix case 8

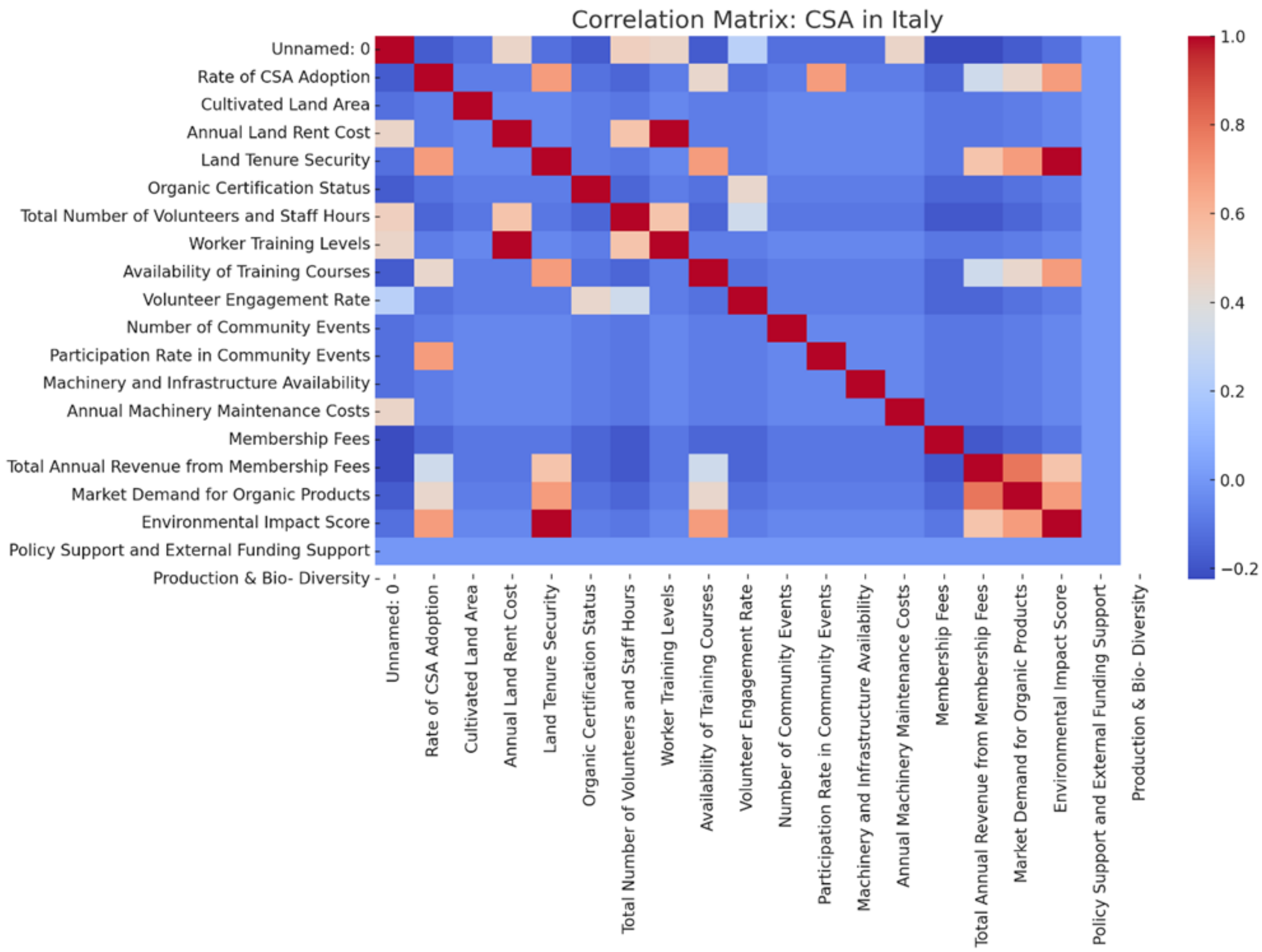


Figure 47 Correlation matrix case 8

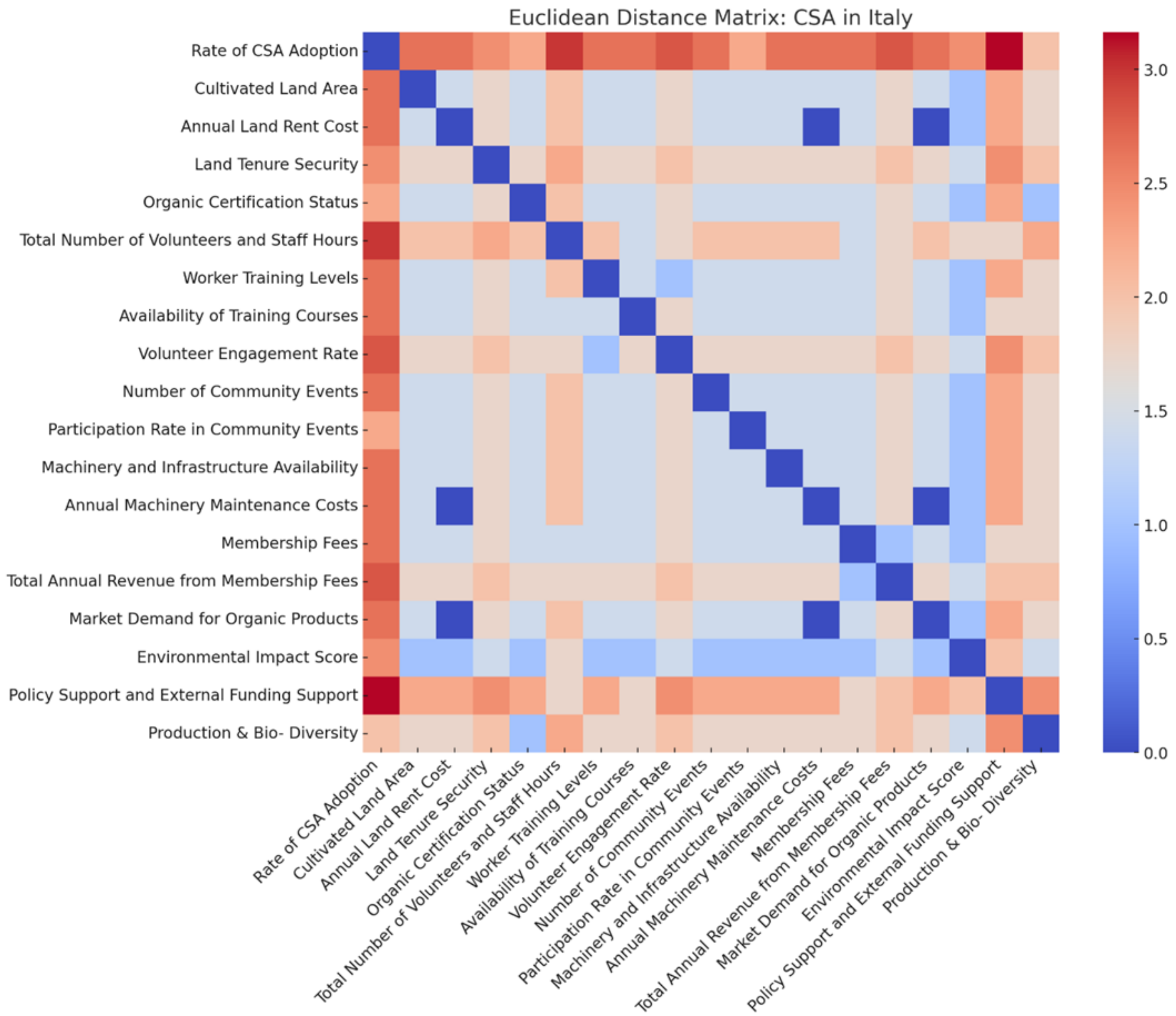


Figure 48 Euclidean Distance matrix case 8

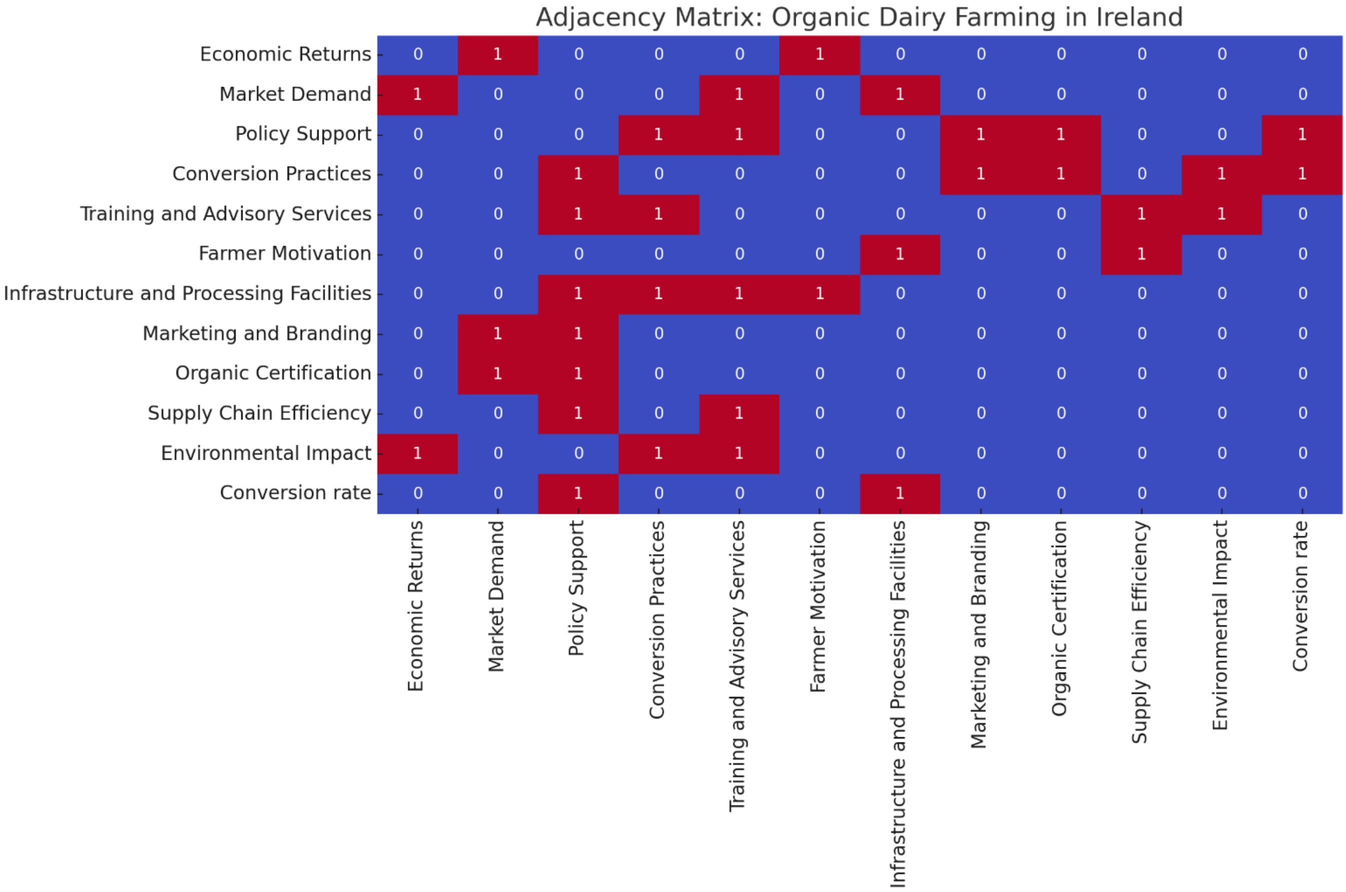


Figure 49 Adjacency Matrix case 9

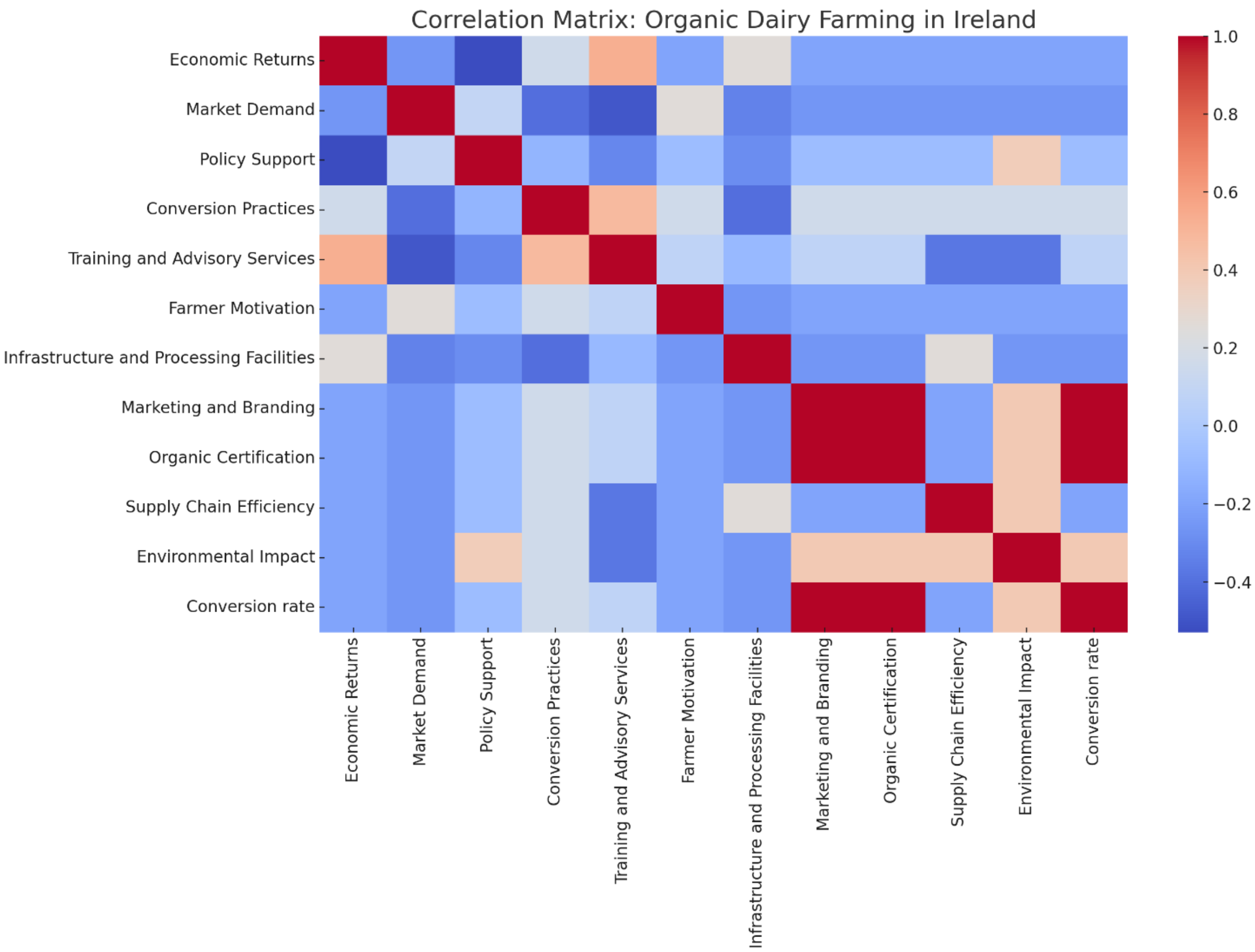


Figure 50 Correlation matrix case 9

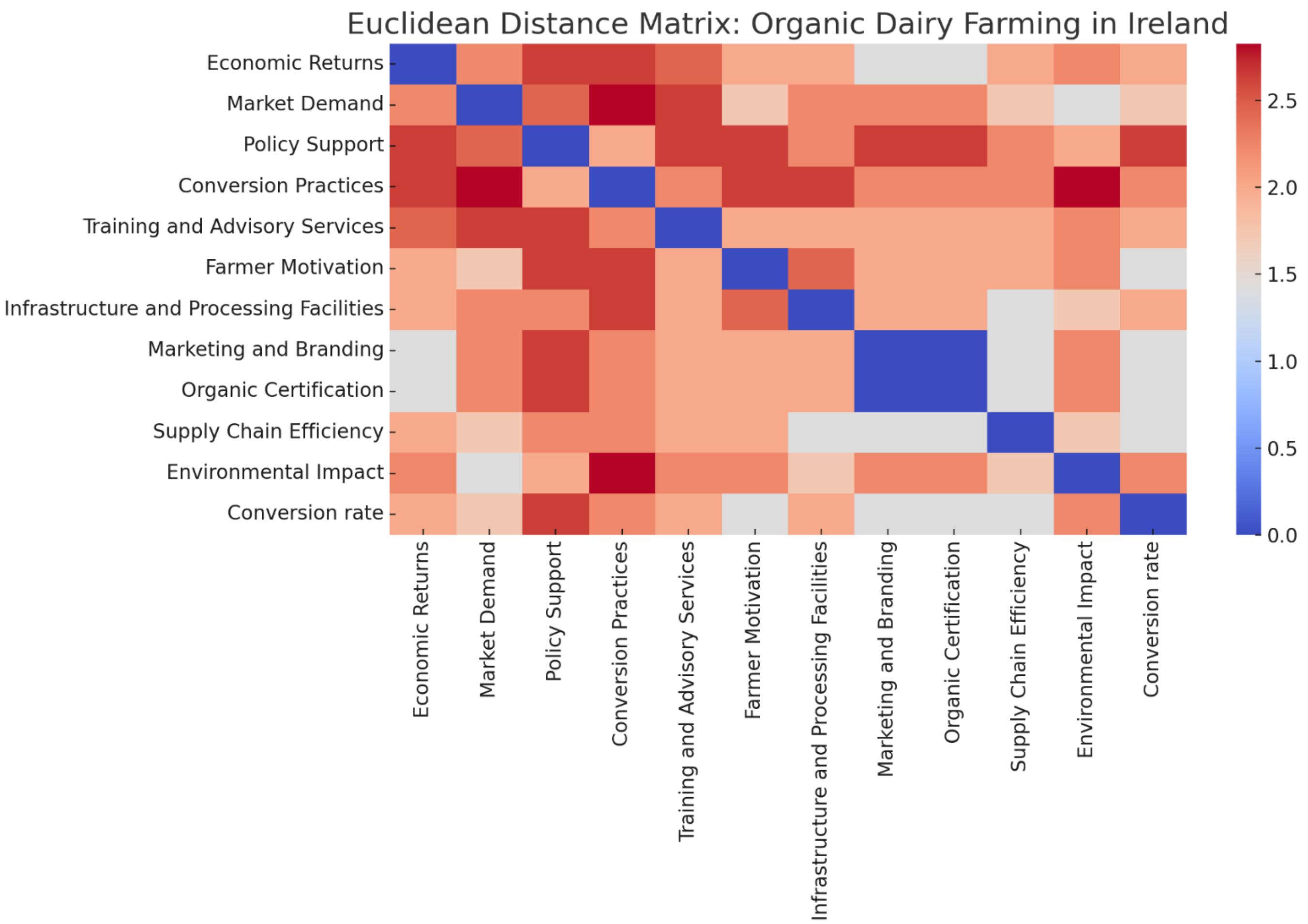


Figure 51 Euclidean Distance matrix case 9

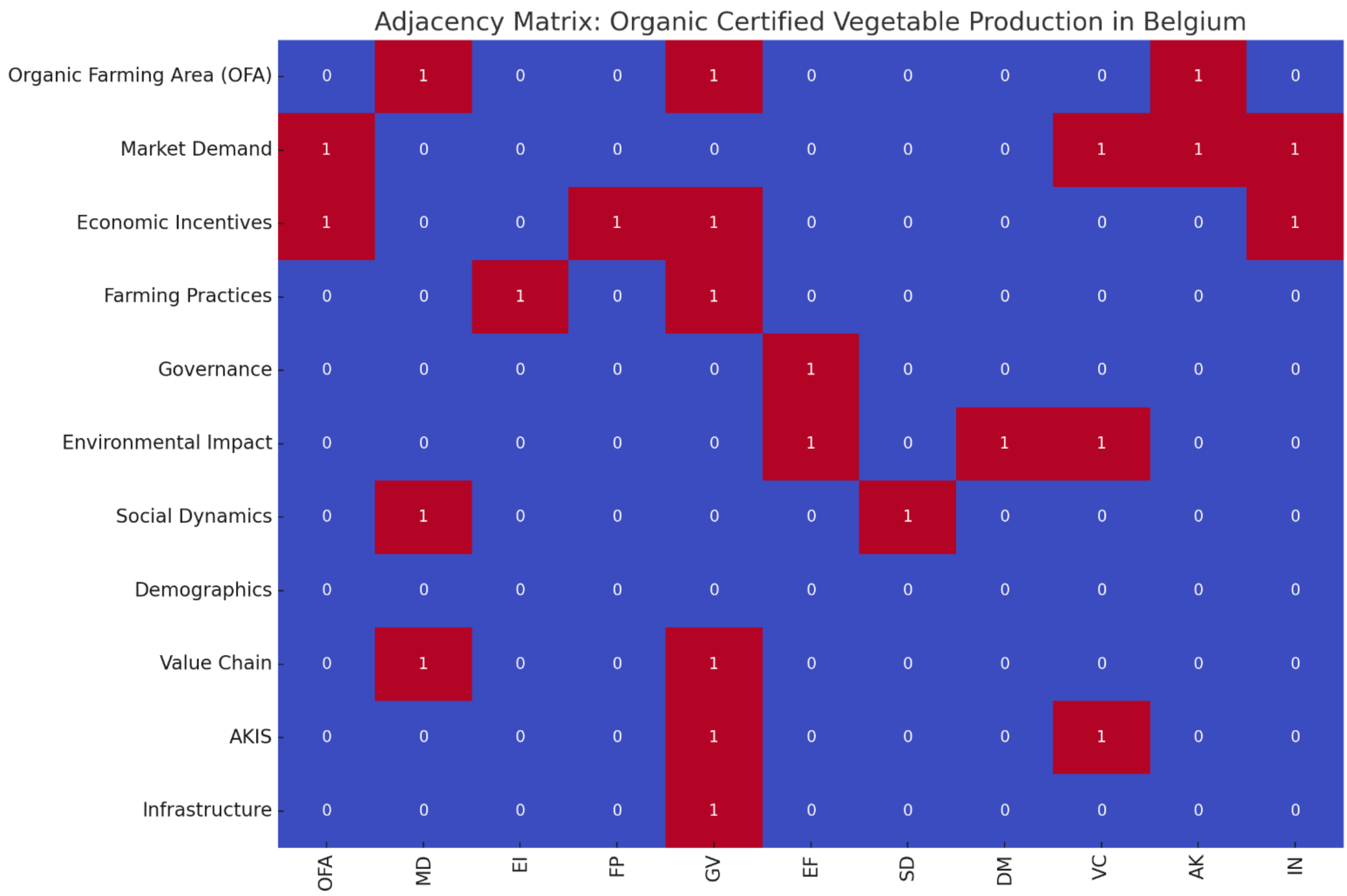


Figure 52 Adjacency Matrix case 10

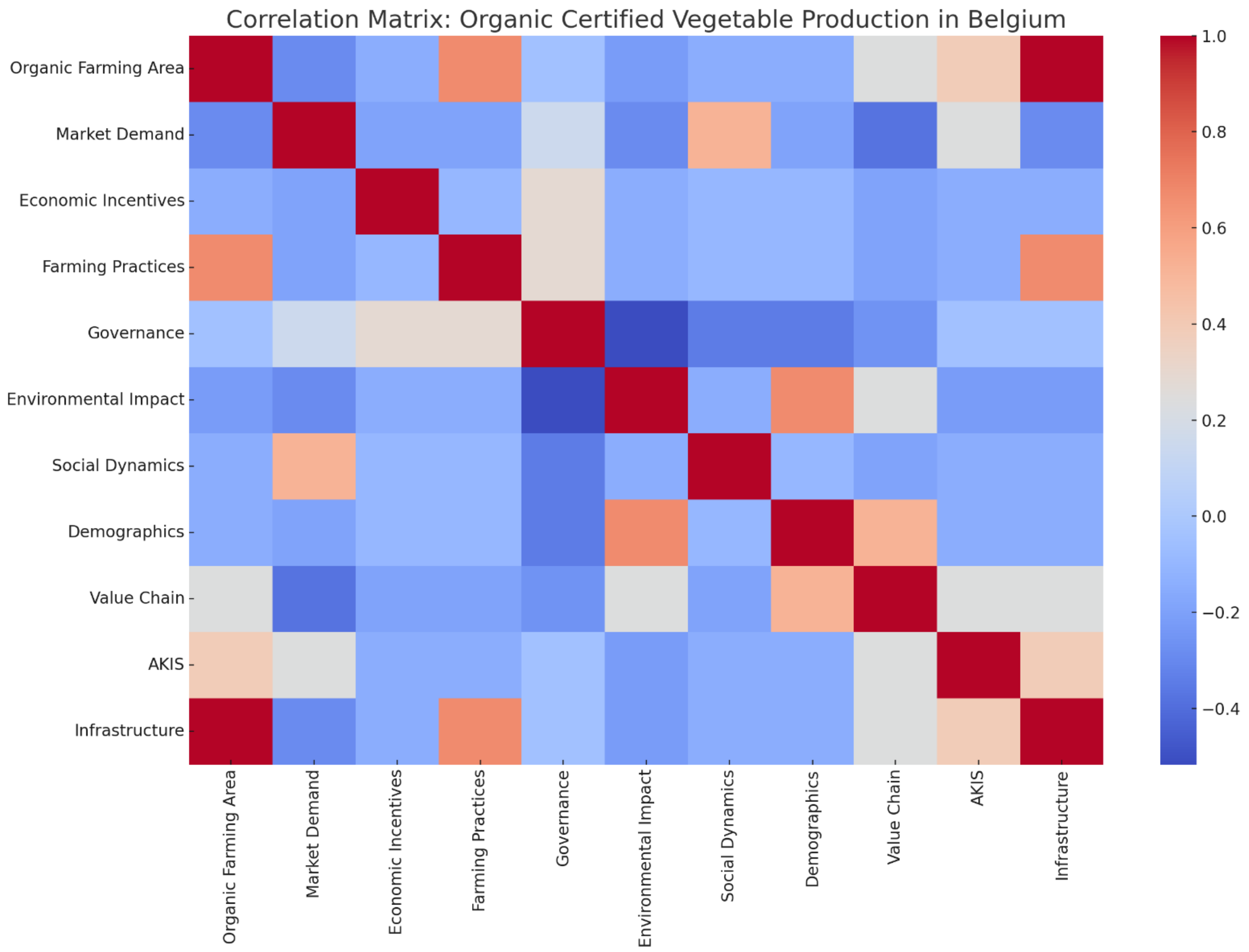


Figure 53 Correlation matrix case 10

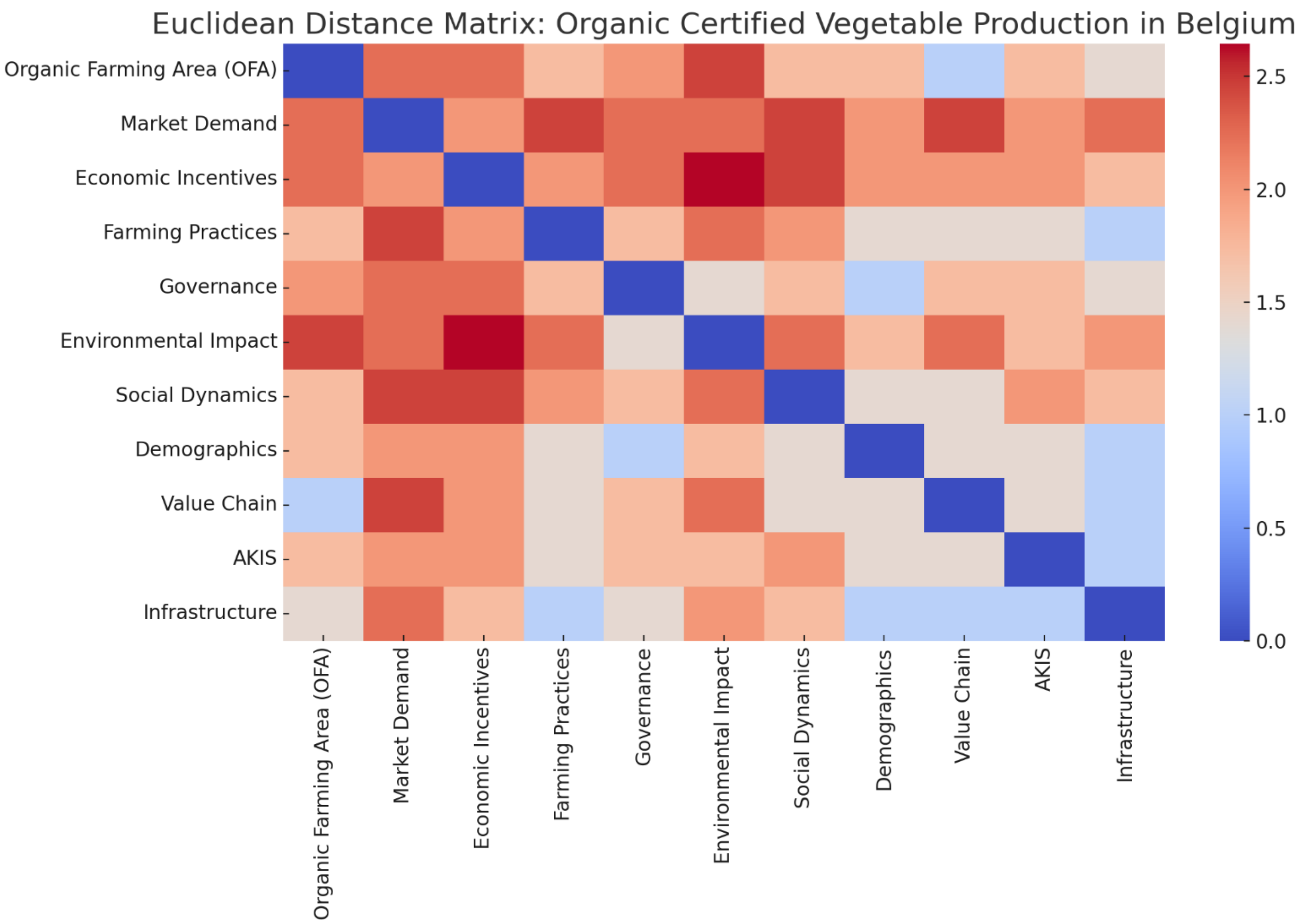


Figure 54 Euclidean Distance matrix case 10

11 Annex 5

A step by step guide for building causal loop diagrams: lessons learnt from task 2.2

This is the theoretical guideline that ideally should be used for the development of Causal Loop Diagrams (CLDs), entailing a systematic process that integrates primary and secondary data to model complex systems, such as agricultural transitions, as described in Task 2.2 of the ENFASYS project. This theoretical guideline provides a detailed methodology to ensure that all significant system dynamics are captured and analysed. Because of the complexity of our project and the number of cases and stakeholders involved, in some instances has been difficult to abide to the theoretical plan and we had to

The methodological approach in **Task 2.2** is centred around the development and refinement of causal loop diagrams (CLDs) to analyse and understand the complex dynamics within agricultural systems. This process builds on the findings from Task 2.1 where we have identified the actors, their interactions and the boundaries of the case study. And as such involves several key steps to ensure comprehensive and accurate system representation. The activity begins with the creation of an initial draft of the CLD for each case study by NIBIO. To construct these initial CLDs, a combination of primary and secondary data sources is utilized. Primary data is collected through key informant interviews and ideally through group model building (GMB) sessions, which provide detailed causal information on the drivers of specific behaviours or phenomena within the system. These interactions with stakeholders not only help in mapping out these drivers but also offer insights into potential systemic leverage points and necessary course corrections for problematic behaviours depicted in the CLD. Secondary data, including published literature, grey literature reports, and policy papers, are also employed to build the CLDs. This data is systematically reviewed, integrated, and classified to create cause-and-effect linkages that can be represented in the diagrams. Combining primary and secondary data sources is common practice, particularly when recurrent access to stakeholders is limited. Presenting the findings from secondary data-based CLDs to stakeholders for validation ensures that the diagrams accurately capture important information and fosters research buy-in and acceptance of the results. The creation of the CLDs involves either ex-post development, which builds the CLDs from collected data, or real-time development, which involves creating the CLDs with stakeholder input. ENFASYS adopts a mixed-method approach where the initial draft CLDs are based on data and then corroborated through stakeholder interaction. Thematic analysis or purposive text analysis can be used to develop the CLDs, with the latter being more suitable for the ENFASYS structure. This involves extracting quotations describing drivers for behaviours of interest and identifying cause-and-effect statements, which are then used to create diagrams representing these relationships.

The process of developing the initial CLD involves several steps:

1. **Defining the Situation:** The first step involves understanding and visualizing a complex problem or situation within its broader reality. This includes exploring factors that might explain the situation and analysing the nature of the relationships between them, considering multiple stakeholders' perspectives.
2. **Identifying Framings**: After defining the situation, the different ways in which it can be understood or framed are identified. This involves bilateral meetings with case study coordinators to review and verify the framing of their respective case studies, ensuring that the perspectives of all relevant stakeholders are considered.
3. **Deepening Framings**: During these meetings, questions based on the CATWOE framework (Customers, Actors, Transformation process, Worldview, Owner, Environmental constraints) are addressed to understand the desirable transformations, the rationale behind them, and the stakeholders involved.
4. **Reflecting on Boundaries and Purpose**: Relevant elements of the situation are identified and transformed into key variables, establishing the boundaries of the system. An interrelationship diagram is used to explore the potential relationships between these variables, providing a basis for developing the CLD.
5. **Creating the Initial CLD**: The interrelationship diagram is transformed into a causal loop diagram by identifying the drivers and outcomes in the system, exploring the cause-and-effect relationships, and determining the polarity of these relationships. Feedback loops within the system are identified, highlighting reinforcing and balancing loops.
6. **Refining the Initial CLD**: The initial CLD is refined through bilateral meetings with case study coordinators and reviewed during targeted meetings. This iterative process ensures that the CLDs are accurate and reflective of the diverse stakeholder perspectives.

7. **Validating the Initial CLD**: The initial CLD is further developed and validated through stakeholder workshops. This validation process ensures that the understanding of the system is accurate and that potential pathways to the desired transformations are identified. In Enfasys this step was carried out unevenly due to the complexity and diversity of the cases.
8. **Aggregation of CLDs**: Following the validation, the WP2 team aggregates the ten CLDs using structural equivalence analysis to develop a general systems-based account of food system mechanisms. This involves hierarchical clustering to group similar nodes based on their degree centrality in the combined network of CLDs, capturing the feedback mechanisms underlying systemic lock-ins and potential levers in each case study.

Building the CLD first draft

1. *Identifying Key Elements and Variables:* The first step in creating a CLD is identifying the main elements and variables that play a significant role in the system. E.g. in one of our case studies these include:
   - Knowledge and Skills in Biodiversity Management
   - Biodiversity Quality and Environmental Benefits
   - Financial Incentives and Policy Adjustments
   - Stakeholder Collaboration and Innovation
2. *Mapping Relationships:* Once the key elements are identified, the next step is to determine how these elements interact. For instance:
   - Increased Knowledge and Skills in Biodiversity Management lead to better management practices.
   - Better management practices enhance Biodiversity Quality, which in turn contributes to greater environmental benefits.
   - Financial Incentives are identified as motivating factors for adopting biodiversity practices. However, there is a dynamic tension as these incentives need to be adjusted to ensure they lead to real improvements in biodiversity rather than just fulfilling financial criteria.
   - Stakeholder Collaboration drives innovation in biodiversity practices, which improves outcomes and further motivates collaboration and improvement.
3. *Identifying Feedback Loops:* In a CLD, feedback loops are fundamental .because they represent the dynamic behaviour of systems, showing how variables influence each other in circular, self-reinforcing (positive) or balancing (negative) ways. These loops are crucial for several reasons:
   - Capturing System Dynamics: Feedback loops help illustrate the cyclical nature of cause-and-effect relationships within complex systems. They show how a change in one variable can propagate through the system and potentially influence the original variable over time, either amplifying or stabilizing the effect.
   - Identifying Drivers of Change: Positive feedback loops, also known as reinforcing loops, highlight areas where small changes can escalate and lead to rapid growth or decline. Understanding these loops is key for identifying leverage points where interventions can amplify beneficial effects or curb negative trends.
   - Understanding Stability and Resistance to Change: Negative feedback loops, also called balancing loops, regulate systems by counteracting changes and maintaining equilibrium. They are essential for understanding the resilience of a system and why certain systems are resistant to change or return to their original state after being disturbed.
   - Exploring Complex Interdependencies: In many real-world systems, multiple feedback loops interact, often in unexpected ways. CLDs make these interdependencies visible, helping to reveal potential unintended consequences or long-term effects of certain actions or interventions.
   - Decision-Making and Policy Analysis: By mapping feedback loops, decision-makers can better anticipate how policies or changes to one part of the system will influence the entire system over time. This is critical for developing strategies that aim to promote sustainable changes without causing negative ripple effects.
   - Revealing Lock-ins and Path Dependencies: Feedback loops can help identify lock-ins—situations where self-reinforcing dynamics make it difficult to change the system. For example, economic or technological lock-ins may occur when positive feedback loops continuously favor the dominant approach, preventing more sustainable alternatives from emerging.
4. *Drawing the Causal Loop Diagram:* Using the relationships and feedback loops, a CLD is drawn. This involves placing the variables in a diagram using Vensim and connecting them with arrows that show the direction of influence, along with signs (+/-) to indicate the nature of the impact (positive or negative). Loops are marked to show feedback dynamics.

5. *Analysis and Interpretation:* With the CLD, stakeholders can visually understand the complex interactions and dynamics within the system. This diagram helps in predicting how changes in one aspect of the system might ripple through and affect other aspects. For example, how a shift in public funding efficiency might impact the financial incentives and, subsequently, the biodiversity practices on the ground.

Further refinement of the CLD

Structural equivalence analysis is a method used in social network analysis to assess the similarity of network structures among different groups or individuals. It helps researchers understand whether two networks have similar patterns of relationships despite differences in the specific nodes or ties within the networks (Lorrain & White, 1971). By using structural equivalence analysis, we can quantify this similarity. We might measure metrics such as density (the proportion of actual ties to possible ties), centrality (the importance of nodes within the network), or clustering coefficient (the degree to which nodes cluster together). By comparing these metrics between the two organizations, we can determine whether their communication networks exhibit structural equivalence (Sailer, 1978).

Structural equivalence can be done so to:

1. *Create the adjacency matrix*: Represent the network as a matrix where rows and columns correspond to individuals, and entries indicate the presence (1) or absence (0) of direct communication.
2. *Calculate similarity or distance measures*: Use metrics like Euclidean distance, correlation, cosine or Jaccard similarity to quantify the similarity between the actors' rows in the matrix.
3. *Identify structurally equivalent individuals*: Look for individuals with high similarity scores, indicating they have similar or identical patterns of connections in the network.
4. Structural equivalence analysis is a powerful tool in network analysis that helps identify actors or variables with similar roles within a system. While primarily used for assessment, it also provides valuable insights for constructing and refining Causal Loop Diagrams (CLDs). As Schoenenberger et al. (2021) notes, this analysis can offer additional structure to the CLD building process.

In the ENFASYS project, Causal Loop Diagrams (CLDs) have been designed not only to identify key lock-ins and levers but also to lay the groundwork for the development of stock and flow models in Task 2.3. These stock and flow models will enable dynamic simulations, allowing us to observe how changes in key variables influence system behaviour over time. To ensure that these models are functional and informative, we prioritized measurable variables in the construction of the CLDs. Measurable variables facilitate accurate simulations and improve the ability to track system evolution and response to interventions. To manage the complexity of the systems being modelled, we employed structural equivalence analysis to streamline the number of variables included in the CLDs. This analysis helped identify variables with similar roles or interactions, allowing us to reduce redundancy by merging variables that convey the same information. This method has been critical in maintaining the balance between comprehensiveness and usability in both the CLDs and the forthcoming stock and flow models. By doing so, we ensure that the models are both robust and practical for identifying leverage points and implementing effective interventions in agricultural systems.

In the context of CLDs, **structural equivalence** analysis can:

1. *Identify key variables*: By revealing which elements have similar patterns of relationships, it can highlight important nodes that might represent leverage points in the system.
2. *Simplify complex systems*: When multiple variables show high structural equivalence, they might be consolidated in the CLD, reducing complexity without losing essential dynamics.
3. *Validate relationships*: The analysis can confirm, or challenge assumed relationships between variables, prompting further investigation where discrepancies arise.
4. *Guide CLD refinement*: By showing which variables are structurally similar, it can suggest areas where the CLD might be expanded or simplified.

However, it's important to note the limitations of this approach:

1. *Over-simplification risk*: Merging structurally equivalent variables might obscure important nuances in the system.
2. *Context loss*: The quantitative nature of the analysis might miss qualitative differences that are important in the specific context of the study.

3. *Static representation*: Structural equivalence provides a snapshot of the system, which might not capture dynamic changes over time.
4. *Interpretation challenges*: The results of structural equivalence analysis require careful interpretation to translate into meaningful CLD modifications.

To address these limitations, we use structural equivalence analysis as one tool among many in our CLD construction process. We combine its insights with qualitative data from stakeholder interviews, literature reviews, and expert knowledge to ensure a comprehensive and nuanced representation of the system in our CLDs.

The **adjacency matrix**, a key component of structural equivalence analysis, is particularly useful in mapping and analysing relationships between elements in a CLD. It provides a systematic way to represent and analyse the direct influences between variables, supporting both the initial construction and subsequent refinement of the CLD. As such, it was seen as an appropriate way to feed into the work of UNIBO on the ex-ante systems dynamics model by providing a coherent qualitative dataset representing the structural relationships between variables. This structural information can then be combined with historical data and other qualitative insights to inform the development of the quantitative system dynamics model

By integrating structural equivalence analysis and adjacency matrices into our CLD construction process, we aim to balance quantitative rigor with qualitative insights, resulting in CLDs that accurately represent the complex dynamics of agricultural systems while remaining accessible and useful for stakeholders and decision-makers. Building the adjacency matrix:

1. Defining the Nodes: Each variable or element in the system that you identified during the structural equivalence analysis (e.g., Knowledge and Skills in Biodiversity Management, Biodiversity Quality, Financial Incentives, Stakeholder Collaboration) becomes a node in the matrix.
2. Constructing the Adjacency Matrix: Create a square matrix where both the rows and columns represent these nodes. The matrix is typically filled with binary values (0 or 1), where 1 represents a direct influence or relationship from the node corresponding to the row to the node corresponding to the column, and 0 indicates no direct influence. For a more nuanced analysis, the matrix can also include weighted values that indicate the strength or significance of the relationships.
3. Populating the Matrix: For each pair of elements, determine if there is a direct causal relationship. If "Knowledge and Skills in Biodiversity Management" directly improves "Biodiversity Quality," then the matrix element at the intersection of "Knowledge and Skills" row and "Biodiversity Quality" column would be 1 (or a positive value representing the strength of influence). Repeat this for all pairs of variables to complete the matrix.
4. Using the Adjacency Matrix: The matrix helps visualize which elements directly impact others. By analysing the matrix, we can also explore indirect effects through matrix multiplication - multiplying the matrix by itself reveals paths of influence that span two steps, and so on. The matrix can be used to analyse the overall structure of the system's network, such as identifying which nodes are most influential (nodes with many outgoing connections), or nodes that are highly dependent on others (nodes with any incoming connections). By tracing paths through the matrix where the start and end points converge on the same node, you can identify potential feedback loops, which are critical in understanding system dynamics in CLDs.
5. Integration with CLD: While structural equivalence analysis is a network analytic method and CLDs are a systems dynamic tool, the findings from structural equivalence analysis can be valuable when building a CLD in the following ways:
    - *Identification of Influential Actors*: Structural equivalence analysis can reveal which actors or entities in a network have similar levels of influence or play similar roles. These actors can be represented as variables or nodes in a CLD, especially if the system being modelled includes social dynamics.
    - *Understanding Relationships*: The analysis may help in understanding how different actors are connected, which can be translated into influences and flows in a CLD. For instance, if two actors are structurally equivalent in promoting an idea or practice, this might be depicted as a reinforcing loop in a CLD.
    - *System Boundary Definition*: By identifying clusters of equivalent actors, structural equivalence analysis can help in defining the boundaries of the system to be modelled in the CLD by highlighting the key components and their interactions.
    - *Guiding Model Complexity*: If a network has multiple groups of structurally equivalent actors, this may suggest a level of redundancy or parallel processes in the system, which could be simplified or aggregated in a CLD to make the model more manageable.

- *Feedback Loop Identification*: Actors that have similar effects on others and receive similar feedback may be part of feedback mechanisms in the system. These can be represented as feedback loops in a CLD.

12 Annex 6

Full list of variables for each case study

Case	Key Variable	Quantitative Indicators
1	Rate of AECM Adoption	Proportion of farmers adopting AECM
1	EU Budget Allocation for AECM	EU budget allocated for AECM
1	Member State Budget Allocation for AECM	Budget from French government for AECM
1	Total Allocated Budget for AECM	Combined EU and French government budget for AECM
1	Subsidies Available for Farm Advisors	Budget for farm advisory services
1	Effectiveness of Advisory Services	Quality and impact of advisory services
1	Environmental Awareness	Level of environmental concern among farmers
1	Total Number of Advisors	Number of advisors available
1	Quota of Advising Service per Farmer for Each Advisor	Advisory capacity per advisor
1	Total Subsidies Available for Farmer Per Measure	Subsidies distribution for AECM practices
1	Subsidies Received by Each Farmer	Financial support received by farmers for AECM
1	Compliance Costs for Adoption	Costs to meet AECM standards
1	Farmer Administrative Burden	Documentation and planning burdens for AECM
1	Penalties related to AECM Contracts	Financial sanctions for non-compliance
1	Access to Knowledge and Expertise	Availability of AECM-related information
1	Training & Education	Training programs for advisors and farmers
1	Yield-increase mindset vs. sustainability mindset	Farmer focus on yield vs. sustainability
1	Sense of ownership and gratitude	Farmer engagement and commitment levels
1	Biodiversity and Ecosystem Services	Impact on on-farm biodiversity and ecosystem services
1	Territorial Initiatives	Local efforts to support sustainability
2	Rate of Adoption of RA	Adoption rate percentage
2	Youth Interest in Farming	Engagement level, new entrants in farming
2	Supply of Knowledge and Expertise of RA	Number of training programs, accessibility of expertise
2	Capacity of Public Extension and Advisory Services	Number of services/advisory sessions per advisor
2	Consultation Fee of Private Advisors on RA	Average cost of private consultation
2	Research on RA at Farm-Level	Number of farm-level RA studies
2	Social Acceptance & Cultural Acceptance	Community support level, cultural alignment with RA practices
2	Total Input Cost	Costs of chemical inputs, labour, machinery, and organic fertilizers
2	Profit	Revenue minus costs
2	Yield	Production output per hectare
2	Soil Quality	Soil health indicators
2	Plant Diversity	Variety of crops per hectare
2	Chemical Input Use	Quantity of chemical inputs used
2	Organic Fertilizer Use	Quantity of organic amendments used
2	Demand for Machinery	Type and quantity of machinery needed
2	Demand for Labour	Labor hours required for RA practices

Case	Key Variable	Quantitative Indicators
2	Supply and Availability of Machinery for RA	Availability and cost of RA-relevant machinery
2	Available Financial Subsidies	Financial assistance provided by government or organizations
2	Market Access	Ease of access to markets for RA products
2	Community Engagement and Education	Level of RA awareness programs
2	Cooperative	Number and activity level of agricultural cooperatives
2	Demand for Seeds	Types and quantity of seeds needed
3	Knowledge and Skills in Biodiversity Management	Number of farmers receiving biodiversity advice; Number of students attending biodiversity classes in basic agricultural training
3	Uptake of biodiversity measures by farmers	Number of farmers applying site specific measures for biodiversity Or Number of farmers engaging in biodiversity programmes (doesn't not really answer the question, but could be an approximation)
3	Biodiversity Quality on farmland	Soil health indicators, species diversity
3	Financial Incentives	Amount of subsidies, financial assistance
3	Stakeholder Collaboration	Number of collaborative projects, stakeholder interactions
3	Biodiversity Friendly Policy Adjustments	Number of biodiversity friendly policy adjustments within 4 years
3	Food and Feed Production	Agricultural production
3	Other environmental Benefits	CO_2 reduction
4	Local Feed Sources	Hectares under legume cultivation
4	Economic Incentives	Amount of subsidies, financial assistance
4	Market Stabilization Tools	Use of futures contracts, price stability metrics
4	Infrastructure Development	Infrastructure spending, number of new facilities
4	Sustainable Agriculture Policies	Number of policies passed, impact assessments
4	Enhanced Pasture Management	Soil quality indicators, pasture yield
4	Market Dependency Reduction	Percentage of local consumption, import statistics
4	Indicator-Based Monitoring	Monitoring data on agricultural practices, specific indicators (e.g., protein autonomy, percentage of pasture usage, legume cultivation areas)
4	Extension Services	Number of training sessions, farmer outreach metrics
4	Skills Enhancement for Legume Cultivation	raining completion rates, practice adoption rates
4	Education & Community Engagement	Community workshop attendance, survey results
4	Resilience Building	Resilience metrics, recovery rates after disturbances
5	Policy Requirements (PR)	Number of policies enacted per year, pig farming compliance rate percentage
5	Farmer Proposals and Adoption Practices (FP+ARSP)	Number of sustainable practices proposed and adopted by farmers
5	Regional Feed Production (RFP)	Tons of feed produced locally per year, percentage of feed consumption that is regionally sourced
5	Animal Welfare Systems (AWS)	Number of farms achieving certain animal welfare standards, amount invested in welfare improvements
5	Value Chain Development (VCD)	Number of stakeholders involved, efficiency index of the value chain
5	Actor Influence (AI)	Number of key actors supporting or obstructing sustainable practices, influence rating (scale of 1-10)
5	External Market Factors (EMF)	Index of market price fluctuations for pork and feed, number of farms affected by external crises

Case	Key Variable	Quantitative Indicators
5	Consumer Willingness to Pay (CWTP)	Degree to which consumers are willing to pay more for sustainably produced pork products
5	Government Funding Support (GFS)	Financial support provided by government bodies
5	Environmental Impact (EI)	Reduction in greenhouse gas emissions, changes in land use efficiency
5	Profit (P)	Financial gain or loss from pig farming operations
5	Arable Production System (APS)	Cultivation of crops used for animal feed
5	Animal Husbandry System (AHS)	Management and care practices for livestock
5	Certification	Process and standards required for sustainable farming practices
5	System Trust	Level of trust in the system by various stakeholders
5	Constantly Changing Regulations	Frequency and impact of changes in regulations
5	Perceived Regulatory Risk	Risk perceived by stakeholders regarding regulatory changes
5	Policy Dialogue	Communication and negotiation between policymakers and stakeholders
5	Regional Quality Label (RQL)	Label awarded to farms/products meeting regional standards
6	Practices to Reduce Fertilizers	Fertilizer application rates per hectare
6	Market Stability	Market stability indices
6	Transportation and Logistics Challenges	Transportation costs, delivery times, number of cooperative initiatives
6	Cooperation Among Small Producers	Number of cooperative initiatives, collaboration rates
6	Investment in Digital Agriculture Technologies	Investment rates, ROI on technologies
6	Knowledge and Training in Sustainable Practices	Training completion rates, practice adoption rates
6	Consumer Education	Consumer awareness programs
6	Willingness to Pay	Willingness to pay surveys
6	Market-Related Barriers	Number of barriers identified, successful mitigation strategies
6	Entry of Organic/Biological Products	Number of new organic products in the market, market share
6	Distribution of Organic/Biological Products	Distribution channels, market penetration rates
6	Market Access for Organic Products	Market entry rates, distribution channels
7	Farmers' Revenue from Direct Selling	Total income generated by farmers from direct selling
7	Investment in Direct Selling Infrastructure	Capital invested in facilities and digital platforms for direct selling
7	Farmer Training and Capacity Building	Number of training programs, participation rates
7	Short Supply Chain Development and Local Economy Enhancement	Number of initiatives, impact on local economy
7	Number of Farmers Using Digital Marketing Tools	Adoption rate of digital marketing strategies by farmers
7	Consumer Demand for Locally-Sourced and Organic Products	Preference and purchase volume of local and organic products
7	Cost of Production and Distribution	Total costs associated with production and distribution
7	Market Prices of Directly Sold Products	Valuation of directly sold products
7	Market Accessibility	Ease of accessing markets, diversity of product range
7	Labor Hours Dedicated to Direct Selling	Total labour investment in direct selling activities
7	Consumer Engagement	Level of consumer interaction and application usage

Case	Key Variable	Quantitative Indicators
7	Consumer Awareness and Trust Levels	Level of consumer awareness and trust in direct selling products
7	Rate of Adoption of Organic Certification and Labelling	Number of farmers with organic certifications and labelling
7	Farmer's Profit	Net financial gain from direct selling activities
7	Rate of Adoption of Farmers Practicing Direct Selling	Percentage or number of farmers practicing direct selling
7	Technical Support and Quality Assurance	Support services provided to farmers
7	Policy and Regulatory Support with Chamber Advocacy	Influence of policy and regulations shaped by advocacy efforts
7	Legislative Compliance	Adherence to regulations
7	Generational Dynamics	Changes due to generational shifts
7	Environmental Impact Score	Measure of environmental impact
8	Rate of CSA Adoption	Rate of CSA Adoption
8	Number of new members per year	Number of new members per year
8	Organic Certification Status, Market Demand for Organic Products	Organic Certification Status, Market Demand for Organic Products
8	Positive influence on community engagement, financial stability, and CSA growth	Positive influence on community engagement, financial stability, and CSA growth
8	Cultivated Land Area	Cultivated Land Area
8	Total hectares used for agriculture	Total hectares used for agriculture
8	Annual Land Rent Cost	Annual Land Rent Cost
9	Organic Certification	Number of farms certified organic
9	Conversion Practices	Adoption rates of organic farming practices
9	Environmental Impact	Soil health, biodiversity indices
9	Economic Returns	Profit margins, market prices
9	Policy Support	Number of policies, amount of subsidies
9	Training and Advisory Services	Number of training sessions, farmer participation rates
9	Infrastructure and Processing Facilities	Investment in facilities, number of processing units
9	Farmer Motivation	Survey results on farmer willingness to convert
9	Marketing and Branding	Marketing campaigns, consumer awareness metrics
9	Supply Chain Efficiency	Cost of logistics, delivery times
9	Market Demand	Sales volumes, consumer preference data
10	Organic Farming Area	Hectares under organic farming
10	Market Demand	Consumer preferences, sales volumes
10	Environmental Impact	Soil health, water quality, biodiversity indices
10	Farming Practices	Adoption rates of sustainable techniques
10	Governance	Number of policies, amount of subsidies
10	Economic Factors	Profit margins, market prices, land prices
10	Social Dynamics	Rural-urban divide, social attitudes, market access
10	Demographics	Age distribution of farmers, labour availability
10	Value Chain	Efficiency metrics, cost of logistics
10	AKIS (Agricultural Knowledge & Innovation Systems)	Number of training sessions, farmer participation rates

13 Annex 7

List of unique variables after merging

#	Variable
1	Rate of AECM Adoption
2	EU Budget Allocation for AECM
3	Member State Budget Allocation for AECM
4	Total Allocated Budget for AECM
5	Subsidies for Farm Advisors
6	Total Number of Advisors
7	Quota for Each Advisor
8	Effectiveness of Advisory Services
9	Total Subsidies Per Measure
10	Subsidies Received by Each Farmer
11	Compliance Costs for Adoption
12	Farmer Administrative Burden9
13	Penalties related to AECM contracts
14	Access to Knowledge and Expertise
15	Training & Education
16	Territorial Initiatives
17	Environmental Awareness
18	Rate of Adoption of RA
19	Youth in Farming
20	Supply of Knowledge & Expertise
21	Capacity of Public Ext and Adv Serv
22	Consultation Fee of Private Advisors
23	Research on RA
24	Social/Cultural Acceptance
25	Total Input Costs
26	Profit
27	Yield
28	Soil Quality
29	Plant Diversity
30	Chemical Input Use
31	Organic Fertilizer Use
32	Demand for Machinery
33	Demand for Labor
34	Supply and Availability of Machineries
35	Available Financial Subsidies
36	Market Access
37	Community Engagement and Education
38	Cooperative
39	Demand for Seeds
40	Knowledge and Skills
41	Uptake of Biodiversity Measures

#	Variable
42	Biodiversity Quality
43	Financial Incentives
44	Stakeholder Collaboration
45	Policy Adjustments
46	Food and Feed Production
47	Other Environmental Benefits
48	Local Feed Sources
49	Economic Incentives
50	Market Stabilization Tools
51	Infrastructure Development
52	Sustainable Agriculture Policies
53	Enhanced Pasture Management
54	Market Dependency Reduction
55	Indicator-Based Monitoring
56	Extension Services
57	Knowledge and skills
58	Resilience Building
59	Policy Requirements
60	Government Funding Support
61	Policy Dialogue
62	System Trust
63	Constantly Changing Regulations
64	Perceived Regulatory Risk
65	Farmer Proposals and Adoption Practices
66	Regional Feed Production
67	Animal Welfare Systems
68	Actor Influence
69	External Market Factors
70	Environmental Impact
71	Certification
72	Arable Production System
73	Animal Husbandry System
74	Regional Quality Label
75	Practices to Reduce Fertilizers
76	Market Stability
77	Transportation and Logistics Challenges
78	Cooperation Among Small Producers
79	Investment in Digital Agriculture Technologies
80	Knowledge and Training in Sustainable Practices
81	Consumer Recognition
82	Willingness to Pay
83	Market-Related Barriers
84	Entry of Organic/Biological Products
85	Distribution of Organic/Biological Products
86	Market Access for Organic Products
87	Farmer's Revenue from Direct Selling

#	Variable
88	Investment in DS Infrastructure
89	Farmer Training and Capacity Building
90	Short Supply Chain Development
91	Number of Farmers Using Digital Marketing Tools
92	Consumer Demand for Locally-sourced and Organic Products
93	Cost of Production and Distribution
94	Market Prices of Directly Sold Products
95	Market Accessibility
96	Labor Hours Dedicated to DS
97	Consumer Engagement
98	Consumer Awareness and Trust Levels
99	Rate of Adoption of Organic Certification and Labelling
100	Farmer's Profit
101	Rate of Adoption of Farmers Practicing Direct Selling
102	Technical Support and Quality Assurance
103	Policy and Regulatory Support with Chamber Advocacy
104	Legislative Compliance
105	Generational Dynamics
106	Rate of CSA Adoption
107	Cultivated Land Area
108	Annual Land Rent Cost
109	Organic Certification
110	Conversion Practices
111	Economic Returns
112	Policy Support
113	Training and Advisory Services
114	Infrastructure and Processing Facilities
115	Farmer Motivation
116	Marketing and Branding
117	Supply Chain Efficiency
118	Market Demand
119	Organic Farming Area
120	Farming Practices
121	Governance
122	Economic Factors
123	Social Dynamics
124	Demographics
125	Value Chain
126	AKIS
127	Yield-increase mindset vs. sustainability mindset
128	Sense of ownership and gratitude
129	Biodiversity and Ecosystem Services
130	Education & Community Engagement
131	Consumer Willingness to Pay (CWTP)
132	Number of new members per year
133	Organic Certification Status, Market Demand for Organic Products

#	Variable
134	Positive influence on community engagement, financial stability, and CSA growth
135	Total hectares used for agriculture

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