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SYSTEMIC CHANGE FOR SUSTAINABLE FUTURES

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THEME 1. TRANSITION PATHWAYS: CHANGING SYSTEMS OF FARMING, SUPPORT AND GOVERNANCE

Convenors: Julie Ingram, Teresa Pinto Correia, Egon Noe, Esther Sanz-Sanz, Elisa Marraccini, Talis Tisenkopfs

METHODOLOGY, METHODS AND TOOLS FOR ANALYSING TRANSITIONS I

Agroforestry design approach: DEXiAF, a tool for sustainability assessment

Aude Alaphilippe[1], François Warlop[2], Nicolas Brault[3], David Grandgirard[3], Catherine Delhoume[3], Laetitia Fourrie[2]

1 INRA, UERI Gotheron, 26 320, St Marcel-Lès-Valence, France

2 GRAB, Groupement de recherche en Agriculture biologique, 84911, Avignon, France

3 UniLaSalle Beauvais – Rouen, 60026, Beauvais, France

Abstract

Design of agroforestry systems (AFS) is challenging. While existing "engineering" guides support AFS conception, they fail to fully satisfy agroforestry project holders. To address this, the DEXiAF tool evaluates AFS sustainability ex ante but lacks dissemination. The MOCA project aims to operationalize co-design and DEXiAF tool. We conducted surveys, interviews, and workshops in order to identify support needs and developed training courses. DEXiAF was refined to align with co-design and tested for usability. Findings reveal varying AFS design approaches and support needs. Proposed training sequences integrate DEXiAF to aid knowledge acquisition and system design. DEXiAF's consolidation involves harmonizing input criteria and addressing agroforestry specificity. Practical implications highlight DEXiAF's potential to guide AFS design and learning. Theoretical implications suggest design and decision-support tools can overcome obstacles to agroforestry adoption. DEXiAF's holistic sustainability approach and educational potential offer promise for widespread use and knowledge transfer, pending statistical validation across diverse agro-climatic contexts.

Purpose

Agroforestry systems (AFS) are complex agroecological systems, particularly because of their multi-species and multi-production characteristics. It thus requests an important effort of ideation and design for farmers to become performant and sustainable innovative agrosystems.

In France, advisors using «Engineering» guides to conceive agroforestry systems (eg Csikvari et al., Warlop et al., 2017) support agroforestry project holders. These “engineering” guides consist in designing, setting up and managing AFS over farms as well as meeting basic requirements concerning trees’ characteristics, administrative and technical parcel limits, investment and subsidies opportunities … Although these guides are well disseminated, it appears that conceived and deployed AFS neither give full satisfaction to owners, nor convince neighbouring farmers to adopt agroforestry. Thus, DEXiAF, a tool to evaluate *ex ante* the sustainability of the future prototypes, was developed to complement this theoretical design approach. However, it has not been disseminated yet.

Trainers, advisors and researchers built the MOCA project in order to make both the co-design approach and the evaluation tool operational. It consists of several actions among which:

- Understanding the support system for project holders and offer appropriate training courses in the co-design of agroforestry systems.
- Consolidation of the DEXiAF performance evaluation tool in line with this co-design process and support/training system;

Both actions will be presented in this paper.

Design/Methodology/Approach

In order to first understand the French support system for agroforestry project holders and to identify their needs in knowledge and training, a) surveys was conducted and then b) interviews and workshop were held to co-build the training course plan. In parallel, c) the DEXiAF tool was improved to be in line with the co-design process and tests of use were conducted.

a. A survey: to understand the support system for project holders and identify needs for training

In order to gain a better understanding of the diversity of agroforestry system design trajectories, a survey was carried out in 2021 on a panel of French agroforestry farmers (n =52). The survey guide was divided into four parts i) the farm's history and the farmer's career; ii) typoly and AFS description; iii) record of the entire AFS design process and iv) the objective (challenges and performances). This survey help to understand the role of both the project holder and advisors and to identify the support needs of farmers/advisers and learners/trainers in particular the 3rd part of the survey. The 4th part aims at discussing the dimensions that make up the tools, the input criteria and the weighting of the elements to be considered in order to reflect these priorities and prefigure the way in which they will be used.

b. Workshop and tests to build the training sequences including DEXiAF

Interviews were conducted to identify the different existing learning situations. Based on the survey outcomes, two workshop bringing together tool designers and trainers/advisers were held in order to propose different training courses. Jointly, adaptation proposals for the DEXiAF tools to better integrate the needs for training were proposed during these workshops.

- on July the 8th July 2022 and, helped to build a framework for the design of AFS, by specifying, in the various stages of design, the knowledge and skills requirements, as well as the possible pedagogical uses of DEXiAF.

- on October the 12th 2023 : adaptation proposals for the DEXiAF tools to better integrate the needs for training.

c. Consolidation of the DEXiAF tool

Adapted on the DEXiPM® model (Pelzer et al., 2012); DEXiAF is an expert knowledge-based tool to rank the sustainability of agroforestry prototypes (excluding livestock so far). It was implemented within the DEXi decision support system (Bohanec, 2009) and is based on a decision tree subdividing the decisional problems of sustainability assessment into simpler units, referring to the three dimensions of sustainability. Experts from various disciplines including agronomy, economy and sociology have defined the choice of criteria, their hierarchy in the decision tree and the qualitative classes.

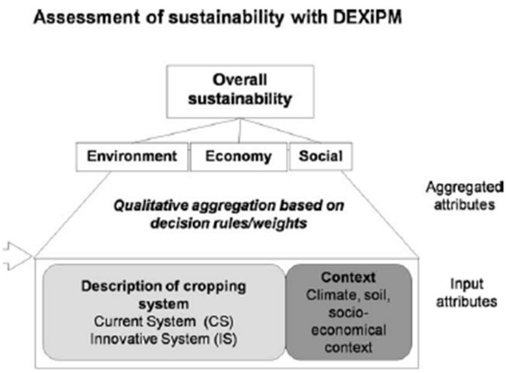

Figure 1. Upper structure of DEXiPM models (Pelzer et al., 2012), used as a basis for the DEXiAF model development

The work conducted since 2017 consisted first in adapting the DEXiPM model to agroforestry considering its specificity, including land occupation and evolution in time, and complexity, in particular in terms of management and work load. The second step of modification aimed to harmonize the input criteria of the tool with those used in the AFS design process. During this evolution process, DEXiAF use tests were conducted with trainers and learners as well as with advisors; five additional questionnaires were completed to specify the entry criteria. Since, the DEXiAF tool seemed too cumbersome to be used as a design support, a work has been undertaken to simplify its tree structure, while ensuring that the specific features of agroforestry systems was taken into account. The final version will be statistically checked in order to improve the discriminating power of the tool by using Monte-Carlo analysis.

Findings

a. Survey outcome and support needs

Analysis of the survey on AFS design trajectories from a panel of 52 agroforesters (project holders and farmers) enabled us to draw up a typology of AFS design approaches used by farmers, with varying levels of delegation to the technical advisor. The main AFS design steps consisted in defining the project holder’s objective and characterising its farm context (assets and constraints) and its available resources (structural planting choices and technical management). The survey pointed out that diagnostics were generally not carried out (or only to a limited extent), while the technical conception of the project (prototyping and design of the AFS) is often delegated to the advisor and rarely at projet project holders.

This survey (4th part of the survey) also showed that a very limited number of farmers as well as of advisers are considering the whole aspects of a SAF global sustainability such as the effects/impacts of adoption of such an innovative cropping system onto social, environmental, agronomic or economical dimensions. All together, the feedbacks from agroforesters' experiences help us to decide of the best way to develop, position and use DEXiAF.

b. Training courses proposal

Analysis of the interviews of advisors and trainers enabled us to identify a diversity of learning situations as presented in table 1 with three learning situation and one consultancy.

Table 1. Diversity of learning situations based on Moisan, 2022

Type of course	**By who**	**For whom**	**Duration**
Consultancy service	Advisor in agroforestry	Project holder	2 days
Training for adult	Agroforestry expert/teacher	Project holder (less mature project)	10 days
Certifying course	Agroforestry expert	Non expert advisor	5 days
Initial training	Agroforestry expert and agronomist	Student in bachelor degree, master 1 &2	1 to several weeks

During the two workshops involving tool designers and training advisors, a typical training sequence was developed, based on the AFS co-design approach proposed in MOCA and aimed to encourage the participation of project holders. Jointly, we tested and determined the following possible contribution of DEXiAF for teaching purposes:

i) during the knowledge acquisition phase to structure knowledge and/or illustrate some of it;

ii) during the prototyping and/or design phase of an AFS to help acquire skills relating to system design.

c. DEXiAF consolidation

In parallel, the DEXiAF tool has been finalised. The 92 input criteria have been harmonised with the data collected during the design process supported by the advisor.

Moreover, some adjustments were made to take into account the specificity of agroforestry production systems in terms of temporal and spatial scales. Regarding the environmental branchThey are context elements regarding the plot and landscape, the farming strategy as well as practices and we introduce elements regarding the layout of the agroforestry systems. As illustrated in Figure 2, input criteria are elements characterising:

- the plot or small farm susceptibility to here "runoff" (<10ha) (classes are linked to soil, climatic and slop)
- the design of the agroforestry system (with element on trees, such as tree density, tree line orientation…)
- the soil occupation with element concerning the bottom layer (including grassland cereals and other non-perennial crops).

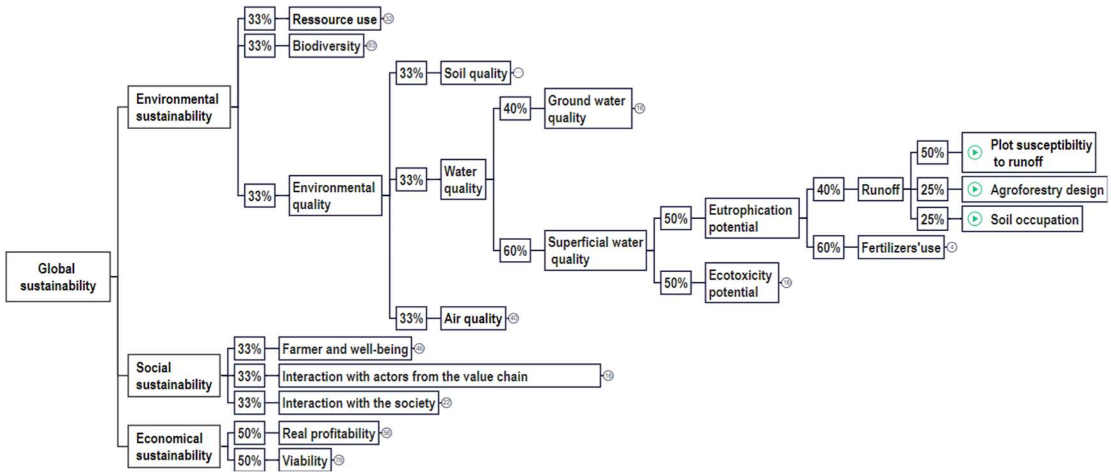

Figure 2. Upper structure of DEXiAF decision tree with detailed concerning the Europhication potential branch down to input criteria

Regarding the social branch of the decision tree has evolved to better integrate the complexity of these systems and in particular the consequences in terms of farmer's well-being including mental workload (figure 2).

At this stage, the statistical analysis are in progress.

Practical Implications: DEXiAF potential usages

The output of the DEXiAF assessment is a global sustainability score as well as a dashboard to determine strengths and weakness of the planned AFS and to identify possible improvements on the global AFS design as well as on strategical choices. The newly proposed structure was chosen to help the project holder or student to reflect on both the layout of its agroforestry system and on annual cultural operations. Based on the tests of the tool, DEXiAF proved to be easy to use and not too time consuming (around 1,5 hour).

We thus proposed an operational version of DEXiAF:

- The 92 input criteria could be used as a checklist of elements to consider for the AFS design;
- The tool output could be used as a dashboard to determine strengths and weaknesses of the evaluated system.

With the aim (figure 3):

- To assist advisors and farmers in defining and optimizing the prototypes to be planted;

- To support learning by allowing interaction among users and thus facilitate communication and knowledge transfer.

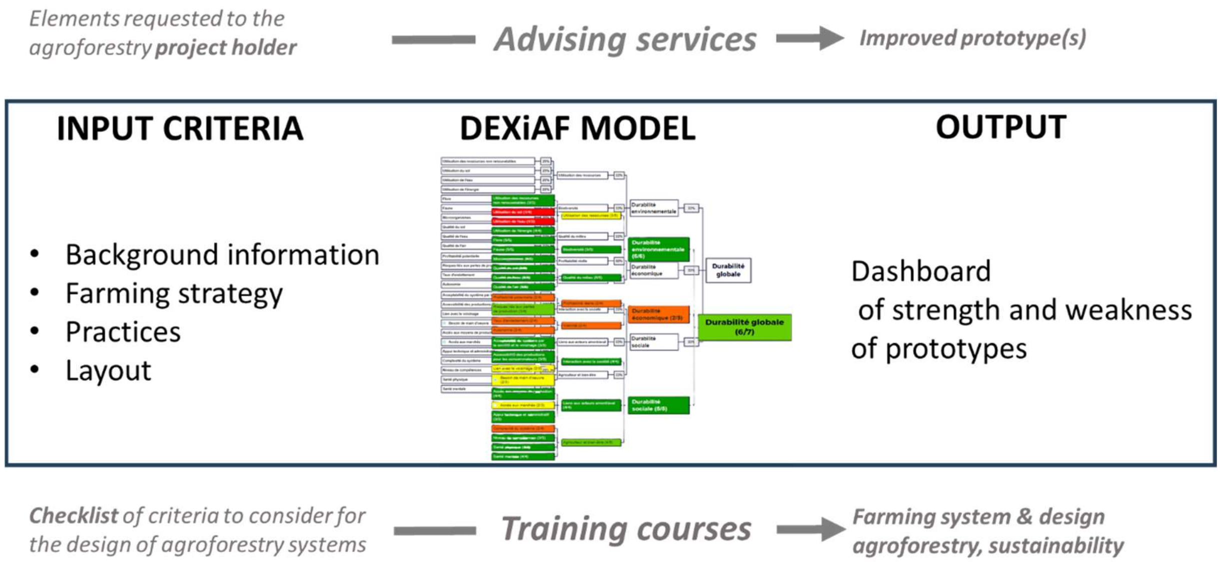

Figure 3. DEXiAF tool and its articulation with training and advising activities.

Theoretical Implications

Agroforestry is one of the major thrusts of the agro-ecological transition plan, but there are still a number of obstacles to the wider adoption of these cropping systems. To overcome these obstacles, design and decision-support tools appear to be well suited, as they provide a better understanding of the complexity of AFS.

DEXiAF adopts the same high structure as DEXiPM and presents a holistic vision of sustainability and its three pillars (figure 4). This new DEXiPM model is consistent with the sustainability as defined in the other DEXiPM models although it concerns a diversified farming system with specific spatial and temporal scales. However, regarding the spatial scale, DEXiAF relates to the farm scale and not to the cropping system scale.

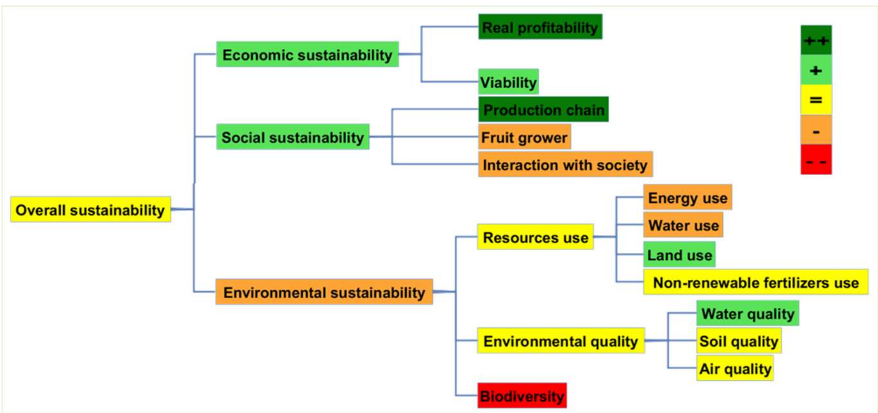

Figure 4. DEXiPM upper structure common to all DEXiPM models

This structure offers significant educational potential.

DEXiAF will be statistically checked and then validated thanks to the tests of several production systems over several agro-climatic contexts in Europe. It already proved to be easy to use and not too time consuming. Last, DEXiAF represents an opportunity for simulation-based design, since it supports co-design approach. It also encourages interactions among users and thus facilitate communication and knowledge transfer.

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Portray agroecological transition initiative in reflexive arrangements

Pauline Cassart[a], Anina Frei[b], Henrik Hauggaard-Nielsen[c], Henrik Kruse Rasmussen[d], Adrien Swartebroeckx[e], Eric Froidmont[f], Didier Stilmant[g]; Walter A.H. Rossing[h]

[a]Sustainability, Systems and Prospectives Department, Walloon Agricultural Research Centre, p.cassart@cra.wallonie.be

[b]Farming Systems Ecology Group, Wageningen University and Research, anina.frei@wur.nl

[c]Department of People and Technology, Roskilde University, hnie@ruc.dk

[d]Agrovi, hkr@agrovi.dk

[e]Sustainability, Systems and Prospectives Department, Walloon Agricultural Research Centre, a.swartebroeckx@cra.wallonie.be

[f]Sustainability, Systems and Prospectives Department, Walloon Agricultural Research Centre, e.froidmont@cra.wallonie.be

[g]Sustainability, Systems and Prospectives Department, Walloon Agricultural Research Centre, d.stilmant@cra.wallonie.be

[h]Farming Systems Ecology Group, Wageningen University and Research, walter.rossing@wur.nl

Abstract

Agroecology emerges as a solution to global agro-food system crises. Transformation to agroecological agro-food systems benefits from transdisciplinary collaboration between societal initiatives and scientists in reflexive arrangements. Developing a shared understanding of the history and current state of societal initiatives reinforce the effectiveness of such science-society interactions. To achieve this, we developed a heuristic framework including three pillars: context, actors and barriers/levers. Context dimensions include the biophysical environment, knowledge, society, policy, economy, and farming systems. Network metrics identify key actors and key barriers and levers through cognitive mapping. Within the Horizon Europe project Agroecology-TRANSECT, the heuristic framework is actively applied to portray eleven agroecological initiatives. As an example, its application to a Danish conservation agriculture (CA) network illuminated the main themes of the initiative, such as its effective facilitative advisory approach, the contested knowledge around CA or the lack of connections with certain groups of actors to improve the visibility and recognition of CA. The framework provides actionable insights for agroecological initiatives and facilitates cross-initiative comparisons and learning through its systematic nature.

Purpose

The urgency to transform agri-food systems in response to global crises is widely acknowledged (Mier Y Terán Giménez Cacho et al., 2018). Agroecology, often considered as a crucial element in this transformation, integrates science, social movements, and agricultural practices (International Forum for Agroecology, 2015).

Transdisciplinary knowledge development is crucial to support agroecological initiatives (López-García et al., 2021). Reflexive arrangements, as temporary collaborations of scientists and non-scientists, aim to co-create knowledge translated into transformative action (Hendriks and Grin, 2007). A shared understanding of an initiative's history and current state fosters trust and social capital, vital for effective science-society interactions (Hoffecker, 2021).

To reach this target, we developed a heuristic framework for portraying agroecological initiatives at the beginning of reflexive arrangements. Developed and tested in a Horizon Europe project called Agroecology-TRANSECT, the framework combines scientific expertise with local actor knowledge to create a shared representation of the initiative's history and current state. Drawing on quantitative and qualitative approaches for systems characterization, participatory reflexive approaches, and evolution of societal initiatives, the framework offers a learning-oriented approach.

The heuristic framework addresses the initiative's context, actors, and barriers and levers for development. The application of the heuristic framework to a Danish conservation agriculture (CA) network, as illustration, demonstrates how a shared understanding facilitated joint action within the project's mandate.

Methodology

The heuristic framework, arising from a systematic review of transformative projects, includes three pillars [(a) context, (b) actors, and (c) barriers/levers] described below.

Data collection involves conducting semi-structured interviews with key actors from the agroecological initiative, complemented by a document analysis (i.e. online information about the initiative, as well as action plan and learning history developed as part of the project's co-innovation approach). Key actors are individuals actively involved in the initiative, with a thorough understanding of its history and current situation. The selected key actors should hold various roles within the initiative to offer diverse perspectives. In the case of the Danish CA network, four key actors were identified, in consultation with one of the initiative's facilitators, for conducting in-depth interviews.

The interviews are transcribed and subjected to coding for analysis. To validate the findings, the results are shared with the key actors of the initiative, and then discussed in an online session. This collaborative process enables the participants to contribute insights, refine the analysis, and validate the conclusions. Following this feedback loop, a final portrait report is made.

Context

Context mirrors the specific conditions in which agroecological initiatives are (Barrios et al., 2020) and is described through six dimensions: biophysical environment, knowledge, society, policy and governance, economy and farming systems.

Actor network

Social networks, pivotal in agroecological transitions (Anderson et al., 2019), facilitate information and material flow and collaboration. Actor positions within the network influence innovation capacity (Gaitán-Cremaschi et al., 2022), and reveal potential levers for change (Rocker et al., 2022). Using cognitive actor mapping, we analyse the agroecological initiative's social network, identifying key actors through metrics like degree and closeness centrality (Cornu et al., 2023; Rocker et al., 2022).

Barriers and levers network

Identification of barriers and levers prompts reflection on interventions and offers cross-initiative learning (Holmén et al., 2022). Barriers and levers are represented as nodes, connected by positive or negative edges depending on their impact, in a cognitive map. Network metrics, i.e. out-degree, in-degree, betweenness centrality (Rocker et al., 2022), determine individual barriers' and levers' roles and importance in the network. Key barriers are categorized as blocking, recurring, or eased, while levers are classified as powerful, influential, connecting, or minor.

Findings

Within the Agroecology-TRANSECT project, the heuristic framework is actively applied to portray eleven agroecological initiatives. We present the results by delving into one of them, the Danish CA Network - a network of approximately 50 farmers with cereal-dominated crop rotations involved in developing CA on their farms since 2016. Their overarching goal is to promote CA by fostering peer-to-peer knowledge exchange, particularly centered around innovative technical solutions.

Applying the framework to the Danish CA network revealed a technologically advanced, export-driven agricultural sector. Specializing in feed crops within arable farming, the sector operates under stringent environmental policies, and many farms face financial challenges with high debts and low-profit margins.

The actor network analysis identified 27 actors to be part of the Danish case study network. Three of them constitute the core of the reflexive arrangement, including an advisory company, CA farmers, and a national university. Next to those three actors, key actors related to policy and research. In comparison with research actors, policy actors displayed stronger connections within the network. Although economic actors were loosely tied to the network, society actors were largely absent.

From the 30 barriers and 36 levers identified, 11 barriers and 10 levers were identified as key. These encompassed diverse themes, including the roles of advisors and scientists, the activation of horizontal knowledge structures, and the absence of financial incentives and visibility for CA.

Practical Implications

Applying the heuristic framework provides a shared understanding of the initiative's transformative journey, illuminating potential avenues for joint action. Actors of the Danish CA network noted that the outcomes prompted a reconsideration of their initiative's position. They specifically highlighted insights into the absence of connections to actor groups essential for enhancing visibility and recognition of CA farmers' positive contributions, the facilitative advisory approach challenging traditional top-down structures and successfully overcoming knowledge deficiencies, and the need to tackle the contested knowledge about CA's impact on carbon sequestration. This reframing of perspectives is recognized as social learning, a crucial element emphasized by scholars for driving transformative change (Rossing et al., 2021). Furthermore, a comparative analysis of portraits of the various agroecological initiatives within the Agroecology-TRANSECT project is anticipated to generate further actionable knowledge for these initiatives and foster learning in transformative endeavors.

Theoretical Implications

Leveraging more comprehensive methods for characterization and assessment, we present a learning-oriented framework to develop a shared portrait of an agroecological initiative. Striking a balance between comprehensiveness and promptness while upholding scientific rigor, the three complementary pillars have proved to form a coherent framework, enabling to pinpoint scientifically robust, locally pertinent characteristics to guide transformative endeavors. By developing a common understanding of the history and present state of societal initiatives, such as living labs, stakeholders can align their efforts by identifying joint actions within reflexive arrangements, ultimately driving transformative change towards agroecological agro-food systems. This shared understanding nurtures trust and social capital, crucial elements for effective science-society interactions (Douthwaite & Hoffecker, 2017). Given the increasing integration of agroecology into the European Commission's policy and the growing acknowledgment of transdisciplinary knowledge for sustainable agro-food system transformation, the development and application of such frameworks appear relevant.

Acknowledgements

The framework to portray agroecological initiative was developed as part of the EU Horizon research project Agroecology-TRANSECT and is being applied to 11 agroecological initiatives called Innovation Hubs (https://www.agroecology-transect.net/innovation-hubs/). The Agroecology-TRANSECT project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101060816. Views and opinions expressed are those of the authors only and do not necessarily reflect those of the European Union or European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

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Responsible integrated pest management transition pathways: co-creation workshops to shape policy advice

Anne-Charlotte Hoes
Wageningen Economic Research, WUR, The Netherlands, anne-charlotte.hoes@wur.nl

Abstract:

The uptake of integrated pest management (IPM) practices by farmers faces challenges across Europe. Changes outside the farm level are needed to overcome barriers and maximise opportunities for the adoption of IPM. This modest study reports on a backcasting workshop with strawberry sector stakeholders from business, education and advisory services, along with policymakers, who co-created desirable future visions for strawberry farming in the Netherlands in 2053. To encourage the participants to 'think outside the box', a presentation was given by a practitioner of organic strawberry growing and selling. Although the vision of some stakeholders focussed on high tech while others promoted high nature, both included zero use of chemical crop protection products and incorporated robotics to monitor plant health. These findings suggest that, despite vested economic interests, established routines and agreements that resist change, stakeholders can co-create a radically different and sustainable future when imagining 30 years ahead. We end this paper with a statement that collaboratively constructing a desirable future vision is important for triggering internal motivation for transformative sectoral change. Both internal and external drivers are important when aiming for sustainability transitions.

Keywords: pest management, backcasting, co-creation, farming, strawberries, systemic change

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Purpose: need for policy and sector advice to responsibly scale IPM usage

Integrated pest management (IPM) has the potential to assist farmers in minimising their use of chemical crop protection products, decreasing costs and contributing to the transition to sustainable food systems. Although IPM approaches have been developed for a wide diversity of crops and contexts, their uptake by farmers remains low across Europe (see https://he-support.eu/). Earlier studies show that farmers sometimes feel stuck in a specific farming system due to economic dependencies and the lack of collectively sharing transition risks, among other issues (Hoes et al., 2023; Meuwissen et al., 2020; Siebrecht, 2020; Vermunt et al., 2022; Vrolijk et al., 2020). This suggests that many farmers cannot simply adopt IPM, necessitating changes to be made at the supply chain (processing, distribution, and consumption) and policy levels as well.

The dominant aspects of the current context, including agricultural value chains, policies and mainstream farming systems, are referred to as the 'regime' level in transition studies (Köhler et al., 2019; Geels and Schot, 2007). Regimes are considered to be rather resistant to change due to vested economic interests, established routines, agreements and historically established infrastructures, which is rather problematic when aiming for transformative change. Some transition studies suggest more attention should be paid to the internal drivers for change from within the regime (Runhaar et al., 2020; Grin, 2020), and to gaining insights into how actors that primarily work at the regime level can overcome these change-resistant dynamics (Wojtynia et al., 2023). Backcasting, in which participants start by defining a desirable future vision and work backwards to determine how to achieve it, has been applied in sustainability transition initiatives (Quist, 2007) to avoid entanglement in the current lock-in situations and to imagine more transformative change.

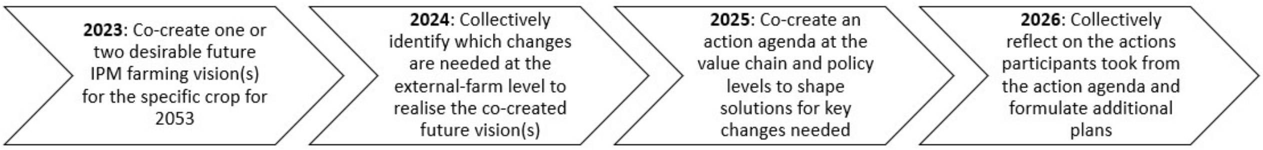
This thinking led to this study, in which backcasting is used to identify changes that are needed at the chain-partner and policy levels to support the scaling of IPM usage among farmers in a responsible way. This study runs from 2023 until 2026, and this paper reports on the activities that took place in the Netherlands in 2023 and 2024. We report on two co-creation workshops on IPM in strawberries, in which farmers, advisors, chain partners and policymakers collectively shaped desirable future visions, an important first step in our applied backcasting approach.

Approach: backcasting to co-create future visions and the required changes

This study analyses two co-creation workshops that took place as part of the Horizon Europe Framework project '**S**upporting **Up**take Integrated **P**est Management and L**o**w-**R**isk Pes**t**icide Use' (the bold letters in the title create the acronym 'SUPPORT', see https://he-support.eu/). These co-creation workshops applied a backcasting approach. Backcasting involves developing a desirable future vision and exploring which changes are needed in the present to move closer towards this goal (Vergragt and Quist, 2011). This approach enables stakeholders to envision more ambitious sustainable solutions than forecasting because they are not starting from the present status quo (Quist, 2007).

Between 2023 and 2026, 32 co-creation workshops will take place: one per year in each of the eight countries involved in the SUPPORT project. Each country focusses on one of the following crops: apple, grape, maize, olive, potato, strawberry, onion, and wheat. Ideally, the same participants would take part in the co-creation workshops each year so that the groups can build on what they co-created in the previous workshop. The goals of the four co-creation workshops are summarised in figure 1.

Figure 1. Goal of each co-creation workshop.



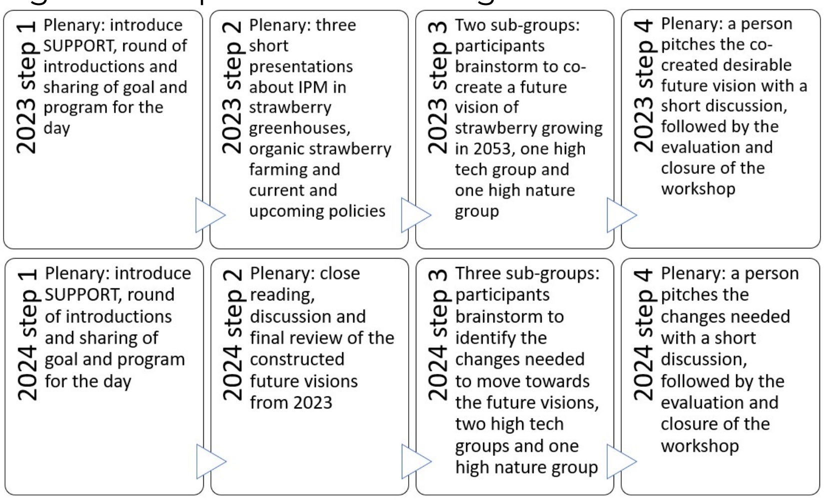
During the writing of this paper, the first co-creation workshops were held in the eight countries (from September 2023 until January 2024). Seven of the workshops were in person, while one was online. They lasted at least 120 minutes. In addition, in the

Netherlands, the second co-creation workshop was held in March 2024. For this paper, we focus on the Dutch co-creation workshops and report the co-created desirable future visions. In addition, we reflect on the overall approach.

Strawberry IPM co-creation workshops held in the Netherlands in 2023 and 2024

Two co-creation workshops took place in the Netherlands involving a group of stakeholders active in the strawberry supply chain, policymaking and education (September 2023 and March 2024). The goal of the first workshop was to co-create two future visions for strawberry cultivation in the Netherlands: one high tech and one high nature. These two directions were proposed because strawberries are increasingly grown in greenhouses in the Netherlands (high tech). In addition, demand for organic strawberries is growing, and the number of Community Supported Agriculture (CSA) initiatives that also grow strawberries is expanding. The goal of the second co-creation workshop was to validate the formulated future visions and identify the changes needed for the realisation of the future visions. Figure 2 shows the steps followed during the co-creation workshops.

Figure 2. Steps followed during the 2023 and 2024 co-creation workshops.



The intention was for the same participants to attend both workshops; however, this was not the case. In total, 16 people were present at the 2023 co-creation workshop and 18 people at the 2024 co-creation workshop, with nine attending both workshops. Both workshops lasted 150 minutes. Unfortunately, strawberry growers were absent during the 2023 co-creation workshop and policymakers did not attend the 2024 co-creation workshop. Below, we specify the stakeholders present in 2023, 2024, or both.

- Strawberry growers (two, in 2024 only)
- Business (three): executive director of the Dutch association of manufacturers and distributors for biological crop protection (2023 and 2024), three representatives of the Netherlands Agricultural and Horticultural Association (two in 2023 and another one in 2024) and the head of research and development at a fresh fruits and vegetables trading company (2024)

- Policy (four, in 2023 only): two civil servants from the Netherlands Enterprise Agency (RVO), a civil servant from the Netherlands Food and Consumer Product Safety Authority (NVWA) and a policymaker from the Ministry of Agriculture, Nature and Food Quality (LNV)
- IPM strawberry researcher (one, in 2023 and 2024)
- Education/advice (three): four lecturers from an Applied University (one in 2023 and three in 2024) and three advisors (two in 2023 and three in 2024)
- One chair (2023 and 2024), three facilitators (2023 and 2024), an expert IPM policymaker (2023 and 2024), an expert organic strawberry grower (2023), and two note-takers (2024).

Findings: co-created high tech and high nature future visions of strawberry growing

Participants actively participated and interacted during both co-creation workshops. When imagining strawberry growing in 2053, they formulated creative ideas and built on each other's suggestions. Although one vision focussed on high tech and the other on high nature, both included zero use of chemical crop protection products or chemical fertilisers, climate-neutral production, and the use of robotics to monitor plant health. The text boxes below report the two future visions that were constructed based on the inputs provided during the 2023 co-creation workshop (step 3), which were critically reviewed and slightly adapted during the 2024 co-creation workshop (step 1). To our regret, no farmers participated in the 2023 workshop; therefore, additional attention was paid to ensure their participation during the 2024 workshop. This also meant more time was taken during the 2024 workshop to collectively read, review and discuss the proposed future visions, and the participating farmers suggested some minor adjustments.

In the preparation of the 2023 workshop, much effort was invested in having an organic strawberry expert present. This was an important goal because there is a dominant belief in the strawberry sector that growing strawberries in the field without chemical crop protection products is unrealistic; however, organic strawberry growers and CSA farms sometimes grow smaller plots of strawberries without these applications. To assist the participants of the strawberry sector to 'think outside the box', a presentation was given by an organic strawberry grower who produces and sells their crop while also working part-time as a teacher at a biodynamic farm community college.

Future vision 1: high-tech strawberry cultivation

In 2053, there will be automated greenhouses in the Netherlands where strawberries are planted in high density. The greenhouses will also house beneficial insects that can combat pests. People rarely walk around in these greenhouses, as this can introduce diseases. Robots care for the plants, pick strawberries and monitor the climatic conditions and plant health. These could include, for example, the moth PATS drone, UV light treatment robots, a picking and vine cutting robot, and so on. In addition, robots can move strawberry plants to an area where growers

can apply their skills, when needed. This allows the optimal use of greenhouse space for growing strawberry plants rather than providing walking space for humans. The cultivation of strawberries from seed and/or meristem culture takes place in the greenhouse, which prevents the introduction of diseases/pests. They are semi-closed greenhouses, and the air that enters from outside is purified with filters. All these measures contribute to a hygienic environment in the greenhouse. Light-transmitting solar panels are placed at strategic locations and provide the energy needed for cultivation. The strawberries are more resilient, tastier and nutrient-rich due to breeding and are grown on substrate. The growers supply strawberries all year round and provide the correct dosage of organic fertilisers because they work with precision fertilisation. These fertilisers are supplied by a manure-processing factory. In addition to strawberry plants, other plants in the greenhouse provide a habitat and food for insects that are used as pest-control agents and pollinators. In addition to strawberries, specific insects that act as natural enemies of pest insects are also bred and housed. These beneficial insects have been deliberately placed in the greenhouse. Consumers have a choice in the supermarket. The packaging shows which grower the strawberries come from and the unique growing method used. In 2020, consumers had no choice in the supermarket but, just like with eggs, in 2053 there is a choice on the strawberry shelf. Furthermore, local residents are happy with the strawberry growers because they grow in harmony with the environment.
Future scenario 2: high-nature strawberry cultivation In 2053, the nature-inclusive strawberry season takes place in the summer. These strawberries are a luxury product that, like asparagus, are temporarily available and appear on seasonal menus. These strawberries come from both agro-ecological and strip-cultivation farms, the latter of which use robotics to monitor plant health and harvest strawberries. In addition, citizens can take out a strawberry subscription with local Community Supported Agriculture initiatives. Harvesting these strawberries yourself is an outing for the whole family. Local residents enjoy visiting these farms and nature-inclusive strawberries are a local product. Breeding has produced tasty and resilient ever-bearing strawberry varieties. Optimal natural fertilisation is applied. The plants are well-rooted and live in harmony with soil-dwelling organisms. The above-ground biodiversity is rich in pollinators, which are also functional for strawberry cultivation, contributing to the natural resistance of the plants. More is known about the connection between nature-inclusive strawberries and the human microbiome. Animals and insects naturally like to snack on the strawberries. Consumers are aware of this and are not concerned by blemishes on the strawberry, which are considered proof that this strawberry has been grown in a nature-inclusive manner. It is transparent to the consumer who, where and how the strawberry was grown; for example, some companies have a small greenhouse for growing strawberry plants. Furthermore, the strawberry taste differs between growers. Strawberries are not one-size-fits-all but span a range of shapes, smells and flavours.

In addition, there is complete transparency about the price structure. The grower receives a realistic price and there are (chain or local) agreements if, for example, a harvest fails.

Practical implications

During the writing of this extended abstract, farmers across Europe were fiercely protesting European regulations, such as the plan to reduce the use of chemical crop protection products by 50% in 2030. Despite these conflicts, stakeholders across the strawberry sector were willing to participate in one or both co-creation workshops in which we applied backcasting. Instead of negotiating sustainability targets, stakeholders co-created a desirable vision of the future 30 years ahead that aligns with the Green Deal and Farm-to-Fork targets. Co-creating a future vision was motivating and did not result in polarised debate.

We recommend applying backcasting approaches more often to constructively work on systemic change for sustainable futures alongside stakeholders across the food system. We also found it beneficial to include participants who work at the niche level to voice alternatives from the status quo.

It was difficult to ensure the same participants were present at these annual workshops. Moreover, key stakeholders were missing at both executed workshops: strawberry growers in 2023 and policymakers in 2024. A practical way to include the perspectives of these stakeholders would be to organise follow-up one-on-one interactions with participants who could not attend.

Theoretical implications

Despite the vested economic interests, established routines and agreements, stakeholders primarily working at the regime level were able to imagine a radically different farming future that was climate-neutral and did not require the application of chemical crop protection products or chemical fertilisers. The first step of the backcasting approach seemed to provide an entry point for stakeholders to let go of the status quo and be more ambitious about the necessary changes.

Moreover, the desirable future visions co-created through backcasting can trigger the internal aspirations of regime-based stakeholders. It is much more motivating to work on change following internal aspirations rather than being driven by external pressures such as stricter regulation. To speed up the transition to sustainability, it would be wise to invest in both internal and external driving forces for change.

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SPoT, a transdisciplinary agroecological field experiment to highlight the key challenges surrounding the transition of mixed crop-livestock farming addressing environmental and food challenges

Michaël Mathot[a], Pénélope Lamarque[a], Didier Stilmant[a], Alexandre Mertens[a], Raphaël Lehuraux[a], Sylvain Hennart[a], Yves Seutin[a], Séverine Lagneaux[a]

[a] m.mathot@cra.wallonie.be, Centre Wallon de Recherches Agronomiques, Rue du Serpont 100, 6800 Libramont, Belgique.

Abstract:
Reaching sustainable goals requires a transition of agricultural systems, in which the role of livestock farming is often undermined despite the several advantages provided (e.g. closing nutrient cycles, maintaining specific biodiversity, maintaining a sector of activity). The SPoT project aims to define and test on an experimental farm new production systems, to commit a transition towards a new sustainable food system that safeguards food security and face at the same time the climate adaptation and circularity challenges. The production system tested are in rupture with the current production system of the territory (Belgian Ardennes) relying mainly on suckler beef production. We, thus, set up a trans-disciplinary co-construction process to test innovative systems addressing the synergies between food crops and cattle breeding. The aim of this contribution is to give an overview to some of the obstacles and levers encountered during the first year of our experiment, through an interdisciplinary analysis. During the first year of the project, the professional skills and values of researchers and technicians came under pressure. This led us to a rethinking of the co-construction process and of how to support these changes on our experimental farm, in order to engage a transition towards innovative agro-ecological systems.
Keywords: mixed crop-livestock farming, climate mitigation and adaptation, food security, circularity, agroecology.

Purpose

Achieving environmental and societal objectives requires a transition towards more sustainable agricultural systems, in which the role of livestock farming is often undermined. However, these systems have many advantages that should not be overlooked (closing nutrient cycles, maintaining specific landscapes and biodiversity, maintaining a sector of activity, etc.). To meet these challenges, the long-term SPoT project (12 years from 2023) aims to define and test, on an experimental farm, new production systems relying on agroecological practices with various ratio of permanent grasslands vs cropped lands for human consumption. This approach was initiated in the Belgian Ardennes. This is a region where the future of suckler systems, based essentially on the use of self-produced forages, is being questioned.

Agroecological transition is a bottom-up and territorial processes providing contextualised solution to local problems. Co-creation and knowledge sharing are at the core of this transition process to deal with local challenges (Barrios, et al., 2020).

Therefore, the SPoT project rely on a trans-disciplinary co-construction process to identify and test systems that address the synergies between food crops and cattle breeding, with a view to (i) optimize the circularity of flows, (ii) to maximize the production of food for humans, and (iii) to meet climate challenges. The aim of this contribution is to give an overview to some of the obstacles and levers encountered during the first year of our experiment, through an interdisciplinary analysis.

Design and Approach

The SPoT project is a systemic experiment focusing on experimental farm trials. It is based on the investigation, analysis and understanding of mixed crop-livestock farming. The experimentation is testing three independent systems in which ruminants are associated with each of them according to the area of permanent grassland and the availability of crop co-products to meet their dietary requirements. The Utilised Agricultural Area (UAA) of the first system includes 70% permanent grasslands and 30% crops. This system is representative of the regional spatial distribution of land use (grasslands-crop lands). In the second system, the UAA is composed of 30% grasslands and 70% of crop lands. It was subjectively chosen as a contrast to the first system in term of grassland-cropland proportion and consequently cattle density at system level. In system three, only crops are grown, while in contrast systems one and two include cattle. The systemic experimentation is guided by:

(a) the historical context in terms of infrastructure, location and previous researches.

(b) the definition and articulation of three systems based on crop rotation, with or without livestock, to meet the three principles guiding the experiment (maximizing food production for human consumption, meeting climate challenges and maximizing the circularity of flows in the area). This process mobilize the contributions of scientists and agricultural technicians from the research unit and the institution, as well as external scientists and industry players. As a result, the process is both interdisciplinary (the result of contributions from different scientific disciplines: agronomy, biology, physics, anthropology), and transdisciplinary (contributions from stakeholders in society broaden the reflection) (Tress, et al., 2005).

(c) setting up a governance structure that encourages co-construction and co-learning, considered as a central element of agroecological transition (Barrios, et al., 2020), in the step-by-step evolution of systemic experimentation. It comprises 3 committees:

1) A restricted committee meets monthly. After consulting other external scientists, value chain and institutional player, it has initially defined the experimentation. It mobilizes the scientists involved in the project. It identifies technical, relational, organizational, cultural and legislative difficulties, etc. It provides starting points for co-constructing practical solutions. It establishes a decision trees for day-to-day practice, based on an articulation between the three principles and the decisions taken by the expanded committee.

2) The expanded committee meets weekly. It includes the scientists and technicians involved in the project. Its mission is to co-construct practical solutions to the problems encountered on a daily basis in implementing the project.

3) A yearly strategic committee, bringing together ten scientists and non-scientist (food chain actors and public policy advisors) to provide an external option to ensure coherence between purpose and means and long-term guidance for the project.
Within this framework, a monitoring and analysis process has been set up using a chrono-systemic timeline (Bergeret *et al*, 2015; Elissalde, 2000). This conceptual and methodological tool enables change to be understood in an interdisciplinary research context. The timeline enables us to visualize dynamic processes and the multiple elements that make up a project. It makes it possible to cross perspectives, but also the components of the system, to link seemingly disparate elements to reveal nodes to be investigated, obstacles to be overcome, levers to be activated, successes to be highlighted. The timeline is based on records of decisions taken by the three committees, input from experts contacted individually to guide the project, the views of "visitors" to the experimental station gathered through questionnaires or observations, and individual interviews conducted with team members at the end of the first year of the SPoT project.

Findings and implications

We will illustrate our provisional results with two examples, among others.

Straw: a limiting resource
Given the objective of circularity of flows based in part on maximizing self-sufficiency, the straw used as animal bedding should come from the crops produced within each system. In the 100% crop system, straw returns directly to the soil, while in the system with 30% grassland, straw is just sufficient. In the system with 70% grassland and therefore a higher number of animals, it quickly became apparent that straw availability would be limiting. The coherence of the autonomy of this latter system, and with it that of the Ardennes region in which it is embedded, is strongly questioned.
To overcome the straw shortage, a number of short-, medium- and long-term solutions were discussed by the enlarged committee: buying straw, optimizing straw use by reducing the quantity through management practices (temporary tethering of animals, increasing absorption by shredding straw), changing rotation to produce more straw, reducing livestock numbers, changing barns and/or replacing straw with litter from agroforestry. Some of these solutions are in contradiction with the project's principles, such as buying straw vs. autonomy, reducing livestock vs. maximizing food, or changing rotation to the detriment of agroecological levers linked to rotation diversification. Others point to a cultural lock-in. For example, the desire to do a sparing use of this resource and/or a reduction in its quality challenges representations of what makes animals and barns clean. The reduction in the quantity of straw also leads to an impression of reduced comfort for the animals. All this, by projection, casts doubt on the quality of the breeder's work and the identity of the breeder himself.

Onions under pressure
Vegetable production is limited in the Centre Ardenne region (500 m altitude, 1200 mm rainfall). However, based on information obtained from experts in market gardening and field crops (producers and/or distributors), in view of the changing climate and in line

with the principle of maximizing food production, it seemed worthwhile to include vegetables in the rotation. The feasibility of growing onions was thus explored. The onions were harvested in September, after a crop with no particular difficulties. Although unusual for our team, and despite limited means (no specific machinery), growing this vegetable was considered satisfactory, even a success, by the team members.
Difficulties arose when we try to sell the products, even though this stage had been partially anticipated. The onions had to be stored because of the administrative procedures inherent in a public research centre and the sorting requirements imposed by the downstream market. As storage conditions could not be optimized (palox packaging, non-refrigerated premises, damp weather), almost half the harvest rotted. As the remaining onions could not be sold, they were offered to staff members and beneficiaries of a local association fighting against waste and malnutrition.
This situation has led to tensions which have been expressed at various times (individual interviews, extended committee) and have been amplified by similar situations for other crops (e.g.: biomethanization of non-bread cereals in the animal-free system). For some, crop planting must be guided by crop profitability. This means maximizing value by planting a crop based on downstream demand and price, if possible secured by a contract. For others, the choice of crop is based on specific SPoT objectives, of which economic profitability observed, is not part of the objectives. Even if the products have been partially valorized, it is above all the notion of waste that is pointed out by the technical team. This is in conflict with the meaning of work and the nurturing vocation of the profession. These episodes are also perceived as a lack of anticipation, suggesting that all stages of the project could be mastered, whereas in a step-by-step vision and learning process, an acceptance of risk is inevitable.

Conclusion

The systemic approach and transdisciplinary co-construction process are strengths of the SPoT project. It brings out tensions that need to be studied. Transdisciplinarity within the project partly calls into question the profession of both scientists and technicians/farmers. It also highlights the need to change not only their know-how, but also their interpersonal skills. These changes are essential if we want to develop a systemic approach that takes into account pragmatic aspects on the farm, while abandoning the idea of "controlling" the various aspects of the mixed crop-livestock system. This seems essential to initiate an agroecological transition avoiding the replication of conventional agricultural models and stimulating innovation while accepting the inherent risks of developing resilient agroecological systems.

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Understanding The Construction Of Autonomy By Farmers Evolving Towards Agroecological And Resilient Farming Systems

Véronique LUCAS

[a] UMR BAGAP, INRAE Rennes, France, veronique.lucas@inrae.fr

Abstract:

Many French farmers, member of farm machinery cooperatives, seek to become more autonomous in relation to markets. To realize it, they develop new practices, ecologically improving their farming system, by further relying on peer-to-peer cooperation. Our article, based on the study of six machinery co-ops, rather highlights a substitution of their interdependences, which reveals the constraining context these farmers are submitted. The analytical framework built for this research provides a relevant methodology to better understand the paradoxical construction of autonomy by farmers evolving towards agroecological and resilient farming systems.

Keywords: Autonomy, farmers, agroecology, methodology, resilience

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Purpose

In agroecological approaches, autonomy emerges as a central concept (Gliessman 2007). The climate change also exacerbates their pursuit of autonomy, to better control the conditions of their farm activities in the current uncertain context (Ploeg 2018).

However, the farmers' concrete strategies to enlarge their autonomy can appear complex at first glance. In France, public policies for the agroecological transition have rendered more visible a movement of collective projects partly motivated by the pursuit of autonomy, such as the farm machinery cooperatives (French acronym: CUMA). 11,000 CUMAs exist in France, covering more than a third of farms (Lucas 2018). They constitute a heuristic object for analysing this pursuit of autonomy, increasingly becoming part of the activities of CUMAs, with increased resource pooling. So why do these farmers need to increasingly share resources to become more autonomous with regards to markets? This article sheds light on these questions through a research on farmers developing autonomization strategies, based on renewed forms of cooperation through their CUMAs. Six CUMAs were studied, whose equipment helps farmers ecologically improve their farming systems to gain autonomy from market operators. After explaining our specific analytical framework, we characterize the autonomization strategies developed by the farmers with their peers. Finally, we discuss the lessons that can be learned for a better understanding of the farmers' growing push for autonomy, which is a key driver of agroecological transition processes.

Design/Methodology/Approach

Autonomy and markets in agriculture: a socio-technical approach

Ploeg (2018) has studied the international phenomenon of the pursuit of autonomy by farmers in unfavourable contexts, especially because of the increasing influence of upstream and downstream firms. He has identified six mechanisms that increase the farmers' autonomy, including the use of peer-to-peer cooperation. To deal with increasingly oligopolistic market operators, 1) Farmers diversify their production, or even their marketing channels. As far as input markets are concerned, 2) Producers tend to develop efficient, low-input farming systems by adopting self-provisioning approaches. Farmers seek to further base their farming practices on their own resources, especially 3) Through increased activation of the ecosystem's ecological functions, and/or 4) Improved technical efficiency of productive processes. 5) Pluriactivity can also be considered as an autonomization mechanism, for example with regard to bank credit. Finally, 6) Forms of local cooperation between farmers help to reduce dependence on sources of industrial and financial capital.

Other empirical studies highlight the complexities farmers face in their pursuit of autonomy, as well as the trade-offs they make. For instance, conservation agriculture developed to reduce mechanization costs generally involves new attachments in relation to machinery for direct seeding and herbicides (Goulet & Vinck 2012). Direct selling to avoid dependence from market operators tends to increase workload, hence some new links with contractors or hired workers to delegate some tasks (Dumont & Baret 2017). These studies illustrate the dependence pathways of the socio-technical systems to which these farmers belong: lack of long marketing channels in organic pork production, dependence on herbicides in no-till agriculture, etc. (Landel 2015).

To conclude, to address the issue of autonomy and markets in agriculture, these studies call attention to the ways in which farmers mobilize their resources and value their products. They also emphasize the need to examine the additional workloads and new constraints that can be induced by each practice designed to make the farmer less dependent on markets, and even the steps the farmer takes to mitigate them. The mechanism of local cooperation between farmers for helping make them independent of markets deserve more scrutiny in these studies.

Case studies & Methodology

Our research aimed to provide an understanding of the new sharing processes emerging in CUMAs and facilitating the development of agroecological practices. We selected six CUMAs (see Table below), whose pooled resources facilitate the cultivation of fodder legumes and/or conservation agriculture with a moderate use of herbicides. There is an increase in the equipment being acquired by French CUMAs to develop these practices, and which is leading to new sharing processes (Lucas 2018).

After studying the literature mentioned above, we considered the six autonomization mechanisms of Ploeg (2018) as dimensions to be observed, whilst also examining how each practice of autonomization raised new issues or workloads to manage, as well as the ways in which farmers seek to mitigate these induced constraints. We conducted semi-structured individual interviews with farmers from 34 farms in the selected CUMAs. These interviews were designed to ascertain these farmers' conception of autonomy and the practices they developed on their farms to this end, as well as their trajectories of involvement in their CUMAs. We recorded the narratives so as to identify these farmers' conception of autonomy, which we correlated with the strategic choices made at the farm and CUMA levels.

Table 1. Characteristics of the CUMAs surveyed

Geographical area	Farms surveyed in each CUMA	Main collective activities	Farm practices developed
<u>Basque Country</u> *Foothill pastures*	3 farms: 2 dairy sheep farms, 1 dairy goat and sheep farm	Sharing of a collective hay dryer, training programme for members	Development of fodder legumes
<u>Tarn</u> *Arable & crop-livestock farming*	6 farms: 2 dairy farms with milking robot (1 organic), 4 grain farms (1 organic)	Sharing of direct seeding/minimum tillage equipment, mutual help, seed exchanges	Minimum tillage and direct seeding, winter cover crop, crop diversification
<u>Ain</u> *Crop-livestock farming*	6 farms: 4 dairy farms, 1 dairy goat farm, 1 grain farm	Sharing of a collective hay dryer, with a shared employee, mutual help	Development of fodder legumes, crop diversification
<u>Aube</u> *Arable farming*	5 farms: 2 sheep-meat farms, 1 cattle-meat farm, 3 grain farms	Sharing of direct seeding/ minimum tillage equipment, mutual help with time bank, seed exchanges, cross-farm grazing of cover crops	Minimum tillage and direct seeding, winter cover crop, crop diversification
<u>Touraine</u> *Crop-livestock farming*			
<u>Brittany</u> *Crop-livestock farming*	4 farms: 3 dairy farms, 1 grain farm	Sharing of tractor and no-till equipment, comparison of results and agronomic training	Development of no-till agriculture and winter cover crop

Findings

A structural distancing from the markets, although to a limited extent

The farmers we surveyed claimed to become autonomous through recent practises. An analysis of their previous strategies using the six mechanisms of Ploeg (2018) reveals that they were already trying to reduce their dependence on markets, albeit to a limited extent.

- *Four mechanisms already mobilized for a long time*

To differentiate and diversify their products and seek new outlets (Mechanism 1), farmers undertake activities complementary to primary production and strive to add value to their products or access multiple markets. Grain farmers diversify their crops to improve agronomic synergies. Other activities such as production of renewable energy or agro-tourism aim to make the most of the available time or farm assets such as old buildings. 4 farmers direct sell the majority of their productions, while 6 others do so partially, selling only within their friends' networks. Farmers involved in traditional long supply chains use quality labels and/or adopt value-addition strategies (such as commercial seed production). To improve the efficiency of productive processes (Mech. 4), these farmers seek to improve the monitoring of their herds and/or crops, especially through participation in discussion groups. In order to limit intermediate consumption or its costs (Mechanism 2), these farmers adopt self-provisioning strategies by producing a part of the feed supplement required for some livestock farmers, while the practice of producing farm seeds is, on the whole, widespread amongst farmers growing wheat. Buying groups make it possible to limit input costs.

- *Cooperation as a mechanism to consolidate these strategies*

These practices of diversification, of technical efficiency and of limiting inputs are nevertheless equipment and labour expensive. To deal with increased workloads, human labour is frequently replaced by capital (investment in new machinery, even robotization of milking in dairy farming) and less important or secondary tasks are simplified or outsourced. Farmers use different methods to mitigate, even if only to a limited extent, the new emerging dependencies. Thus, farmers who own milking robots rely on their peers to understand and master this technology and to limit the dependence on external assistance services.

Peer-to-peer cooperation (Mech. 6) is a way of mitigating increased workloads, primarily through their CUMA. Secondly, farmers enter into various arrangements, often informal, for sharing and exchanging resources concerning equipment acquired individually or in co-ownership, labour (through joint operation), material (for example, the exchange of livestock manure for straw from grain farms) and services. Thirdly, farmers' discussion groups strengthen peer-to-peer cooperation, primarily by facilitating experiences sharing, comparison of results, and the organization of collective training (conducted by external experts).

To conclude, cooperation between peers has helped the farmers minimize the input and equipment costs generated by practices allowing to distance themselves from market operators. However, in the last 15 years, these strategies have been unable to cope with various recent problems and issues that are making these farmers more vulnerable.

A vulnerabilization intensifying the pursuit of autonomy

By cultivating legumes or developing conservation agriculture, farmers use Mechanism 3, which relies on the ecological functioning of the agroecosystem, and Mechanism 2 more intensively, i.e., reducing input costs. However, this also leads to additional challenges.

- *Conservation agriculture and cultivation of legumes to respond to new problems*

Farmers are turning to conservation agriculture to deal with soil degradation and/or to reduce costs and workloads. Legume cultivation allows for more protein production from pastures and winter cover crop, thus improving the quality of fodder production and animal nutrition. Conservation agriculture and the cultivation of legumes are also perceived by some producers as means of adapting to climate change. In addition, the unsatisfactory experiences of producers in their interactions with agricultural supply markets is also behind their desire to reduce the external inputs. For example, farmers have faced problems with the quality of inputs from some suppliers, such as in the case of feed supplements whose quality is impaired by industrial manufacturing processes. In this context, price volatility, especially exacerbated since 2007, has turned out to be the 'straw that breaks the camel's back' for farmers.

However, these practices induce new constraints, additional workloads and lead to problems in obtaining the needed resources. For example, self-provisioning strategies require additional operations, such as managing and harvesting winter cover crops. Producers adopting conservation agriculture have initially increased their use of herbicides to deal with weed growth, though some of them have managed to reduce this reliance on herbicides over time. On two farms in Tarn that have switched to organic farming, conservation agriculture is being practised today without any use of herbicides. Most farmers have difficulty obtaining certain seeds, especially for legumes and cover crops. Their usual suppliers do not always offer the diversity of the desired species at the right time and at affordable prices. This has led a majority of them to self-produce farm-saved seeds, which leads to new operations or even new needed equipment (sorting, storage and drying for example.

- *Cooperating to give themselves greater room for manoeuvre*

In order to implement their new practices and to cope with the constraints they raise, these farmers are deepening the three forms of cooperation already used. Firstly, they rely on their CUMAs to invest in suitable tools or even storage equipment needed by self-provisioning strategies. To this end, new sharing processes are emerging within CUMAs, such as the pooling of members' hay in collective artificial dryers and the organization of new collective harvesting operations. Secondly, farmers are also entering into new exchange and resource-sharing arrangements, such as the exchange of farm-saved seeds. This allows a farmer to obtain the diversity of desired species without having to produce himself the full range of necessary seeds. Thirdly, to address the lack of knowledge, farmers are relying on spaces for sharing experiences and collective training through their discussion groups. In this way, increased cooperation leads to accrued interdependence among peers, but offers farmers greater room for manoeuvre.

- *Why do farmers prefer the new interdependencies?*

Why do farmers claim to become more autonomous when there is simply a reconfiguration of their dependencies? In fact, they prefer the new induced interdependencies that seem to them to be better under their control and less asymmetrical.

The farmers prefer a lower dependence on purchased animal feed even though this lower reliance requires expensive equipment or additional labour, because of advantages it brings them. The greater feed self-sufficiency for their herds allows to become part of quality agri-chains with demanding specifications but ensuring a profitable quality differentiation on downstream markets. Cooperation allows farmers to lower their individual costs of equipment and labour. And conservation agriculture practices and the development of legume cultivation contribute in part to the agroecological improvement of their productive systems.

Finally, the farmers perceive increased interdependence among themselves positively, as it provides more room for manoeuvre, as well as opportunities to exchange information and share their doubts. With farmers having experienced profound contextual changes in the last 15 years or so (increased climatic variability, greater price volatility, etc.), experiences sharing serves to reassure each other: “In this group, where we are all at the same stage of research and everything, we can speak freely, we can say, ‘We can try this or that’, while with outsiders we have to be more restrained.” (a farmer from Tarn), or “Every meeting between us, we are happy to go there, and it feels good because it’s an opportunity to discuss.” (a farmer from Ain).

Theoretical & Practical Implications

Our methodology, inspired by Ploeg (2018), has identified various mechanisms that farmers can use to become more autonomous. More specifically, it has helped to reveal several practices, even if limited in extent, for reducing dependencies on market operators, especially upstream ones, which is little studied until now by the research. Our results lead us to better understand how the sixth mechanism of cooperation is used in this context. To us, this mechanism seems transversal to the other mechanisms, and not one that is simply used in addition. Indeed, our results show that local cooperation can contribute to 1) a diversification of production and/or marketing channels (through, i.e., collective short circuits), 2) a reduction in external purchases (buying groups, sharing of on-farm seed production), 3) the activation of the ecological functions (joint investment in specific tool for agroecological practices), as well as 4) increased technical efficiency (joint investment in hay making equipment adapted to legumes to avoid losses). Our work shows that this analytical grid benefits by the consideration of the new dependencies and workloads induced by each such practice, as well as of the steps taken by farmers to mitigate them. This analytical framework can be applied to diverse contexts of farmers wanting to become autonomous, to better illuminate their complex strategies, given the new dependencies they seem to generate. Indeed, this pursuit of autonomy has gained strength among the French farmers and in other countries (Arnauld de Sartre & al. 2019; Forney 2016).

Our work then reveals the details of these farmers' efforts to become less reliant on markets, by reducing the inputs and improving the use of their resources, especially the ecological functionalities of the ecosystem. We consider this phenomenon as an interesting departure point for the agroecological transition of farming systems. In doing so, they organize new place-based collaborative arrangements and innovations, which converge with the scientific literature that highlights the need for local collaborations to bring about the much-needed agroecological transition (Tittonell & al. 2016).

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POLICY PERSPECTIVE

Supporting agroforestry systems in Italy within the EU Common Agricultural Policy

Rosa Rivieccio [a], *Sonia Marongiu* [b], *Erica Mazza* [c], *Antonio Papaleo* [d], *Raoul Romano* [e]

a Council for Research in Agriculture and Analysis of agricultural economics, Research Centre Policies and Bioeconomy (CREA-PB), Roma, Italy, rosa.rivieccio@crea.gov.it

b Council for Research in Agriculture and Analysis of agricultural economics, Research Centre Policies and Bioeconomy (CREA-PB), Legnaro (Padua), Italy, sonia.marongiu@crea.gov.it

c external consultant with Council for Research in Agriculture and Analysis of agricultural economics, Research Centre Policies and Bioeconomy (CREA-PB), Roma, Italy, erica.mazza@crea.gov.it

d Council for Research in Agriculture and Analysis of agricultural economics, Research Centre Policies and Bioeconomy (CREA-PB), Roma, Italy, antonio.papaleo@crea.gov.it

e Council for Research in Agriculture and Analysis of agricultural economics, Research Centre Policies and Bioeconomy (CREA-PB), Roma, Italy, raoul.romano@crea.gov.it

Abstract:

Agroforestry systems have been existing in the Mediterranean basin from over 3000 years, when integrating trees with crops and/or livestock made possible to satisfy the need for subsistence/self-sustainability of the farmers. After the second world war, due to the mechanization of agriculture, these systems nearly disappeared in some areas. Recently, their role has been reassessed: European policies have recognized the importance of agroforestry in the mitigation of climate change and in the framework of the sustainability of modern agriculture.

The Common Agricultural Policy (CAP) is the main instrument for the promotion of agroforestry, funding the establishment and maintenance of these systems.

The aim of this work is to provide an overview of the level of CAP support that agroforestry have received in Italy in three programming periods (from 2007 to 2027), and to understand whether and how CAP facilitated their adoption. The study is a financial analysis of the resources planned and spent in the whole Italian territory.

The results showed that agroforestry measures in Italy have had a limited application in the past. In the new programming period there is a slight improvement but not significant.

Keywords: Agroforestry, Measures, Common Agricultural Programme, Rural Development Programme, Sustainability

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Purpose

According to FAO, agroforestry identifies land-use systems and technologies where woody perennials are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. Agroforestry systems are five diverse main practices: silvoarable systems, silvopastoral systems, forest farming, riparian buffer strips and windbreaks/hedgerows (Mosquera-Losada et al., 2022). Agroforestry exists all over the world and, according to FAO, it is practiced on around 1 billion hectares of land worldwide. It can also be defined as a dynamic, ecologically based, natural resource management system that, integrating trees on agricultural systems, allows the production diversification, the multifunctionality, and the increase of social, economic, and environmental benefits (relevant for small holders living in rural areas). However, agroforestry is usually more complex and knowledge intensive than conventional agriculture and may involve a greater administrative burden (EU Parliament, 2020).

Agroforestry in Europe is also a very ancient traditional practice. After the mechanization of agriculture, many agroforestry systems have been abandoned or converted to intensive agriculture, pastures, or forests (Ferrario, 2021).

The high ecological and social value of agroforestry was recognised at EU level for the first time in the Council Regulation (EC) 1698/2005 on support for rural development in the Common Agricultural Policy (CAP). Nowadays, agroforestry is a key point of the wider EU policy framework, being considered an element of the European Green Deal (2021) and Farm to Fork Strategy (2021), as well as strategic for the European Climate Change Program (ECCP, 2000), and the EU Bioeconomy Strategy (2020), as effective practices to pursue the ambitious objectives of guaranteeing European citizens access to healthy foods, produced in a sustainable way, mitigating climate change and safeguarding biodiversity (Santiago-Freijanes et al., 2021). Moreover, the EU Biodiversity Strategy for 2030 suggests that ‘the uptake of agroforestry support measures under rural development should be increased as it has great potential to provide multiple benefits for biodiversity, people and climate'.

Several Member States have applied specific interventions to support the agroforestry in their Rural Development Programme (RDP). In the 2007-2013 RDP for the first time new planting of agroforestry systems was included among the forestry measures (Measure 222). A further step was done in 2014-2020, when agroforestry farmers and foresters received support from both pillars of CAP and the measures (Measure 8.2), also for the maintaining. However, in Italy few Italian Regions have provided subsidies for agroforestry measures, and without reaching a full coverage of the country. This work provides an overview of the application of CAP support for agroforestry in Italy in terms of financial resources planned and spent in the last programming periods (PPs). For the next period, the support is still provided: it will be crucial to design the measure to meet the farm requirements and avoid the frictions that during the past have negatively influenced the application on the field.

Methodology

The work presents a financial analysis of the application of agroforestry measures in Italy, according to the results coming from the monitoring activity of RDP. In Italy, rural development policies are planned and programmed at national level, but each Region (19 Regions plus 2 Autonomous Provinces) defines its own Rural Development Plan, including the measures that are more suitable to be applied in the specific territory. The amount of resources and the entity of the payment is decided by each regional administration, on the basis of the importance and application of the intervention. This analysis lays the foundations in the Annual Implementation Reports (AIRs) that each Regional Authority must define at the end of each PP. Three periods are considered: 2007-2013, 2014-2022 and 2023-2027 (for which only the planned resources can be verified in the next months).

Even if not specifically encouraged, the first incentive for the establishment of agroforestry schemes was promoted by the EEC Regulation 2078/92 supporting the conservation of individual trees, the establishment of hedgerows for the conservation of wild areas of woodlands. Then, the EEC Regulation 2080/92 provided support to partially finance the costs of afforestation of agricultural lands, their maintenance, the improving of existing woodlands and the compensation of the income losses resulting from the agricultural land use changes. Since 2000, forestry issues were integrated and supported by the RDPs (Council Regulation 1257/1999) and during the PP 2001-2006 two types of actions were set: afforestation of agricultural land and other forestry measures including preserving woodlands. The afforestation programme continued in the following period 2007-2013 (Council Regulation 1698/2005) with the first measure specifically devoted to agroforestry practices (Measure 222) introducing the first establishment of agroforestry systems on arable land. In the CAP 2014-2020 agroforestry was promoted under the Regulation 1305/2013 in the sub-measure 8.2 devoted to the establishment and maintenance of agroforestry systems. Compared to the past, a wider definition of agroforestry systems was given together with the provision of a contribution to the maintenance for a period of 5 years. Table 1 shows an overview of the declination of agroforestry interventions during the CAP 3 PPs considered in the analysis.

Table 1. CAP programming periods (PP) and support measures/intervention for agroforestry.

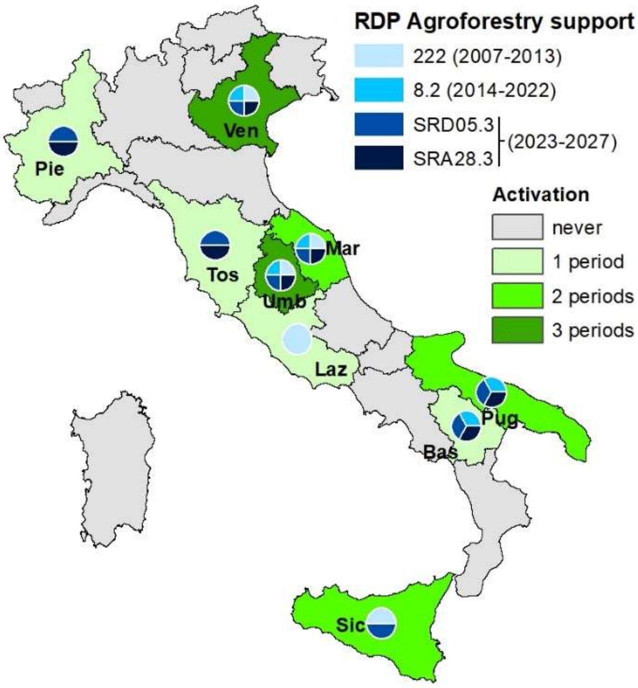
PP	Measure/Intervention
2007-2013	**Measure 222**: First establishment of agroforestry systems on agricultural land
2014-2022	**Measure 8**: Investments in forest area development and improvements of the viability of forests.
	Submeasure 8.2: Support for establishment and maintenance of agroforestry systems.
2023-2027	**SRD05**: Establishment of agroforestry systems.
	Action 5.3: Establishment of agroforestry systems on agricultural surfaces
	Subaction 3.1: Silvoarable systems on agricultural and pastoral surfaces. Subaction 3.2: Silvopastoral systems on agricultural and pastoral surfaces.

	SRA28: Maintenance support for afforestation and agroforestry systems
	Action SRA28.3: maintenance of agroforestry systems on agricultural surfaces.
	Subaction 3.1: Silvoarable systems on agricultural and pastoral surfaces.
	Subaction 3.2: Silvopastoral systems on agricultural and pastoral surfaces.

Findings

The evaluation of the AIRs has permitted to analyse the support for agroforestry measures in Italy over the time. Since 2007, only 9 Italian regions have supported agroforestry in their RD Plans. (Figure 1).

Figure 1. Activation of agroforestry support (measure and interventions) in programming periods 2007-2013, 2014-2022, 2023-2027.



In 2007-2013 only 5 Regions have activated the measure 222 with about 8 million Euros destined for the introduction of agroforestry systems. Only 0.3% of total planned resources has been effectively spent by one region (Veneto) for an amount of 27,554 euros. In 2014-2020 the ratio between total planned and spent rose up until 14%, only because one Region (Apulia) spent about than 1,280 million euros.

For the current PP (2023-2027) 6 Regions have planned measures for agroforestry (SRD05.03 and SRA28.03). Two of them (Piedmont and Tuscany) will give the incentive for the first time.

The analysis is still in progress to understand the allocation of resources by regions. Sicily has activated only SRD05.3 intervention (not SRA28.3). Regions are currently preparing the calls; at present, only Piedmont allocated €300,000 for SRD05.3.

Table 3. Allocated resources supporting agroforestry systems in Rural Development Programs in CAP 2023-2027 programming period.

Regions	SRD05.3 Establishment		SRA28.3 Maintenance	
	Maximum eligible expenditure (€/ha)		Compensatory payment (€/ha/year)	
	3.1 Silvoarable[a]	3.2 Silvopastoral[p]	28.3.1 Silvoarable[m]	28.3.2 Silvopastoral[m]
Piedmont	5,000	4.000	600	600
Puglia	5,000	4.000	1,200	1,200
Sicily	5,000	4.000	Not activated	Not activated
Tuscany	6,500	5.300	800	800
Umbria	5,000	4.000	600	600
Veneto	5,000	4.000	300	350

Notes: [a]on agricultural surfaces, [p]on grazing surfaces, [m]maintenance; sys: systems.

Practical and theoretical implications

The financial analysis shows the application of the RDP support on agroforestry systems in Italy. The analysis highlights the low level of application of the measures, both in terms of surface and of financial resources. The reasons of this failure seem to be related both to the context (e.g. cultural landscapes, agricultural structural characteristics) and the overall policy framework for the CAP (e.g. eligibility criteria for the direct payment scheme in relation to tree density, for the greening payment scheme, and the implementation of RDP measures). Moreover, agroforestry seems to be perceived by the farmers as a scheme with high costs, foregone income, and difficulties in mechanization operations. Another aspect to consider is the capacity to inform farmers about agroforestry potentialities: according to a survey made in Italy, often farmers do not know that is possible to have accession to these contributions.

Considering that the CAP support for agroforestry introduction covers only a share of investments, one further contribution could come including the agroforestry practices in the eco-schemes, representing a stronger incentive because of the connection with direct payments.

Funding is foreseen only for newly established agroforestry systems, so farmers are not incentivised to keep existing agroforestry systems.

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Policies for agroforestry, a narrative review of four 'continental' regions: EU, India, Brazil and the U.S.A

Rosemary Venn[a], Jesse Buratti-Donham[b], Fernando-Esteban Montero-de-Oliveria[c], Jonathan Eden[a], and Sabine Reinecke[d]

[a]Centre for Agroecology, Water and Resilience, Coventry University, rosemary.venn@coventry.ac.uk & jonathan.eden@coventry.ac.uk

[b]Agroecology Europe, jessica.donham@agroecology-europe.org

[c]Department of Forestry and Rural Development, University of Freiburg, esteban.montero@waldbau.uni-freiburg.de

[d]FiBL, Switzerland, sabine.reinecke@fibl.org

Abstract:

Agroforestry is receiving renewed interest due to its highly diversified, multifunctional nature. Agroforestry systems offer a 'win-win' for biodiversity, carbon sequestration, on-farm profitability, resilience, and social wellbeing. However, the re-integration of trees on farms goes against the previous decades' push for de-mixing, intensifying, and simplifying production methods, and farmer uptake remains low. As understanding and support for more integrated, complex farming systems builds, an enabling policy landscape is needed. This narrative policy review considers policies for agroforestry across four 'continental' regions: the EU, India, Brazil, and the U.S.A, exploring the content, development, objectives, and alignment of both direct and indirect policies to provide insight into: how policies for agroforestry are currently framed; the governance process of their development; and, whether over-lapping and interconnected policy objectives are included. We find that policies for agroforestry are increasing gradually, but are typically confined to an agronomic understanding, with limited inclusion of the socio-political aspects of food and farming. Except in Brazil, policies appear to be narrow in scope, with few stakeholders included in their development. Policies do not challenge the status quo of the dominant corporate agri-food system and appear to miss the transformative potential of agroforestry.

Keywords: agroforestry, multifunctional, sustainable food systems, policy coherence

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Purpose

Agroforestry systems (AFS) are receiving renewed interest by those searching for self-sustaining, low-input, diversified systems (Mosquera-Losada *et al.,* 2018). This is primarily due to AFS' ability to combine ecosystem services (ES) with environmental benefits and climate mitigation (Jose 2009). However, the benefits of agroforestry go beyond just the biophysical. AFS can add diversified income streams, improve rural livelihoods, provide shelter, food, fuel, fodder, and other products (Leakey 2012). The restoration of degraded landscapes using AFS can also increase the resilience of farms and communities to shocks such as drought and food shortages. Although agroforestry is considered a regenerative, agroecological approach to land management (Peredo Parada et al., 2020;

Snapp et al., 2021), it can take many forms in practice. Depending on what objectives are prioritized, the transformative potential of AFS on food systems is impacted. Within this context, this paper reviews agroforestry policies in four major food producing regions of the world, with the aim to understand how these policies are being developed and with what narratives, reflecting on the scope of AFS to contribute to a fairer and more sustainable food system.

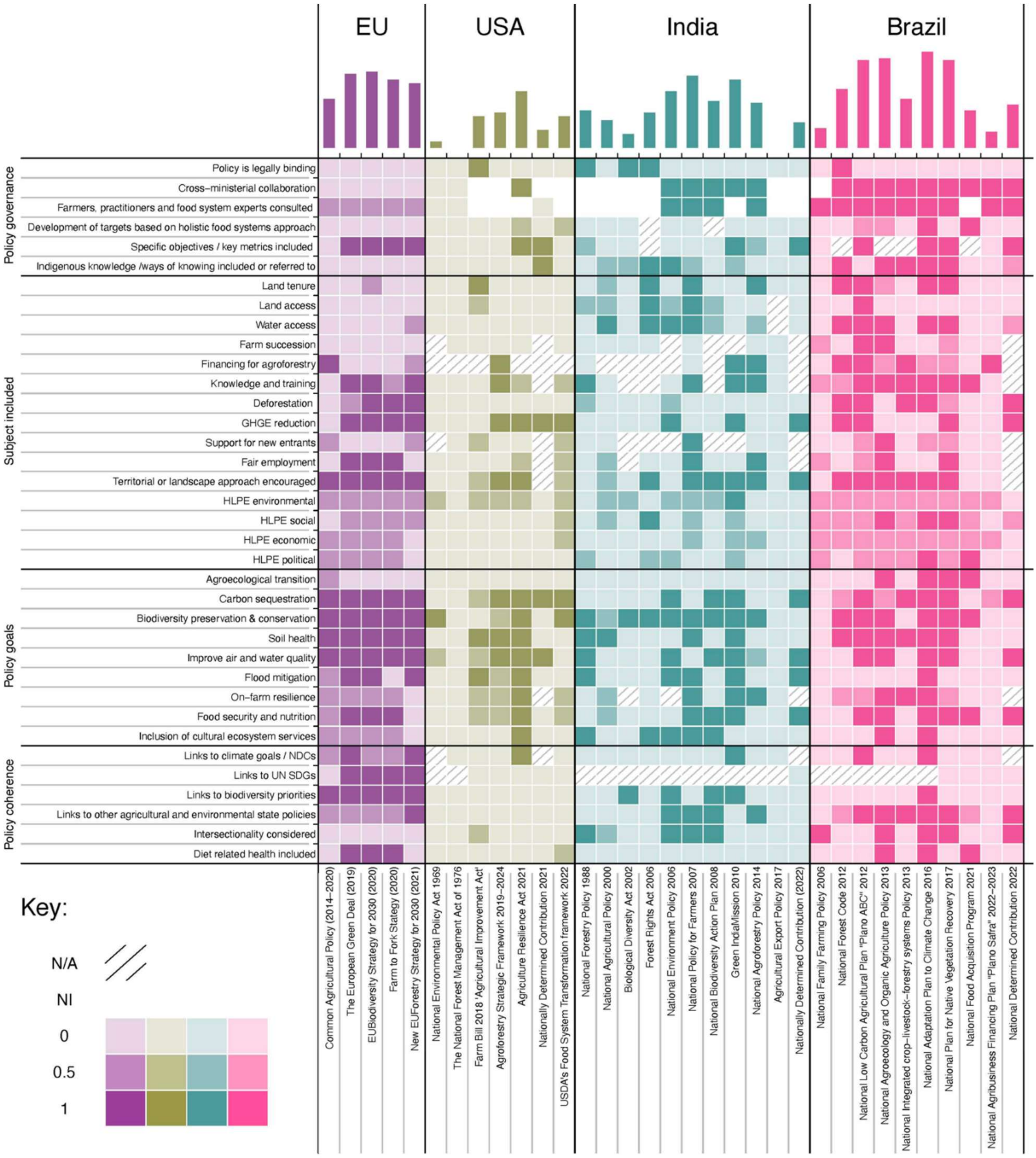
Approach

Four 'continental' regions were chosen for this analysis: the European Union (EU), India, Brazil and the United States of America (U.S.A). These four regions are highly relevant given their collective contribution to global agricultural production and therefore their subsequent contributions to global greenhouse gas emissions (USDA 2019). The EU, India, Brazil and the U.S.A have comparable policy models in that they all have a combination of overarching policies at the federal level (or supranational level in the case of the EU) as well as at the individual state or member state level, which can work against or in tandem with the broader policies. Policies, both direct and indirect were identified for each region following a 'snowball sampling' approach (Parker et al., 2019).

To address the aims, a novel policy framework was developed. A list of attributes in line with environmental and societal sustainability were identified and grouped into four categories: *policy governance*, *subject included*, *policy goals* and *policy coherence*. Given their relevance to the agroecological discourse on transition pathways to SFS, the High Level Panel of Experts' '13 Principles of Agroecology' (2019) serve as a basis for defining whether policies adhere to an agroecological reading or not.

Findings

Figure 1. Policy summary matrix showing the results of the policy framework analysis. Regions and corresponding policies are shown along the horizontal axis; attributes and their respective categories are shown along the vertical axis. Shaded boxes represent each policies' score as the key denotes.



Both direct and indirect policies for AF were identified across the regions. The USA and Brazil do not have direct national policies for AF but provide direct policies at the state level. India has a National Policy for Agroforestry (2014) but no regional or state policies and the EU has direct policies both at the regional and individual member state (MS) level. The more recent policies appear to include a greater diversity of policy goals, such as carbon sequestration, improving air and water quality and biodiversity preservation and conservation. The socio-political aspects of food governance and AFS are not being included to the same extent, with policies omitting to address land tenure, financing, employment, food security and nutrition or diet related health.

Practical Implications

Collaboration may lead to greater policy integration

There is a slight trend towards greater policy integration the more recent the policy (Figure 1). It is not possible to say from the data whether increased cross-ministerial collaboration and the inclusion of farmers, practitioners and food-system experts directly leads to greater policy integration, however for the USA, low scores within policy development match with low scores for integration. Whereas the results for Brazil could highlight how increased cross-ministerial collaboration results in greater integration, particularly when looking at links to other agricultural and environmental state policies (Figure 1). This would be in line with thinking that inclusion of a greater diversity of stakeholders within the policy process results in more effective policies (Parsons & Barling 2022). There is some 'joined-up' thinking when it comes to AFS and other agricultural and environmental state policies particularly within Brazil and the EU. A surprisingly small amount of policies link directly to climate goals or NDCs. As for diet-related health, most regions do not make the link between AFS and the potential for improved nutrition or health.

Policies for AFS lean towards agronomic reading of NbS concept, limiting its transformative potential

The majority of policies included in this review lean towards an agronomic understanding of AFS as a NbS, favouring policy goals and content linked to environmental objectives such as carbon sequestration, biodiversity preservation and conservation, air and water quality and flood mitigation. Objectives linked to diet, health, access to land and water are generally left out, thereby limiting the transformative potential of AFS as a NbS.

People and practitioners are absent within policy

For the most part, the EU, and the USA, the two 'higher income' regions included in this review do not include the framework of intersectionality in their policies (The USA Farm Bill scores 0.5, all others 0). Taking an intersectional approach to policymaking and policy analysis requires identifying, understanding and addressing the structural inequalities in a given context that account for these different lived experiences and inequalities (Munro et al., 2014, Mitra and Roa 2019). This omission of intersectionality within the policy arena is unsurprising but noteworthy. Brazil and India, which both score higher on in terms of wealth inequalities, both have four policies that include intersectionality. This could be perhaps due to a greater recognition of the diverse countries' demographics, including a stronger recognition of indigenous and traditional peoples and cultures. Other lowest scoring attributes include farm succession, support for new entrants and, surprisingly, links to the UN SDGs.

Theoretical Implications

Our analysis shows that despite mounting evidence for the severity of the climate crisis on food and agriculture policy is lagging behind. The link between agriculture and climate (both in terms of its impacts to and fragility in the face of), is not sufficiently reflected in recent policies within this review. The policies do not question the basis of the conventional agri-food system and for the most part are based on growth strategies and neo-liberal trade policies. Land tenure and access rights remain unaddressed across most policies, despite this being a well-documented barrier to scaling of AFS. Across the regions reviewed, policies for agroforestry are increasing gradually, but appear to be confined to an agronomic understanding of the practice. The focus is primarily on the provisioning of ES these systems can offer, as opposed to seeing it as a tool for food system change or linking with other policy objectives around health and improved livelihoods. This implies that improving policy coherence is critical as we seek to address the multiple, interconnected crises of climate change, biodiversity loss and inequality. Seemingly, there is a big opportunity for AFS and agriculture more broadly, to be firmly integrated into key targets around biodiversity loss, carbon emissions and diet related health.

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Farm to tech: evidence on the demand for public support to innovation systems in Italian agriculture

Francesco del Puente[*a], Concetta Menna [b], Rossella Ugati [b], Giuseppe Panella [b], Maria Bonaria Lai [c], Teresa Del Giudice [d], Alessandro Sapio [a]*

*a Corresponding author, University of Naples Parthenope (IT),
francesco.delpuente001@studenti.uniparthenope.it

b CREA – Center of Political and Bioeconomy, Naples (IT), concetta.menna@crea.gov.it

b CREA – Center of Political and Bioeconomy, Naples (IT), rossella.ugati@crea.gov.it

b CREA – Center of Political and Bioeconomy, Naples (IT), giuseppe.panella@crea.gov.it

c University of Pisa (IT), mariabonaria.lai@agr.unipi.it

d University of Naples - Federico II (IT), teresa.delgiudice@unina.it

a University of Naples Parthenope (IT), alessandro.sapio@uniparthenope.it

Abstract:

This paper aims at understanding which economic and financial features of agricultural firms affect their decision to participate in EIP-AGRI operational groups and therefore to pursue innovations through multi-actor arrangements. We estimate econometric models on a dataset of the Italian FADN, including the "aiuti" dataset that allows identifying farms that were beneficiaries of Measures 1, 2, and 16. The dataset involves several balance-sheet variables that we employ as explanatory variables in logit and probit models of the probability to participate in OGs and related innovation-oriented measures. The explanatory variables are selected having in mind hypotheses concerning the role of farm size, age, credit rationing, and knowledge base on the propensity to take part in multi-actor arrangements for innovation.

Keywords: AKIS, Operational Groups, Multi-actor arrangements, Innovation, FADN, Panel data, Logit model.

Purpose

Radical technological and organizational solutions are needed to address a sustainable transition in agriculture and are favoured by the implementation and definition of network models (Brunori *et al*. 2013, Garcia-Alvarez-Coque et al., 2021), such as the Agricultural and Knowledge Innovation System (AKIS) (Mirra *et al.,* 2020).

An instance of multi-actor arrangements, stressing the importance of knowledge-sharing among parties, is given by Operational Groups (OGs) funded within the 2014-2020 Rural Development Policy (RDP), through Measure 16 for cooperation, sub-measure 16.1 "Support for the establishment and management of European Innovation Partnership (EIP) operational groups on agricultural productivity and sustainability".

Which farmer types are more propense to set up OGs and therefore to demand public financial support for their R&D endeavours is highly interesting for policy. The emphasis of EIP-AGRI on interactive innovation involving scientific entities is reminiscent of science-based sectors in the Pavitt (1984) taxonomy. If agriculture (or part of it) has been shifting towards science-based modes of innovating, we should find relatively small and young firms as being among the most propense to participate in GOs. This would confirm the usefulness of a policy support strategy inspired by interactive innovation theories.

On these grounds, the study aims at understanding which economic and financial features of agricultural firms affect their decision to participate in OGs and therefore to pursue innovations through multi-actor arrangements. We estimate econometric models on a dataset of the Italian FADN (i.e. RICA), including the "aiuti" dataset that allows identifying farms that were beneficiaries of Measures 1, 2, and 16.

Design/Methodology/Approach

For the purposes of this paper, we rely on the Italian FADN dataset, called RICA. The dataset includes an overall number of 10,252 farmers, over the period 2014-2021, totalling 38,882 observations. Each farm was observed, on average, for 3.8 years in a row. For each farmer, we have balance sheet data and, most interestingly for our research goals, the public subsidy programmes that each farmer benefited from. We focus in particular on Measures 1, 2, and 16, which deal with multi-actor arrangements for innovation. The hypothesis tested in this paper are the following:

H1 (*farm size*). *The propensity of farmers to setup operational groups depends on farm size.*

H2 (*farm age*). *The propensity of farmers to setup operational groups depends on experience on the market.*

H3 (*credit rationing*). *The propensity of farmers to setup operational groups is higher for farmers with less collateralisable assets.*

H4 (knowledge base). *The propensity of farmers to setup operational groups is higher for farmers endowed with intangible knowledge-based assets.*

Variable OG is a dummy assuming value 1 for farmers who benefited from Measures 1, 2, or 16, in the years when they received the subsidy. To measure business size (H1), we rely on sales, a common measure of size that takes account of the farm's success on the market. Our measure of collateralisable assets (H3) is given by total fixed assets. Age is captured by dummy "young", equalling one for farmers who have been on the market for less years. Finally, dummies "concessions, licenses and trademarks" and "biological" provide information on the previous development of a knowledge base by farmers (H4). All non-dichotomic variables are included in the regressions after taking logarithms, to reduce their variability as customary in the econometrics of firm-level data.

Summary statistics for the selected variables are available upon request.

Our dependent variable is dichotomic, and our dataset is organised as a panel; therefore we estimate logit and probit models for panel data. After some preliminary testing, we find that unobserved heterogeneity among farmers is best captured by models with random effects, rather than with fixed effects. Therefore, we estimate logit models for the probability to participate in OGs, using the variables in Table 1 as explanatory variables, plus controls. Coefficient estimates may be biased, for a number of reasons. To avoid simultaneity bias, we lag all explanatory variables (except those that do not vary over time).

Findings

Table 4 displays results of estimating Eq. 1 as a logit model, in which we focus first on the main explanatory variables (col. 1) and then add control variables (NUTS regions in col. 2, strategic profile in col. 3). We find that the propensity to set up OGs is higher for younger and larger farms, whereas no significant effect is found for collateralisable fixed assets. Marginal effects associated to total sales and age are significant with p-values below 1%. The OG probability is also positively associated with our proxies for the knowledge base, but only biological displays a very low p-value. The certifications / licenses / trademarks dummy is significant only at the 10% level and only when we control at least for cross-regional differences (col. 2 and 3 in Table 4). Among the strategic profiles included as controls, farms defined as "conventional small" (namely, not diversified and not differentiated) are significantly less likely to take part in OGs (see col. 3 in Table 4).

Table 4. Estimates of panel logit models with random effects for the propensity to participate in OGs. conv. = conventional. * denotes 90% significance, ***99% significance.

Variable	**(1)**	**(2)**	**(3)**
Dep. var.: OG			
Young	1.0433***	1.0790***	1.0763***
Log total sales	.8729***	.6407***	.6704***
Log fixed assets	.1022	.1098	.1269
Log certifications	.0423	.1882*	.1876*
Biological	1.1214***	1.2334***	1.2190***
Strategy: conv. large			-1.2358
Strategy: conv. small			-1.3384*
Strategy: differentiated			-1.6680
Strategy: diversified			-.7981
Constant	-22.3634***	-17.6412***	-17.0796***

NUTS regions	no	yes	yes

These results are confirmed through the following robustness exercises, Table 5 summarizes the outcomes of testing our hypotheses:

- probit models;
- changing the farm size proxy (product sales, significant; total farm surface, non-significant);
- changing the regional proxy (EU regions instead of NUTS);
- robust standard errors.

Table 5. Summary of hypothesis testing results

The propensity of farmers to setup operational groups…		
H1	*depends on farm size*	yes
H2	*depends on experience on the market*	yes
H3	*is higher for farmers with less collateralisable assets*	*no*
H4	*is higher for farmers endowed with intangible knowledge-based assets*	yes

Practical Implications

Our results are only preliminary, yet some takeaways for policy-makers can be outlined. The evidence based on our econometric estimates identifies relatively young and large farms, endowed with knowledge assets, as the ones that are more willing and/or best positioned to participate in OGs. As noted before, we cannot identify farms whose projects were not financed, hence our results mix up the effects of size and age in motivating demand for publicly funded R&D, and their effects in fostering the success of R&D funding applications. Still, if policy-makers had in mind different farm targets when designing programmes to finance innovative multi-actor arrangements, our results may stimulate reflections about why other farm types did not (successfully) participate to the OG measures, and what should be done to foster their participation.

Lastly, it is interesting that among the variables proxying for the knowledge base, the most robustly associated with OG participation was a dummy identifying "biological" farms. Seemingly, this confirms the relevance of biological processes and products in the innovative efforts of Italian OGs, in line with the programme goals to foster sustainability transition pathways.

Theoretical Implications

In theoretical terms, the results provide implications in two respects: (i) the explanatory power of evolutionary innovation theory; (ii) the classification of agriculture within innovation mode taxonomies.

First, based on our results, apparently farms were not pushed to participating in OGs by credit rationing issues. A proxy for collateral failed to be significantly associated to OG participation. One may argue that the effect of young age is consistent with a market

failure story, as younger farms may struggle more on the credit market; however, we also find that larger firms, which typically suffer less from credit rationing, are more propense to participate in OGs. An alternative theoretical interpretation, such as the evolutionary one, is also suggested by the positive effects of the knowledge base proxies, consistent with the persistency in innovative paths along technological trajectories.
Second, the combined evidence of large size and young age being relevant drivers of OG participation provides mixed support to the view that agriculture is transitioning towards science-based innovation modes.
Though, it is worth reminding that, as shown by Arzeni et al. (2023), farms in OGs are mostly involved downstream in the innovative process, in activities such as experimentation of new technologies, an activity which may not need capital outlays as large as needed by R&D proper. At the same time, research entities may prefer experimentation of agricultural innovation in larger farms, for at least two reasons: large farms allow for larger “samples” to experiment new techniques; and they may be part of a larger network (through rural associations or buyer-customer relationships), thereby facilitating the diffusion of the experimented innovation.

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Assessing the Diverse Trajectories of Regionalised Mediterranean Member States towards the European Green Deal

Alessandro Giacardi[a], Roberto Cagliero[b], Giampiero Mazzocchi[b], Alessandro Monteleone[b], Fabio Pierangeli[b], Pietro Manzoni di Chiosca [b], and Federica Morandi[c]

[a]Sapienza University, Dept Social and Economic Sciences, alessandro.giacardi@uniroma1.it

[b]*CREA PB – Agricultural Policies and Bioeconomy, roberto.cagliero@crea.gov.it*

[c]CREA PB – Agricultural Policies and Bioeconomy, federica.morandi@crea.gov.it

Abstract:
This study examines how three Mediterranean EU member states' CAP Strategic Plans (CSPs) align with the European Green Deal (GD) goals. Specifically focusing on Italy (IT), Spain (ES), and France (FR) due to their regional governance system, we compare planned interventions and budgets with GD targets. Results show a gap between intentions and actions. Spain prioritizes a balanced approach across GD objectives, while Italy focuses on farm income. France emphasizes the environment but allocations differ. This study underscores the necessity for a more rigorous evaluation of CSP effectiveness, including real-world implementation data and negotiations between member states and the EU. Additionally, examining other policies like National Recovery and Resilience Plans (NRRPs) could strengthen external coherence analysis, especially in countries with regionalized rural development.
Keywords: Green Deal; Common Agricultural Policy, CAP Strategic Plans; interventions mix, coherence

Purpose

The European Green Deal (GD) represents a transformative vision for the European Union (EU), aiming to achieve sustainability and climate neutrality by 2050. In this context, agriculture is a crucial sector with a substantial impact on achieving sustainability and addressing climate change. The Common Agriculture Policy (CAP) will be an important instrument in managing the transition to sustainable food production systems and strengthening the efforts to contribute to the EU's climate objectives, and to protect the environment. The European GD reveals diverse approaches among Member States (MSs) in the CAP Strategic Plans (CPSs)' implementation and funding allocation (Münch *et al.,* 2023). Our research seeks to explore why some Mediterranean MSs, with regional governance structures, have developed distinct CPSs to achieve GD objectives. We aim to understand whether these CSPs align with country priorities and their effective integration of GD-related objectives such as the Farm to Fork Strategy (F2F) and the Biodiversity Strategy. Our approach involves a comparative analysis evaluating the alignment between the prioritized needs quantified by the MSs and budget allocations in CAP implementation.

Design of the analysis process and data source

The analysis involves comparing two policy streams operating at different levels: the determination of the CSP at the MS level and the determination of the GD at the EU level. The analytical approach is primarily based on consistency analysis, as proposed in several documents related to the evaluation of plans or programs (Cagliero & Cristiano, 2013), focusing on both internal and external coherence. The analytical process aims to address two main research questions:

1. To what extent do the declared CSP strategy and the planned interventions framework align with the sectoral and territorial needs identified in the context analysis?
2. How do the strategic declarations of the CSPs align, complement, or contradict the GD, considering their respective needs and interventions?

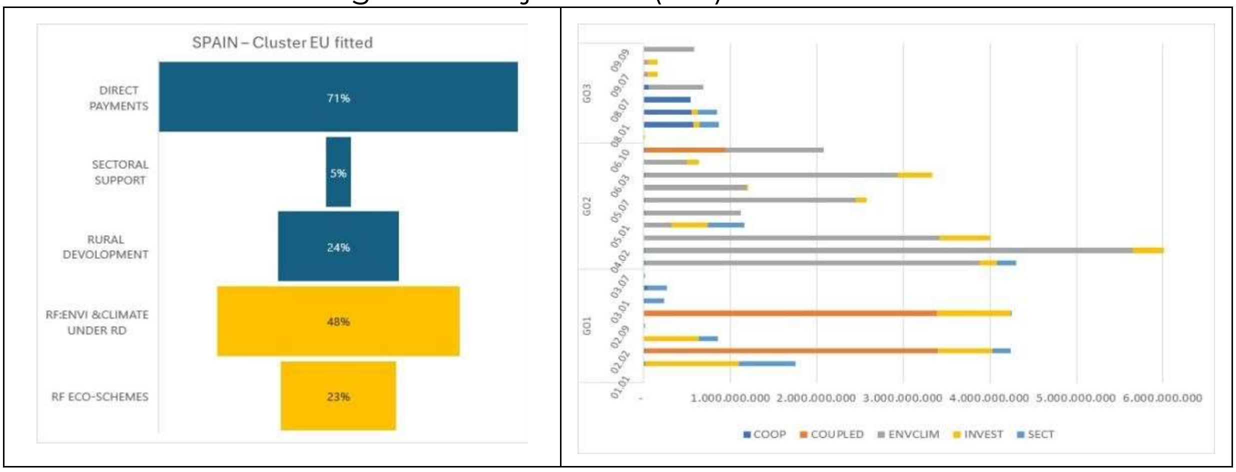
The first part of the study concentrates on assessing the CSP intervention logic and its internal consistency. The CAP's National Development Plan (NDM) mandates each MS to develop a unique CSP structured around nine strategic objectives (SO), grouped into three general objectives (GO: economic, environmental, and social), along with a cross-cutting objective on knowledge and innovation (AKIS). Despite considerable diversity in the contexts and needs of EU's rural areas (Erjavic *et al.*, 2018), the CSP strategies are required to contribute to the attainment of the objectives outlined in the EU GD. Information related to the approved CSP constitutes a valuable dataset of for conduction a comprehensive analysis of their consistency. In *clustering the CSP,* we refer to Cagliero et al (2023), who employed a Text Mining-Clustering process to categorize CSPs Strategic Statements into five distinct groups: EU framework; Supply Chain; Farm resilience; Env. & climate; AKIS. The intervention *needs identified* are presented in CSP Chapter 2, along with their priority levels. To ensure comparability, we decided to select only those with high priority levels. For the analysis of *budget allocations* among interventions (CSP Chapter 6), we aggregated them into macro-typologies using the cataloging method proposed by Cagliero et al. (2023): Income support, Risk management; Investments; Coupled support; Environmental & climate actions; Cooperation; Young Farmers; AKIS. In the second part of the study, to assess the connection between needs and GD 2023 targets (Morandi *et al.,* 2023), we employed a specialization index. The Balassa index (BI), introduced by Balassa (1989), and widely utilized across various fields of study, including CAP analysis (Cagliero and Henke, 2005), involves comparing the actual performance of a specific region with the expected performance with respect to the higher territorial and/or administrative aggregate, e.g. a State or the EU (Cagliero et al., 2023). Following that, we evaluated the interventions that were implemented along with their associated budgets in comparison to the targets established in the GD. This assessment also considered the interventions mix in place.

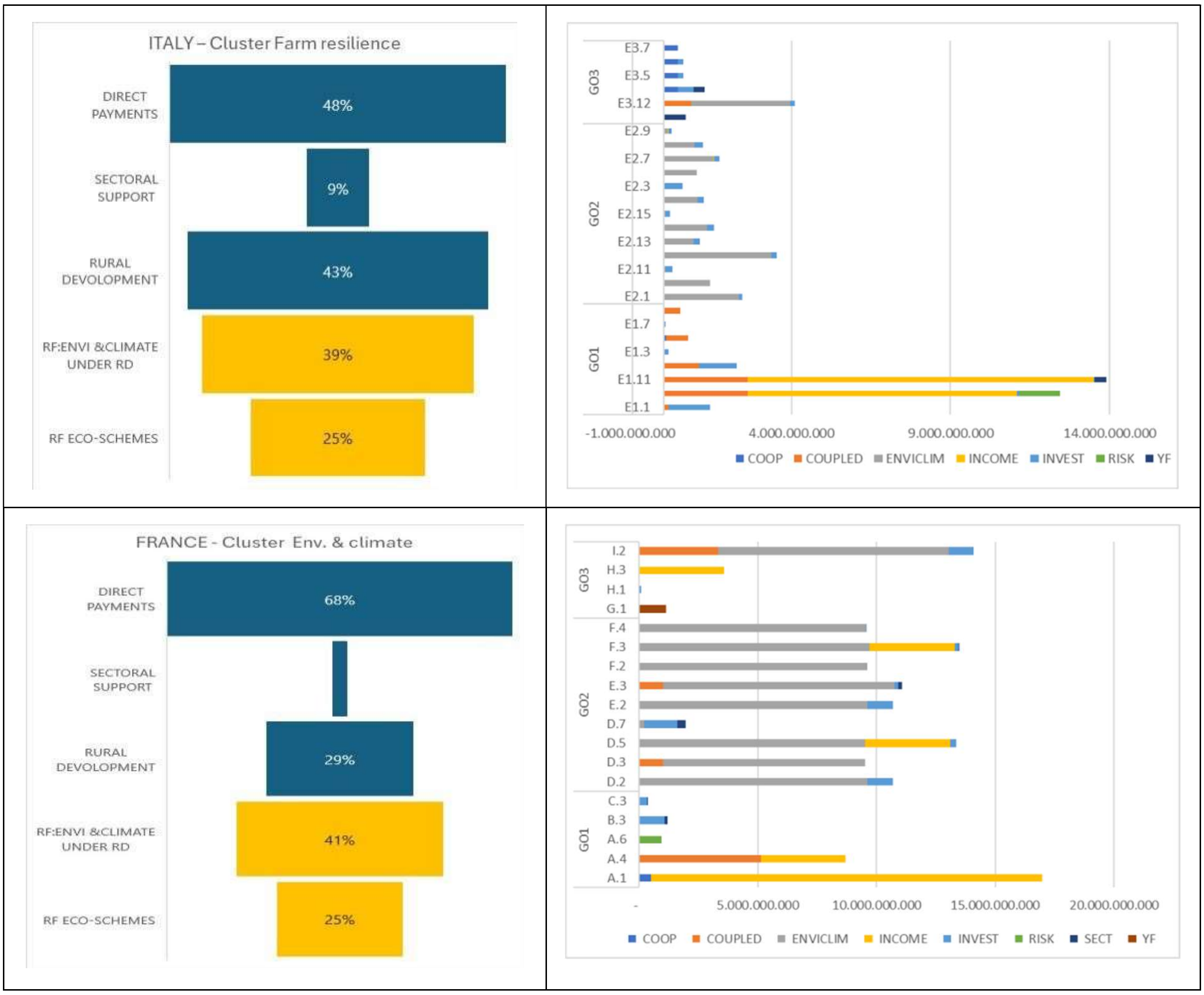
Findings

The Text Mining process on Strategic Declarations positions the three MSs in distinct clusters: the Spain (ES) cluster exhibits a strong connection to the formulation of the

EU strategy (EU fitted); the Italy (IT) cluster focuses on achieving a fair income for farmers and enhancing their competitiveness (Farm resilience); the France (FR) cluster emphasizes the environment and climate change (Env. & Climate). These three clusters were subsequently examined in terms of actual budget allocations under CAP pillars and ring-fence and principal needs relative to CAP objectives (Fig.1). The analysis exposes differing approaches among MSs, which are not always consistent with the declarations made in CSPs (Münch et al., 2023; Cagliero et al., 2023). ES aligns closely with the EU strategy by allocating resources extensively across various objectives and interventions. Notably, there is a focus on environmental concerns (GO2), confirmed also by the Rural Development (RD) ring-fence allocation (48% vs 35%, the regulatory minimum). IT CSP reflects emphasis on farm resilience, exposing a balanced allocation between direct payments and RD, deviating from the EU average. IT maintains coherence by prioritizing income supports under GO1. Peculiarly, there is a significant allocation to risk management intervention. Despite a clear declaration on environmental and climate issues, FR CSP demonstrates similarities to the EU average, distributing resources across diverse needs and interventions. However, we find a mismatch between the declared CSP focus and the actual budget allocation per type of intervention.

Figure 1 – Budget allocation by pillar, with environmental ring-fence depicted on the left, and type of intervention categorized by priority need on the right, clustered within three general objectives (GO).





Source: own elaborations using the data as per the Catalogue of CAP interventions, Oct 2023. Note: Double counting allowed.

Regarding *external coherence*, the BI analysis (Figure 2) evaluates the correlation between CSP under CAP GOs, where GO2 serves as a proxy for the GD issues. ES exhibits a low incidence of priority needs for GO2 (BI = 0.82), while IT and FR indicate the opposite, with respective BI of 1.39 and 1.47. In the case of IT, it is also necessary to observe the BI value for GO1, which places the Italian CSP in coherence, like the FR one about environmental issue. Figure 2 also provides a summary of the comparison between GD targets and financial allocation. Distinct strategies of the MSs are evident in their budget allocations. IT demonstrates a balanced distribution among various GD issues, with emphasis on animal welfare, a particularly Italian sensitive topic. FR choices appear more coherent with the GD, surpassing IT and ES, with emphasis on organic farming. Organic farming is also relevant for ES, along with a focus on soil.

GO	ES	ITA	FR
High relevance needs			
GO1	27%	30%	28%
GO2	**30%**	**48%**	**50%**
GO3	24%	22%	22%
Total needs			
GO1	30%	27%	36%
GO2	**37%**	**35%**	**34%**
GO3	33%	38%	30%
BI high relevance needs			
GO1	0,92	1,10	0,76
GO2	**0,82**	**1,39**	**1,47**
GO3	0,73	0,58	0,75

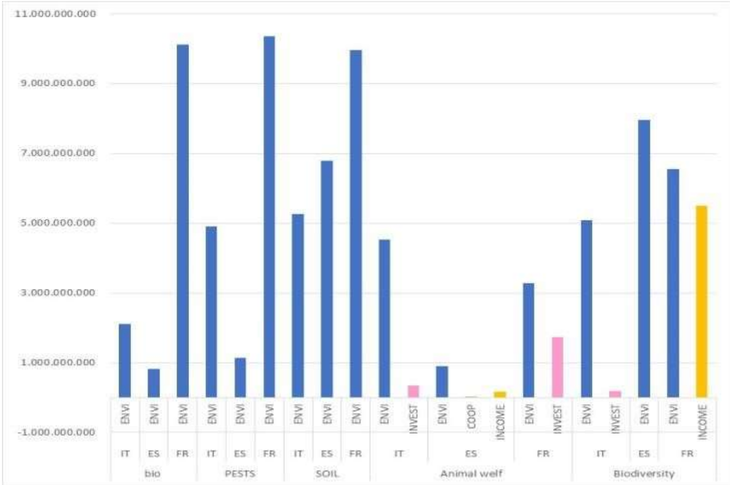


Figure 2 - The CSP needs by Balassa index (left) and GD issues allocation by Macro Intervention Classes (right)

Source: own elaborations using the data as per the Catalogue of CAP interventions, Oct 2023, and Morandi et al., 2023.

Note: Double counting allowed

Practical and Theoretical Implications

This study aims to initiate a discussion on the strategic choices made by certain regionalised MSs and the coherence of interventions adopted in alignment with the GD. MSs demonstrate a considerable focus on the GD objectives, as evident in both their Strategy Statements and the allocation of resources across various types of interventions. The Strategic Statement provides an overview of the MSs CSP, focusing on objectives, interventions, needs, and summarizing financial allocation. Hence, robust internal coherence is anticipated. However, the Statements do not always consistently align with the actual shape of the CSPs, and this discrepancy is noticeable in the FR CSP. The examination of environmental ring-fencing, which, due to its ambitious nature and magnitude, leads to similar applications, reveals a distinctive effort made by ES (48%) compared to a lower effort in FR, despite its Declaration. IT demonstrates consistency in resource distribution, supporting firstly agricultural businesses and famers. IT prioritizes the substantial use of risk management and income support tools. ES exhibits a balanced intervention mix, relatively consistent with its Statement. FR, however, displays less coherence between the Statement and the actual budget allocation, where a stronger emphasis on environmental issues might have been expected. Regarding external coherence, the estimation of a BI on priority needs indicates a specialization towards environmental and climate aspects for FR and IT, while the opposite is observed for ES, suggesting a less consistency with the GD. FR allocates the highest budget to GD issues, ES sets lower targets, and IT is positioned between the two countries. Generally, the CSPs primarily reference agri-environmental measures in Pillar II and eco-schemes in Pillar I, with limited utilization of other types of interventions to achieve GD objectives (e.g., investment or cooperation). The environmental measure under RD, involving national co-financing, could indicate a specific interest. However, eco-schemes allow annual payments to a broad range of beneficiaries and could trigger widespread benefits. Constraints triggered by ring fences further limit the maneuvering margins of MSs. The future challenge lies in assessing the ability of CSPs to achieve GD outcomes. Information on actual implementation will be crucial. Negotiations between MSs and the EU Commission will also play a relevant role. The justifications presented by MSs may depend on national sensitivities in aligning CSPs with the GD. Furthermore, expanding the evaluation of GD objectives not only to the CAP but also to other policies, such as National Recovery and Resilience Plans (NRRP) and LIFE program, could provide significant value in external coherence analysis. However, these challenges will be even greater for countries, such as those under consideration here, where rural development has a regionalized implementation, since, despite national declarations and the need for coherence, each region may implement different strategies.

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Ask the farmers: Evaluating dairy sustainability standards from the perspective of farmer participants in Ireland

K. McGarr-O'Brien[a,b], *J. Herron*[b], *I.J.M. De Boer*[a], *E.M. De Olde*[a]

[a]Animal & Grassland Research and Innovation Centre, Teagasc, Moorepark West, Fermoy, County Cork P61 P302, Ireland

[b]Animal Production Systems Group, Wageningen University & Research, P.O. Box 338, 6700 AH Wageningen, The Netherlands

Abstract:
Market-based sustainability standards are increasingly deployed with stated aims of increasing dairy farm sustainability alongside market differentiation. Evaluating the perspective of farmers who must comply with sustainability standard criteria is essential, and until now had not been done. Our study aimed to reveal farmer participant perceptions of Ireland's Sustainable Dairy Assurance Scheme (SDAS) as a case study for dairy standards.
We added supplemental survey questions to the 2022 Irish National Farm Survey. Questions gauged farmer satisfaction with the accessibility of the standard; views of standard credibility regarding environmental, social, and economic sustainability; and whether farm changes are made due to standard participation. Questions were developed using the devil's triangle framework, highlighting tension in standard aspects of accessibility, credibility and continuous improvement.
Overall, participants are satisfied with the credibility of standard criteria; feel SDAS shows consumers a positive Irish dairy sustainability story; feel support to participate could be improved and feel strongly that farmer participation in standard creation is important. Significant response differences were noted among certain farmer groups (age, gender, agricultural education level, stocking density). These results may be useful to sustainability standard organisers working to ensure accessibility and confidence among farmer participants, and as a framework to assess other standards.

Keywords: Sustainability Standards, Dairy Farming, Sustainable Development

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Purpose

Sustainability transitions will rely in part on market-based initiatives to enable broad, systemic change (Boon et al., 2022). Such market-based initiatives rely in turn on farmer acceptance and participation. One market-based method aimed at increasing farm sustainability and transitioning to more sustainable food production is the sustainability standard. Standards set out criteria farmers must meet to be certified as standard participants, and in exchange farmers should see a price or market access benefit. Farmer participant support for such standards is crucial to enable them to continue

The last 15 years has marked a large increase in the number of dairy sustainability standards in Europe and North America (McGarr-O'Brien et al., 2023; Sandøe et al., 2023). Despite the increasing number of standards, there is so far a lack of evaluation of farmer participants' perceptions. A market-based quality and sustainability programme, Origin Green, was introduced in the Republic of Ireland in 2012 (Bord Bia, 2023). Over 95% of Ireland's dairy production is enrolled in Origin Green and all enrolled farmers participate in the associated on-farm producer standard, the Sustainable Dairy Assurance Scheme (SDAS) (Bord Bia, 2023). The SDAS involves an on-farm external audit every 18 months against a list of 170 criteria for farmers must meet, covering topics such as land management, animal health and welfare, farm worker health and welfare, pollution control, and product quality.

Understanding farmer perception of sustainability standards, as well any farm changes being made due to participation in sustainability standards, is important for assessing the standard and its contribution to sustainable development. Integrated sustainability standards such as SDAS are also subject to trade-offs which should be examined to assess their potential sustainability impact. The devil's triangle framework presents three important but often opposing aspects of sustainability standards: *credibility, accessibility*, and *continuous improvement* (Bush et al., 2013; Samerwong et al., 2018). By evaluating each of these aspects, the possible impact of sustainability standards can be explored. Evaluations of these topics are lacking in current literature on dairy sustainability standards. Therefore, this research aimed to understand the perspective of Irish dairy farmers who participate in the Sustainable Dairy Assurance Scheme (SDAS) and thus the nation-wide Origin Green sustainability programme, as a case study in farmer perception of market-based dairy sustainability standards.

Methodology/Approach

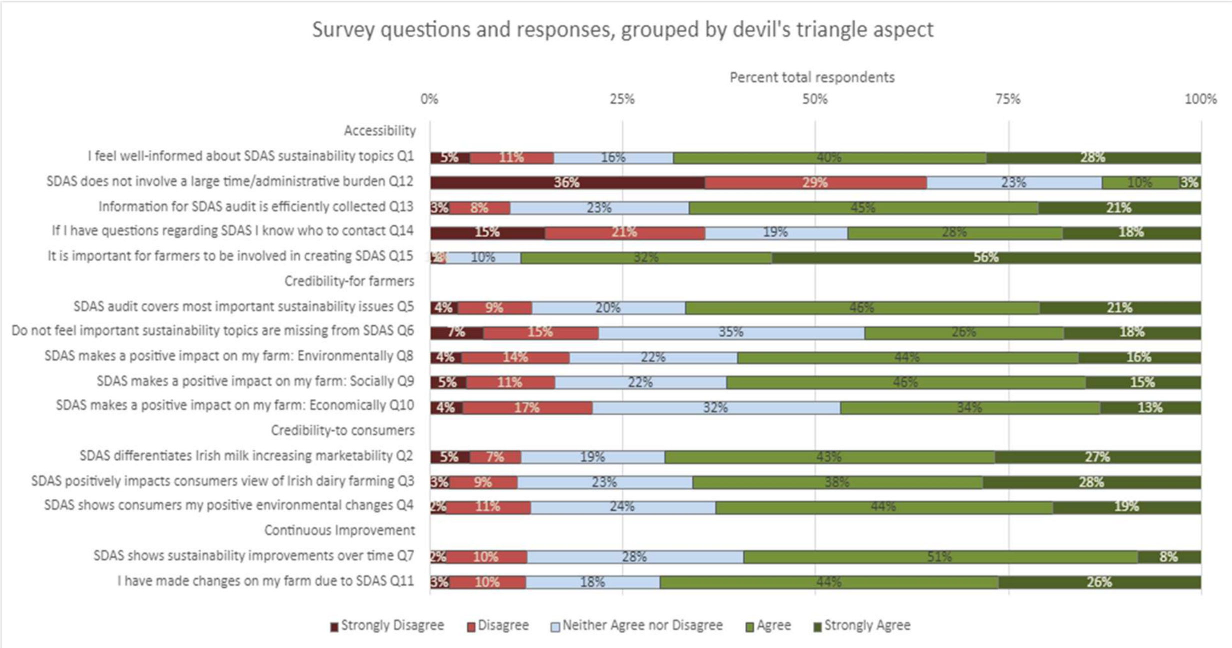
To address the research questions, we added voluntary supplemental survey questions to the 2022 National Farm Survey (NFS) in the republic of Ireland, which collects economic and sustainability data from a subset of Irish farmers annually (Teagasc, 2023). Farmers surveyed for the NFS are a representative sample of all Irish farms. Our survey consisted of sixteen questions including fifteen 5-point ascending Likert scale type ranking questions and one open-ended question. The survey questions were structured according to the devil's triangle framework, with each question addressing one of the aspects of credibility, accessibility or continuous improvement (Bush et al., 2013). For our survey, 'credibility' questions were split into how farmers themselves perceive the credibility of SDAS (credibility-farmer), as well as how farmers feel SDAS impacts consumers' view of dairy farm sustainability (credibility-consumer). The survey received 213 responses from dairy farmers throughout Ireland. After removing those with missing or incorrect data there were 192 valid responses. Data were organised and analysed using Microsoft Excel and IBM SPSS version 29.01.0.

Findings

Ranking survey

The ranking survey results illustrate that overall, respondents feel positively about *credibility* and *continuous improvement* aspects of SDAS (Fig. 1). Respondents felt especially positive that the scheme illustrates credibility to consumers, creating a positive image of Irish dairy farming sustainability. However, credibility in positive economic change due to participation was noted by less than 50% of respondents, illustrating lack of confidence in financial benefit to farmers from SDAS participation. Results also show *accessibility* as the devil's triangle aspect with the most variability in responses. Respondents felt strongly that farmer participation is essential in creating new versions of the standard and that SDAS creates a large time and administrative burden.

Figure 1: Ranking survey questions and responses, grouped by devil's triangle aspect



The non-parametric Mann-Whitney U test was performed in SPSS to reveal any significant differences in survey responses among farmers across different characteristic groups. Of numerous groups of farm and farmer characteristics, statistically significant differences were revealed in certain age, gender, agricultural education level, and nitrates derogation pairs.

Younger farmers (40 and under) were significantly more confident that SDAS is creating positive environmental *(P= .037)* and social *(P= .011)* changes on their farms, as compared to the middle-aged farmer group. Farmers with no formal agricultural education were significantly more confident that SDAS is creating positive economic change on their farms, as compared to farmers who have undertaken medium (*P= .019*) and high (*P= .037*) levels of formal agricultural education. Non-derogation farmers (used here to indicate those farming at lower stocking rates, so less intensively), were more positive about the efficiency of the SDAS audit process, as compared to derogation farmer respondents *(P= .033)*. Female farmers were also more confident that positive social change is occurring on their farms due to SDAS participation as compared to male farmers *(P= .052).*

Open-ended survey question

Forty-two suggestions (from 15% of respondents) were provided in response to the single open-ended question of the survey: '*if you feel there are important sustainability topics not included in SDAS, please provide suggestions*'. Suggestions were split into six sustainability groups: nature and biodiversity (8), environment/climate (8), farmer welfare (8), farm management practices (10) and the audit process itself (3). Suggestions repeated by multiple respondents included biodiversity value and education; hedgerow management; carbon accounting; farmer health, safety and welfare; and excessive audit paperwork. While provided by a minority of survey respondents, responses do illustrate concerns among some participants that SDAS is not comprehensively addressing all important sustainability topics.

Practical Implications

Standard organisations should account for the variable survey responses from different farmer groups when communicating with farmers and working to improve accessibility to the standard. In response to the open-ended question, farmers provided suggestions topics of nature, climate, farmer welfare, animal welfare, farm management, and process improvements that would enhance the standard. The sustainability comprehensiveness and focus of standards should be reflected on by standard organisations.

Theoretical Implications

This was the first study of its kind to establish perceptions of farmer participants of market-based dairy sustainability standards. Without farmer support, the ability of such standards to continue is at risk. Benefits to farmers for taking part in standards should be further researched; particularly in this case, whether farmers realise an economic benefit from participation. The sustainability impact of market-based sustainability standards requires further investigation and is complicated by the wide range of sustainability topics included in integrated standards such as SDAS. This research can also be utilised as a framework to evaluate participant perceptions and reflect upon the impact and potential improvement of other sustainability standards.

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ENACTING AND NAVIGATING TRANSITIONS: EXPERIENCES AND IMPACTS I

Harmonizing Biosecurity Perspectives: Exploring collaborative Strategies for disease control in the Dutch pig farming sector

- Rolien Willmes, Lecturer at Strategic Communication – WUR

- Marijn Poortvliet, Associate Professor at Strategic Communication – WUR

- Bob Mulder, Assistant Professor at Strategic Communication – WUR

- Jasper de Vries, Associate Professor at Land Use Planning – WUR

Abstract:

This study delves into the complex interplay of biosecurity strategies and perspectives among farmers and veterinarians, focusing on their implications for disease control and herd health management in intensive pig farming. Biosecurity measures encompass both external and internal strategies to mitigate pathogen transmission, with veterinarians prioritizing on-farm measures while farmers emphasize concerns over external influences. Collaboration is identified as crucial for crafting biosecurity plans that address both internal and external threats. Challenges arise in convincing farmers to prioritize internal biosecurity, with consultations often prioritizing immediate problem-solving. Strategies such as centralized viral sequencing diagnostics offer potential solutions. Veterinarians exhibit diverse perspectives on biosecurity strategies, highlighting the need for clarity and consensus on implementation levels. The study suggests a shift towards community-based biosecurity approaches, fostering collaboration among farmers and reframing neighboring farms as allies. However, both groups tend to view infection control primarily in terms of externalization rather than resilience. In conclusion, addressing disparities in biosecurity perspectives necessitates open consultations and evidence-based strategies to enhance collaboration and disease prevention within farming communities. Integrating such insights into biosecurity practices is vital for effective disease mitigation in intensive pig farming.

Purpose

The Dutch pig sector faces multifaceted challenges related to health, welfare, and sustainability. The overreliance on antibiotics for disease management has heightened concerns about the emergence of antibiotic-resistant bacteria, prompting a shift towards preventive herd health management strategies (Bergevoet, 2019; Seilbergeld, 2019). Additionally, growing imperatives to address animal welfare and sustainability issues necessitate comprehensive sector reform in farming practices and revenue models (Maes et al., 2020). Amidst these challenges, veterinarians play a pivotal role as advisors and collaborators with pig farmers. However, the dynamics of herd health co-production within the farmer-vet interaction remain poorly understood. Existing research often focuses on isolated consultations rather than long-term collaboration (Bard et al., 2019; DeGroot, 2020; Jansen et al., 2010; Kleen et al., 2011). Therefore, this study aims to deepen our understanding of herd health management within the context of ongoing interactions between farmers and veterinarians on intensive pig farms, providing insights to facilitate this collaborative process. Moreover, investigating how farmers and veterinarians collectively shape herd health will shed light on their perceptions and roles in managing it, uncovering potential challenges and opportunities for leveraging the farmer-vet relationship to drive sectoral reform, as envisioned in veterinary practice regulations. Can veterinarians cultivate enduring trust relationships with farmers while also maintaining a critical perspective and guiding them towards management reform? What role does the farmer-vet relationship play within the broader agricultural network? These are the central questions guiding this research, which aims to contribute to a deeper understanding of the intricacies of collaborative herd health management in intensive pig farming and its implications for sectoral sustainability and resilience.

Design/Methodology/Approach

Qualitative methods were selected to understand how farmers and veterinarians collaborated on improving pig health in intensive pig farms enabling us to explore human behavior, interactions, and contextual factors. Through interviews, observations, and focus groups, we delved into the dynamics of farmer-veterinarian partnerships, uncovering communication nuances, decision-making processes, and underlying beliefs. Qualitative research was ideal for capturing contextual nuances such as cultural norms and socioeconomic conditions, shedding light on challenges, strategies, and barriers in collaborations.

Fifteen semi-structured interviews were conducted with both farmers and veterinarians. In addition to these key stakeholders, representatives from various other stakeholder groups were interviewed to gain a more comprehensive insight into the broader network within which farmers and vets operate. These included feed advisors, nutritionists, breeding advisors, representatives of pharmaceutical companies, and members of producer organizations, among others.

Furthermore, to foster group discussions and gather collective insights, focus groups and workshops were organized. Two focus groups were held with farmers, each comprising eight participants, while two separate sessions were conducted with veterinarians, with each group consisting of 5-8 participants.

To observe firsthand the interaction between farmers and veterinarians in practical settings, observational work shadowing of veterinarians was employed. The researcher accompanied three different veterinarians on farm visits to four distinct farms, meticulously recording subsequent discussions between farmers, veterinarians, and farm employees regarding the observed situations and their implications for farm management.

The collected data were analyzed thematically to identify common threads and patterns. This mixed-methods approach facilitated a comprehensive understanding of the intricate dynamics between farmers and veterinarians within the context of intensive pig farming.

Findings

This research explores the nuanced dynamics of biosecurity strategies and perspectives among farmers and veterinarians, with a particular focus on implications for disease control and herd health management.

Disparities in Biosecurity Perspectives between Farmers and Veterinarians

Biosecurity measures encompass a comprehensive approach, integrating both external and internal strategies to mitigate pathogen transmission. While veterinarians prioritize "internal biosecurity," emphasizing on-farm measures, farmers tend to favor "external biosecurity," emphasizing concerns over external influences. These differences underscore the importance of collaborative efforts in crafting biosecurity plans that address both internal and external threats.

However, challenges arise in implementing these strategies, particularly in convincing farmers to prioritize internal biosecurity. Veterinarians often face constraints in providing critical advice during consultations, as consultations prioritize immediate problem-solving over reevaluating existing practices. Nonetheless, potential strategies emerge to address these challenges, such as providing veterinarians with indisputable evidence of internal disease causes through centralized viral sequencing diagnostics.

Diverse Perspectives on Biosecurity Strategies among Veterinarians

Discussions among veterinarians reveal a spectrum of views regarding biosecurity strategies, ranging from advocating for stringent measures to eliminate lingering infectious diseases to promoting herd replacement and enforcing strict regulations. These diverse perspectives highlight the need for clarity and consensus on the appropriate level at which biosecurity strategies should be implemented.

Towards Collaborative Biosecurity

The findings suggest the potential for a shift towards community-based biosecurity approaches, fostering collaboration and trust among farmers. By reframing neighboring farms as allies rather than threats, the transition from individual farm-focused biosecurity to a community-based approach holds promise for enhancing disease prevention and resilience within farming communities. However, it is noteworthy that both farmers and veterinarians tend to view infection control primarily in terms of externalization rather than resilience.

Conclusion

In conclusion, the disparities in biosecurity perspectives between farmers and veterinarians underscore the importance of research in understanding and addressing challenges in disease control and herd health management. This necessitates more open, evaluative, and critical consultations to bridge the gap in perspectives. Moreover, evidence-based strategies to foster collaboration and enhance disease prevention within farming communities offer a promising trajectory for bolstering biosecurity and safeguarding herd health in the long term. This highlights the significance of integrating insights like these into biosecurity practices to ensure their effectiveness in mitigating disease risks in intensive pig farming.

Practical Implications

The findings of this study offer valuable insights for shaping a more resilient and sustainable future for the Dutch pig farming sector. One practical implication is the urgent need to bridge the communication gap between farmers and veterinarians. By fostering open dialogue and mutual understanding, stakeholders can collaboratively develop innovative solutions to enhance biosecurity practices on pig farms. This could involve organizing joint workshops or forums where farmers and veterinarians can share knowledge, experiences, and best practices, fostering a culture of continuous learning and improvement within the sector.

Moreover, there is a clear opportunity for policymakers to enact supportive measures that incentivize and facilitate the adoption of sustainable biosecurity practices. Government funding and support programs could be directed towards initiatives that promote biosecurity innovation and infrastructure development on pig farms. Additionally, regulatory frameworks should be designed in collaboration with stakeholders to ensure they are practical, effective, and aligned with industry needs, thereby facilitating the widespread adoption of biosecurity measures while promoting sector-wide resilience.

Innovative approaches to biosecurity management, such as the integration of digital technologies and data-driven decision-making, hold promise for enhancing disease prevention and control in the pig farming sector. Investing in research and development initiatives that explore the potential of emerging technologies, such as sensor networks for real-time disease surveillance or predictive modeling for risk assessment, can empower farmers and veterinarians to make informed decisions and proactively manage biosecurity risks.

Overall, fostering a culture of collaboration, innovation, and shared responsibility within the Dutch pig farming sector is essential for driving systemic change and building resilience to future challenges. By working together to improve communication, enact supportive policies, and embrace innovative approaches to biosecurity management, stakeholders can pave the way for a more sustainable and future-proof pig farming sector that prioritizes animal welfare, environmental stewardship, and long-term viability.

Theoretical Implications

This research has theoretical implications for both the dynamics of farmer-veterinarian interaction and the broader context of agricultural knowledge and innovation systems (AKIS). In terms of farmer-vet interaction theory, the study highlights the complex nature of communication and decision-making processes between these two stakeholders. The disparities in biosecurity perspectives underscore the importance of understanding power dynamics, communication barriers, and the influence of socio-cultural factors on collaborative efforts in disease control and herd health management. By exploring how farmers and veterinarians navigate these challenges, the research contributes to theories of relational coordination, social network analysis, and collaborative governance in agricultural contexts.

Furthermore, the findings offer insights into the functioning of AKIS within the pig farming sector. The shift towards community-based biosecurity approaches suggests a reconfiguration of farming networks, where neighboring farms are seen as allies rather than competitors. This aligns with theories of social capital, collective action, and knowledge exchange within agricultural networks. By examining how collaborative biosecurity initiatives emerge and evolve within farming communities, the research advances our understanding of how AKIS can facilitate innovation, resilience, and sustainability in livestock production systems.

Overall, the study emphasizes the need to integrate social science perspectives into theoretical frameworks related to farmer-vet interaction and farming networks. By acknowledging the socio-cultural and institutional dimensions of biosecurity practices, theory can better capture the complexities of decision-making processes and knowledge dynamics within agricultural systems. This holistic approach to theory development is crucial for informing policy and practice interventions aimed at enhancing disease prevention, resilience, and sustainability in intensive pig farming and beyond.

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Navigating Transitions: Exploring the Diversity of New Forms of Agricultural Work in France

Lisa Vincent[a], Benoît Dedieu[b] , Pierre Gasselin[c] , Nathalie Hostiou[d]

[a]UMR Selmet, Univ Montpellier, CIRAD, INRAE, Institut Agro Montpellier, lisa.vincent@supagro.fr

[b] UMR Selmet, Univ Montpellier, CIRAD, INRAE, Institut Agro Montpellier, benoit.dedieu@inrae.fr

[c]UMR Innovation, Univ Montpellier, CIRAD, INRAE, Institut Agro Montpellier, pierre.gasselin@inrae.fr

[d]Université Clermont-Auvergne, INRAE, AgroParisTech, VetAgroSup, UMR Territoires, F- 63000 Clermont-Ferrand, nathalie.hostiou@inrae.fr

Abstract

This qualitative study explores the changing landscape of agricultural work in France, with a specific focus on transitions. The political emphasis on agroecological transition within the 2014 Law for the Future of Agriculture underscores the pursuit of a triple performance—economic, ecological, and social. Thematic analysis reveals four main categories of new forms of agricultural work. Firstly, "New farms" encompass diverse structures, such as collectives of non-family farmers, micro-farms, alternative projects, and firm-based agriculture. Secondly, "New workers" highlight shifts in the agricultural workforce, with increased professional mobility, diverse profiles, and various employment contracts. Thirdly, "New tasks and activities" showcase innovative practices, including changes in crops, non-agricultural income sources, and shifts in animal-related tasks influenced by regulatory, market, and societal demands. Finally, "New work organizations" detail transformations in farm work structures through outsourcing, collective initiatives, and collaborations with non-agricultural stakeholders. Practical implications stress the need for adapted extension systems, while theoretical considerations emphasize the simultaneous examination of structural and individual perspectives. The study suggests multiple transitions in French agriculture—agroecological, demographic, digital, etc. —potentially resonating with similar trends in non-agricultural professional sectors.

Keywords

Work – Agriculture – Farm – Worker – Activities – Work organization

Purpose

Agriculture is currently facing ecological, demographic, and economic challenges. In response to these issues, the concept of "transition pathways toward sustainability" is being widely discussed. In France, there is a political focus on agroecological transition (AET), a project embedded in the Law for the Future of Agriculture, Food, and Forestry adopted in 2014. AET transition is one of the drivers of change in the work of farmers and farmworkers (Dedieu et al., 2022). This includes changes in the professional world (Coquil et al., 2018) i.e. norms, values and indicators that guide action, as well as changes in the concrete tasks done by farmers (less chemical, short supply chains, etc.) and their working conditions (Duval, Blanchonnet and Hostiou, 2021). However, other transitions, including demographic, digital, dietary, and climate-related shifts, are also underway and are impacting the work of farmers.

Work in agriculture is therefore changing, due to the emergence and development of new forms of work (farms, workers, etc.). They can help meet the major challenges facing agriculture today, such as renewing the agricultural workforce, increasing the sustainability of farming practices, and improving working conditions, etc. These new forms of work are multifaceted, highly heterogeneous and still largely unknown. This article aims i) to identify new forms of agricultural work through expert interviews, using the case of France as an illustrative example of OECD situations, and ii) to understand the factors driving their emergence as well as their consequences on income, working conditions, professional identities, and the meaning of work.

Design/Methodology/Approach

Our research methodology focused on qualitative semi-structured interviews, which were thematically analyzed and complemented by a literature review about work in agriculture (Dedieu, 2019; Malanski et al., 2022). The group of interviewees consisted of 21 French agricultural experts including 13 senior researchers from various disciplines, such as ergonomics, agronomy, animal science, economics, geography, and sociology. They are recognized for their research and publications on agricultural work and played active roles in facilitating discussions and debates on innovation, AET, and work in agriculture at both national and international levels. The remaining eight interviewees were agricultural development stakeholders, some of whom were specialized in specific regions or production sectors, or were actively engaged in national networks focused on agricultural work.

To analyze the diversity of these new forms of work, we have developed an analytical framework that addresses the following points:

- Why is this form of work considered new?
- Which transformations does it induce in the following categories: (i) Technical and economic performance (capital, resources, etc.), (ii) Farmers' and farms' legal status (self-employed, spouse collaborator, agricultural cooperative, worker cooperative, etc.), (iii) Organization (work organization, interaction with various stakeholders, etc.), (iv) Professional Identity (standards, values, skills, professional worlds, etc.), (v) Other relevant aspects.
- What are the determinants of this new form of work (agroecological transition, digital agriculture, market positioning, etc.)?
- Why is this new form of work interesting? : (i) New analytical framework? (ii) Development issue? (iii) Emerging trend?

The interviews underwent thematic analysis using Taguette software (Rampin and Rampin, 2021). Categories were constructed incrementally as the analysis progressed. The new forms of work were classified into four categories: new forms of farm structure, new profiles of farmers and agricultural workers, new tasks and activities and new work organizations.

Findings

New farms

Experts have presented a diversity of new forms of farms, particularly i) those managed by collectives of non-family farmers (e.g. three or more non-related farmers), ii) micro-farms (e.g. 1 hectare of market gardening, embedded in short chain supply), iii) farms opposing to the dominant agricultural model in France (where agricultural production is tied to a comprehensive life project, which often conflicts with the practices of conventional farmers), and iv) firm-based agriculture (involving dissociation between capital, land, and work).

The consequences of the emergence of these new categories of farms on work are diverse. Most of these farms involve a large number of workers, requiring effective human resource management, collective work ability, and considerations for income sharing. Remuneration varies significantly among workers and across different types of farms. Each of these new forms of farms claims to address the challenges facing agriculture. For instance, with more farmers working on a same farm, tasks can be rotated, enabling everyone to have vacations and weekends off. Conversely, establishing very small farms allows for reduced investments and thus lower indebtedness for assets. Farm advisers express a sense of being unprepared to assist these projects, as their innovative forms often do not align well with existing assistance or agricultural support mechanisms.

New workers

The agricultural sector is also experiencing a renewal through its workforce. Experts have observed an increase in professional mobility, with more individuals entering farming activities later in life (over 40 years old) and leaving earlier (before retirement). In certain small and/or collective farms, an increasing number of individuals, including a growing proportion of women, are taking up farming without experience or background in agriculture. The experts also noted that the proportion of salaried workers has significantly increased, with a wide variety of profiles and contracts : hired either directly by farms or through subcontracting structures, encompassing various positions, from farm laborers to new functions such as assistant project managers.

It appears that these new workers are less directly tied to a single farm. A low level of investment (small farms) or employee status enable agricultural activity for short to medium periods without committing to lifelong engagement. Experts have emphasized the importance of fair recognition for some often overlooked workers, such as women, waged workers (especially seasonal workers), and animals (some experts consider animals to be workers, or partners in human labor).

New tasks and activities

Farmers are implementing innovative practices on their farms, which are renewing both agricultural and non-agricultural activities. For instance, farmers are diversifying their activities by introducing new agricultural crops or non-agricultural sources of income such as energy, processing, and local marketing. Some farmers transitioning to agroecology reduce or eliminate pesticide use, while others stop plowing and opt for soil conservation through cover crops. Animal-related tasks are changing due to legislative changes in farming conditions and the return of wolves to France. These modifications require heightened monitoring and surveillance of animals, resulting in additional workload. In order to improve relationships with society, agricultural advisors and unions recommend that farmers communicate about the realities of their profession. This can be achieved through direct sales, farm visits and social media. Finally, the experts noted that the increasing use of digital technologies is driving the transformation of agricultural work. This includes spending significant time analyzing data and performing machine maintenance.

The emergence of these new tasks can be attributed to various factors, such as regulatory changes (animal welfare, interdiction of certain pesticides), market shifts (evolving demand), societal demands (environmental protection, animal welfare), or farmers' preferences, including increasing revenues, reducing working hours (e.g. ‘once a day milking’), and/or reconnecting with animals, nature, and consumers. Adopting new practices requires time for training and adaptation to become operational. Implementing these new practices often requires a substantial investment of time in observing crops and animals.

New work organizations

The organization of work within farms is being transformed by various factors including the rise of outsourcing, the establishment of new collective structures (farmers' markets, small dairy cooperatives, methanizers, hay dryers, or pig maternity units), the arrival of new machines such as milking robots, as well as collaboration with non-agricultural stakeholders like local authorities, associations, and industrial partners.

Workers may specialize in specific tasks (robots, management, sales, etc.) based on their skills and preferences. The highly collective nature of some work arrangements underscores the importance of interpersonal skills, as it often involves reconciling divergent interests. These new forms of work organization may arise from a desire to reduce working hours (tasks sharing, robots), cut costs (stores, dryers), regain control over intermediaries (dairies), or develop a new activity (biogas plant), among other objectives. They may lead to the distancing, whether intentional or forced, of some farmers from agricultural tasks (relying on robots, dedicating time to union activities, and delegating production).

Practical Implications

These transformations impact every dimension of agricultural work, including changes in the profile of workers (increasing socio-demographic diversity of the farmers’ origin and experiences, and a rise in wage labor), the structure of enterprises (corporate farming, delegation), in the tasks performed or which have been left out (agroecological practices, no-till farming, digital monitoring, communication, on-farm sales), the allocation of tasks (enlarging workgroups) and a redefined sense of work (entrepreneurial spirit, focus on environmental stewardship, relation to animals and nature).

All of these new forms of work entail acquiring skills, underscoring the importance of dialogue with training institutions and among farmers. Most of these new skills are not directly related to agricultural practices. Instead, they are similar to those utilized in other professional sectors (management, industry, sales, law, digital, etc.). As a result, the daily work of some farmers is becoming increasingly similar to that of a small business owner.

New agricultural practices such as alternative farming, biogas production or milking robots are prevalent in specific categories of farms, depending on their size, production sector, or geographical location. On the other hand, changes related to management, communication, short food supply chains, and diversification are occurring on a wide range of types of farms.

The diversity of these new forms of work requires a reconsideration of extension systems to meet the new needs of farmers. Additionally, they raise inquiries regarding the regulation and legal structure of agricultural work, such as self-employment status, legal responsibility, and compliance with labor laws, notably safety standards.

It is surprising that new forms of work in agriculture do not seem to be addressing the challenge of decarbonizing the agricultural sector, despite its significant greenhouse gas emissions. The topic of climate change is frequently portrayed as a circumstance that farmers must adjust to, rather than a phenomenon that they can address by decreasing their greenhouse gas emissions. Furthermore, AET is rarely associated with work issues, especially with regard to farm types and workers. Considering its impact on work in agriculture is crucial for the success of AET, as it may increase its attractiveness for some (neo-rural) workers, while potentially discouraging others, but also because it leads to significant consequences for agricultural practices and activities.

In addition, it is important to note that agricultural enterprises involved in these new forms of work may be transitioning towards other systems, such as entrepreneurship, digitization or biodynamics. These changes reflect diverse visions of a desirable agriculture for the future. Therefore, it is essential to consider all of these transitions together, taking into account their interactions and feedback.

Theoretical Implications

Examining demographic, agroecological, digital, and other transitions in agriculture through the lens of work provides insights into their tangible impacts on the agricultural sector. The experts often approached new forms of work from either a structural or individual perspective. The structural perspective focused on legal entities, regulations, and external determinants, while the individual perspective considered working conditions, hours, projects, the meaning of work, and internal determinants. This study highlights the significance of examining both perspectives simultaneously.

Reviewing our work through the concept of transition has allowed us to realize that there are transitions of different natures in agriculture in France. Firstly, the agroecological transition, a project that is openly supported by institutions, but struggles to have a concrete and impactful translation in the daily lives of farmers. Then, a demographic transition as the reconfiguration of farmers' career paths. This includes a decrease in the number of farm owners, an increase in professional mobility, and the emergence of new partnerships in large farms. The demographic transition is presented as an inevitability and a problem that must be addressed by strengthening the attractiveness of agricultural professions. Furthermore, we have observed a digital transition. It may be presented as an opportunity to address current agricultural challenges (working conditions, AET) or as a risk to the independence of farmers. The risks include permanent connectivity, data security, indebtedness, and disappearance of certain skills.

These transformations have impacted the agricultural sector, but they may also go beyond and extend to non-farm professional sectors. All professional sectors are marked by the increasing demographic diversity, the rise of digitalization, the importance of ancillary tasks, efforts to reduce the environmental impact, the trend towards liberalization, and the coexistence of seemingly opposing worldviews. Those common changes suggest a possible convergence between the agricultural sector and other professional domains. These similarities call for further research, conducted in collaboration with specialists in non-agricultural work to identify similarities and differences between these new forms of work in agriculture and new forms of work in other professional sectors.

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Analysis of practice change in vineyard farms according to their engagement in the agroecological transition

Elsa Robelot[a], Marie-Hélène Jeuffroy[b] and Anne Merot[c]

[a] INRAE, CIRAD, Institut Agro, UMR ABsys, Montpellier, France – elsa.robelot@inrae.fr

[b]Université Paris Saclay, AgroParisTech, INRAE, UMR Agronomie, IDEAS, Palaiseau, France - marie-helene.jeuffroy@inrae.fr

[c] INRAE, CIRAD, Institut Agro, UMR ABsys, Montpellier – anne.merot@inrae.fr

Abstract:

Viticulture is facing challenges such as the reduction of pesticide use, and agroecology is being presented as a solution. However, there is a lack of knowledge about how winegrowers design innovations to foster the principles of agroecology. This study aims to analyze the innovations implemented by a range of farmers who are more or less committed to the agroecological transition. Special attention is given to the systemic approach and the scale of reflection when developing these innovations. To assess the level of agroecology, a grid structured by 7 principles divided into 20 indicators was developed. Agronomic logics were formulated to analyze the systemic reasoning behind these innovations. The analysis of the grid showed a wide diversity in the progress of the agroecological transition among the surveyed farms. The agroecology principles that most explained the differences between farms with extreme scores were synergy, efficiency, and social and solidarity-based economy. A comparison of the agronomic logics of two farms showed that the farm with the highest agroecology score employed systemic reasoning and mobilized several resources when changing its practices, in contrast to the farm with a low score. A method will be developed to conduct this analysis on all the farms surveyed.

Keywords: innovation, farm scale, systemic reasoning, design, pesticide use, crop-livestock integration

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Purpose

Viticulture is facing numerous challenges such as reducing pesticide use, adapting to climate change, or limiting biodiversity erosion, while maintaining a sufficient economic return for the farmers (Prost et al., 2017) These current challenges require an urgent renewal of vineyard systems (Mailly et al., 2017). Agroecology is increasingly presented as a process-based solution that can steer food systems transformation towards the improvement of their sustainability (HLPE, 2019).

Agroecology is based on several main principles: limiting the use of synthetic inputs, fostering natural regulation of pests, weeds and diseases, enabling nutrient recycling (Altieri, 1995). Agroecology also promotes new approaches: sharing and hybridize scientific and expert knowledge, enhance bundles of consistent innovations, stimulate individual and collective learning (Meynard, 2017). It is no longer defined only by environmental scope but also cover social, human, economic, and political dimensions (Gliessman, 2006)**.** It extends beyond the plot to the food system (Francis et al., 2003)**.** Some innovations are mentioned in the literature as agroecological (Wezel et al., 2014)**,** but there is a lack of knowledge about how winegrowers implement and adapt these innovations. To transform farms, deep changes and redesign are awaited. This kind of change is also more likely to impact the farm resources (land, equipment, economic) and the agroecosystem components, as (Merot et al., 2020) have demonstrated in the context of the conversion to organic agriculture in viticulture. Agroecology requires the mobilization (and therefore design) of levers, with a systemic rationale that considers the interactions between practices and their indirect effects (Meynard, 2017).

Farm transition to agroecology, as conceptualized by (Prost & Martin et al., 2023)**,** is a path starting from an unsatisfactory initial situation with (or without) some agroecological principles implemented, through a transitional phase characterized by gradual changes that lead to a specific point where agroecological principles are more widely implemented. The trajectories have mainly been described for some particular practices, as the use of pesticides (Fouillet et al., 2023), the use of all types of inputs (Chantre & Cardona, 2014) from plot and cropping systems (Mawois et al., 2019) to farm scale (Dupré et al., 2017). (Teixeira et al., 2018) have developed a farm typology to assess farm diversity and its implications for the development of strategies to promote agroecological transitions. This work aims to characterize the level of agroecological transition in 25 farms and understand the contribution of innovations, specifically in studying the systemic approach and the consideration of the farm scale in developing their innovations.

Design

A range of 20 farmers in four French wine-growing regions was surveyed, chosen to encompass a broad spectrum of pedoclimatic conditions, economic contexts and farming practices, including both traditional and disruptive practices. Each survey consisted of one semi-structured interview, conducted in order to gather information on the current situation of the farm and any changes in farming practices and production systems that had occurred since the beginning of the farmer's activities. The reasons (farmer's motives, characteristics of the situation) that drove and explained the changes, the expected results, the farmers' satisfaction criteria were identified.

A grid structured by 7 main principles and divided into 20 indicators, was built (table 1) to characterize the degree of advancement in agroecological transition in vineyard farms. The grid is inspired by the grid developed by the FAO (Barrios et al., 2020) to consider agroecology throughout agri-environmental and socio-economic dimensions. Only seven principles were retained, those that directly concern the production context of winegrowing countries. Each indicator is defined by qualitative modalities scored from 0 to 3, and built from the IDEA4 method (Zahm et al., 2023) to make them more specific to viticulture. The scores for each indicator were then summed up by principles and in a global score to determine the level of agroecology of each farm. The concept of agronomic logic (Salembier et al., 2021) is employed to analyze the systemic approach and farm reasoning.

Findings

The 20 farms surveyed were ranked according to their overall agroecological score (fig. 1). The average scores of the farms ranged from 5.5/20 to 17/20, with a median score of 10.7/20, showing the large diversity on transition progress. No general trend can be observed for the *Diversity* scores, except that the highest agroecological farms have a high diversity within vineyard plots (fruit trees, market gardening) whereas the least agroecological farms have a high product diversity in addition to vine. The *Synergies* scores are low for the least agroecological farms, which can be explained by large field and little connectivity and no animals. The *Efficiency* scores are low for the least agroecological farms, due to the use of synthetic pesticides and non-organic fertilizers. Intermediate farms have the highest scores for the *Recycling* indicator, partly because they apply green manure on their plots and produce renewable energy. The *Social and Solidarity-based Economy* scores are higher for the most agroecological farms, as the social link with the consumer and the share of local products in marketing methods is greater. The *Resilience* scores tend to be higher for the intermediate farms, as these farms are considered economically viable. However, regardless of their agroecology score, winegrowers are not satisfied with their yields.

Table 1. Grid to characterize the level of agroecological transition of vineyard systems

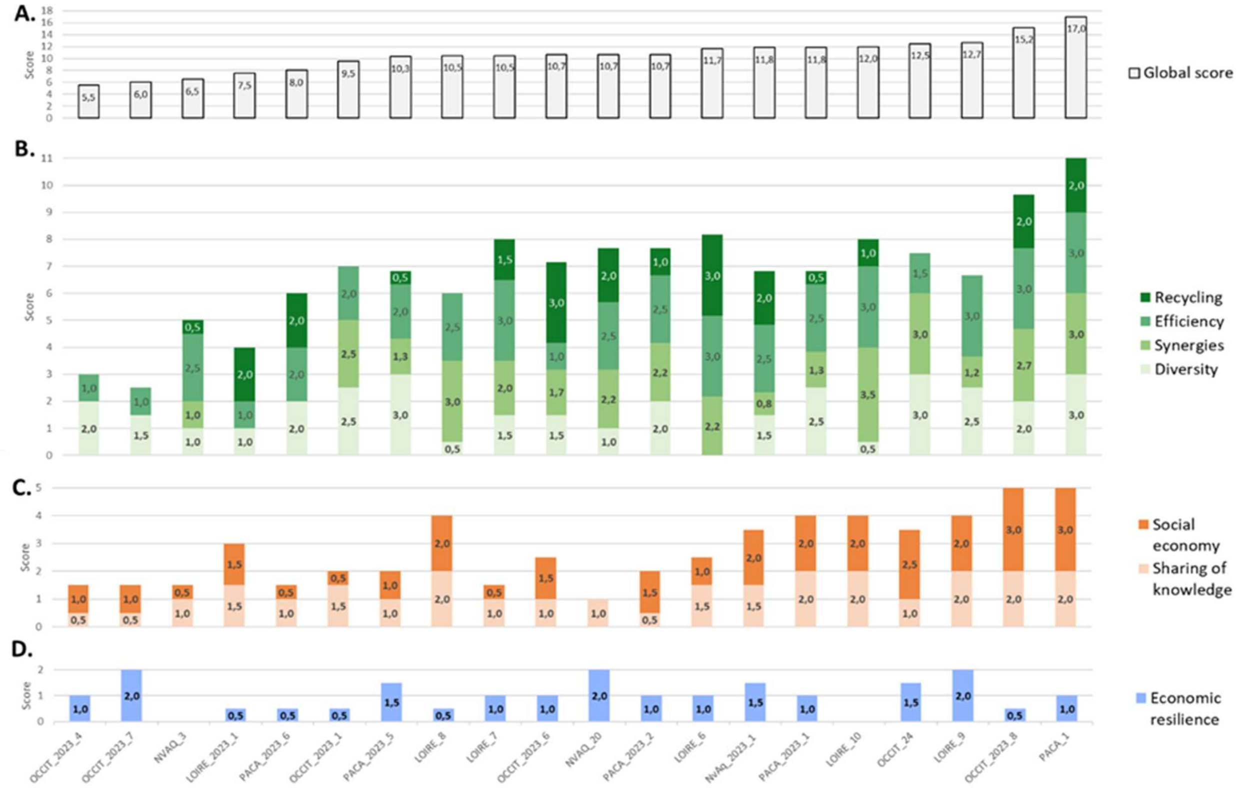
Principes	**Indicators**	**Score : 0**	**Score: 1**	**Score: 2**	**Score: 3**
Diversity	Diversity of productions	Viticulture only	Viticulture and one other production	Viticulture and other productions	-
	Genetic diversity	< 3 varieties	[4 ; 7] varieties	> 8 varieties	-
	Diversity of products	Wine	Wine and one other product	Wine and 2 or more products	-
Synergies	Connectivity agro-system and landscape	Low	Medium	High	-
	Integration of livestock	No grazing	Grazing of animals (shepherd)	Grazing of animals (winegrower)	-
	Management of soil-plant system	Herbicides used	Tillage of rows and inter-rows	1/2 row maintained during the season and tillage of the other inter-row	All inter-rows permanently grassed
	Integration of trees or	No trees	Trees or associated	Trees or associated	-

	associated crops		crops (<10% of the vineyard area)	crops (>10% of the vineyard area)	
Efficiency	Management of soil fertility	Synthetic or organic-mineral fertilizers	Organic amendments	-	-
	Management of pests and diseases	Prevalence of synthetic products	Copper (high quantity)and biocontrol	Copper (low quantity) and biocontrol only	-
	Management of water	Irrigation (>10% of area)	Irrigation (<10% of area)	No irrigation	-
Recycling	Recycling of biomass and nutrients	No	Green manure or compost produced on the farm	-	-
	Water saving	No	A device but not significant	A device and significant	-
	Production or use of renewable energy	No	Yes, produced or consumed	-	-
Sharing of knowledge	Interest of producers in agroecology	Low	Medium	High	-
	Participation of producers in networks	No	Participation in few networks	participation (trials, trainings) in several networks	-
Circular and solidarity economy	Products marketed through direct sales	direct sales : < 5% of wine	direct sales : [5% ; 50%] of wine	direct sales : > 50% of wine	-
	Valorization of local resources	No	Supply of inputs from local businesses	Recovery of by-products from the local community	-
	Relationship with consumers	No links with the consumers	On-farm sales	On-farm sales and group hosting	-

Resilience	Yields stabilisation	Target yields not always achieved	Target yield mostly achieved	-	-
	Economic viability	Farm financially unsustainable	Farm is temporary financially unsustainable	The farm is viable	-

We propose a focus on two farms, PACA_1 (highest agroecology score) and OCCIT_2024_7 (one with the lowest scores) and two principles: crop diversification and reducing the use of pesticides. To reduce pesticide use, PACA_1 involved systemic reasoning on several compartments of the system: the vine, by using natural biostimulants to stimulate the plant's defenses, but also by raising the trellising of some vines to limit the influence of the soil (humidity, splashing) ; the soil, by leaving grass cover to limit splashing ; and the inter-row, by planting species of interest (Aliaceae which produce blown molecules, etc.). For OCCIT_2024_7, the reasoning is less systemic because the main focus was reduced to herbicide reduction, with mechanical weed management. Diversification for PACA_1 mixed plot and farm reasoning. It was both in the activities and within vineyard plots with market gardening and fruit trees (planted or spontaneously). It meets several sub-objectives, to maximize the use of land, to plant species of interest to the vine (beneficial or repellent plants). Fruit trees also provide multiple services to the vine, including root mycorrhization, shading, and staking for some vines. Both products are sold locally, thus enhancing the farmer selling of his wine locally. This diversification was made possible because the winegrower changed his production system: he has teamed up with a market gardener, increased his working time in the vineyard, and reduced the number of mechanical interventions on the vineyard plots. For OCCIT_2024_1, truffle oaks and olive trees were planted on the edge of vineyard plots to provide a few complementary products with no precise production target.

Figure 1. Agroecology scores of 20 farms surveyed : standardization of the score of each indicator and summation of *A*. global scores *B*. Scores for agroecosystem principles *C*. Scores for social principles *D*. Scores for the economic principle



Practical Implications

This grid is user-friendly for farmers or advisors, serving as a tool to manage the farm's transition and assess its progress in agroecological transition. Moreover, it enables to highlight systemic practices that impact various agroecological principles. These practices could be recommended as priorities for farms looking to advance in the agroecological transition.

Theoretical Implications

This is the first time that vineyards are characterized by their degree of advancement in agroecological transition. One innovative research path identified by (Prost et al., 2023) to support fam transition to agroecology is improve the understanding of what happens on farm during transition. This work contributes to improving this knowledge at the farm level, which has not been done much to date. The next step will be to define a method for analyzing the systemic reasoning and the mobilization of farm resources of all the farms surveyed.

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Toward autonomous integrated crop-livestock systems: What can we learn from biodynamic farming?

Marion Lebrun[a, b], *Martin Quantin*[b] *and Cyrille Rigolot*[a]

[a] UMR Territoires, Université Clermont Auvergne, INRAE, VetAgro Sup, AgroParisTech, 63170 Aubière

[b] Association Biodynamie Recherche, 5 place de la gare, 68000 Colmar

Abstract:

Integrated crop-livestock systems (ICLS) are promising for agroecology but they have been decreasing in the last decades. Biodynamic farming (BF) is a form of organic agriculture, based on the premise that each farm should aim to become an autonomous ICLS. To understand BF farmers' experiences, 23 semi-structured interviews were conducted in France, in three types of systems: diversified crop-livestock; "wine and livestock" farms; specialized wine production. In addition to common motivations (i.e. decreasing external expenses) and constrains (heavy workload) which can be found in every farming systems, some specific emphases appear in BF farmers' discourses. Particularly, questions of meaning are essential, as BF is also a way of living "*a simple and happy life*". Importantly for farmers, animals are a major source of well-being, and the "atmosphere" they convey is a motivation for itself. In the transitions toward ICLS, specific BF preparations and the moon calendar play an important role, as other more or less common tools, such as animal communication. These tools could inspire innovative solutions and surprising pathways toward ICLS, such as the development of on-farm slaughter. More generally, the strategic role that BF might play in future sustainability transitions opens to stimulating new research questions and perspectives.

Keywords: Organic Farming; Crop-livestock integration; Diversification; Autonomy; Human-Nature relationships; Transition Pathways

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Purpose

Integrated crop-livestock systems (ICLS) are considered as a promising option for agroecology (Bonaudo et al., 2014; Ryschawy et al., 2017; Hendrickson, 2020). Interactions between crops and livestock indeed often improve nutrient cycling, soil fertility, resilience and multifunctionality (Moraine et al., 2014). The diversification of production processes is also an important lever to reduce economic risks, and adapt to various hazards (Hendrickson, 2020). Yet, ICLS have been decreasing in the last decades. Specialized farming systems are considered more profitable and easier to manage, and they have often been encouraged by incentive public policies. There is also a lack of attractivity for keeping animals on the farm (Ryschawy et al., 2017).

Biodynamic farming (BF) is a century old form of organic agriculture, based on a specific conception of life and nature, in which farmers' creativity play a key role (Rigolot and Quantin, 2022). In practice, BF is often characterized by three specific interrelated principles: 1) the perception of the farm has an “individual organism”; This principle relies on the balance and synergy between plant and animal productions, and on the integration of areas of biodiversity (forest, hedges, wetlands, natural flower bands…). Importantly, the agricultural “organism” is not considered as just a material entity, it also includes socio-cultural, mental and spiritual dimensions (Brock et al., 2019); 2) The use of biodynamic preparations, herbal teas and specific composts. Made from minerals (silica), dungs or medicinal herbs (dandelion, chamomile, nettle, achillea millefolium, oak bark, valerian, horsetail), these preparations are used in small doses as bio stimulating and bio regulating agents in composts, soils and cultivations (Krause et al., 2022); 3) the integration of “cosmic rhythms” in the organization of farming activities (the cycle of the moon and planets in relation to the Earth and the zodiac).

Although BF is controversial in some countries because of its spiritual dimension, it has been shown to be a valuable source of innovation for sustainability (Rigolot, 2023). The basic BF principle of “individual organism” includes the idea of tight interactions between crops and livestock (as in ICLS), combined with higher possible degrees of material and decisional autonomy (Rigolot and Quantin, 2022). The aim of this study is to investigate biodynamic farmers try and/or manage to apply the principle of “individual organism” in practice, given their resources, constraints and specific contexts, and whether general lessons can be drawn to foster the transition of farming systems toward ICLS.

Design/Methodology/Approach

A survey based on semi-structured interviews was conducted in contrasted biodynamic farms in France. According to the Demeter BF international certifying body, there would be between 700 and 1000 biodynamic farms in France, of which around 600 are certified. More than half of certified farms appear as specialized winegrowers, indicating a first gap between the ideal of the agricultural “organism” (an autonomous ICLS) and current BF systems. In order to understand BF transition pathways toward ICLS and diversification, the choice was made to investigate three types of farming systems: diversified crop-livestock farms (n=11); “wine and livestock” farms (n=6); specialized wine production systems (n=6). These farms are diverse (more or less experienced farmers, women and men, individual and collective farms, different agroecological regions covering a large part of the French territory…). The area of diversified crop-livestock farms ranges from 23ha to 100ha. All 11 diversified crop-livestock and the 6 “wine and livestock” farms have at least one herd of ruminants, always combined with other animal species.

A total of 23 semi-structured interviews were conducted to understand farmers’ experience of autonomy and crop-livestock integration, as well as the constraints and levers to diversification. Following a general description of the farm and of its history, the farmers were questioned more specifically about: 1) the integration (or lack of) of an animal presence (domestic and/or wild) on the farm (role, interest, modalities…); 2) their perception of input autonomy (fodder and manure) and decision-making autonomy; 3) the link between the farm and the outside world (consumers, local actors…); 4) their conception of the living world (including potentially a more subtle, immaterial dimension); 5) the use of specific biodynamic preparations, herbal teas and composts; 6) the use of a lunar calendar (cosmic rhythm). These different topics include classic dimensions of crop-livestock integration (topics 1, 2, 3), and more specific aspects of biodynamic agriculture (which can appear in every topic, but especially in topics 4, 5, 6). All the interviews were recorded and transcribed in full.

The analysis of the interviews is articulated around four axes of analysis, that will be used to structure the presentation of the findings and their practical implications in the two next parts: 1) The perceived advantages of autonomous crop-livestock BF system; 2) The limits to diversification and the internal constraints to the farm; 3) The role of tools in the implementation of the diversification process; 4) External obstacles to diversification in the environment of the farm, which can be related to public policies.

Findings

For biodynamic farmers, the transition toward more diversified ICLS is always related to a question of *meaning* of their activity. From the interviews it appears clearly that biodynamic agriculture is not only a specific way of farming, but also a way of living ("… a simple and happy life", as a farmer says). The diversification process must therefore be understood from this perspective:

> *"We always have something to do at the farm. Work is not only about earning money, it is about being part of what we like to do in life. It is intellectually stimulating, and we enjoy seeing things being materialized on the farm. We are satisfied, because we have everything we need here"*

In particular, the animals of the farm always seem to play a major role as a source of well-being in the interviews:

> *"The presence of animals brings a kind of fulfillment in the atmosphere when you are near them, and also in environments where they grazed. Since I've had animals, I understand better why organic farmers are so cool, it must be connected to their relations with animals. I can feel this serenity that is being created, animals soothe me. If we can feel that, every being on the farm, plants, they must feel it too… I feel like the physical presence of the animal creates a sense of balance. The people coming here feel good."*

In a similar way to other kinds of farming systems, the economy is often an important motivation to develop a more autonomous crop-livestock system, which enables to decrease external expenses and related financial dept. Some farmers also stress the advantages of ICLS for their decision-making autonomy. For two interviewed farmers having known an intensive and specialized way of farming, the transition toward BF and ICLS is described as an escape from a previous painful moral and psychological situation.

Nevertheless, as in other farming systems, transition toward ICLS in BF has important drawbacks and limits. Interviewed farmers mention heavy workload, low profitability levels regarding the work provided and the difficulty to transmit a diversified farm. The winegrowers stress the need of specific skills they do not have yet to raise animals on the farm, and the difficulty to hire skilled workers.

When they describe their pathways toward more diversified ICLS, BF farmers mention different types of innovations, more or less common, such as partnerships between BF wine growers and sheep herders. According to most farmers interviewed, the making and use of BF preparations "by their own hands" play a key role in both fertilizer and decision-making autonomy. Depending on the local context, how they perceive the needs of their farms and their own sensitivity, each farmer gives his own priorities to the various types of BF preparations on her/his farm. Often made collectively during "preparation days", preparations are also important for the exchange of knowledge and practices between peers. The integration of "cosmic rhythms" is made with the help of a moon calendar, specifying the presumed favorable periods for different farming activities. Interestingly, for most farmers, the moon calendar is not seen as an additional constrains, but rather as a resource to organize diversity on the farm. As it is annotated each year, the moon calendar helps farmers to cultivate their own organization and their own remembrance of the place, with actions inscribed in both the past and the present. Moreover, to develop their autonomy for the health of their herds, interviewed farmers are trained for alternative medicines such as acupuncture, osteopathy or homeopathy, often seen as a way to avoid calling veterinarians. For them, raising animals as close as possible to their natural environment enables self-medication. Although health issues such as parasitism may appear, the variety of aromatic and medicinal plants, natural pastures, and every space made available (edges, grazing lands, moors and forests), ensure a diversified diet and treatments that animals take if they need to. Other techniques such as "intuitive interspecies communication" are also instrumental for farmers to develop relationships of care with other living beings on the farms. Particularly, there are as many ways to communicate with animals as there are farmers (speaking aloud, or "through their thoughts", through the construction of mental images, or thanks to tools such as kinesiology or pendulums. As strange as some of these methods might seem, from a conventional scientific perspective, they do have major consequences for farmers' decision-making (decisions about slaughter, diets, treatments for animals and plants…).

Practical Implications

In our study, a large part of the motivations, resources and limits to diversification emerging from the interviews with BF farmers mostly confirm the scientific literature already available. For example, economic motivation and workload are essential considerations in the transition toward diversified ICLS (Moraine et al., 2014; Garrett et al., 2020). However, the specific relationship between BF farmers and nature also result in specific motivations, resources and perceived constrains. Particularly, the major role of the animals as a source of well-being for farmers and communities must be highlighted. Importantly, this perception of the animals having a value for themselves can be "trained", for example through careful observations methods or even intuitive interspecies communication (Barrett et al., 2021). Furthermore, whatever our opinion might be about the biological effects of BF preparations, the moon calendar, or animal communication (which are beyond the scope of this paper), our study demonstrates that these tools are seen as useful by biodynamic farmers for the development of their autonomy. These tools could inspire innovative solutions for other farmers without necessarily implying the philosophical background of biodynamics. We can think about collective activities (such as during BF preparations' days), new tools to organize a diversified system (such as the moon calendar) or new observation methods (such as animal communication). As regard the dynamic of the transition, our study is consistent with the analysis proposed by by Coquil et al. (2014), for who "which tools are used and when they are used depends on what is meaningful to farmers at various stages of the transition"

Biodynamic farmers themselves identify specific obstacles to ICLS development, from their perspective. Particularly, for the farmers interviewed, the slaughter of animals and the fate of males are paramount and recurring notions regarding the development and thriving of autonomous crop-livestock farming systems. This conception is in line with the approach proposed by Porcher (2017), giving prominent importance to animals in the design and management of livestock farming systems. In France, the slaughter of animals must be done in a certified slaughterhouse (for sanitary and environmental reasons), the only exception being for family consumption (which excludes however bovines and equines). Facing this legal reality, BF farmers claim for their responsibility to accompany their animals until their death, and for several of them, to slaughter their own animals. Several farmers are involved in experimental slaughtering projects, at the farm or locally. As regards the fate of males, the current practice is to bring them, as young as possible, to a conventional fattening farm. "Getting rid of the males" is perceived as incoherent by farmers from a BF perspective. For them, finding new practices and value chains is essential to the future of ICLS development. From an economic perspective, interviewed farmers call for evolutions of the socio-economic environment to better compensate for non-market-oriented services (biodiversity, cultural heritage…). They also stress the need for training and support from extension services, confirming previous observations by Aare et al. (2021) with BF farmers in Denmark.

Theoretical Implications

Nowadays, in some countries, academic research on BF has become as controversial as BF itself. In this communication, our approach consists in considering BF knowledge in a comparable way to indigenous knowledge, as part of a broader body of Traditional Ecological Knowledge (TEK) (Rigolot, 2023). According to Albuquerque et al. (2021), TEK and academic knowledge can differ as much as they can coincide, but it is important to move beyond the idea of a simplistic divergence/convergence dichotomy. Instead, these authors propose to see convergences "as evidence for developing more robust decisions", and divergences as opportunities for dialogue and complementarity building (Albuquerque et al, 2021). Our study provides multiple examples of such convergences (economy, labor…) and opportunities for dialogue (on human-nature relationships, for example).

For the study of agroecological transitions, particularly, BF appears as a promising resource to inspire new transition pathways, and to challenge deeply current systems of farming, support and governance. For example, with reference to Toffolini et al. (2019)'s four "ways of acting" for an agroecological transition (i.e. local integration, flexible management, learning dynamics and development of a room for maneuver), from the findings of our study BF could be seen as a possible fifth "way of acting", toward an enhanced connection with the living world. Some policy implications are quite common (need for training, payment of services…) but others are original and thought provoking. Particularly, while these elements have not been identified to date as major aspects for the development of crop-livestock systems, on-farm slaughter and the fate of male animals are essential for BF farmers. More generally, this study illustrates how understanding and sharing a diversity of visions for agroecology (BF among others) can be instrumental to enrich transition pathways in an inclusive way (Pervern et al., 2023). As a next step, transdisciplinary coproduction of knowledge with BF farmers is a stimulating perspective to further inform and activate ambitious transition pathways, as demonstrated in the wine sector by Masson et al., (2021). In the context of a transdisciplinary action-research project in France, Switzerland and Germany, these authors show how the contribution of BF farmers, in collaboration with academic research and other actors has been essential to generate not only scientific breakthroughs, but also tangible changes in practices, discourses, and a substantial decrease of herbicides use in the vineyards (Masson et al., 2021; Madouas et al., 2023). The specific conception of knowledge underlying BF could also inspire new transdisciplinary methodologies for the agroecological transition, involving experiential knowledge and intuition, which could be further explored for a variety of research topics and development goals (animal welfare, food quality…) (Rigolot, 2023).

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Energy consumption and efficiency in vegetable farming systems: Is saving energy or sparing land the priority?

Antonin Pépin[a] and Hayo M. G. van der Werf[a]
[a]INRAE, Institut Agro, UMR SAS, F-35000 Rennes, France

Abstract: Yield, defined as the mass of product per unit area, is central in the assessment of agricultural performances. The implicit assumption behind the importance of yield is that land is the main limiting factor to produce food. But energy could become a new limiting factor that we should consider for assessing the performance of emerging farming systems. We compared vegetable production systems including outdoor production, greenhouses and plant factories. Our results show contrasting levels of energy consumption and annual dry matter yields. Yield increases as energy input increases, which indicates that land and energy inputs are substitutable. However, energy use efficiency decreases as energy input increases, hereby challenging the promises of high-tech production. The implications are (1) the need of considering energy use efficiency in addition to (area-based) yield when assessing the performances of farming systems, (2) the need of tackling the food system transition with the farming system transition, and (3) that 'area-extensive' farming systems can be very energy use efficient, thus being promising transition pathways.

Keywords: Yield, energy, vegetable production, land

Purpose

Yield, defined as the mass of product per unit area, is central in the assessment of the performances of agricultural systems (e.g. Burchfield and Nelson, 2021; Lesur-Dumoulin et al., 2017; Lobell et al., 2009). The implicit assumption behind the importance of yield is that land is the main limiting factor to produce food. Indeed, a farmer, a country and the world has a limited agricultural area, where it matters to produce a satisfactory amount of food, especially as the world's population increases. In the industrial era, considerable efforts were made to increase yields, notably through the development of fertilisers, machinery, irrigation, pesticides and genetics (Harchaoui and Chatzimpiros, 2019). However, these efforts were made in a world where energy was relatively cheap and abundant. The world is now facing a new situation where energy is getting increasingly expensive, scarce, and uncertain (Dittmar, 2013; Kaufmann, 2014; Patterson and Perl, 2007). As for land, energy could become a new limiting factor that we should consider for assessing the performance of emerging farming systems (Martin et al., 2023).

Vegetable production systems present major variability in production technologies, including outdoor production, greenhouse cultivation (heated or not), and plant factories (i.e. soilless, fully-closed controlled systems relying on artificial lights, also called 'vertical farms'). In this paper, we explore the relation between (area-based) yield and energy efficiency of contrasting vegetable farming systems, including emerging farming systems, using a life cycle approach.

Design/Methodology/Approach

We used the life cycle assessment (LCA) framework to assess the cumulative energy demand (CED) (Frischknecht et al., 2015) of three organic vegetable farms in France : a microfarm producing outdoors and in an unheated greenhouse, a farm specialised in sheltered (unheated) production and a large open-field farm. They were assessed in a farming system approach, i.e. all inputs and operations were estimated for the entire farm, and the output was the total production of vegetables. The data of the three case study farms were collected through interviews. We used the Ecoinvent database for indirect energy (i.e. energy used in the production of inputs and infrastructure). We considered both renewable and non-renewable energy for growing the vegetables, excluding energy captured by photosynthesis. We used the CIQUAL database (https://ciqual.anses.fr/) for the dry matter and energy content of the vegetables.

We compared these three farms to other vegetable production systems from the literature, including conventional open-field, heated greenhouse with or without energy saving systems, including winter production, and vertical farming. The energy input in Ntinas et al. (2017) was calculated using CED (Frischknecht et al., 2015). (Graamans et al., 2018) calculated the energetic loads including artificial illumination by LED, LED cooling, sensible cooling, dehumidification, heating and installed power. It excluded the background system energy demand, i.e. energy used to produce fertilisers, pesticides and infrastructure. This indirect energy use account for 12.4 to 13.4% of the CED in similar systems of Ntinas et al. (2017), which gives an approximation of the underestimation of the energy values of Graamans et al. (2018).

The (area-based) yield was expressed as dry matter mass produced per unit of area. The energy use efficiency was expressed as Energy Return On Investment (EROI), calculated as EROI = energy in vegetables produced / energy input.

Findings

The vegetable farming systems had contrasting levels of energy consumption (from 29 to 70 900 GJ.ha^{-1} yr^{-1}) and annual dry matter yield (from 1.2 to 50 t DM.ha^{-1} yr^{-1}) (*Table 1*). Yield increased as energy input increased (i.e. producing a given quantity of vegetables required less land as energy input increased), which indicates that land and energy inputs are substitutable. However, energy use efficiency, expressed as EROI, decreased as energy input increased, from ca. 1 for outdoor conventional and organic production to 0.01 for a plant factory. The outdoor systems produced 72.7 kg DM per GJ invested (i.e. the equivalent of 1 L of fuel produced 32 kg of fresh vegetables). The plant factory produced 0.7 kg DM per GJ invested (i.e. the equivalent of 1 L of fuel produced 0.4 kg of fresh vegetables).

Table 1. Product, energy input, yield, energy output, and energy return on investment (EROI) of contrasting vegetable production systems

System	**Product**	**Energy input (E_{in}, GJ.ha^{-1}.yr^{-1})**	**(area-based) Yield (t DM.ha^{-1}.yr^{-1})**	**Energy-based yield (kg DM.GJ^{-1})**	**Energy output (E_{out}, GJ.ha^{-1}.yr^{-1})**	**EROI (E_{out}/E_{in})**	**Source**
Organic, outdoor, France	Mix of vegetables	29	1,2	42,1	19	0,640	Pépin et al., 2022
Conventional, outdoor, Greece	Industrial tomato	103	7,5	72,7	103	1,000	Ntinas et al., 2017
Organic, outdoor/unheated greenhouse, France	Mix of vegetables	157	3,1	19,5	45	0,285	Pépin et al., 2022
Conventional, outdoor, Greece	Fresh tomato	275	2,4	8,6	32	0,118	Ntinas et al., 2017
Organic, unheated greenhouse, France	Mix of vegetables	387	3,4	8,8	49	0,126	Pépin et al., 2022
Conventional, soil, heated greenhouse with Energy Saving System, Germany	Fresh tomato	3981	10,6	2,7	145	0,036	Ntinas et al., 2017
Conventional, soil, heated greenhouse, Germany	Fresh tomato	6809	8,7	1,3	119	0,018	Ntinas et al., 2017
Conventional, in winter, soilless, heated greenhouse with Energy Saving System, Greece	Fresh tomato	7155	3,8	0,5	53	0,007	Ntinas et al., 2017
Conventional, in winter, soilless, heated greenhouse, Greece	Fresh tomato	8507	3,4	0,4	47	0,006	Ntinas et al., 2017
Conventional, soilless, greenhouse, Netherlands	Lettuce	12100	21,0	1,7	297	0,025	Graamans et al., 2018
Conventional, plant factory, Netherlands	Lettuce	70900	50,0	0,7	706	0,010	Graamans et al., 2018

Implications

Vertical farming is often seen as a solution to feed the growing global population by increasing resource and land-use efficiency (Csordás and Füzesi, 2023), and in the near future as an alternative agricultural production system in complement to traditional agriculture (Zaręba et al., 2021). Indeed, its (area-based) yield was 7 to 42 times higher than that of outdoor cropping, and 2 to 15 times higher than production in greenhouses. This optimism regarding high-tech solutions to feed the world is challenged by their very low energy use efficiency. Despite slightly better values for EROI, heated greenhouse systems also had a very low energy use efficiency. Energy saving systems, such as insulated greenhouses, allow lower energy use for similar (area-based) yield, resulting in higher energy use efficiency compared to classic heated greenhouses, but still lower efficiency compared to unheated systems.

Considering that the use of both land and energy are critical points of a transition towards more sustainable farming systems, there is a major challenge to develop systems with satisfactory yields and a limited energy use. In this perspective, the (area-based) yield should not be looked at without energy efficiency indicators, such as EROI or the energy-based yield (i.e. the quantity produced per energy invested) in order to find the best trade-offs.

The heated greenhouse systems that produce tomatoes in winter had a lower energy use efficiency than other heated greenhouse systems, due to the high need of energy to heat the crops and the relatively low yields. This calls for reconsidering the demand of tomatoes in winter and shows that the transition of the farming systems is connected to the transition of the food system (Martin et al., 2023).

Farming systems with outdoor production or in unheated greenhouses may seem to have unsatisfactory yields compared to the most productive heated greenhouses or plant factories, but they need little energy to produce and are more energy efficient. In a context where energy becomes more expensive, scarce while still contributing to climate change, those low-tech systems, including small organic farming, may be promising transition pathways, calling for more research and development effort in this direction (Gaitan-Cremaschi et al., 2020).

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INNOVATIVE PRACTICES FOR TRANSITION

Analyzing farmers' innovative practices to give up glyphosate in orchards and producing knowledge to foster systemic change

Emma Le Merlus[a], Marie-Thérèse Morrisson[b], Jean-Marc Meynard[a] and Marie-Hélène Jeuffroy[a]

[a]Université Paris-Saclay, Agroparistech, INRAE, 91120 Palaiseau, France, emma.le-merlus@inrae.fr; jean-marc.meynard@inrae.fr; marie-helene.jeuffroy@inrae.fr

[b]Institut Agro Montpellier, CIRAD, UMR ABSys, 34000 Montpellier, France, marie-therese.morrisson@cirad.fr

Abstract:
Supporting glyphosate withdrawal in orchards is an important issue. Understanding the practices and trajectories of farmers who have successfully dropped glyphosate seems an interesting way to produce knowledge to support transition. Thus, we combined on-farm innovation tracking, grey literature analysis, and a systemic approach to formalize knowledge on orchard weed management. Our study showed that farmers employed very diverse weed management practices, influenced by individual satisfaction criteria and available resources. Drawing from farmers' experiences, we identified the specific conditions for success of each practice. Through cross-case analysis, we identified common reasoning patterns, illustrating generic action logics concerning glyphosate-free fruit crops, but also situations of systemic blockage in transition pathways towards glyphosate-free fruit systems. We highlighted that a systemic description of weed management practices and trajectory insights are often missing in grey literature, while they were of importance for the farmers crafting new strategies. Our study provides benchmarks for rethinking the formulation of knowledge-based resources on glyphosate alternatives to be widely circulated in the aim to foster transitions on more farms. We further discuss the low relevance of the dichotomy between alternatives and dead ends to address the issues of transitions in agriculture, as well as our contribution to the conceptualization of farmer action logic.

Keywords: innovation tracking, transition pathways, systemic obstacles, farmers assessment criteria, farmers action logics

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Introduction

Farmers are being urged to change their practices in order to reduce pesticide use. Glyphosate is one of the most widely used herbicides, but also the most controversial one as it has negative impacts on human and environment health, while a lot of farming systems depend on it. It is used in orchards as a cheap and efficient way of destroying weeds, in order to prevent competition for resources, optimize tree growth, facilitate manual interventions in orchards and destroy potential habitat for pest. Numerous European countries have intended to ban its use, but are delaying the procedure arguing they don't want to leave farmers without achievable alternative solutions. Even if several non-chemical weed management options in orchards are described in scientific and grey literature, numerous fruit producers are still using glyphosate to control weeds on tree rows (in most French fruit farms, herbicides are no longer used in inter-rows). Our aim was then to unearth and analyze farmers' innovative practices implemented to manage weeds without glyphosate in orchards, and to highlight which information is crucial to convey to farmers to describe and foster systemic change.

Methodology

We combined tracking on-farm innovations (Salembier et al., 2021), formalizing knowledge on orchard weed management using a systemic approach (Quinio et al., 2022), and analyzing grey literature in relation to our findings. Investigating within the DEPHY-Farm network (a national farmer network enhanced to develop alternative practices to pesticide use), we identified farmers who had already partly or totally abandoned glyphosate to control weeds in their orchards. We conducted interviews with 16 French fruit producers, working under diverse situations (in terms of soil types, climate, landscape, etc). Our interviews aimed at understanding the practices implemented by these farmers to manage weeds, the reasons of this choice, their satisfaction criteria, their link to contextual characteristics and the consequences on the farm. After describing their actual system, farmers were encouraged to develop the various steps they went across while shifting to a glyphosate-free orchard. We then produced narratives of each individual weed management strategy, in order to highlight the farmer's action logic (Quinio et al., 2022), which provided us a framework to represent the way farmers reason the systemic interaction between weed management practices and other components of their system. We also shed light on the way these logics were built over time. To do this, we analyzed how farmers modified the elements of their action logic step by step (Meynard et al., 2023) in order to improve the coherence of their system. Then, a cross-case analysis allowed us to identify common traits in the farmers' reasoning, allowing to characterize generic action logics concerning glyphosate-free fruit crops and to shed light on situations of systemic blockage in transition pathways towards glyphosate-free fruit cropping systems. We finally analyzed the 9 technical resources describing alternative options to glyphosate in orchards, available on the dedicated national online platform GECO. We especially studied whether these resources were mentioning or not the traits we used to describe farmers' action logics, and solutions to overcome the main obstacles to glyphosate withdrawal mentioned by farmers.

Findings

A diversity of practices and satisfaction criteria among the interviewed farmers

The sample of studied farms covers very diverse situations, regarding climate (mild, Oceanic, Mediterranean), types of fruits (apples, pears, peaches, apricots, kiwi, nuts), farm areas (from 7 to 170 ha). In glyphosate-free orchards, we noticed a great diversity of practices to manage grass cover on tree rows, varying in the number of weeding operations (from 3 to 10 per year), the intervention periods, the type of tool used and its action on the vegetation and the soil, as well as the combination or not of several tools (harrows, hoes, brushes, blades, mowers). A same tool was sometimes used differently between farmers, depending on the desired effect. Consistently with this diversity of practices, we observed a diversity of criteria that farmers sought to satisfy. They quite often targeted a satisfactory yield and size of fruits by limiting competition from grass cover on tree rows, but some farmers also mentioned other criteria: reducing damage from insect pests by promoting the abondance of auxiliaries and from diseases by limiting the splashing effect through permanent soil cover ; improving soil structure and the composition of flora through tillage ; limiting working time per hectare by combining different operations in the orchard.

Four generic action logics concerning glyphosate-free weed management

The analysis of farmers' action logics made it possible to understand the links between the practices chosen by the farmer and their satisfaction criteria, by highlighting the underlying stimulated agronomic processes and the characteristics of the situation that oriented practice choice. The cross-case analysis allowed us to identify four generic action logics for managing grass cover on the row without herbicides : i) Permanent grass cover on tree row and mowing, ii) Permanent grass cover on tree row and animal grazing, iii) Tillage practices to regulate weed growth on tree row, iv) Using a 'sandwich system' to regulate weed growth on both sides of the row.

Transition pathways

Various factors drove farmers to consider abandoning glyphosate and initiate a transition. Some were willing to anticipate the withdrawal of the molecule from the market, while others aimed at complying with label specifications for better selling prices, such as in organic agriculture. Technical challenges, like yield variability linked to poor soil structure or biodiversity concerns, also prompted reconsideration of glyphosate use. For instance, observations of insect population decline post-insecticide use or discussions with advisors and peers about alternative practices triggered reflections on weed management without glyphosate. Yet, implementing an innovative practice rarely happened overnight. It was part of a longer process of continuous adjustment of the action logic, shaped by personal experiences, observations of external systems, and exchanges with peers. In particular, iterative loops between learning and adjustments enabled farmers to gain deeper insights into underlying agroecological processes, thereby identifying conditions for the success of new practices. These loops sometimes led to the discovery of emerging properties of the system and the reassessment of satisfaction criteria when implementing a new practice.

Four situations of systemic blockage along the pathways

Despite the development of non-chemical weed management practices on part of their orchards, some producers were maintaining the use of glyphosate on a more or less significant part of the total surface area. Thus, being motivated and practicing new methods are not always enough to give up glyphosate. We showed that producers encountered various obstacles depending on their situation, and that these obstacles combined in a systemic way. We highlighted four types of systemic blocking situations: i) Farmers on large farms whose fruit production systems are built according to a logic of cost optimization, ii) Producers on smaller farms who lack resources to go further in their process of change, iii) All-rounder farmers who wish to maintain freedom to use any type of technical tools (including glyphosate), iv) The "on the way" farmers.

Lack of diversity, systemic approach, and pathways in technical resources

One part of online technical resources presented as "synthesis" provide lists of glyphosate alternatives but often lack detailed agronomic description and fail to represent the diversity of systems, practices, and action logics behind these alternatives. Instead, they evaluate alternatives based on limited, generic criteria such as adoption rates, cost, and labor requirements. Additionally, these resources often present a large list of the disadvantages of mechanical weeding on tree rows, which may deter farmers from adopting new practices. Consequently, only the most commonly used alternatives, with minimal economic and practical drawbacks, are presented as realistic alternatives. As for "technical sheets", they offer a superficial analysis of practices within production systems, lacking farmer evaluations and key pathway elements for successful implementation. Among nine resources reviewed, only three incorporate farmer criteria evaluations, while others rely on criteria chosen by the author. Furthermore, only one resource outlines the trajectory of change from glyphosate use to non-chemical weed management on tree rows.

Practical implications

Spreading tracking to highlight diversity and uncommon practices

Tracking on-farm innovations is a relevant way to complete the available "basket of options" (Ronner et al., 2021) to give up glyphosate, as it allows to unearth and study in depth and context-dependent practices designed and implemented by innovative farmers. In this study, we described innovative practices in situations which are identified as dead ends in the grey literature, such as managing permanent grass cover through mowing or grazing in orchards where the fruits are mechanically harvested from the ground. Tracking on-farm innovations also allows to capture the diversity within a broad category of practices. We thus highlighted that mechanical weeding, often perceived as a singular alternative, actually encompasses a wide range of practices depending on farmer's tool combinations, the way each tool is used, and targeted agronomic processes. Exploring that diversity is recommended to foster transitions in other farms (Teixeira et al., 2018).

Mobilizing a systemic approach and shedding light on farmer's own satisfaction criteria

The grey literature we analyzed consistently evaluates alternative techniques to glyphosate based on economic and time-related criteria determined by the authors. However, our analysis, exemplified by Salembier & Meynard (2013), reveals that farmers use their own specific satisfaction criteria, and therefore an alternative can be relevant for one but not for the other. For instance, the significance of "working time" varies among farmers, with some emphasizing factors such as soil quality and protection of orchards by crop auxiliaries. Using a systemic approach allowed us to assess how glyphosate alternative practices could fit into a system or not. Thus, rather than describing practices unrelated with their action context, our analysis emphasizes the systemic coherence of a practice, or a combination of practices, with the farmer's satisfaction criteria, the agronomic processes he seeks to favor, and the specificities of his environment. Similarly, whereas grey literature often presents lists of generic obstacles to give up glyphosate in orchards, our systemic approach highlights that not all farmers meet the same obstacles, but that these obstacles vary and combine differently among farmers situations. In our opinion, acknowledging and emphasizing farmer's satisfaction criteria and the logic of the derived practices is the first step to feed the scaling out of glyphosate-free production systems.

Highlighting transition pathways

A second step is to highlight the diversity of transition pathways. The resources we reviewed rarely show how farmers transition from the current situation (glyphosate-based weed management) to the desired situation (glyphosate-free orchards), while our results show that it requires learning. Variability in these trajectories is large and highlighting them could enhance others farmers' engagement in transition pathways (Chantre & Cardona, 2014; Coquil, 2014; Lamine, 2011; Meynard et al., 2023; Prost et al., 2023). The concept of action logic is well compatible with the study of transition pathways : the analysis of how various farmers adjust their practices toward glyphosate-free systems, in connection with other elements of their system, makes it possible to identify the conditions for success of these practices. It also shows that changing one's weeding practice involves a progressive and systemic redefinition of the action logic, linked to processes of learning and re-evaluation of target and satisfaction criteria along the way (Argyris, 1976; Meynard et al., 2023).

Theorical Implications

The classification of glyphosate exit routes as either alternative or dead ends, according to fixed criteria defined by the authors of technical resources, lacks agronomic relevance and does not seem to work well with the objective of fostering transitions to a larger scale. Indeed, comparing glyphosate use to a non-chemical substitutive alternative solely in economic terms gives no chance for the alternative, and for system redesign. Girard (2013) argues that this "optimization paradigm" in knowledge production systems perpetuates the dominant model, in particular by assessing alternatives through the criteria of productivism (reducing costs and working time while maximizing production, as the first situation of systemic blockage described above). Our findings suggest overcoming the dualism between alternatives and dead ends by the analysis of the logic of farmers' actions and their evolution over time. From this perspective, rather than labelling paths as "dead ends", we show that producers sometimes encounter situations of systemic blockage during their transition, which others have succeeded to overcome.

This article makes a theoretical contribution regarding the concept of action logic, which has been discussed in various scientific literature on farming systems (Benouniche et al., 2014; Marquardt et al., 2022; Ploeg, 1985; Quinio et al., 2022; Salembier, 2019). However, we observed a lack of consensus on a clear definition of this concept. Drawing from Quinio et al.'s (2022) definition, we applied it to describe innovative practices and enhance understanding of situations where farmers struggle to transition away from glyphosate, integrating it with a pathway approach. This article thus contributes to the potential future theorization of the concept.

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Agroecological transition pathways through the changes in ground management practices of French wine producers under Geographical Indications. Application in the Anjou-Saumur wine area

Faustine Ruggieri[a,b], Cécile Coulon-Leroy[a] and Armelle Mazé[b]

[a]GRAPPE, Ecole Supérieure des Agricultures, USC INRAE 1422, 49007 Angers, France – *faustineruggieri@outlook.fr* and *c.coulon@groupe-esa.com*

[c]INRAE, UMR 1048 SADAPT, AgroParisTech, Université Paris-Saclay, 91120 Palaiseau, France – *faustineruggieri@outlook.fr* and *armelle.maze@inrae.fr*

Abstract:
Agroecology is often put forward to address the growing challenges that the agricultural world faces today, including for viticulture. Yet, in French viticulture, most of the production is under Geographical Indications (GI) making practices highly regulated by product specifications, thus questioning practice changes in the context of Protected Designations of Origin (PDO). This study aims at analyzing changes in viticultural practices at farm level in the context of an evolution of regulations toward zero-pesticide use. We propose an analytical approach to study viticultural practices at the farm-level by adapting the Social-Ecological System (SES) framework of E. Ostrom, defining the viticultural system as an agroecological resource system. We operationalize this framework using a mixed quantitative and qualitative approach, with 34 semi-structured interviews conducted in the Anjou-Saumur vineyard in France. We analyze the diversity of agroecological practices implemented at farm level, with regard to the representations that winegrowers have of their practices with three data analyses. Winegrowers were classified into five groups with resembling practices. Overall, winegrowers had a clear vision of the agroecological issues they must face and many of them consider several issues when they choose their practices.

Keywords: agroecological transition; viticulture; agronomy; France; PDOs

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Purpose

To ensure a sustainable agricultural production, the agroecological model has often been put forward as an alternative to the dominant agrifood system. The transition to agroecology requires transformations at institutional and political levels, but above all at the level of producers and their farming practices (Duru et al. 2015). In viticulture, while reducing the use of phytosanitary products has become a major issue, the use of pesticides, and herbicides in particular, remains very high. Certain agroecological practices have already been developed to reduce the use of pesticides in viticulture (Mailly et al. 2017), and their implementation has become essential to meet the global challenges facing viticulture (Macary et al. 2020). In France, about 95% of wine production falls under geographical indications (GIs), which indicates extensive regulation of winemaking practices (Mazé 2023), while changes in practices are encouraged by the institutions related to GIs in France (Ruggieri et al. 2023). Therefore, the question arises of how to effectively drive changes in viticultural practices and how to analyze these changes and their contribution to the agroecological transition in viticulture under GIs. This study aims to analyze the farm-level changes in ground cover management practices in the context of GIs and an evolution of regulations towards a reduction of pesticide-use. To develop a more comprehensive approach distinct from the conventional “technical management route” typically used to study viticultural practices (e.g. Renaud-Gentié et al. 2013), we chose to examine practices across both productive and non-productive areas, such as plot headlands. We developed a new analytical approach by adapting the social–ecological system framework of E. Ostrom (Ostrom 2009), enabling us to characterize the viticultural system as an agroecological resource system. We apply this framework to analyze the nature of change in practices of PDO winegrowers through the example of ground cover management practices.

Design, methodology and approach

In order to consider all elements of the vineyard landscape, we enhance the concept of agroecosystem with that of socio-ecological system. We use the variables of the "resource system" as developed in the SES framework of Ostrom (2009) to define the vineyard agroecosystem as an "agroecological resource system," thus enabling us to consider both the ecological processes that allow the implementation of transformative agroecological practices, and the role of the representations that winegrowers have of their system and practices. As viticultural practices are heavily regulated by specifications associated with PDOs, the transformation of viticultural practices must reconcile the global challenges of viticulture with the strong codification of practices by specifications. In order to address these two constraints simultaneously, we have chosen to study ground cover management practices, which include the handling of spontaneous herbs (or “weeds”), as well as the cultivation of deliberately sown cover crops. Ground covers exist within inter-rows, headlands, and beneath the rows of vines, making it a crucial focal point for understanding viticultural practices.

For this study, we relied on a case study in the Anjou-Saumur wine region, within the Loire Valley wine area (France). In this region, changes in winegrowers' practices are encouraged by an agroecological transition through collective strategies implemented at various geographical scales (Ruggieri et al. 2023). One such strategy, adopted in 2016 by the Anjou-Saumur Wine Federation and endorsed by the National Institute of Origin and Quality, involves integrating a new measure into all the PDO specifications of the area, banishing the use of synthetic herbicides. In addition to this measure, headland vegetation cover was also previously mandatory in all PDO specifications. Since precipitation is higher in the Loire Valley than in the vineyards of southern France, winegrowers in this region are accustomed to managing grass in vine plots, and ground cover management has always been part of viticultural practices. Data was collected through 34 semi-structured interviews with winegrowers producing at least one PDO at the time of the survey. We conducted these interviews within the “Coteaux du Layon” PDO area, South of the city of Angers (although 10 PDOs overlap in this area). First we conducted a statistical analysis on 12 variables describing ground cover management practices, with a multiple correspondence analysis (MCA) and a hierarchical ascendant classification (HAC), in order to cluster winegrowers according to their ground cover management strategies. Then, we qualitatively analyzed winegrowers’ representations of their ground cover practices with a thematic coding analysis of their responses to the question “what is the objective of this cover?” for headlands and inter-rows.

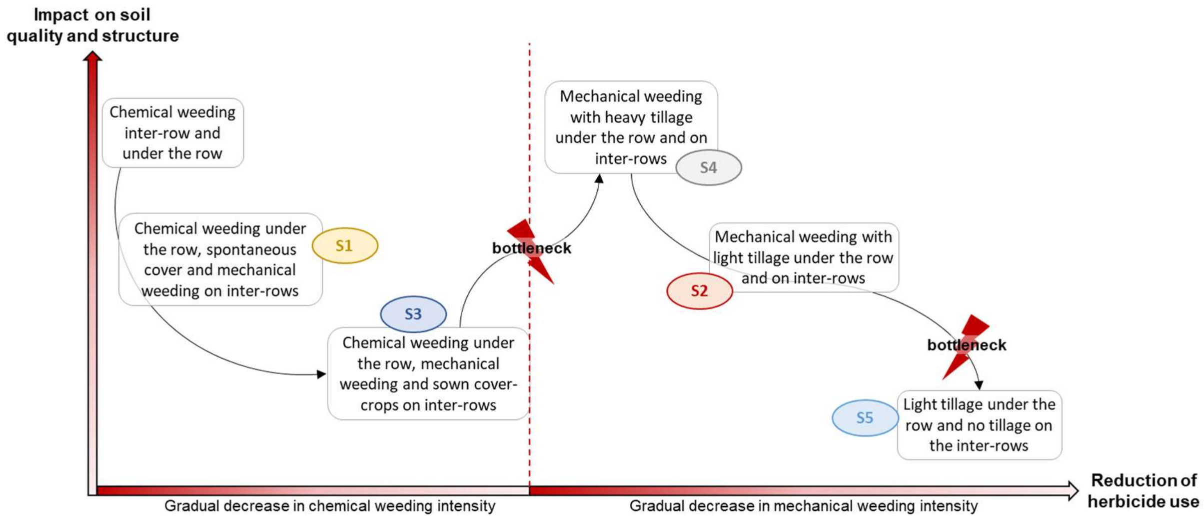
Findings

Our results are twofold. First, the statistical analysis of ground cover management practices gave 5 clusters of winegrowers with homogeneous practices, which reflected a possible transition pathway towards stopping the use of herbicides and reducing tillage. Second, we found that differences in winegrowers’ representations could explain why some winegrowers overcome pathway bottlenecks while others don’t.

Statistical clustering of winegrowers according to their ground cover management practices

The statistical analysis resulted in five clusters of winegrowers’ strategy. The first strategy (S1) followed conventional practices, with a mechanical weeding of every other inter-row and chemical weeding under the row, and concerned 12 winegrowers. The second strategy (S2) did not use any herbicides, and practiced mechanical weeding under the row, concerning 11 winegrowers. The third strategy (S3) concerned 4 winegrowers who chose to sow all their ground covers, even in headlands. The fourth strategy (S4) concerned 4 winegrowers having recently stopped herbicides and practiced intensive tilling to weed under the row. Finally, the fifth strategy (S5) concerned 3 winegrowers who chose to stop tilling the inter-row, and chose either mechanical or chemical weeding under the row. Beyond these practices generally applied at the farm level, many winegrowers cited secondary practices where they tested new practices in small areas, such as mechanical weeding under the row for those who still used herbicides, or sowing cover crops for those who mainly had spontaneous grass covers.

Figure 1. Analytical positioning of clusters according to a theoretical transition pathway towards a total ban of herbicides, while considering the impact of ground cover management practices on soil quality and structure.



The five different ground cover management found with the statistical analysis reflect changes in practices operated by winegrowers. If we consider a theoretical transition pathway towards a total ban of herbicides, we can identify five steps of transition (figure 1). The first step is to stop herbicides in the inter-row (corresponding to S1), which has been implemented in our case study's PDO specifications. The second step would be to start sowing cover crops to better control competition and reduce the need for mechanical and chemical weeding (S3). The third step could be to completely cease herbicide use, but this may lead to intensive tilling as a substitute for chemical weeding (S4). Next steps are then, number four to gradually reduce tilling practices (S2), and number five to completely stop tilling the inter-row (S5). Considering these five steps of a theoretical transition pathway, we can identify two major bottlenecks. The first is to completely cease herbicide use, and the second is to cease tilling as well. These two bottlenecks are difficult to overcome without a real change in representations of ground covers, to consider them more as an auxiliary for vine cultivation and preservation of biodiversity, rather than as competing weeds.

Analysis of winegrowers' representations of ground covers

The winegrowers' responses to the question "What is the objective of this cover?" encompassed all agroecological stakes (Macary et al. 2020). Concerning the inter-row, two main reasons emerged: managing competition in relation to the vine, and preserving the soil, especially crucial for the passage of tractors for various practices like fungal treatments. In the case of headlands, the reasons were more evenly distributed. While soil bearing capacity remained a significant concern for all winegrowers, headlands played a more pronounced role in biodiversity preservation compared to the inter-row. There were three response levels: pragmatic and practical responses (e.g., aesthetics or soil bearing capacity), which constituted the majority; responses related to soil quality and structure; and finally, responses that encompassed broader issues such as biodiversity preservation or water conservation. Winegrowers' representations differed in two key aspects: first, in how they viewed viticultural practices, sometimes disconnecting them from agronomic purposes and attributing other intentions, while others recognized ecosystem services and aligned practices with agroecological goals. Second, perspectives on the agroecosystem's spatial scale varied, with some focusing on the vineyard plot and others considering the entire resource system, allowing broader agroecological choices at the territorial scale. These differences may explain why pathways toward transformative practices at the resource system scale can face bottlenecks.

Practical implications

Our approach provides a more comprehensive integration of non-productive areas and the corresponding management practices employed by winegrowers. In the context of participatory research aimed at guiding winegrowers along their transition pathways, this method can help them effectively integrate non-productive areas and practices into their work, thus enhancing their ability to address agroecological challenges at the landscape level. Despite all winegrowers recognizing the issues surrounding their viticultural practices and engaging in transition pathways, they held varying representations on necessary changes. While these representations were not the only driver for practice changes, they held significant influence. Giving access to knowledge to help change these representations could accelerate a transformative change in practices.

Theoretical implications

Our analytical approach provides a new perspective on the analysis of practice changes at the farm level. By defining the agroecosystem as an agroecological resource system, encompassing all elements of the surrounding landscape of the plots, we can consider both the balance of ecological processes necessary for the implementation of agroecological practices and how farmers interact with their system. By giving equal importance to winegrowers' representations and practices as to the ecological interactions among elements of the resource system, we adopt a holistic approach to the study of agroecological transition at the farm level, which promotes the paradigm shift necessary for the transformation of agri-food systems.

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Agricultural transitions: dimensions, pathways and outcomes. A review.

Richard Kraaijvanger[a] *and Eelke Wielinga*

[a] HVHL University of Applied Sciences, *richard.kraaijvanger@hvhl.nl*

[b] LINK Consult/Netwerk&Co, *eelke.wielinga@gmail.com*

Abstract

Transitions towards more sustainable forms of agriculture are considered mandatory, tend, however, to be variable with respect to dimensions like scale level or vision. To achieve transition multiple pathways are possible, which likely will differ in dimensions. We hypothesized that transitions can be characterized by a comprehensive set of dimensions, acting in a way as its DNA. Specific sets of dimensions might be captured in a typology, which again might serve as a reference for developing transition pathways. We reviewed 20 documented cases of agricultural transitions and explored if transition processes indeed can be characterized on the basis of dimensions and how these dimensions relate to each other. Dimensions for each case were graded using predefined criteria. To obtain a general picture, patterns were made visible using cluster analysis. Cluster analysis resulted in a set of seven relevant dimensions. A set of four clusters was considered optimal and used a reference for a typology of transitions. Typifying transition processes on the basis of dimensions, may provide insight in relevant pathways for transition. Highlighting connected dimensions and capture these in a typology may generate essential inputs for design and governance of transition pathways.

Keywords: agricultural transition, dimensions, pathways, review, cluster analysis

Introduction

Transitions in the agricultural domain are, just like transitions in other domains, in most cases understood as fundamental change of system states at different levels. Transitions towards more sustainable forms of agriculture are mandatory given the diverse environmental, economic and social urgencies faced. Transitions are not necessarily always clearly defined, but on the contrary tend to be variable with respect to dimensions like scale level, stakeholder participation, vision pursued, implementation process, sectors and actors involved, networks or governance. Dimensions appear to relate to either input, process or output factors.

Multiple pathways to achieve transition are possible and these pathways likely will differ in dimensions and outcomes, and at the same time be dependent on context. Although blueprint approaches are, given this diversity, not very likely, still dimensions, outcomes and context may be connected in specific constellations.

Purpose

Different approaches have been used to bring more clarity on the way transitions work (Zwartkruis et al. 2020; Roberts and Geels, 2019). An approach frequently used is Multi-Level Perspective (MLP), which focuses mostly on the process by examining how niche, regime and landscape levels interact and determining in what way the actual transition evolves (Geels and Schot, 2007). By adding to the MLP-concept also dimensions on input and output, transitions towards more sustainable forms of agriculture might be understood better.

In this review we therefore will embark on the diversity of dimensions in order to arrive at a set of dimensions by which transitions can be described, representing in a way the DNA of a given transition. In a second step we will analyse in what way specific dimensions relate to each other and if a typology of on the basis of specific constellations can be developed. Such a typology eventually then could serve as a reference for developing pathways for transition adjusted to specific input, process, output and contextual factors.

Design

To identify relevant cases for our exploration, the platforms Web of Science and Scopus were searched using the key words “transition”, “agriculture” and “sustainable”. Out of an initial short list of about 80 articles, twenty studies were selected documenting 21 cases of agricultural transitions. Topics of the transitions were manifold and included, for example, precision agriculture, agritourism and organic agriculture.

The 21 cases selected were subsequently reviewed considering an initial set of 12 dimensions. Grades for each dimension were predefined, using a seven step Likert scale in combination with a descriptive rubric (Table 1). For the individual cases, grades for each dimension were attributed on the basis of the information provided in the case description.

Two Step Cluster Analysis (IBM-SPSS) was used to identify clusters of cases for the 12 initial dimensions. Using descriptive statistics, a smaller set of dimensions (seven in number) was identified. On the basis of these seven dimensions a final analysis was conducted, which resulted in three sets of clusters. The final number of clusters (four) was selected iteratively based on the distribution of cases over the clusters and the statistical quality of the clusters. Finally, average grades for the dimensions of the separate clusters were used to develop a typology of transitions.

Table 1: Dimensions and grades

		Grade				
Dimension	**Factor**	**1**	**↔**	**4**	**↔**	**7**
scale level	input	grassroots		Province		global
Vision	input	absent		some reference points		clear and comprehensive
governance	input	bottom up		moderately top down		strictly top down
sectors involved	input	one		3 – 4 sectors		multiple sectors involved
interacting institutions	input	absent		2 – 3 institutions		multiple
implementation	input	voluntary		societal push		forced by law

Drivers	input	absent		2 – 3 drivers		multiple drivers
stakeholder involvement	process	absent		in some phases		in all phases incl. evaluation
process control	process	spontaneous		iterative, learning by doing		strongly regulated
network	process	one group		3 – 4 groups		complex network
change rate	output	gradual (> 30 years)		15-20 years		shockwise (5 - 10 years)
aspects included	output	one aspect		3 – 4 aspects		holistic

Findings

Cluster analysis for the initial set of 12 dimensions resulted in a fair cluster quality for sets of 3, 4 and 5 clusters. Statistical analysis revealed that the dimensions stakeholder involvement, sectors involved, rate of change, implementation and initial drivers only slightly deviated over these sets of clusters and were therefore omitted from further analysis.

Cluster analysis of the remaining set of seven dimensions (scale level, vision, governance, institutions involved, process control, network and aspects included) resulted in a set of four clusters having a good statistical cluster quality and an optimal distribution of cases. This specific set was extrapolated into a typology of transitions on the basis of the averaged grades and their definition (Fig. 1 and Table 2).

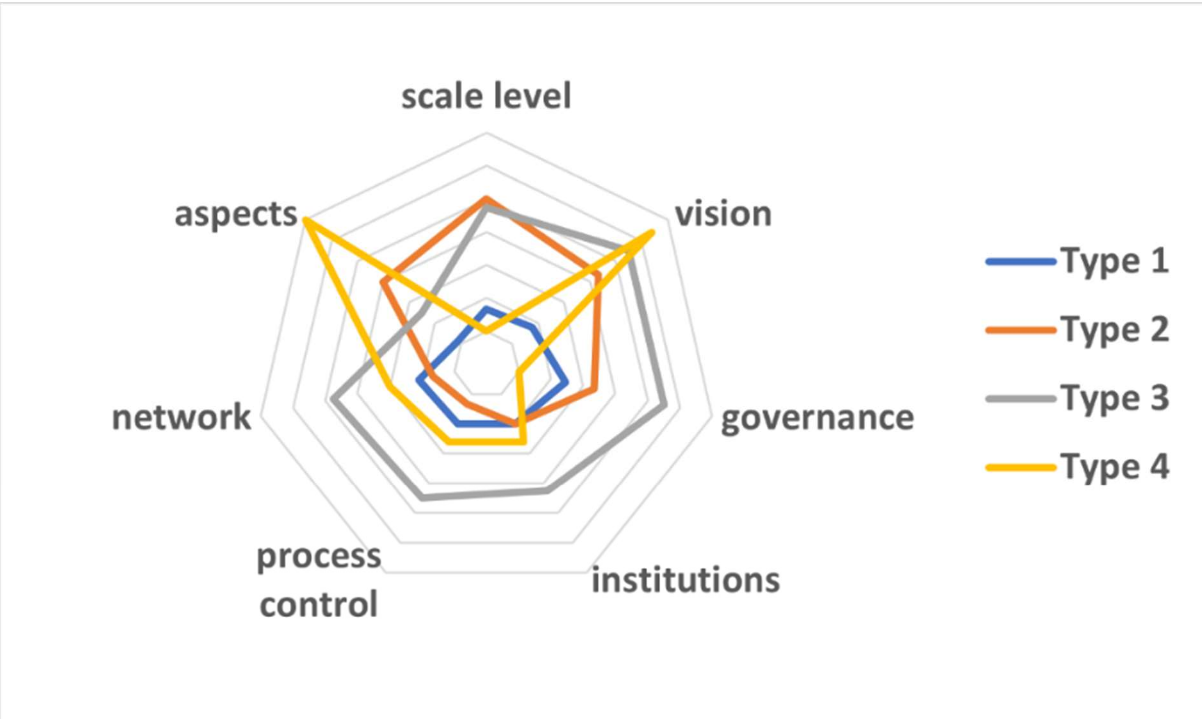

Fig. 1: Clusters and grades based on 7 dimensions.

Table 2: Descriptive grades based on averages for the four cluster types identified.

Type	scale level	vision	governance	institutions	process control	network	aspects included
1	grass-roots (1.7)	limited (1.8)	slightly bottom up (2.4)	only a single institution involved (2.0)	some regulation (2.0)	some 2 parties included (2.1)	single issue (1.1)
2	country (5)	almost compre-hen-sive (4.3)	to some extend bottom up (3.3)	only a single institutions involved (2.0)	sponta-nuous (1.3)	1-2 parties included (1.7)	multiple aspects (4.0)
3	provin-ce / country (4.8)	compre-hen-sive (5.5)	mostly top down (5.5)	3-4 institutions involved (4.3)	quite regulated (4.5)	quite diversified (4.8)	2-3 aspects (2.5)
4	grass-roots (1.0)	compre-hen-sive and clear (6.4)	bottom up (1.0)	1-2 institutions (2.6)	some regulation (2.6)	some 3 parties included (3.0)	holistic (7.0)

Practical implications

The typology presented provides a first indication of some reference types of transitions characterized by unique sets of dimensions. Typifying in a similar way actual or intended transition processes ex ante, and contrasting these with reference types may be helpful to identify relevant and effective pathways. Highlighting in an analogous way, dimensions that are possibly required within a specific context, may provide essential inputs for optimizing transition pathways.

Theoretical implications

The typology developed, even though it was based on a relatively modest data set, still appears sufficiently robust and comprehensive, since it is grounded on dimensions relating to input and process factors, as well as to one output factor. Relating the four reference types identified, with MLP-theory appears to provide interesting congruency and even suggests that MLP and dimension based typologies might complement each other:

- Type 1: grassroots; limited vision, bottom up, single issue, relatively spontaneous : early niche innovation
- Type 2: national level; strong vision, reasonably bottom up, no process control: regime level
- Type 3: national level, strong vision, top down, very regulated, diversified network involved: regime level
- Type 4: grassroots, clear vision, bottom up, big network, holistic: mature niche innovation

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Identifying innovations underlying agroecological transitions: A review.

Ana Fonseca[a], Fabíola Polita[b], Lívia Madureira[c]

[a] Centre for Transdisciplinary Development Studies (CETRAD), University of Trás-os-Montes e Alto Douro (UTAD), Quinta de Prados, Vila Real Email: anaftfonseca@hotmail.com

[b]Centre for Transdisciplinary Development Studies (CETRAD), University of Trás-os-Montes e Alto Douro (UTAD), Quinta de Prados, Vila Real, Portugal. Email: fabipolita@hotmail.com

[c]Centre for Transdisciplinary Development Studies (CETRAD), University of Trás-os-Montes e Alto Douro (UTAD), Quinta de Prados, Vila Real, Portugal. Email: lmadurei@utad.pt

Abstract:

Agroecological transitions address many of the sustainability challenges associated with conventional agricultural systems. The concept of agroecological transitions has been adopted to reduce the negative impacts of agriculture and agri-food systems on ecosystems and climate change. In this context, various types of innovation are fundamental for the transition from conventional practices to more sustainable and environmentally friendly approaches. Although crucial for the environment, the transition to sustainable systems faces several barriers that hinder adoption by farmers. However, there are also motivations that can serve as levers for the transition. The lack of research studies justifies further exploration in the literature review of the specific barriers and motivations encountered by farmers during the transition process to agroecological practices. Understanding these factors is crucial to developing effective strategies and policies to support and encourage the adoption of agroecology on a larger scale. Furthermore, exploring how different innovation systems facilitate or hinder the transition to agroecological systems could provide valuable information for policymakers and stakeholders. 107 articles were analysed, showing that the biggest barriers to transition are related to difficulty in accessing resources and economic restrictions.

Keywords: agroecological transitions, farming systems, farm types, innovation, sustainability.

Purpose

The agroecological transitions refers to the gradual shift that farmers make toward adopting agroecological farming practices, involving changes in technology, society, institutions, and organization within the food systems (Tittonell, 2014). The transition to agroecological practices is a crucial step towards sustainable food systems and agriculture. However, there are numerous barriers preventing this change. Robust markets are needed that cater for agroecologically grown products, supported by social solidarity economies, institutional purchases of agroecological products, increased public awareness and inclusive governance mechanisms (Wezel et al., 2020).(Altieri et al., 2020) Dumont et al. (2021) highlight concerns about weak guidance, inadequate resources, and the lack of market development as significant barriers to the agroecological transition. In addition, value chain limitations and a lack of policies are also major obstacles to agroecological transitions (Gava et al., 2022). With a review of the available literature, this work aims to explore the specific barriers and motivations encountered by farmers during the transition process to agroecological practices. Understanding these factors is crucial to developing effective strategies and policies to support and encourage the adoption of agroecology on a larger scale. Furthermore, exploring how different innovation systems facilitate or hinder the transition to agroecological systems could provide valuable information for policymakers and stakeholders.

Design/Methodology/Approach

For this study, research was conducted in two databases to identify articles dealing with agroecological transitions: Scopus and Web of Science. These databases were chosen for including only peer-reviewed articles and allowing for systematic research. We selected the expression “agroecologic* transition*”, using “” and * to include multiple words for each term, resulting in 731 documents found, with 344 from Scopus and 387 from Web of Science. After refinement to filter only scientific articles and removal of duplicate, 321 documents were left for analysis and full reading. Reading the full articles helped identify theorical and empirical studies, as well as those containing some form of innovation. For this study, only empirical studies were relevant, resulting in 107 articles in the end.

The PRISMA method was used to construct the article database (Liberati et al., 2009; Moher et al., 2009).

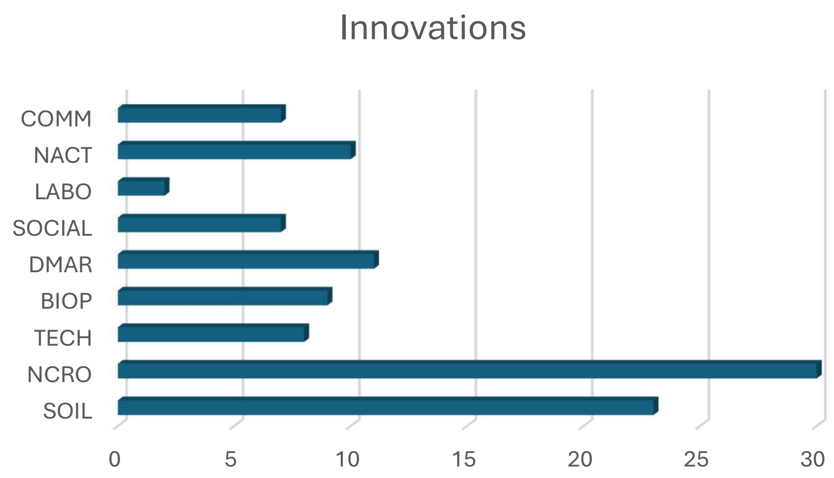
In this review, we analysed the types of innovations in agriculture and how they have contributed to agroecological transition. Agroecological innovations refer to practices, techniques, and technologies developed and applied within agroecology. This study addressed 9 types of innovation (Table 1).

Innovation	**Description**
BIOP	Biological Pest Control
COMM	Natural Resources Common Management
DMAR	Direct Marketing
LABO	Labor and Machinery
NACT	New Activities
NCRO	New Crops
SOIL	Soil-improving Cropping Systems
TECH	Digital Technologies
SOCIAL	Social and Education

Findings

In the studies analysed, 28% were related to the introduction or diversification of crops (NCRO), demonstrating the importance of innovation for agroecological transition. Innovations for soil improvement (SOIL) also proved to be relevant in achieving the sustainability of agri-food systems, accounting for 21.5% of the studies analysed.

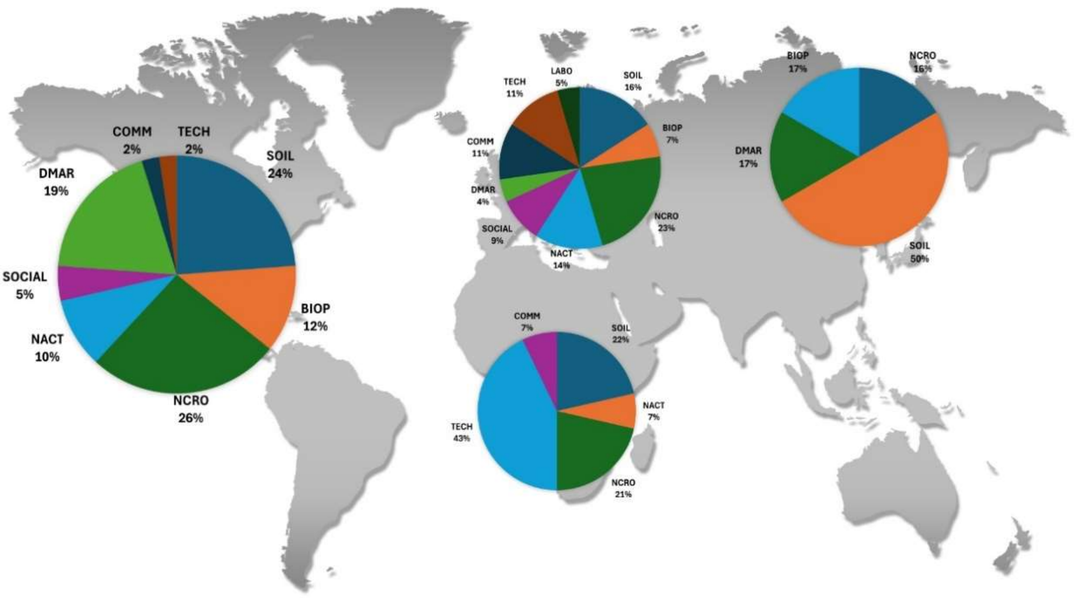
Figure 1 Types of innovations



The analysis of the data shows that in the studies analyzed, agroecology prevails as a set of practices, which is justified by the need for a radical change in agricultural practices to achieve the ecologization of agricultural systems, with agroecology being the path to sustainable development (Holt-Giménez, 2002; Cools et al, 2003; Lanka et al, 2017; Ryschawy et al, 2017; Simon et al, 2017; Bezerra et al, 2019). The diversification of crops (Lucantoni et al., 2020; Meynard et al., 2018; Stratton et al., 2021) is seen as an essential pillar of the agroecological transition, increasing biodiversity, ecosystem services, and the resilience of agricultural systems. This type of innovation is often related to small-scale and family-based farms, allowing for the promotion of sustainability and the satisfaction of economic needs and family self-sufficiency.

Crossing the type of innovation and the geographic location, the results show that the European and American continents stand out in the number of studies. In the American case, the innovations focus mainly on soil improvement and the introduction of new crops, with little relevance in the application of technologies. The European case is similar in terms of the most used innovations, soil improvement and new crops, but already shows the emergence of new technologies to support agroecological transitions. This suggests that the development and adoption of agroecological practices varies across different geographic regions, likely influenced by factors such as agricultural traditions, access to resources, and research priorities.

Figure 2 Distribution of innovations by continent



The lack of resources and economic difficulties are among the main barriers pointed out by farmers for the poor adherence to more ecological models. In the 107 articles analyzed, 44 present economic barriers and 46 barriers related to access to resources. The lack of support policies and the difficulty of accessing markets are also obstacles to the transition.

The main motivations for the agroecological transition are environmental sustainability and economic viability. For example, farmers believe that crop diversification allows for greater economic viability.

Practical Implications

This study has practical implications for several sectors, including agriculture, the environment and society. Reviewing agroecological innovations and the underlying barriers and motivations can inform and guide multiple stakeholders, including farmers, policymakers, researchers and communities, to make informed decisions that contribute to more sustainable and resilient agricultural systems. Understanding is crucial for developing effective strategies and policies to support and encourage the adoption of agroecology on a larger scale. Furthermore, exploring how different innovation systems facilitate or hinder the transition to agroecological systems could provide valuable information for policymakers and stakeholders.

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What are the links between farmers' perceptions, management practices regarding soil fertility and their determinants? A socioecological investigation

Yves Cartailler [1,2,3], Sabrina Gaba[1,2,3] and Elsa Berthet[1,2,3]

[1]USC 1339, Centre d'Etudes Biologiques de Chizé, INRAE, Villiers-en-Bois, France,

[2]UMR 7372 Centre d'Études Biologiques de Chizé, CNRS & Univ. La Rochelle, Beauvoir-sur-Niort, France,

[3]LTSER Zone Atelier "Plaine & Val de Sèvre", CNRS, Villiers-en-Bois, France

Abstract:
Agricultural intensification has reduced the potential of soil biodiversity to provide ecological services beneficial to crop production, and studies have shown that few farmers perceive soil biodiversity as a driver of soil fertility. In this study, we assess farmer's perceptions soil fertility drivers and determinants of adoption of practices that improve soil fertility, to better understand farmers' decision-making process, especially for adopting practices that improve soil fertility. We surveyed 78 farmers with open-ended questions aiming to characterize their perceptions, determinants and practices. Our results show that the perception of soil biodiversity as a driver of soil fertility is low among farmers. However, correlation analysis revealed that soil biodiversity and legal obligations were important determinants of soil practices. Farmers justified practices such as reduced tillage, cover crops and crop association by socio-economic and environmental determinants. Our study provides a new emphasis for the agroecological transition to consider farmers' determinants when studying how farmers perceive biodiversity for farming.

Keywords: farmers' perception, management practices, soil fertility drivers, determinants.

Purpose

Soil fertility depends on both soil biodiversity and soil physico-chemical properties [1]. As part of the soil fertility, soil biodiversity contributes to crop production[2], but agricultural intensification has reduced the potential of soil biodiversity to provide ecological services that benefit to crop production. Agricultural practices such as reduced tillage, cover crops and crop association have been shown to improve soil biodiversity, which benefits crop production[3]. Furthermore, farmers' perceptions have been reported in the literature as a driver of behaviour[4], and a key to agroecological transition[5]. We therefore wonder to what extent farmers' perception of soil biodiversity as a driver of soil fertility leads them to agricultural practices that enhance soil biodiversity, in comparison to other determinants.

In line with other studies we define perception as a subjective and unconscious interpretation of the environment around the individual, giving it a coherent meaning [6] while determinants are sufficient needs to drive behaviour or to obtain some satisfactions, close to a motivation[7] but broader than it. However, few studies on agricultural practices to improve soil fertility consider farmers' perceptions of soil fertility,

agricultural practices and farmer's determinants as a whole (but see Kuria et al. (2019) for an exception).
Here, we first assess how farmers perceive soil biodiversity as a driver of soil fertility, taking into account other drivers. Then, we analyse the relationships between farmers' perceptions, practices and determinants to understand the drivers of farmers' adoption of practices that improve soil fertility. Finally, we investigate whether practices perceived as less harmful to soil biodiversity[3] are associated with the perception of soil biodiversity as a driver of soil fertility.

Design/Methodology/Approach

This study takes place in a long-term socio-ecological research (LTSER) site area called "Zone Atelier Plaine & Val de Sèvre", with 430 farms spread over 450 km^2 [9]. The area is an intensive cereal plain where the main crops are wheat, oilseed rape, sunflower and maize, and 13.5% of the area is composed of grassland. Twenty percentof the farmers are in organic farming and 40% of the area is cultivated by mixed livestock farmers[9]. During the winter of 2022-2023, we targeted 20% of the population of interest and sampled 78 farmers who were representative of the area according to two proxies, farm size and crop diversity. Twenty-two farmers interviewed were organic and 33 were mixed livestock farmers.
Farmers were interviewed by telephone for an average time of 25 minutes and were asked about the drivers of soil fertility (Q1), the practices used to maintain or improve soil fertility (Q2) and their determinants for using these practices (Q3). We used open-ended questions rather than Likert scales or multiple choice questions. We then carried out an inductive coding process based on the farmers' responses. These were categorised into different variables depending on whether the responses related to practices, inputs, environmental or economic issues (see **Table 1**). As some farmers gave more than one answer per question, we summed the number of answers per category and per farmer. We then performed descriptive and correlation analysis using R software and the "Corrplot" package[10]. As the variables were non-parametric, we performed Spearman correlation tests between pairs of variables.

Findings

a. *Descriptive results*

More than a half of the farmers perceived their own practices and input use as the main drivers of soil fertility (**Table 1**). 'Organic fertilizer' was the most frequently mentioned driver of soil fertility in terms of responses and per farmer. A third of farmers also perceived abiotic factors such as soil chemical properties as drivers of soil fertility, while soil biodiversity was rarely identified as a driver of soil fertility (**Table 1**).
Farmers reported several practices related to organic or conservation agriculture. Sixty-three farmers used organic fertilizer (**Table 1**) while ten farmers used both synthetic and organic fertilizers. Twenty-eight farmers mentioned 'reduced tillage' while only seven mentioned 'conventional tillage' of which three cited both 'reduced' and 'conventional tillage'. For 40 farmers, 'cover crops' was the most important practice cited in the

category ‘crop arrangement’ and was negatively correlated with ‘crop association’ (see **Table 2**).

Farmers were mainly determined by the search for autonomy and savings for 29 respondents, representing 20.41% of the responses in Q3 (**Table 1**). Notably, few respondents cite determinants related to improving crop growth, which accounts for only 19% of the responses, compared to socio-economic or environmental reasons, which account for more than 80% of the responses (**Table 1**). Farmers are more likely to justify their practices in terms of cost saving, legal reasons or environmental concerns than in terms of improving yields and crop growth.

Table 1. Descriptive statistics of responses to each question.

Types of variables	**Variable**	**Percentage of responses**	**Number of farmers**	**Average number of responses per farmer (standard deviation)**
Inputs (Q1)	organic fertilizer	15.1	21	1.1 (0.4)
	synthetic fertilizer	12.0	19	1.0 (0.0)
No idea (Q1)	« I do not know »	0.6	1	1.0 (0.0)
Agricultural practices (Q1)	cover crops and crop association	7.6	11	1.1 (0.3)
	crop rotation	7.6	12	1.0 (0.0)
	farmer technicity	3.1	5	1.0(0.0)
	tillage	10.7	16	1.1 (0.3)
Abiotic drivers (Q1)	water resources	5.7	6	1.5 (0.8)
	soil types	14.5	18	1.3 (0.5)
	physico-chemical properties	17.6	25	1.1 (0.3)
Biotic factor (Q1)	soil biodiversity	5.7	8	1.1 (0.4)
Inputs (Q2)	organic fertilizer	41.6	63	1.4 (0.5)
	synthetic fertilizer	9.1	18	1.1 (0.0)
Crop arrangement (Q2)	cover crops	19.6	40	1.0 (0.0)
	crop rotation	6.2	11	1.2 (0.4)
	crop association	6.2	11	1.2 (0.4)
Mechanical operations (Q2)	reduced tillage	13.9	28	1.0 (0.0)
	tillage	3.4	7	1.0 (0.0)
Socio-economic system (Q3)	search for autonomy and savings	20.4	29	1.0 (0.2)
	peer influences	5.4	8	1.0 (0.0)
	Improving working conditions	10.9	16	1.0 (0.0)
	legal compliance	8.2	12	1.0 (0.0)
To improve crop growth (Q3)	optimising yields	10.9	16	1.0 (0.0)
	meeting crop needs	8.8	13	1.0 (0.0)
Environmental-related system (Q3)	soil biodiversity	13.6	18	1.1(0.3)
	soil physico-chemical structure	17.0	20	1.3 (0.4)
	reducing environmental impact	4.8	7	1.0 (0.0)

b. Relationships between perception, determinants and agricultural practices

i.Socio-economic and environmental determinants drive soil management practices

'Cover crop' practice was highly correlated with legal compliance. 'Crop association' was positively correlated with the aim of reducing environmental impacts and improving soil biodiversity, but negatively correlated with the soil physico-chemical structure. This suggests that farmers use crop association to improve soil biodiversity and reduce environmental impacts, regardless of the soil types on their farms.

ii.The perception of soil biodiversity is barely correlated to farming practices.

Few relationships were found between biotic and abiotic drivers of soil fertility (Q1) and practices (Q2). Only crop rotation was positively correlated with the perception of soil microorganisms at a significant level (**Table 2b**). Farmers tended to perceive more their own practices as drivers of soil fertility and these perceptions were more strongly correlated with soil management practices (**Errore. L'origine riferimento non è stata trovata.b**) than with the perception of a soil biodiversity as a driver of soil fertility.

Table 2. Outcome of the Spearman correlation tests *between responses to the three questions. "rs" presents the correlation coefficient**p-value<0.0001, **p-value<0.001, *p-value<0.05.**

(a) Soil management practices (Q2)	*Determinants (Q3)*	r_s	significance
Cover crop	Legal compliance	0.34	**
Crop rotation	Economic reasons	0.32	**
Crops association	Soil biodiversity	0.28	*
Reduced tillage	Soil biodiversity	0.28	*
Crop rotation	Reducing environmental impact	0.27	*
Crops association	Reducing environmental impact	0.27	*
Crops association	Soil geochemical structure	-0.24	*
Tillage	Economic reasons	-0.24	*

(b) Soil fertility Drivers perceived (Q1)	*Soil management practices (Q2)*	r_s	significance
Tillage	Crops rotation	0.41	***
Cover crop/ crop association	Cover crop	0.39	***
Soil biodiversity	Crops rotation	0.25	*
Tillage	Crops association	0.23	*

2. Practical Implications

Our study suggests that the European Nitrates Directive implemented 30 years ago is effective in promoting 'cover crops', although farmers do not associate crop production with the benefits of cover crops for soil biodiversity. Furthermore, practices such as reduced tillage and crop association are motivated by the need to preserve soil biodiversity and reduce environmental impacts, and could therefore be promoted by public policies to encourage a conscious and widely accepted agroecological transition.

Theoretical Implications

As farmers, in our study, perceived organic fertilizers, tillage and crop arrangement as drivers of soil fertility, our findings echo the work of Dossouhoui et al., (2023) where farmers identified monoculture, chemical inputs and tillage as the main drivers of soil fertility decline. In line with previous studies[12], our study highlights that soil biodiversity is not considered as a major driver of soil fertility compared to soil physico-chemical properties and farming practices. Our results highlighted that soil biodiversity was a determinant for adoption of practices that rely on agroecological principles (see **Table 2**b), which is more accurate than previous studies that showed environmental motivations without further precision[13] or economic determinants[12]. More generally, our study has two important implications for research on the social drivers of agroecological transition, by examining both perceptions and determinants of practices. Studies of farmers' perceptions of soil fertility alone generally use direct questioning method [14], which may explain the discrepancies between their findings and ours. For instance, Omokaro et al., (2023) asked farmers for what they thought about earthworms, with narrow responses pre-selected, resulting in 85% of farmers believing that earthworms increase soil fertility, whereas an open-ended question gave us a 5% response rate in this study. Studies of the drivers and barriers of agroecological transition generally use more qualitative methods, highlighting the influence of cropping systems [15] or knowledge diffusion [16] but without linking this to farmer's perceptions of soil fertility.

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PERSPECTIVES AND CONCEPTS FOR UNDERSTANDING TRANSITION

Risk as unifying concept for sustainable food production transitions: Integrating the psychology of risk in interdisciplinary research

P. Marijn Poortvliet[a] and Katrien Descheemaeker[b]

a Section Philosophy, Innovation, Communication & Education, Wageningen University, marijn.poortvliet@wur.nl

b Plant Production Systems Group, Wageningen University, katrien.descheemaeker@wur.nl

Abstract:

Research on sustainability transitions has gained prominence over the past years; one key domain focuses on food production transitions. Dominant agricultural systems and agricultural policy have seen a shifting emphasis from only food security and high yields towards more attention also for sustainable and ecological intensification and the environmental impacts of food production. Mirroring this change, agricultural research has gradually made a similar shift – from research paradigms with a dominant focus on technical (i.e. agronomic) and economic analyses (e.g. during the era of the green revolution), towards more input from social science research that aims to understand farmers' decision making. We present a conceptual framework that proposes how risk may act as a boundary object that connects different disciplines that study transition in food production systems. We expect this model will contribute both to further development in the transition literature as well as the field of risk analysis. We discuss guidelines for interdisciplinary research in this domain, and we propose four concrete research questions that may guide future research initiatives.

Keywords: sustainability transitions; decision-making; interdisciplinarity; adoption; risk

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Introduction

Agricultural research has gradually made a shift from research paradigms with a dominant focus on technical (i.e. agronomic) and economic analyses (e.g. during the era of the green revolution), towards more input from social science research that aims to understand farmers' decision making (Foguesatto, Borges, & Machado, 2020). Within the broad range of social sciences, more individual and behavioral types of analyses have started to emerge in the literature. This development is important, because, in the end, on-farm decision making takes place mainly at the individual level, where every farmer is different. Moreover, alternative ways of agriculture that include a wide array of paradigms such as precision agriculture, vertical farming, urban farming, agro-ecology and climate-smart farming will require ambitious transformations and applications of novel techniques and practices (e.g., Stringer et al., 2020). Doing something new in farming implies getting out of the comfort zone. So, for farmers, adoption of innovations may be associated with experiencing a level of risk and uncertainty, and their appraisal of the latter will therefore inform their actual adoption behavior. We therefore put forward the notion that an individual's risk perceptions are at the heart of understanding decision making in farming.

Against this background, an incomplete appreciation for the individual level limits our understanding of how agricultural systems work. While the adoption literature may look at individual-level processes, much transition work looks at the systemic level, without much attention for risk. This is problematic because the ambition to transform agriculture into more sustainable production systems will require changes in individual or household-level decision making. We put forward the notion that risk is a central concept that needs to be studied in order to better understand sustainability transitions in agriculture. Indeed, working in agriculture implies dealing with risks that are variegated (e.g. production, market, and other risks; Huet et al., 2020), and play out across several levels (Meuwissen et al., 2019). However, current understanding of the role of risk in agricultural decision making is limited and hampered by the facts that some types of risks receive much less attention, that risks are studied in different ways across disciplines (Joffre et al., 2018), and that farmer diversity is not always duly considered (Emerton & Snyder, 2018). In this conceptual contribution we argue for a more interdisciplinary understanding of transitions towards sustainable agriculture by emphasizing the complementary value of individual-level research, with a specific emphasis on individual risk perceptions. Furthermore, we make this perspective actionable by discussing an integrated framework that puts risk at the center of studying sustainability transitions. As such, risk has implications for the individual farm level, as well as the broader production system.

2. Current perspectives on adoption

The search for technologies and practices that maximize yield and resource use efficiency, or benefit soil fertility is at the core of agronomic research. Information on such practices is useful for farmers when it is translated to their bio-physical and socio-economic context, but it is not the only determinant of their decision making (Meijer et al., 2015). Agronomy primarily focuses at field-level processes, whereas farmers take decisions by considering the whole farm level, where issues of e.g. labor, cash or land availability may complicate the application of practices that seem optimal from a field-level analysis (Descheemaeker et al., 2019). Also, common constraints and barriers (e.g. limited market access) for the uptake of practices are playing at higher levels beyond the control of farmers (Sietz & Van Dijk, 2015). Besides the fact that farmers, depending on their perceptions of and attitude towards risk, may value yield stability more than a high average yield, they may also consider other criteria such as taste, grain color, cooking properties, variety in maturing times or labor requirements. These criteria are not always captured through classical agronomic research, but can be evaluated through participatory evaluation of on-farm experiments (Ronner et al., 2019).

A traditional view in agricultural economics is that people strive for profit maximization and, as such, are driven by utility – how much something is valued, mainly in terms of price. This thinking has been instrumental in understanding basic economic phenomena like supply and demand, and has been very dominant in agricultural economics (e.g. Lin et al., 1974). However, in modern behavioral economics (in agriculture) it is assumed that people try to satisfy not maximize utility and that their rationality is bounded, and the role of risk and learning dynamics are important in economic analyses of adoption (Marra et al., 2003). Moreover, the optimal level of production for a farmer is not only determined by maximal economic profit (e.g. Silva et al., 2018). For example, it has been shown that farmers with strong positive attitudes toward soil conservation displayed high levels of soil conservation practices, independently of receiving a financial incentive (i.e. a government subsidy scheme) that incentivized this behavior (Bopp et al., 2019).

The field of psychology offers an array of models that predict (pro-environmental) behavior and decision making, some of which are relevant for understanding behavior that could enable the transition towards sustainable agriculture. First, the theory of planned behavior (TPB; Ajzen, 1991) states that people's behavior is predicted by forming behavioral intentions, which in turn are driven by a person's attitudes, perceived social norms, perceived behavioral control – the extent to which one thinks to be able to execute the behavior. TPB does not acknowledge the role of personal norms related to environmental decisions, and this factor is covered in the value-belief-norm theory (VBN; Stern et al., 1999), which states that personal values predict pro-environmental behavior via a person's belief system and the personal norms one adopts.

In the context of decision making in agriculture, a key factor that drives a farmer's behavior is the experience and perception of risk (Sjöberg, 2000). This notion is important, because farmers have a rich and fine-grained understanding of farm-related risks (Van Winsen et al., 2013). Risk perceptions are not incorporated in models like TPB and VBN – a major omission. However, protection-motivation theory (PMT; Witte, 1992) predicts that people will only act against a threat – such as the risk of a late start of the rainy season – if they assess the threat to be serious and relevant for them (i.e. they have a risk perception) and also believe that they can effectively act – such as when they know they can plant different varieties of a crop, or different crops – and that this action will truly help (i.e. they have an efficacy perception).

The above models have been influential in behavioral science, but any of them, in isolation, falls short in explaining behavior in all its complexity. For example, TPB is parsimonious, but neither includes people's value systems nor their risk perceptions (cf. Läpple & Kelley, 2013). PMT is very effective in predicting self-protective behavior, but in the context of adoption of innovations it is crucial to also incorporate a person's intrinsic motivation or one's habits. Inspired by these (and other) behavioral theories, more comprehensive models aim to predict agricultural decision making and include factors like intrinsic motivation, perceived barriers to adoption, social norms, and self-identity (Greiner et al., 2009; Mills et al., 2017). These models have the advantage that they offer a richer explanation of decision making (i.e. they explain more variance) compared to any of the more traditional models in isolation. Also, the process of human decision making does not take place in a social vacuum but is embedded in the structural and social context of and around the farm. Therefore, psychological processes are shaped by and in close interaction with biophysical, sociodemographic, cultural, economic, and policy regime characteristics (e.g., Meijer et al., 2015).

Sustainability transitions

By definition, transitions are not static. Studying the transition towards sustainable agriculture through the lens of a single discipline may be flawed because in reality transitions are influenced by variegated factors and take place simultaneously across several levels. To give an example, in studying a farmer's propensity to engage in zero-tillage, one can look exclusively at psychological factors that drive a farmer's decision making: risk perceptions, attitudes, values, perceived barriers, etc. Yet, a government program may be in place that hands out financial incentives to farmers who engage in certain ways of soil conservation, and/or policy could be installed that simply bans certain practices. In this case, it is relevant to combine the perspectives from agronomy, psychology, agricultural economics and policy, because subsidies and policies will be altered in reaction to farmers' individual choices, and vice versa – thereby recognizing the bi-directionality of interactions between individual actors and the farming context. By allowing the integration of disciplinary and multi-level perspectives, interdisciplinary research is effective in detecting such mutual responsiveness (Engler et al., 2019).

We put forward the principle that approaches should complement rather than substitute each other, as this will result in a more comprehensive view on adoption of agricultural innovations in the context of risk. In understanding the uptake of agricultural practices, several streams of research have advocated the use and development of comprehensive and multidisciplinary models (Pannell et al. 2006; Streletskaya et al, 2020) that offer rich and multi-level insights into adoption processes. They include individual levels (risk perceptions, habits, personality), more collective levels (social capital, cultural theories), and also systemic and structural levels (geographic characteristics, governance structures). In theory, such comprehensive understanding of the adoption process in diverse farming communities would enable researchers to generate recommendations for interventions aiming at behavioral change towards sustainable farming practices. Indeed, as an example, Jambo et al. (2019) studied the adoption process by smallholder farmers by integrating aspects of individual motivation and perception with farm- and higher-level socio-economic and biophysical factors. The resulting insights into the intertwined roles of intrinsic and external motivation, farmers' expectations of the agricultural innovations and their perceived risks and constraints, can provide the basis for interventions instigating the adoption process. In this case, Jambo et al. (2019) concluded that farmers' motivation could be stimulated by supporting farmers' autonomy in making choices and their ownership of the R&D programs, besides better alignment of the agricultural practices to farmers' expectations and risk aversion.

Risk as a unifying concept

We have argued that to gain a better understanding of agricultural adoption processes, input is needed from multiple disciplines, and these should study the problem from different levels. We argue that risk acts as a unifying concept that ties different relevant disciplines together. That is, looking at risk from these different perspectives (e.g. agronomic, economic, institutional, organizational, psychological) will offer both broader and deeper insights into farmer decision making. In particular, risk can be studied from the individual or farm level (i.e. the micro level), or from the broader systemic level (i.e.

the macro level). We posit that these levels are not static but are dynamic and interact. This interaction takes place at an intermediate level (i.e. the meso level).

Doing interdisciplinary research in sustainable agriculture is easier said than done. Even when researchers with diverse background are brought together, they may fall back on their default paradigms, and think from their own silos, each talking in a different academic language. As a minimum requirement, research teams need to be task groups with a multidisciplinary profile. However, working in multidisciplinary teams by itself is not enough – such teams need to set interdisciplinary ambitions, which go beyond simply combining approaches and create scientific value by influencing each other and integrating different lines of knowledge. In order to do this, we put forward the notion that risk is a concept that can be studied in different ways by different disciplines (e.g. individual risk perceptions, yield risks, economic), and as such, may act as a boundary object to promote discussion to find a common ground in understanding and enabling the transition towards sustainability.

One avenue is the use of mixed-method designs by blending in (methodological) elements from various paradigms (De Haan & Rotmans, 2011). Depending on the study problem, one can combine elements from life science (e.g. agronomic observations) with social science (e.g. stakeholder analyses). For example, through detailed monitoring of agronomic practices and (social) learning processes, Marinus et al. (under review) revealed that both knowledge and capital constraints of smallholders need to be relieved to spur the uptake of sustainable intensification options. Also, within disciplines one can combine 'hard data' or objective behavioral measures (e.g. how much tillage is applied on a plot of land) with more 'soft data' or subjective measures (e.g. a farmer's risk evaluation of a particular practice). Sometimes subjective data are considered unscientific or unreliable, but if the ambition is to study adoption of sustainable practices it is inefficient not to take into account a person's perceptions and thoughts, knowing that these intra-individual processes matter (Huet et al., 2020).

There are currently many developments and innovations happening in agriculture, and the agri-sector will look very differently in 20 or even 10 years from now. For example, precision agriculture, robotization, virtual observations, ICT, and so forth already have and will increasingly have impact in the future. However, innovations are not always high-tech and can be as simple as improved rotation systems and using strip plantations that have the potential to reduce pesticide use, increase soil and water quality and boost biodiversity. It is self-evident that these are many different innovations, and a critic might also note that the current system is locked in and therefore not open to change. Henceforth, we argue that developments like these need to be studied from different angles simultaneously.

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Towards a common understanding of transformation pathways to sustainable agriculture

Robert Home[a], Rebekka Frick[b], Lena Stadler[c], Tamina Felder[d]

[a]Research Institute of Organic Agriculture (FiBL) robert.home@fibl.org;

[b]Research Institute of Organic Agriculture (FiBL) rebekka.frick@fibl.org

[c]Research Institute of Organic Agriculture (FiBL) lena.stadler@fibl.org

[d]Research Institute of Organic Agriculture (FiBL) tamina.felder@fibl.org

Abstract:

Research into transformation pathways to sustainable agriculture is commonly interdisciplinary, which introduces the potential for different, and sometimes contradictory, understandings of transformation pathways among the members of research projects. However, a common understanding is needed if scientists are to be coherent in their approaches to addressing sustainability issues in farming systems. We followed the process described by Jankowicz (2005) to apply the Repertory Grid Technique (RGT) to identify the different personal constructs used by researchers working within the Horizon Europe project: ENFASYS, to understand and explain transformation pathways towards sustainable, productive, climate-neutral, biodiversity-friendly, and resilient farming systems. The RGT procedure revealed 103 personal constructs, which were grouped into 11 thematic clusters. The constructs were aggregated into a consolidated structure of pathways using the approach described by Honey (1979), which was calculated on the basis of their correlation with evaluations of the transformation potential of initiatives. By collating these findings through a clustering of constructs, and comparison between the different project partners' assessments of transformation potential within each thematic cluster, themes such as *stakeholder inclusion*, *anchoring in farming*, *autonomy*, and *change ambitions*, were found to correlate strongly with transformation potential. The subsequent validation workshop emphasized *market orientation* and *clear transformation aims* as pivotal to the transformation potential of initiatives. With these results, we have developed a shared understanding of which thematic clusters of constructs are considered to be important to promote transformation.

Keywords: Transformation pathways; Farming systems; Governance; Repertory grid; Personal constructs

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Purpose

In a time of rapidly growing population, economic uncertainty, and changing climate, there is little disagreement about the need to stimulate just and robust change towards sustainable, productive, climate-neutral, biodiversity-friendly, and resilient farming systems (SFS). There is similar agreement that research has a role to play, but researchers approach the inherently complex, uncertain, and normative questions about farming system transformation from a variety of disciplinary backgrounds, while working within specific, and different, contexts, and bringing individual professional experiences that have shaped their worldviews. The interdisciplinary nature of transformation research means that there are different, and potentially contradictory, understandings of transformation pathways among the members of research projects. We recognised this diversity but, for scientists to be coherent in their approaches to addressing sustainability issues in farming systems, there is a need to reach a common understanding of what constitutes a transformation pathway.

Gaining a common understanding, within a specific group (in this case scientists), of a particular phenomenon (in this case transformation pathways) is not the same as agreeing on an optimum, or best practice pathway, but rather means collating the ways in which the individuals think about the given phenomenon in their world. This paper starts from the position that understandings of transition and transformation pathways towards sustainable farming systems are constructed according to individual ontological and epistemological positions, which influence analyses of the current Agri-Food systems (AFS), the properties and desirability of newly configured AFS, and the design of innovative or transformative processes towards sustainable AFS.

The aim of this contribution is to make existing understandings explicit and to map out common, as well as diverging, views so that generalizable attributes of transformation pathways can be separated from attributes that are specific to particular contexts. We did this by collecting and collating the different ways in which individual researchers think about the phenomenon in their world. In this way, we highlight the constructs that are shared by all, or most, members of the group, which suggests that they are generalizable and context-independent, and we identify which constructs are specific to the individual and are therefore context-dependent.

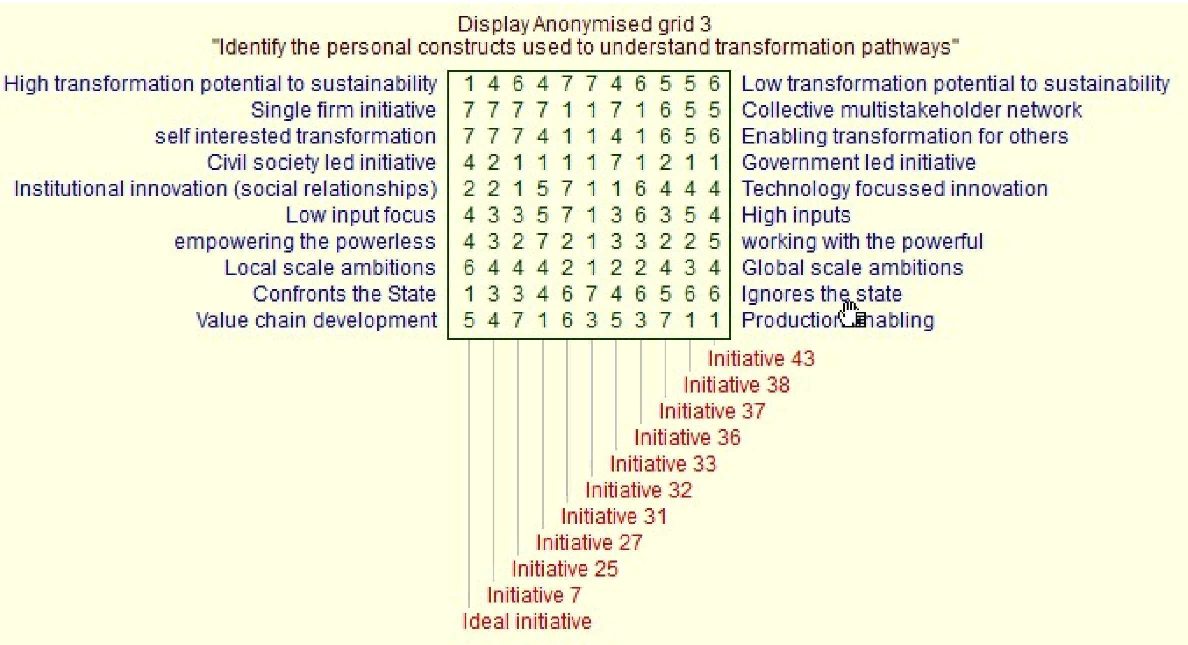
Design/Methodology/Approach

The Repertory Grid Technique (RGT) is a method for eliciting such constructs that is widely accepted in the literature (Jankowicz, 2005). RGT is guided by Personal Construct Theory (Kelly, 1955), which states that a person's understanding of objects they interact with is built from a collection of related similarity–difference dimensions, referred to as personal constructs. Furthermore, the theory postulates that we, as humans, reduce even complex phenomena, such as nature or justice, to manageable numbers of 'key' constructs: typically, around 10. The theory can be applied in research projects on a wide variety of themes (Whyte and Bytheway, 1996), is applicable to any domain, and has been used for conceptual modelling across a very wide range of disciplines (Gaines and Shaw, 2021).

We followed the process described by Jankowicz (2005) to apply the RGT to identify the different personal constructs used by researchers working within the Horizon Europe project: ENFASYS, to understand and explain transformation pathways towards SFS. Specifically, 11 project partners were interviewed to identify the constructs they use to describe and understand specific transformation initiatives that they were familiar with, as they had recently completed a review of the initiatives as part of the ENFASYS project. During the interview, they were given randomly selected groups of three transformation initiatives and asked to divide them into two groups based on any attribute of their choosing. They were then asked to nominate the attribute they had used and to define polar opposites of this attribute to define a differentiating construct before rating, on a Likert scale, each of the transformation initiatives against this construct. The process was repeated with further randomly chosen sets of initiatives until no new constructs were forthcoming. The result of this procedure was a repertory grid for each respondent that consists of their repertoire of constructs to describe transformation initiatives, along with the rating for each initiative against each construct. An example grid is shown in Figure 1.

Figure 1: Example repertory grid

The rows are the extremes of the constructs identified in the repertory grid procedure. The columns are the initiatives that are the study elements. The numbers represent the rating of each initiative against each construct, on a scale of 1-7, with the left extreme coded as 1 and the right extreme coded as 7.


Display Anonymised grid 3
"Identify the personal constructs used to understand transformation pathways"

	Ideal initiative	Initiative 7	Initiative 25	Initiative 27	Initiative 31	Initiative 32	Initiative 33	Initiative 36	Initiative 37	Initiative 38	Initiative 43	
High transformation potential to sustainability	1	4	6	4	7	7	4	6	5	5	6	Low transformation potential to sustainability
Single firm initiative	7	7	7	7	1	1	7	1	6	5	5	Collective multistakeholder network
self interested transformation	7	7	7	4	1	1	4	1	6	5	6	Enabling transformation for others
Civil society led initiative	4	2	1	1	1	1	7	1	2	1	1	Government led initiative
Institutional innovation (social relationships)	2	2	1	5	7	1	1	6	4	4	4	Technology focussed innovation
Low input focus	4	3	3	5	7	1	3	6	3	5	4	High inputs
empowering the powerless	4	3	2	7	2	1	3	3	2	2	5	working with the powerful
Local scale ambitions	6	4	4	4	2	1	2	2	4	3	4	Global scale ambitions
Confronts the State	1	3	3	4	6	7	4	6	5	6	6	Ignores the state
Value chain development	5	4	7	1	6	3	5	3	7	1	1	Production enabling

While the repertory grid technique is a powerful method to elicit the constructs that an individual respondent uses to understand a phenomenon, in this case, transformation pathways, the outcomes are specific to the individual and context. However, the aim of this contribution is also to identify generalizable and context-independent constructs that are shared by all, or many, members of the group, so the personal constructs from the individual respondents need to be aggregated. This is not a trivial task. The constructs were elicited from respondents who used their own words and who had no knowledge of one another, so there was no collaboration in finding agreement in terminology. To complicate matters further, there is no inherent ranking of the elicited constructs in terms of relevance in understanding and explaining transformation pathways.

In order to aggregate the personal constructs that were elicited from different respondents into a consolidated structure of pathways that could be ordered according to relevance, we worked with the method described by Honey (1979). This method relies on including a common, and broad, construct, to serve as a reference point, so that distances of the constructs elicited by individuals from this common point can be calculated using a correlation analysis. In this study, and in accordance with Honey's (1979) recommendation that the common construct should be a generalization related to the aims of the study, the predefined common construct to which the partners' personal constructs could be related was the "transformation potential (high or low)" of each initiative. The results were then revisited in a validation workshop with the 11 respondents who had completed the grid exercise as well as the rest of the project partners.

Findings

The RGT procedure revealed 103 personal constructs, which were grouped according to their content into 11 thematic clusters, shown in Table 1. The columns in the table indicate groupings of constructs according to the strength of correlation, calculated using Honey's (1979) method, with the fixed term: 'Transformation potential to sustainability'. The numbers in the table indicate the number of constructs for each correlation grouping in each theme. These allow an interpretation of the relevance, or importance, of each cluster in terms of transformation potential, in which clusters with more constructs with strong correlation are more relevant, or important, than clusters with fewer constructs with weaker correlation. Essentially, these allow us to place the clusters in order from most relevant to least relevant, as shown in Table 1.

Thematic cluster	**Correlation >0.8**	**Correlation 0.65-0.8**	**Correlation 0.5-0.65**	**Correlation 0.3-0.5**	**Correlation <0.3**	**Total**
Degree of stakeholder inclusion	3	2	1	5	8	19
Degree of anchoring in farming	3	1	4	1	6	15
Orientation to market/supply chain	0	0	1	1	12	14
Degree of autonomy and self-determination	4	1	4	1	2	12

Scope of ambitions for change	3	2	1	2	0	8
Scope of ambitions of reach	1	1	0	4	2	8
Degree of research integration	0	2	0	1	4	7
Input focus	0	1	1	2	2	6
Clarity of aims	0	1	1	2	2	6
Funding	0	0	1	4	0	5
Planned longevity	0	1	0	0	2	3

Table 1: Numbers of constructs at different levels of correlation with transformation potential in each thematic cluster.

Collectively, these identified clusters, which consist of the elicited constructs, provide an understanding of transformation pathways expressed in terms of the characteristics that contribute to the success or otherwise of initiatives that are navigating these pathways. From the construct elicitation we learn that the *degree of stakeholder inclusion*, the *degree of anchoring in farming*, the *degree of autonomy and self-determination*, as well as *scope of ambitions for change* are considered to have high relevance for transformation because these clusters contain constructs that correlate strongly with the transformation potential of initiatives. The degree of *autonomy and self-determination* and *scope of ambitions for change* were also rated as important, although less so than the first two thematic clusters. *Autonomy and self-determination* appear to be of minor importance when it comes to system changes that require radical confrontation. *Ambitions for change* was ambiguous because, on one hand, the assessment of whether a change is big enough is subjective and the initiative's level of consciousness about the interconnected nature of the issues at hand defines its potential for change. It is not only the action itself that matters but the underlying intention is also relevant. On the other hand, not all partners agreed that *ambitions for change* of single initiatives needed to be large. Some thought that a major change at system level can also take place by going forward in small steps.

At the validation workshop, project partners unanimously confirmed the importance of *stakeholder inclusion* and *anchoring in farming*. The validation workshop revealed two more aspects as important for promoting high transformation that didn't emerge as primary aspects in the construct elicitation: Almost unanimously, workshop participants regarded *orientation to market* of high importance because a change towards SFS can be stimulated if value chains adapt to consumer demands for a sustainable food supply. As long as food is a commodity, its relation with markets is fundamental, especially from a farmer's perspective. Moreover, the participants highlighted the role of *clear transformation aims* of transformation initiatives making it the most important aspect overall emerging from the workshop.

Implications

The research is not intended to prescribe a distinct ontology and epistemology, but rather to stimulate reflection on potentially diverging understandings of transformation pathways. A clear limitation of this study is that it was based on the understandings of 11 researchers in the context of transformation initiatives in European countries, so caution is advised when applying these results in different contexts. Despite these weaknesses, the robustness of the methodology and the selection of respondents produced a rich data set that allows confidence in the interpretation that may be useful for researchers investigating similar phenomena in other contexts.

In summary, the individual assessments of the transformation potential are subjective and related to the diverse ways in which the respondents think about the given phenomenon in their world. By collating these findings through a clustering of constructs, and comparison between the different project partners' assessments of the transformation potential within each cluster, we developed a shared understanding of which themes are considered to be important to promote transformation. Specifically, *stakeholder inclusion*, *anchoring in farming*, *autonomy*, and *change ambitions*, correlated strongly with transformation potential, and the subsequent validation workshop emphasized *market orientation* and *clear transformation aims* as pivotal.

The comprehensive examination of transformation initiatives and project partners' personal constructs identified the themes that are used to understand transformation pathways, which provides a resource for understanding and explaining the characteristics of transformation pathways to sustainable AFS. Recognition of the context dependency of the identified constructs facilitates reflection on potentially diverging understandings, which has implications for the conclusions and recommendations of research into transformation pathways.

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Building Sustainable and Resilient Food Systems: A conceptual framework to Evaluate territorial Food systems

Nassim Chahid

Abstract:

In a context of global transition, and to address the main challenges impacting our food systems, it is necessary to implement a significant change regarding food production systems, ecosystem management, and food related activities that supports achieving the sustainable development goals. The objective of this contribution is to explore how to achieve a cohesive, sustainable development of the food system at a territorial level through the assessment of food system sustainability and resilience. The literature today provides a multitude of frameworks to assess food systems performance, resilience and sustainability. However, there is still a lack of knowledge and conceptualization on how to adapt these food system frameworks to territories. As a result, we propose a conceptual framework that allows the identification of levers of action through a participatory process with stakeholders from different backgrounds to build more sustainable and resilient food systems.

Purpose

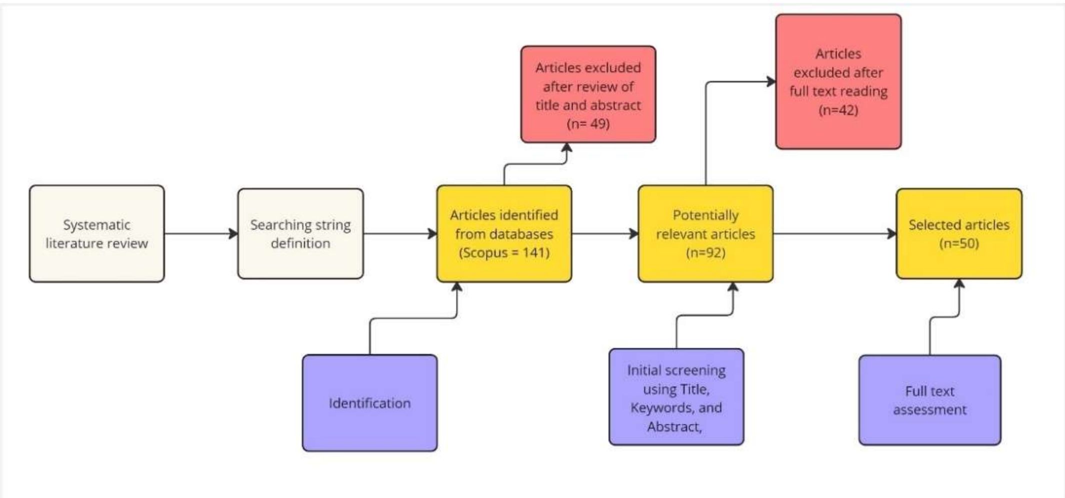
Food systems are interconnected to economics, life sciences, engineering, agriculture, education and much more (Newnan, 2017). They are facing a multitude of challenges encompassing economic, environmental, agricultural and social dimensions that have an impact on food security and livelihoods (of both consumers and economic actors). A global environmental, social, digital and economic transition must occur to foster food system sustainability and territorial resilience, in order to ensure long-term food security and environmental protection. The literature provides a multitude of frameworks to assess food systems performance, resilience and sustainability, that involve stakeholders at national and sub-national scales (regional/territorial/local) (SAFA framework; TEEB, 2018; HLPE, 2020; Hebinck et al., 2021; Allen and Prosperi, 2016; Les Greniers d'Abondance/CRATer, 2020; Butler et al., 2021; David-Benz et al., 2022; Sirdey et al., 2023). Despite previous significant efforts to develop comprehensive food system frameworks, there remains a deficiency in understanding and conceptualization regarding the analysis of food systems at the territorial level. Some frameworks rely on a rigorous indicator protocol, emphasizing quantitative metrics at a national scale rather than qualitative data (Sirdey et al., 2023). Others target a very specific context with data that may pose problems for replication in other territories. Some come across data availability problems. Some frameworks fail to consider the link between action levers and policy implications, or mention it in a generic way. One of the issues that food system frameworks face is the lack of implication of stakeholders on a territorial scale. According to Sirdey et al. (2023), there is a need for more systemic, consultative and multiscale methodologies that consider dynamics, in order to effectively support policy dialogue and decision making. The articulation between decision-making levels, as well as actor-centered approaches that emphasize the contribution of each category of actors are lacking (Sirdey et al., 2023). Further attention needs to be given to the identification of local context specificities to identify adapted levers of action, which is why we have decided to focus our work on rural territories, making it our entry point.

Drawing from the existing literature on a) multidimensional assessment of sustainable food systems, b) territorial and rural policies related to food system management, c) the role of territorial stakeholders, and on d) ecosystem resource management linked to food system dynamics, we build a comprehensive conceptual framework that analyzes food system dynamics at a territorial scale to guide local action towards more sustainable and resilient food systems. This framework englobes a holistic vision to assess the food system that includes socio-cultural, equity, power relations, trade-offs, synergies, and other dimensions such as food security, value chains and food supply chains, foodsheds, food system drivers, resilience, sustainability, nutrition, policies and governance. The goal is to provide policymakers with the necessary information about the needs of rural territories. Our work builds on sustainability and resilience theories in a global food system context to provide insights into the complexity of the food system assessment at a territorial/local level. We also discuss the role of local policies which support a sustainable transition, and their implementation in a territorial and rural context.

1. Design/Methodology/Approach

To grasp the diversity of the approaches and methodologies which assess the food system, we conducted a systematic literature review and meta data analysis by reviewing documents on the dynamics and transitions of territorialized food systems for a better sustainability and resilience, through lever action indicators alongside measurement indicators. We conducted a keyword search in Scopus, the search protocol is represented in a diagram (fig 1) and includes the following terms: (food system* OR agrifood system* OR agri-food system* OR agrifood chain OR agri-food chain OR agrifood supply OR agri-food supply*) AND (asses* OR map* OR indicator* OR metric* OR method* OR approach*) AND (polic* OR instrument*) AND (dynamic* OR transition* OR transformat*) AND (resilien* OR sustainab*). The criteria included papers related to our research domains which are Environmental science, social science, Agriculture and Biological sciences, Decision sciences and Economics, and Econometrics and Finance. This allowed us to obtain our initial database of 141 papers. First, we reviewed the title, abstract, and keywords of each publication. We excluded 49 which did not contain relevant information for this research, they discussed topics like e-commerce, environmental footprint, agribusiness. Following a rigorous review of the body of the papers, and taking into consideration the inclusion/exclusion criteria, we defined whether it answered the research question. 50 papers were maintained. We strictly adhered to the English language criterion since the proportion of studies not written in English is less than 5%, and limited the search to papers published between 2015 and 2024 to reduce the volume of the documents to be screened, focusing on relevance. We also conducted semi-structured interviews with local stakeholders. This brings a more nuanced understanding of the functioning of territorialized food systems and the governance system at small-scales. It also helps in collecting data and building indicators using the dimensions of the framework.

Fig. 1 – Flow chart for the database search of publications for systematic review

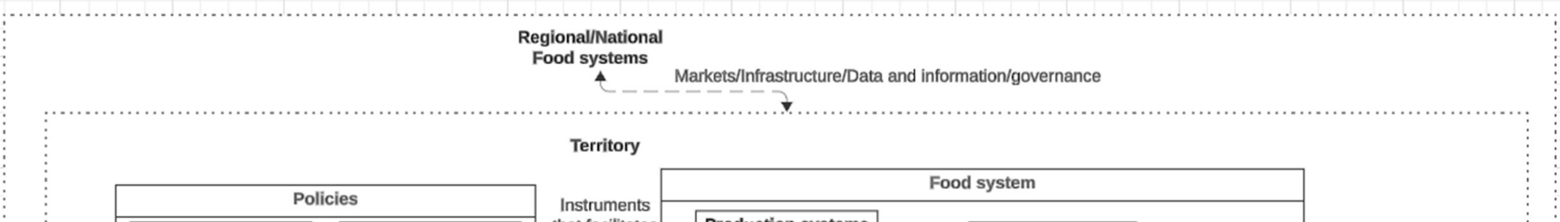


Findings

By following a systemic research method that includes food system drivers, context, dynamics, scales, and feedbacks, through a participatory process, the framework can help identifying what needs to be included to tackle territorial food system challenges. Several studies have covered food system sustainability through various lenses, 38% of the documents selected discuss sustainability and resilience in agri-food systems, 11% focus on the analysis of food systems using a circular economy and food waste approach, 15% discuss policies and governance and bring insights for more sustainable and resilient systems. 17% of the papers explore food value or supply chains, 8% papers address food security and nutrition by discussing diets and health, and 11% consider the dynamics of the system to go towards a transition and a transformation of the food system.

Building on this literature review, the conceptual framework that we have developed (fig 2) relies predominantly on frameworks established in the literature review and particularly on the two frameworks discussed in this section. Existing conceptualizations of food systems bring out the dynamic relationship between food system components (Gaitán-Cremaschi, 2019). Other conceptual models (Ericksen, 2008) focused on global environmental drivers and put emphasis on socio-economic and environmental feedbacks. Our framework shows the link between food systems dimensions, feedback loop dynamics, policies, and land tenure, with a focus on the dynamics to achieve food security at a territorial scale in a more sustainable and resilient way. Understanding the interplay among these components is essential for shaping effective strategies that address the complex challenges faced by food systems. This can be achieved through collaborations, partnerships among farmers, businesses, government agencies, establishing regional food hubs that facilitate coordination among local producers, processors, and consumers, or resource and knowledge exchange. Land tenure is also a critical factor which provides farmers the incentive to invest in sustainable agricultural practices, and balances the utilized agriculture area. Ensuring equitable access to land contributes to food security (ILC, 2021), Policies play a crucial role in shaping these dynamics by setting regulations, incentives, and frameworks that govern food production, trade, and consumption. Food policies shape the conditions in which people make food choices, which affects food environments. Although this framework focuses on territorial food systems, we cannot deny that territorial food systems are embedded into broader systems (regional, national, international) in various forms such as supply chain integration (selling to regional/national distributors), infrastructure development to improve market access. Combining top-down and bottom-up actions within territories is a complex process that requires a deep understanding of a local framework of rules, tools, and dynamics (Basso et al., 2022). Stakeholders can therefore create a more integrated and resilient approach to food security, sustainability and equity. As territories work towards food security, which is the main outcome of food systems, they also improve social justice, power imbalances, and deliver better socio-economic conditions to the rural community.

Fig. 2 - Conceptual framework of territorial food systems dynamics



Practical Implications

An implication of these findings revolves around the importance of empowering local decision-makers to effectively utilize the proposed framework to design tailored actions for their territorial food systems. By understanding the components and dynamics of the food system, decision-makers can strategically allocate resources, implement specific interventions and foster collaborations to assess critical issues within the territory such as equitable food access, fair value distribution within the food chain, and the preservation of ecosystem services. Furthermore, we can also discuss the possibility to apply the framework to other European and non-European rural territories to support community leaders, stakeholders, and organizations to assess, plan, and implement strategies that strengthen local food systems, ultimately promoting community well-being, resilience and sustainability.

Theoretical Implications

Our conceptual framework is in line with the literature on food system assessment which encompasses a multitude of methodologies and theories that provide diverse lenses through which researchers are able to analyze and evaluate different aspects of food systems. It contributes to a more comprehensive understanding of the overall resilience, and sustainability of food systems. The particularity is that it is based on multidimensional approaches for the quantitative and qualitative assessment of food systems, as well as a dialogue with local stakeholders who have a solid understanding of their territory which gives more power to our methodology. With a better understanding of the dynamics within the territory that this framework is intended to, stakeholders can identify levers of action by implementing policy interventions to improve the farming system and the allocation of resources, to tackle market and infrastructures issues, and to raise awareness about the benefits of local food products.

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Justice conceptualisations in the context of explorative circular food system scenarios

Annemarieke de Bruin[a], Lieneke Bakker[a], Niels R. Faber[b], Evelien M. de Olde[a], Katrien J.A.M. Termeer[c], and Imke J.M. de Boer[a]

[a] Animal Production Systems group, Wageningen University and Research, the Netherlands, Annemarieke.deBruin@wur.nl

[b] Centre for Sustainable Entrepreneurship, University of Groningen, the Netherlands

[c] Public Administration and Policy group, Wageningen University and Research, the Netherlands

Abstract:

Across the world, as well as in the Netherlands, a transition is ongoing towards a circular food system. To support this transition researchers have developed ecological principles to theoretically model environmental implications of circularity. However, it is unclear what uncertainties and systemic challenges arise in practice. This is particularly important when considering recognition, distributive, and procedural justice implications of the transition towards circular food systems. We present a case study in which academics and regional stakeholders together developed explorative circular food system scenarios for the North of the Netherlands in 2050. Scenarios were developed in relation to two key uncertainties: different levels of government steering and the geographic scale of the food system. During the process participants used a range of distributive and procedural justice conceptualisations. Across the scenarios they recognised producers, consumers, marginalised communities, and nonhumans as subjects of justice. In terms of distributive justice, participants felt the region has an obligation to use its fertile land to produce food for people elsewhere. Procedurally, they identified that a transition depends on geo-political stability and trust in government. Our study shows how explorative scenarios help to examine assumptions related to justice implications of a transition towards a circular food system.

Keywords: Circularity, food systems, transitions, scenarios

Introduction

Across the world, as well as in the Netherlands, a transition is ongoing towards a circular food system. To support this transition researchers have developed ecological principles that contribute towards a circular food system (De Boer and Van Ittersum, 2018; Muscat et al., 2021). Muscat et al. (2021) summarise these principles as: "*1) safeguarding and regenerating the health of our (agro)ecosystems; 2) avoiding non-essential products and the waste of essential ones; 3) prioritizing biomass streams for basic human needs; 4) utilizing and recycling by-products of (agro)ecosystems; and 5) using renewable energy while minimizing overall energy use*". These principles have so far only been used by researchers to theoretically model environmental implications of circularity at different scales (e.g. van Selm et al., 2022; van Hal et al., 2023) or to model certain transition pathways (e.g. Alvarez-Rodriguez et al., 2024). However, it is unclear what key uncertainties and systemic challenges arise in practice in the context of a transition towards a circular food system. This is particularly important when considering the justice implications of a transition towards circular food systems.

Transition processes in general, and food system transitions in particular, have recognition, distributive, and procedural justice implications. Transition processes can contribute to a just transition by addressing injustices, but can also exacerbate existing injustices or create new ones (de Bruin et al., 2024). Stakeholders involved in transitions need to recognise and reflect on assumptions about, for example, who should carry the costs of the transition and who should be involved in decision-making processes. It is important to make these assumptions explicit as different people conceptualise justice differently and have different perspectives on what is just (Cadieux and Slocum, 2015; Dirth, Biermann, and Kalfagianni, 2020). For example, de Bruin et al. (2024) found a wide range of justice conceptualisations used by authors in the food systems literature. Scenario exercises can help to examine assumptions related to justice implications of a transition and make people's justice conceptualisations more explicit. Participatory foresight approaches, and more specifically explorative future scenarios, investigate plausible, challenging futures with the aim to examine assumptions about what is needed in a transition (Hebinck et al., 2018; Kok et al., 2011; Kok and van Vliet, 2011). The aim of this paper is to offer insights into the justice conceptualisations that emerged within explorative circular food system scenarios.

Methodology

This paper draws on a learning process of a larger project[2] in which we developed explorative future scenarios. The overall aim of the project was to evaluate and further develop the transition towards a circular food system in the context of the North of the Netherlands. This region constitutes the provinces of Friesland, Groningen, and Drenthe and is characterised by a linear food system (Tamsma et al., 2024). In the region an increasing number of circular agricultural initiatives contribute to the ongoing food system transition (Hoogstra et al., 2024). The learning process brought together stakeholders from across the regional food system with academics from the social and natural sciences over the course of two years (2022-2023). Stakeholders were purposively sampled from across the food supply chain and related domains including the financial sector, local and national government, and nature organisations. In this way we were able to bring together people with a wide range of views and experiences from across the food system.

For the explorative scenario development we followed the first three stages of the explorative future scenarios process as described by Kok et al. (2011). The strength of this particular process is that it allows participants to explore alternative food system futures and to imagine what is needed to bring about transformative change. In this process different groups work at the same time with the same preconditions, but with different starting points for their scenarios. This allows us to compare the outcomes of the scenarios and to analyse underlying assumptions about justice implications. As results of one stage of the process inform the setup of the next stage we describe the scenario

[2] The 'Circular Agriculture in North-Netherlands: Daring scenarios and Interlinked Transformation' (CAN-DO-IT) project runs from 2020 to 2025

methodology in more detail in the results section. During the scenario process we did not inform participants that we would analyse the results from a justice perspective to limit our influence on their conceptualisations of justice.

To identify the range of justice conceptualisations used by participants we analysed the outcomes of the explorative scenario process using the framework developed by de Bruin et al. (2024). This framework defines a conceptualisation of justice as consisting of three parts: 1) who is recognised as subject of justice?, 2) what is (re)distributed or how are decisions made?, and 3) the relevant principles of justice. Through this we can identify recognition, distributive, and procedural justice conceptualisations.

Findings

We first describe the outcomes of the three stages of the scenario process and then present the justice conceptualisations that emerged.

3.1. The scenario process

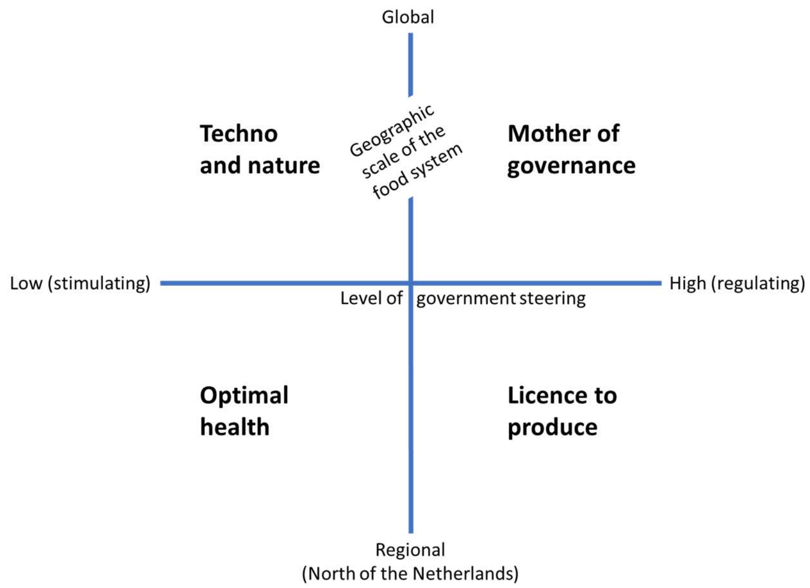
In the first stage participants identified main changes and concerns about future developments in the region. We held one-to-one semi-structured interviews with the stakeholders from across the food system, whom we had recruited for the learning process. In these interviews we asked participants to describe the current regional food system, which changes they had noticed in the food system in the region, whether they perceived that the food system was becoming more just or more unjust, how they would describe the future regional food system in 2050, and what they thought about circular agriculture. From the interviews we identified a wide range of themes related to main changes and concerns. These included government steering, diversity of business models, polarisation in society, improved health and wellbeing of natural resources, dietary changes, and unequal power dynamics in the supply chain.

The second stage involved the discussion of key uncertainties and driving forces. In a workshop we first presented and discussed the current state of the food system transition in the region. After this we went through the themes related to main changes and concerns that had emerged from the interviews. We asked all participants to vote on which of these they found most uncertain and which they found most important. The themes that were considered most uncertain and most important were: consumer behaviour, the real price of food, and government steering. Polarisation and power dynamics in the supply chain were also considered uncertain and participants also considered knowledge exchange and new economic models for farmers important. Based on these results we identified two main uncertainties and their extremes for the food system in the region. One uncertainty was the geographic scale of the food system (extremes ranging from regional to global) as this drives changes in consumer behaviour, food prices, and circularity of the food system. The second uncertainty was the level of government steering (extremes ranging from a low level of steering, also referred to as stimulating government, to a high level of steering, also referred to as regulating government), as this interconnects also with power dynamics in the supply chain, food prices, consumer behaviour, and polarisation. These two main uncertainties together created the spaces in which we developed scenarios (Fig. 1).

In the third stage we developed the scenarios for the food system in the North of the Netherland in 2050. Participants were assigned to four different groups. Each group was given the five ecological principles mentioned in the introduction as pre-conditions. We then asked participants to explore the four extremes of the two main uncertainties (Fig. 1). To develop their scenario they were asked to discuss: 1) the food chain including which products make up the diets in 2050 and how much of these products are imported or exported; 2) possible collaboration across the supply chain focused on the use and reuse of biomass; 3) economic models for farmers in relation to public goods and services as well as food production; 4) and what roll the government plays in this future, including the types governance instruments that will be used. In a plenary session the groups presented their final scenarios and participants reflected on similarities and differences. The following keywords describe each scenario and Figure 1 shows where on the axes each scenario is situated:

- Scenario 'Techno en nature': Global, glocal, eco-modernism, abundance of energy, trust and transparency, urbanisation, local-for-local, technology and innovation.
- Scenario 'Mother of governance': Sustainable Trade Organization; International nutrient balance, transparent systems, true pricing, food education, global networks, regional circularity.
- Scenario 'Optimal health': Technology, quality and healthiness of food, plant-based diet, short supply chains, custom made order, local circularity, diversity, use of human excreta
- Scenario 'Licence to produce': Short supply chains, diversity, healthiness and quality of food, plant-based diets, food education, production area, use of human excreta

Figure 1. The four scenarios that were developed along the two axes of uncertainties (level of government steering and geographic scale of the food system)



3.2. Justice conceptualisations

Preliminary results show that in terms of conceptualisations of justice participants used a range of distributive and procedural conceptualisations across the scenarios. Within these conceptualisations they recognised the following subjects of justice: producers, consumers, citizens, and nonhumans in the region and elsewhere. Distributive conceptualisations included ensuring the health and wellbeing of nonhumans such as animals and nature; providing accessibility of healthy and enough food for communities who are marginalised due to their vulnerability; and viable livelihoods for producers who produce sustainably. Humans elsewhere were considered in all the scenarios. Participants felt it was an obligation of the region to use its fertile land to produce food for the benefit of people who live in areas where less food can be produced. In the context of the global food system scenarios this meant people across the world whereas in the regional scenarios this referred to people within Europe. Some scenarios specifically mentioned diversity in production approaches, including high-tech and smallholder, nature-based, food production, as a characteristic of the future circular food system in the region. Procedural justice conceptualisations came up in relation to different governance arrangements. Most scenarios focused on a government that sets goals rather than particular measures to allow farmers autonomy in how they reach these goals. Transparency across the (global or regional) supply chain was another procedural justice conceptualisation. The scenario 'Mother of governance' included a global 'Sustainable Trade Organisation' in charge of global information sharing and certification. Others explored self-regulation in addition to government safeguarding of minimum levels of societal values. Participants noted that all scenarios assumed a noticeable trust in the ability of governments to steer the transition.

Practical implications

In terms of practical implications, we can reflect on three insights related to the key uncertainties and systemic challenges that the process have made explicit. First, a transition towards circularity is dependent on other sustainability transitions, especially the energy transition. Participants became aware that circularity has a high energy demand and that without sustainable energy the transition towards circularity will be undermined. Second, the transition depends on trust in governments and a stable geopolitical context. Here it is important to recognise that the workshop took place during a time of increasing polarisation in the Netherlands and international geopolitical unrest. Third, participants frame the government as having the obligation to address injustices and safeguard societal values in the transition towards circularity. Across the scenarios participants felt that government steering was needed to ensure support for marginalised communities and to encourage healthy diets.

Theoretical implications

Our study shows how explorative scenarios can help to examine assumptions related to justice implications of a transition towards a circular food system. Through the exercise different conceptualisations of justice were made explicit. In addition, the ecological principles as developed by Muscat et al. (2021) challenged participants to think in more detail about circularity. At the same time participants challenged the principles by placing them within a practical context in which issues of governance, finance, and justice play a role. The scenarios also show how these circularity principles interrelate with other assumptions about the food system transition, including dietary changes towards a more plant-based diet.

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Nature-Positive Agriculture for People and Planet: Gender Considerations for Transition Pathways

Kristin Davis[a], Dickson Kinuthia[b], Elsa Wallin[c], Elizabeth Bryan[d], Balentine Oingo[e], and Salome A. Bukachi[f]

[a]International Food Policy Research Institute, k.davis@cgiar.org

[b]International Food Policy Research Institute, d.kinuthia@cigar.org

[c]Swedish University of Agricultural Sciences, elsawallin77@gmail.com

[d]International Food Policy Research Institute, e.bryan@cgiar.org

[e]Passion Africa Ltd., oingobalentine@gmail.com

[f]Passion Africa Ltd., sallybukachi@yahoo.com

Abstract: Nature-positive solutions are a transition pathway to sustainable food system transformation. We bring a gendered perspective to inform the transition process for Kenyan smallholder farmers, using qualitative data collected in three counties as part of the CGIAR Initiative on Nature-Positive Solutions. The analysis uses a theoretical framework focusing on gendered motives, means, and opportunities to adopt nature-positive farming practices. The findings show distinct gender roles and responsibilities, with women predominantly engaged in agricultural tasks. Motives, such as closeness to nature and sustainability focus, vary with these gendered roles. Resources were generally allocated favouring men, further strengthening their traditional role as household head and main decision-maker. This influenced men's and women's means and opportunities to adopt nature-positive solutions, and must be carefully considered when planning, implementing, and evaluating programmes supporting smallholder farmers in this transition pathway. Practical implications include the need for gender-sensitive information and training and to ensure that nature-positive practices promoted are equally accessible and beneficial for men and women. As a theoretical implication, women's and men's roles in nature conservation and sustainable farming practices are nuanced and are the result of motives and means shaped by prescribed gender roles rather than inherent gender differences.

Keywords: Gender, nature-positive, resources, rights, sustainability

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Purpose

Nature-positive solutions are one transition pathway to more sustainable farming systems; supporting the restoration of natural resources, smallholder resilience, and prevention of biodiversity loss and environmental degradation under a climate crisis (FAO 2019; von Braun et al., 2021). The CGIAR Initiative on Nature-Positive Solutions helps smallholders transition to food systems delivering nutritious food and equitable livelihoods while ensuring that agriculture is a net positive contributor to nature. Because women and men have different roles, preferences, control, and access to resources and services (Momsen, 2020), we must examine gender-differentiated motives, means, and opportunities to adopt nature-positive solutions. The objective of this paper is to provide insights into gender considerations for nature-positive production, by describing farming practices, gendered roles in natural-resource-based livelihoods, and uptake of nature-positive solutions, using qualitative data collected Kenya.

Methodology

This paper uses a case study approach to facilitate deep understanding of gender considerations for nature-positive solutions as a farming system transition pathway (Baxter & Jack, 2008). We collected data using key informant interviews, semi-structured interviews with individual farmers, participatory resource mapping, seasonal calendars, and focus group discussions. We purposively selected 19 communities from the Initiative implementation sites in Kajiado, Kisumu, and Vihiga counties for data collection to cover a range of agroecological conditions and farming systems. Interviews and focus group discussions were recorded, transcribed, and translated to English. Inductive and thematic approaches (Cooper et al., 2012) were used for data analysis by developing coding schemes to guide the data analysis. We used open coding along with the constant comparative method (Glaser & Strauss, 1967) to identify emerging themes (codes) and sub-themes, patterns, and trends. A codebook was developed at this stage. Data were analysed using NVivo 14.

The analysis is structured around an adapted version of the conceptual framework by Meinzen-Dick and colleagues (2014) which draws on ecofeminist theory, feminist political ecology, and intrahousehold and natural resource management literature to understand women's and men's contributions to sustainable use of natural resources. Using the framework, we explore how gender influences motives, means, and opportunities of smallholder farmers to use nature-positive solutions. We analyse the following framework categories, which move from more intangible to more tangible aspects: closeness to nature, focus on sustainability, rights to resources, opportunities to exploit resources, and adoption of sustainable practices.

Findings

Motives: Closeness to Nature

Ecofeminist scholars argue that women are closer to nature materially, socially, ideologically, and biologically (Meinzen-Dick et al., 2014). We focus on the material factors, which are the environmentally based tasks and duties of women and men, and on the social factors, based on cultural norms of women's and men's use of s paces.

Women were perceived to adopt nature-positive practices because of their "nurturing" nature which drives their desire to ensure that agriculture remains productive to provide sufficient food for their families. Women and men had distinct production roles that varied by crop and livestock type. Agricultural production for household consumption was almost exclusively the domain of women, while men were more involved in commercial production. Women focused on crops like maize and vegetables, and poultry destined for household consumption or lower-value market sales. Men engaged more in producing beans, maize, millet, and high-value livestock fetching higher market prices. A man in Kisumu County stated, “Somebody who is doing it for commercial purposes doesn’t leave it to women.”

A clear gender division of labour was reported. Women had more responsibilities tied to the domestic sphere, such as cooking, cleaning, and fetching firewood and water, and thus were more limited in mobility and time constrained than men. Despite higher domestic demands, women also contributed a large share of the agricultural labour on family farms or as casual labourers in all three counties. Agricultural tasks were divided according to the perceived strengths of women and men. For instance, women performed tasks such as planting and weeding, "because they can bend a lot more," whereas digging or ploughing was viewed as requiring a man’s strength. Pesticides were used to a higher degree on plots destined for commercial activities, and men carried the main responsibility of applying them. The gendered division of labour and its impact on interactions with nature and agricultural production have implications for women’s and men’s concerns about sustainability, discussed next.

Motives: Focus on Sustainability

Ecofeminist scholars further argue that women focus more on sustainability and conservation due to their inherent nature to care and conserve (Meinzen-Dick et al., 2014). However, we find that inclination to conserve comes more from socially prescribed gender roles. Due to different roles and responsibilities, men and women were impacted differently by improvements or degradation in the natural resource base, leading to distinct preferences for nature-positive solutions. While all respondents recognized the deteriorating quality and availability of water in their area, women and girls spent more time fetching water for domestic and irrigation uses and thus were more likely to highlight these issues as a challenge. The degradation of river water quality from heavy pollution did cause a slight shift in gender roles. Men began to participate in some traditionally female-dominated tasks, such as fetching water using motorbikes; this has also become a new source of income for men. Women actively participated in planting trees (especially fruit) in the homesteads, a task that was previously reserved for men. This shows that it is not always the task itself that is inherently gender-coded, but rather the way in which it is performed. Gender roles thus seem to shift in the face of crises.

Means: Rights to Resources

Meinzen-Dick and colleagues (2014) state that rights to resources contribute to motives as well as means and opportunities. Our application of the framework shows that it better applies to means. Even when motivated to take up nature-positive solutions, rights to resources are required to undertake conservation (Meinzen-Dick et al., 2014). The literature on property rights highlights the concept of bundles of rights to natural resources, and includes an individual’s ability to access, decide, withdraw, manage, control, and benefit from resources in addition to outright ownership rights (Schlager & Ostrom, 1992). Men and women often have different rights to resources that shape how they interact with natural resources and their ability to conserve (Meinzen-Dick et al., 1997). Although ecofeminist arguments on closeness to nature and sustainability preferences of women imply that women are less likely to exploit resources, women have fewer rights to resources. The differing level of access and rights to resources is shaped and reinforced by contextual social gender norms, negatively impacting on the agency of women to make decisions on the use of nature-positive solutions.

Despite changes in Kenyan law in 2010, which allow women to own and inherit land (Farnworth et al., 2013), land ownership was dominated by men in the study sites. The underlying social norms favour male inheritance, frequently excluding women from owning land and decision-making processes. This meant that long-term investments in the natural resource base, such as planting trees, were more likely to benefit men and increased men's interest in such practices. Women often had the right to use a smaller plot of land for vegetable and subsistence production but were expected to provide labour on plots destined for commercial production controlled by their husband. It was often the task of women to bring these products to the market and sell them, but revenues belonged to their husband; thus, women did not have fructus (benefit) rights.

Men owned larger animals, such as cows, goats, or sheep, and could sell them without consulting their wife. Women owned poultry to a larger extent than men and provided care for the larger male-owned animals. Men dominated decisions on spending agricultural income, which puts limited resources at women's disposal, discouraging their adoption of nature-positive practices and conservation of natural resources.

Opportunities to Exploit Resources

The previous sections dealt with motives (closeness to nature and focus on sustainability) and means (rights to resources), which affect opportunities. That is, motives and means affect the ways in which men and women engage in decision-making over the use of resources and adoption of sustainability practices and their bargaining power in those negotiations. Decision-making and bargaining power are crucial elements as they influence who can exploit available resources, and how (Meinzen-Dick et al., 2014).

Both men and women in Kisumu emphasized the importance of consultation before reaching decisions on agricultural production, however, men had the final say in decision making even in cases where decisions were taken jointly. According to one woman, "discussing brings success, while if you don't discuss you are doomed to fail." However, within the household, men were typically seen as the primary decision-maker, so that in a disagreement "the wife has to yield." Men perceived the decision-making process to be more equitable than women.

Beyond the household, respondents also observed increased recognition and roles for women in leadership in natural resource management committees, such as community forest associations. This provides another avenue for women to exert influence over natural resource decisions at the community level, which may be particularly important if their ability to influence household decisions is limited.

Motives, Means, and Opportunities to Adopt Sustainability Practices

The combination of unequal resource rights and decision-making power favouring men reduces opportunities for women to adopt sustainable farming practices. Even if there are motives and resource rights to use nature-positive practices, limited access to complementary resources, such as information and knowledge, time, labour, or finances, can prevent adoption (Meinzen-Dick et al., 2014; Njuki et al., 2022).

Men and women had extensive knowledge about agricultural tasks for which they were traditionally responsible. Women showed in-depth knowledge about traditional crop varieties, and men had knowledge about modern farming techniques. For both, information was acquired through social networks, such as community seed banks in Kisumu County. Extension services and trainings were also important sources of information, and in some cases, targeted women. Another source of farming information was mobile phones. Generally, men were more likely to own a mobile phone and receive this information directly, while women more often received it through their husbands. This can deter opportunities for women to adopt sustainable practices.

Women saw financial constraints as one of the main barriers to adopt nature-positive practices, as they were perceived to be “very expensive" and not cost effective. A respondent in Kisumu noted, "I can’t do something that is not profitable." Time constraints, particularly for women already working long hours to perform household chores, were a hindrance. There was limited interest in practices that would potentially increase labour burdens, even if they were seen as more sustainable. Women welcomed low-input, accessible, and labour-saving practices.

Practical Implications

We found that men and women have distinct roles and responsibilities that influence their interactions with the environment and lead to diverse needs and preferences. However, targeting them with solutions must be done with the support of men in the household, using gender-transformative approaches that involve whole communities to effect change. This is to ensure that both men and women can actively contribute to these initiatives based on their individual preferences and roles, and that they both equally benefit.

As women were more engaged in agriculture and involved in the environment through activities such as water and firewood collection, they should be targeted with information and practices relevant to their sphere of life. However, this observed closeness to nature does not necessarily make women more sustainability minded. Rather than an inherent characteristic as ecofeminist scholars claim, willingness to conserve may be attributable to gender-prescribed roles.

Programmes must consider gender differences when promoting sustainable practices. Men may be more interested in some practices, such as tree planting, because they own the land. Women's responsibility for domestic water and food production could lead to their heightened concern about the negative health risks associated with pesticide use. However, men’s role in applying pesticides may make them more motivated to adopt nature-positive practices.

Community education along with gender quotas in trainings and decision-making groups can help both women and men to exploit resources in a nature-positive way. Our findings also suggest that increasing women's access to information about sustainable farming practices can have a positive impact on their participation in decision-making. Finally, when considering solutions for nature-positive production, consider women's differential access to information and their time poverty given their domestic tasks.

Theoretical Implications

The study in part supports the conceptual framework by Meinzen-Dick et al. (2014) and its underlying theories on ecofeminism and feminist political ecology, and the intrahousehold and natural resource management literature linking adoption of nature-positive practices with motives, means, and opportunities. It also suggests amendments to the framework.

On motives, women and men interact differently with their environment. While we found that women were more involved in agricultural production and responsible for natural-resource-based domestic duties, and, thus, more inclined to adopt nature-positive practices, this does not mean that they are inherently more conservation-oriented. Previous literature has shown that in situations of poverty, women may be more likely to act unsustainably due to their responsibility for cooking fuel and food provision for the family (Agarwal, 2000).

Rather than combining means and opportunities as with Meinzen-Dick and colleagues, we suggest separating them. Means implies that smallholders have the rights to use resources, whereas opportunities implies they have the agency (e.g. bargaining power) to use resources. For instance, women may have rights to land but still not take advantage of those rights due to agency reasons.

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TRANSFORMATIVE POTENTIAL OF INNOVATIONS FOR TRANSITION

Driving the agri-food sector towards the Voluntary Carbon Market in Europe

Mariarita Cammarata[a], Alessandro Scuderi[a], Gaetano Chinnici[a], Agata Matarazzo[b], Donatella Stefania Privitera[c] and Giuseppe Timpanaro[a]

[a] Department of Agriculture, Food and Environment, University of Catania, Via S. Sofia, 100, 95123 Catania, Italy. mariarita.cammarata@phd.unict.it; alessandro.scuderi@unict.it; chinnici@unict.it; giuseppe.timpanaro@unict.it.

[b] Department of Economics and Business, University of Catania, Corso Italia, 55, 95129 Catania, Italy. amatara@unict.it.

[c] Department of Educational Sciences, University of Catania, Via Biblioteca 4, 95124 Catania. donatella.privitera@unict.it.

Abstract:

The phenomenon of climate change has led the European Commission to set an ambitious goal: to achieve climate neutrality by 2050. The agricultural sector has the potential to support the achievement of this purpose through appropriate management of production systems. In this study, the quantification of the Carbon Footprint in a life-cycle perspective was carried out to compare conventional and innovative management of Sicilian almond orchards. The results showed that the conventional almond orchard has a Global Warming Potential of 3.93 t Co2-eq ha-1 yr-1 compared to 1.50 t in innovative management. The substitution of synthetic fertiliser with the application of manure has helped the innovative almond orchard to become more sustainable. However, this has resulted in a slightly lower yield than the conventional one. In order to encourage farmers to rethink their production model and move away from schemes aimed solely at maximising yield, incentives are needed to compensate for reduced production. To this end, since the quantification of emissions is only the first step on the path to sustainability, our study aims to continue with the quantification of carbon sequestration in the almond orchard in order to investigate the possibilities of access to the Voluntary Carbon Market for farmers.

Keywords: Carbon farming, Carbon Footprint, Life Cycle Assessment, environmental impact, almond orchard.

Purpose

Climate change has given rise to extensive political debates on the reduction of greenhouse gas (GHG) emissions and the need to find sustainable solutions. Therefore, political and economic guidelines aimed at GHG reduction and promoting mitigation measures have been defined at the global level. In this scenario, the European Union has set the ambitious goal of achieving climate neutrality by 2050 (European Commission, 2021). This translates into the implementation of sustainable practices aimed at reducing emissions and capturing carbon dioxide (CO2) in marine and terrestrial ecosystems, geological reservoirs and products (European Commission, 2022). Europe's environmental efforts are highlighted by the new Common Agricultural Policy (CAP) measures for 2023-2027 and the proposal of certification framework for carbon removal. In the first case, the European Commission introduced ecoschemes. These are strategic plans to promote sustainable agriculture through the reduction of antibiotics in animal breeding, grassing of tree crops, preservation of the olive tree heritage of landscape value, extensive fodder systems with rotation and sowing of beekeeping essences (Meredith & Hart, 2019). The second is a proposal to facilitate the spread of carbon removal among European agricultural operators in order to create voluntary carbon trading in Europe (European Commission, 2022). The Voluntary Carbon Market (VCM) is in fact an instrument to drive companies and society towards sustainability through the creation of a dense network of debtors and creditors cooperating for a single purpose: combating climate change. The role of VCMs is to transform production, consumption and investment towards sustainability and low carbon. The agricultural sector, given its primary role in meeting the growing population's demand for food, needs to change and rethink its production models in order to make them more sustainable. In this scenario, the European 'ON FOODS' project aims to provide farmers with solutions to make their processes environmentally friendly. The research aims to evaluate sustainable production models as an alternative to conventional farming. On the basis of the existing literature, there is a recurring question mark over the future of agricultural models in relation to ongoing climate change. There has been a shift from the conventional-industrial model to the organic one in the 2000s and then to the demand for a model based on sustainability. In light of the above, the objective of our study is the quantification of the Carbon Footprint (CF) in a life cycle perspective of conventional and innovative almond orchard. The innovative model bases its references on process and product innovations and sustainability. In the case of the almond orchard, these innovations are based on models with a higher planting density, hedge training, minimal tillage, grassing of the inter-row strip, biological pest control systems, etc. All the practices adopted define a new production model that, while incorporating some aspects of organic production and agro-ecological standards, escapes the mandatory standards. It is oriented less towards the constrained model and more towards a free sustainable model so that all the practices functional to obtaining quality productions can be applied in the principle of maximum environmental, social and mainly economic sustainability. Comparing these two systems allows, on the one hand, to highlight environmentally friendly practices, on the other hand, represents the starting step for farmers to participate in the VCM and to add value to the product through the Carbon Neutral label. Creating value for farms requires an environmental, social and economic transition path. Carbon farming is a winning strategy in combating climate change to produce sustainable food, and a transition path starts with becoming aware of the truly sustainable models. To this end, measuring the carbon footprint is the first step in moving from carbon-source to carbon sink production systems.

Design/Methodology/Approach

The almond orchards considered for the study are located in eastern Sicily. In order to quantify their CF, one year of the full production phase was considered. This phase is the most representative in terms of management practices, inputs administered and environmental impacts as it characterises more than half of an orchard's life span (Ingrao et al., 2015). Our study therefore analyses the tenth year of cultivation of the two almond orchards with an area of 10 hectares each. The conventional almond orchard (CA) represents the business-as-usual scenario, while the innovative almond orchard (IA) underwent a change of management based on regenerative farming practices suggested by us to the farmer. They are characterised by the replacement of synthetic fertiliser with the application of manure and the implementation of cultural operation for management improvement. For the CF quantification, the guidelines of ISO 14067 (ISO, 2018) were followed, which is based on the principles of the Life Cycle Assessment (LCA) methodology established by ISO 14040:2006 and 14044:2006 (ISO, 2006a, 2006b). It was conducted according to GWP100 (IPCC, 2021), a methodology included in the SimaPro 9.5.0.1 software, that converts direct and indirect emissions over a fixed period of 100 years. It represents the time-integrated climate forcing (perturbation to the Earth's balance between incoming and outgoing energy) due to a one-off pulse emission of one tonne of a GHG over the 100 years following its emission, relative to the corresponding impact of a one-tonne pulse emission of CO2" (Allen et al., 2016). In order to understand the methodology applied, it is necessary to define the Functional Unit (FU) and the system boundaries of the study. FU is the measure of the performance provided by the system, so it can be represented by the quantity of a product, a process function or a service (Bernardi et al., 2021). In the present study, it is 1 ha of almond orchard in order to study the ecological and land management function (Nemecek et al., 2011). Concerning the system boundaries, these were set from cradle to farm gate to highlight the impacts strictly related to the cultivation process. These include the procurement of raw materials (fertilisers, pesticides, etc.) and their transport from the production site to the field, as well as all the cultivation operations involved in the management of the almond grove, with the exception of the pruning, which is done manually). CF was calculated as the sum of process and material contributions included in the system boundaries. The impact due to direct land use change (dLUC) was not considered as the land has been used to produce almond for more than 50 years (ISO, 2018).

Primary data, collected by ad-hoc questionnaires, and secondary data were used to carry out the analysis in order to create a representative model of reality. The first ones refer to the quantity and type of fertilizers, crop protection products and machinery used. Secondary ones are related to the production of materials, transport means and cultivation operations. For secondary data, the Ecoinvent 3.9.1 database was used. In order to model the cultural operations and fertiliser emissions were used the suggestions of Nemecek and Kagi (2007), whereas for pesticide the Ecoinventi approach has been used in which the entire quantity of pesticides administered to the crop is assumed to end up as an emission into the soil (Timpanaro et al., 2021). Table 1 shows the main inputs used in cultivation processes.

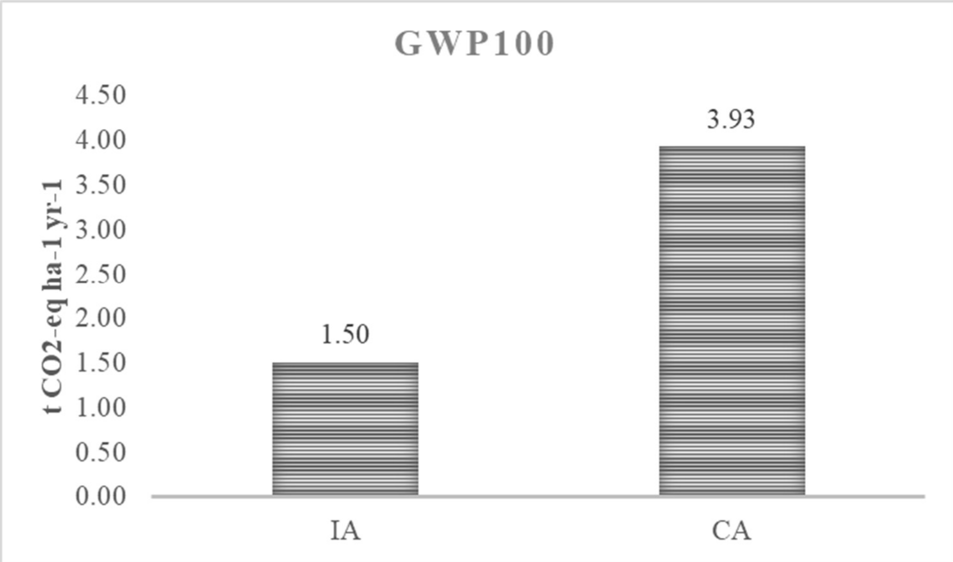
Table 2 Almond orchard data inventory per year

Source	**Measure unit**	**CA**	**IA**
Fertilizers NPK	kg ha^{-1}	832	0
Manure and digestate	kg ha^{-1}	0	1515
Diesel	l ha^{-1}	150	373
Bordeaux mixture	kg ha^{-1}	0	4.5
hydrated lime	kg ha^{-1}	0	250
yield	kg ha^{-1}	3996	3181.5

Findings

The CF results of the conventional and innovative almond orchard show a result of 3.93 and 1.50 t CO2-equivalent ha-1 yr-1 respectively (Fig. 1). The greatest impact of CA is attributable to the use of synthetic nitrogen fertilizer as opposed to IA characterized by the application of manure. Although the amount of synthetic fertilizer in CA is reduced compared to that administered in IA, the emissions produced far exceed innovative management despite this being characterized by a higher number of tillage operations, including greater use of fuel and the application of crop protection products. The greatest impact of CA is also due to the tractor and trailer passing through the field during manual harvesting operations. The machinery used by the farmer is older and therefore characterized by a higher impact, furthermore, the transported mass of almonds is higher than IA where the yield is lower. The use of synthetic fertilizer in CA also contributes substantially to the total impact. These products are not produced locally, as in the case of manure sourced from companies in the region. Another important contribution to the increased impact of CA is mechanical weed control. Here, too, the use of obsolete machinery has a negative effect. IA on the contrary is characterized by mechanized harvesting, the implementation of crop protection operations for which no synthetic products are used, and this management approach elects it as a sustainable model.

Figure 2 Conventional and regenerative almond orchard CF per ha and year



Practical Implications

Regarding the environmental function, the results showed that firstly, the substitution of synthetic fertiliser with organic one contributed to the reduction of the impact. Our result is supported by scientific evidence in which the amount of GHG produced by an orchard system is mainly due to the production and use of synthetic nitrogen fertilisers (Zhao et al., 2021). Furthermore, the choice of manure for fertilisation is characterised by the benefit of being more concentrated in terms of nutritional principles unlike chemical fertilisers (Ingrao et al., 2015). Bartzas and Komnitsas (2017) clearly state in their study that manure management makes a substantial contribution to achieving sustainability in agriculture by halving the value of CF. Moreover, the production of synthetic fertilisers often takes place in plants that are not energy efficient. This contributes to increasing the impact of the conventional system. The sourcing of local materials transported over limited distances is an undoubted advantage in achieving sustainability as also demonstrated by Bartzas and Komnitsas (2017). From a production perspective, IA experienced a slight reduction in yield compared to CA; this could be attributed to the different fertilisers applied and/or the timing of application. As reported by Wu et al. (2018) proper application timing can lead to yield maintenance and halve the loss of nitrogen fertilisers. Certainly, the study highlights how appropriate management, innovative by the usual standards of Sicilian almond growing, can allow the farmer to reduce emissions. At the same time, a more sustainable product is able to position itself on the market with added value and would allow the farmer to reward the loss of yield through a premium price for a carbon neutral product.

Theoretical Implications

Innovative almond orchard management is a tool farmers can use to combat climate change. Compared to the ambitious targets set by the European Union to achieve climate neutrality by 2050, the quantification of emissions in agricultural systems is the first step. On the one hand it makes operators in the sector aware of the impact of their activities, on the other hand it allows consumers to be guided in conscious purchasing processes. The measurement of emissions is also the first step to access the Voluntary Carbon Market. In order to understand whether this really represents an opportunity for the farmer, our study will continue with the quantification of carbon sequestration in the almond orchard and the carbon credits that can be generated.

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Transition to Mixed Farming and Agroforestry Systems for the development of a more resilient, effective and circular agriculture

Tommy Dalgaard[a], Pip Nicholas-Davies[b], Robert Home[c], Christine Watson[d], Kairsty Topp[d], Francesco Accatino[e], Catherine Pfeifer[c], Anne Grete Kongsted[a], Marie Trydeman Knudsen[a], Lisbeth Mogensen[a], Mónica Quevedo-Cascante[a], Miranda PM Meuwissen[f], Frederic Ang[f], Guy Low[f], Murilo Almeida-Furtado[f], Simon Moakes[b], Sara V. Iversen[a], Henrik Thers[a], August Kau Lægsgaard[a], Mette V. Odgaard[a], Troels Kristensen[a], Jørgen Dejgaard Jensen[g], Simone Sterly[h], Holger Pabst[h], Claudia Marques-dos-Santos[i], Joana Marinheiro[i], Camelia Anisoara Gavrilescu[j] and Lise Andreasen[k]

[a] Aarhus University, Dept. Agroecology, DK. tommy.dalgaard@agro.au.dk Land-CRAFT.dk

[b] Aberystwyth University, Wales, UK

[c] Research Institute of Organic Agriculture, FiBL, Switzerland

[d] Scottish Rural and Agricultural College, SRUC, UK

[e] INRAE, AgroParisTech, Université Paris Saclay, France

[f] Business Economics, Wageningen University, the Netherlands

[g] Department of Food and Resource Economics, University of Copenhagen

[h] Institute for Rural Development Research (IfLS), Germany

[I] University of Lisbon, School of Agriculture, CEF, Terra, Portugal

[j] Institute of Agricultural Economics, Romanian Academy, Romania

[k] International Centre for Research in Organic Food Systems, Denmark

Abstract:

This paper explores Mixed Farming and Agroforestry Systems (MiFAS), the transition pathways to more circular, resilient and efficient farming systems, and related benefits and trade-offs to climate, environment and society.

Results from networks of organic and conventional farmers within the MIXED-project.eu and related studies are presented, including data collection from different European regions, with selected results on how to best facilitate a wider take-up of MiFAS. It is demonstrated how MiFAS, as an alternative to specialisation, can operate within a field, a farm, and between farms in an entire landscape or food-chain, including policies and governance strategies to support this.

Results include examples on better use of resources through collaboration and diversified production with a mix of crops, livestock and trees, making use of grasslands, woody vegetation as feed and shelter, provide biobased fertilisers, enhancing carbon sequestration and biodiversity. Specifically, it is demonstrated how an integrated production system, with more local production and landscape level exchange of fodder and biobased fertilisers can enhance resilience to climate change, economic shocks etc. Via a newly developed model for integrated, circular farming systems, we also show that,

by supporting a more circular use of resources, these systems gain a better overall economic as well as environmental efficiency and the regeneration of natural systems.
Keywords: mixed farming systems, agroforestry, resilience, efficiency, circular systems, green transition

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Purpose

The aim of this paper is to present results collected and reviewed in the European MIXED-project.eu on "Multi-actor and transdisciplinary development of efficient and resilient mixed farming and agroforestry systems"[3], including the involvement of farmer networks, recommendations for future European policies and the integration of related European and national research studies and results.
In the MIXED project, Mixed Farming and Agroforestry Systems (MiFAS) have been proposed as a sustainable pathway to more circular, resilient and efficient farming systems, with related benefits to climate, environment and society. The purpose is thereby to present frameworks derived for the assessment and implementation of transition to such systems on real farms. Recently, the benefits of similar diversification approaches have been put forward in a global study, focusing on Northwestern America and The Global South (Rasmussen et al., 2024) but there is a lack of research studies from a European context.

Research design, methodology and approach

A definition of Mixed Farming and Agroforestry systems (MiFAS)

In our definition, Mixed Farming and Agroforestry Systems (MiFAS) include combinations of cropping, livestock and forestry systems, and the MIXED project addresses the combination of these into the following themes: i) integrated crop-livestock systems, ii) integrated crop-forestry systems, iii) integrated livestock-forestry systems, or the total combination in form of iv) crop-livestock-forestry systems (Low et al. 2022; adapted from Embrapa 2016).

European research projects, literature review on MiFAS

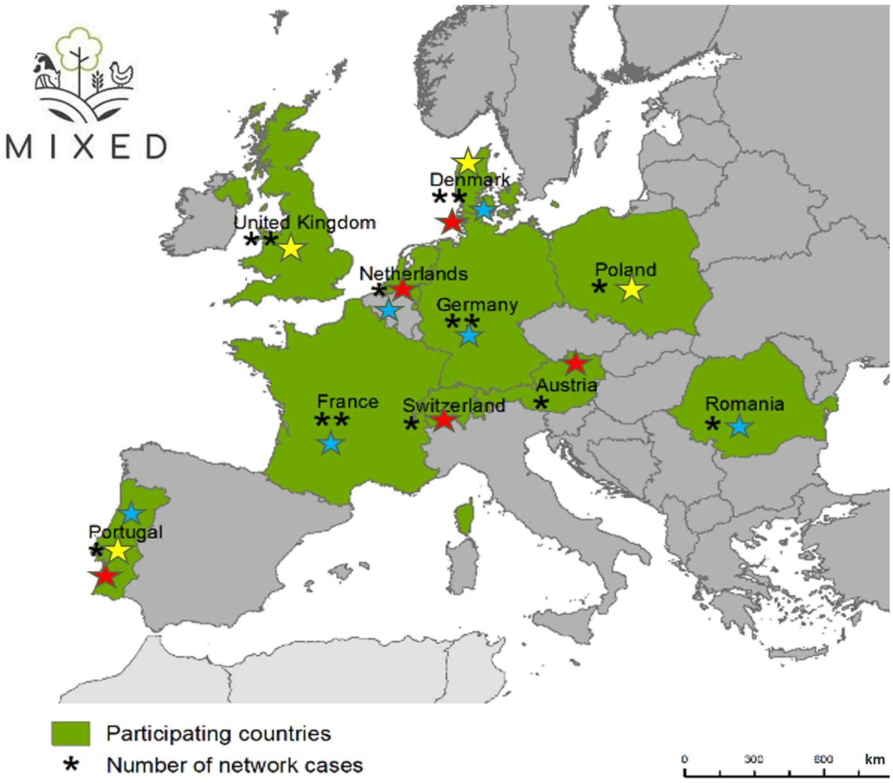
As an initial task a series of workshops were organized between researchers and practitioners in the MIXED project and the two sister projects of Agromix (https://agromixproject.eu/) and Stargate (https://www.stargate-h2020.eu/), funded under the same EU SFS-19 Research and Innovation Action. Moreover, a review of relevant scientific literature on MiFAS in a European context was performed via Web of Science and the following search string: "mixed farm* system*" OR "agricultural diversification*" OR "agricultural diversity" OR "crop-livestock integration" OR "integrated crop-livestock system" OR "mixed crop-livestock systems" OR agroforestry)) NOT [countries] (Iversen et al., 2021).

[3] The www.mixed-project.eu (MIXED) is an EU H2020 SFS-19 "Climate-smart and resilient farming Research and Innovation Action on Mixed Farming and Agroforestry Systems" (Grant agreement N° 862357), coordinated from Aarhus University, Department of Agroecology and the International Centre for Research in Organic Food Systems (ICROFS) 2020-2025.

Empirical data collection

Figure 1 gives an overview of the studies in MIXED, where data is collected from 14 farm networks, covering the all the MiFAS themes. Seven of the networks study agroforestry systems, in particular with combinations of energy crops/fodder trees with livestock, or combinations of fruit/nut trees/bushes with livestock and arable crops. In total, the study involves 20 institutional partners in ten countries, with detailed data collected from 87 farms, supplemented by existing national, and pan-European databases, for example Eurostat and the Farm Accountancy Data Network (FADN) across all of Europe (Ang et al., 2024)[4]. In six countries landscape level case studies were performed, focusing on the effects of interactions between farms, e.g. in form of exchange of fodder crop products, livestock and/or livestock manure, leading to a higher landscape level mixedness (Accatino et al. 2021; Ryschawy et al., 2022). Moreover, in five countries, the whole value chains have been mapped and assessed via Life Cycle Assessment (LCA) methodologies (Quevedo-Cascante et al. 2022), and in four countries, farm level innovation studies have been developed, together with selected local networks of farmers, farm advisors and other relevant local actors.

Figure 1. Overview of data collection in the mixed project, involving 14 networks of farmers, researchers and other relevant local stakeholders (black stars), six landscape level studies (blue stars), five value chain studies (red stars) and four farm level innovation studies (yellow stars) of Mixed Farming and Agroforestry Systems (MiFAS).



[4] Agroforestry and "alternative systems" data were only available from the 87 farms and not from present pan-European data sources, which however included selected time series for the study of farm resilience and efficiency 2004-2018.

Circular agricultural systems and value chains

In line with Sutton et al. (2022), mixed agricultural systems, and value chains with MiFAS (Quevedo-Cascante et al. 2022) have a potential to promote circularity and lower emissions. Landscape scale measures are especially promising (Dalgaard et. al., 2022), and are therefore included as a special test case in the present studies.

Findings

European research project and literature review

Fifty-two MiFAS related European research projects were identified from the MIXED-AGROMIX-STARGATE workshop review, including 28 projects from a follow-up questionnaire that identified key contacts. Research results published in English were catalogued into focus areas, with the following dominating headlines (and number of related projects in brackets): 'organic' (13), 'conventional' (3), 'agroforestry' (21), 'crop-livestock' (11), 'mixed crops' (12), 'energy-crops' (2), and 'networking' (17). There was often an overlap between focus areas and although all projects had an element of research, some were related to practical farming, advocacy groups or professional organisations. The review highlighted that within the identified projects there is a tendency towards mixed systems that focus on organic as opposed to conventional farming approaches.
The Web of Science literature review reported by Iversen et al. (2021) on MiFAS studies yielded more than 1400 papers. The first study was published in 1984. This increased to 5-10 per year in the early 2000s and has since risen exponentially with 80-100 papers published per year since 2018 Most of them related to agricultural (416), environmental science (316) or (agro)forestry related studies (250), but there was also a number of papers on science and technology studies (83), or more specialized topics around biodiversity (40), sociology (32), engineering (26) or energy and biofuels (23). The review of projects and the literature review both highlight the importance of agroforestry systems, and there is a high degree of similarity in the topics covered in both reviews.

Overview and performance MiFAS, crop-livestock integration & circular systems in Europe

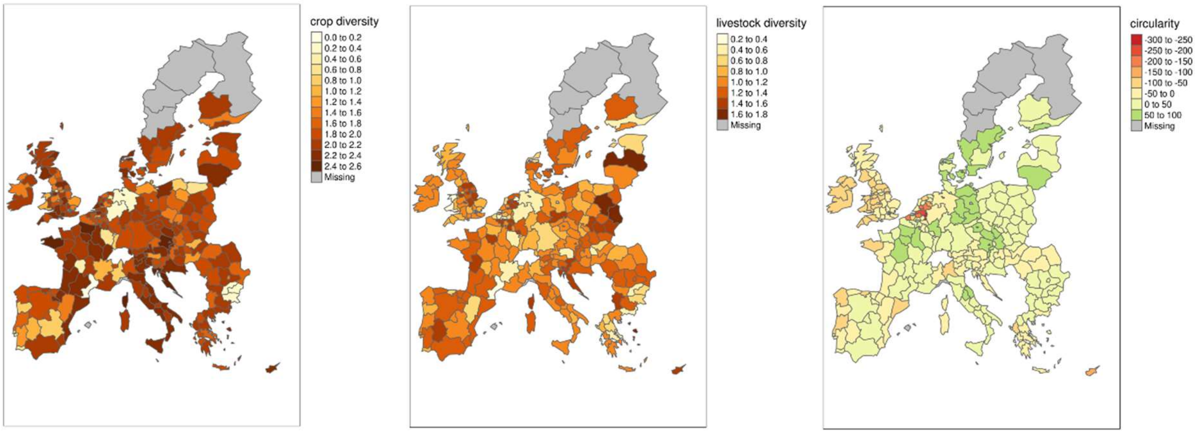
Multiple combinations of the Mixed-farming studies in Figure 1 have been described in sets of practice abstracts available[5], and corresponding scientific impact assessments published in deliverables and scientific journals (e.g. Quevedo-Cascante et al. 2022, Low et al., 2022) or in publications currently under review (e.g. Ang et al. 2024).

In general, the studies support the hypothesis, that transition to more MiFAS can serve as a sustainable pathway to more resilient and efficient farming systems, including benefits from circularity. Moreover, the preliminary analyses of the Pan-European FADN data support that mixed farming systems have the same or probably a higher revenue compared to variable costs, as compared to specialized crop or livestock farming systems (Ang et al. 2024). There is even a tendency towards a better performance, and a

[5] https://projects.au.dk/mixed/mixed-farming-and-agroforestry-systems-mifas/mixed-project-publications/mixed-practice-abstracts-1.

potential for further improvements, in regions where the different farm types are close and can collaborate. In addition, top-down methods were developed to map the regions of Europe with the highest crop and livestock diversity, and thereby potentials for Mixed farming systems, and to identify potentials for more circular farming systems via the development of an indicator derived from the relation between livestock and crops (Figure 2).

Figure 2. Mapped regional indicators for crop and livestock diversity, based on Shannon indices calculated from Eurostat data, and a related circularity indicator, calculated as a gross soil nitrogen balance without fertilizer (Ang et al., 2024), which can be used to identify regions with special potentials for transition to more MiFAS, either within farms, value chains and/or whole landscapes, as exemplified via the case studies of Figure 1.



Practical and Theoretical implications

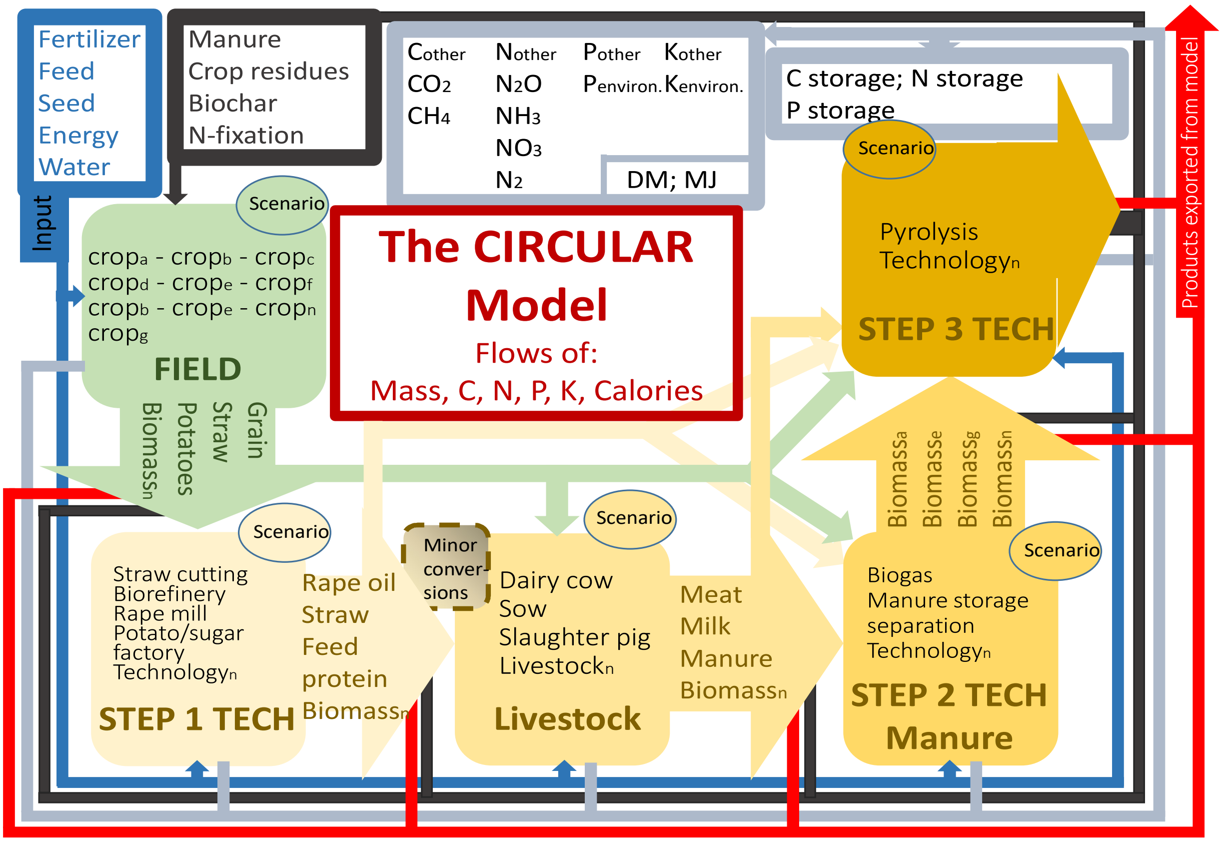
The importance of circularity for resilience and efficiency

As previously mentioned, more circular systems (e.g. in the form of nutrient cycling) are a potential co-benefit of MiFAS and have a large potential for implementation at the farm and landscape level. This also leads to more resilient and efficient systems in the way that local production and optimized utilization of manures and other biobased fertilisers, fodder crops and locally produced protein is promoted. This will reduce our dependence on imports from an uncertain world market, and potentially mitigate the effects of climate change and other geopolitical crises.

The practical implications of such landscape level mixed systems, supported by an increased circularity of nutrients, especially nitrogen, were studied in the MIXED landscapes of Denmark, The Netherlands, UK and France (Figure 1; Ryschawy et al. 2022). Figure 3 shows an example from the Danish landscape, where a whole circular system model was developed to assess the effect of different combinations and degrees of mixed crop and livestock system integration via technologies implemented either in the crop production (step 1 TECH in Figure 3), the livestock production (step 2) or external to the farming systems, but still with consequences for the nutrient cycling (step 3). Such models are being developed together with the Mi-Bicycle project[6] for the Netherlands, UK, Denmark and France to identify agricultural production scenarios that will reduce the impact of agriculture on the environment, protect soil organic matter and mitigate greenhouse gas emissions. The development of these tools should be an important turning point for helping to identify sustainable, circular, resilient and mixed systems combined with embedded value chain management, e.g. via more local forage and biobased fertiliser production, and decision-support for transition to such new production systems (Dalgaard et al. 2024).

In conclusion, the studies presented in this paper show the importance of a sustainable Mixed Farming and Agroforestry Systems management for the transition of European farming systems, landscapes and value chains towards a more resilient, effective and circular future with lower emissions to the environment and a more stable, biobased and locally integrated agriculture and food production.

Figure 3. CIRCULAR system model developed to explore mixed farming systems and environmental impact scenarios of technologies (Danish Agric. Agency 33010-NIFA-19-732).



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[6] https://www.suscrop.eu/funded-projects/3rd-call/mi-bicycle

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The transformative potential and circularity impact of dairy initiatives in the North of the Netherlands

A.G. Hoogstra[1], E.M. de Olde[1], M.K. van Ittersum[2], I.J.M. de Boer[1]

[1] Animal Production Systems group, Wageningen University & Research, the Netherlands, anne.hoogstra@wur.nl

[2] Plant Production Systems group, Wageningen University & Research, the Netherlands, office.pps@wur.nl

Abstract

To produce food while respecting planetary boundaries, there is a need for a food system transformation to more circular agriculture. However, whether a circular initiative is indeed transformative ultimately depends on multiple factors including its transformative potential, internal development and contribution to circularity impact. This study aims to analyse the circularity impact of circular agriculture initiatives and is specifically focused on dairy farms. From a database of 171 circular agriculture initiatives in the North of the Netherlands, we derived different development pathways for dairy farmers, which are represented by a case study from the database. The research will consist out of 3 steps: (1) utilizing a developed framework, we assess the transformative potential of these initiatives; (2) evaluate their circularity impact using the FarmDESIGN model supplemented with qualitative indicators to quantify the productive, socio-economic, and environmental performance of a farm system; (3) discuss the potential of these different development pathways based on the results of the previous steps and the opportunities and threats of spreading these innovations within the region. This offers valuable information for policymakers and other stakeholders to stimulate dairy initiatives that show actual transformative potential as well as a positive impact on circularity.

Keywords: circular agriculture, dairy farming, sustainability assessment, food systems transformation

AgriFoodTech start-ups as drivers of innovation for food systems transformation: synthesis and research agenda

Laurens Klerkx [1,2] and Pablo Villalobos [1]

[1] Departamento de Economía Agraria, Facultad de Ciencias Agrarias, Universidad de Talca, Chile

[2] Knowledge, technology and Innovation Group, Wageningen University, The Netherlands

Short abstract

In the debate on food system transformation, there has been a lot of discussion on different transition pathways to achieve this, such as Agriculture 4.0 and Food 4.0, regenerative agriculture, protein transitions, and agroecology. Each transition pathway encompasses different values, practices and technologies, and envisions realizing food security and sustainability in different ways. Increasingly, AgriFoodTech start-ups have become relevant players in realizing the innovations shaping these transition pathways, but so far these have been studied only to a limited extent. In this perspective paper, we argue that AgriFoodTech start-up ecosystems should receive more attention as a relative new component of agrifood innovation systems, which are increasingly mission oriented. To this aim, we provide a brief synthesis of this emerging field of study and outline a research agenda for studying the role of AgriFoodTech start-ups in different food systems transformation pathways and food security outcomes.

Developing digital platforms for short food supply chains: Transformative potential, open issues, and users' training needs

Evagelos D. Lioutas[a], Chrysanthi Charatsari[b], Marcello De Rosa[c], Anastasios Michailidis[b], Dimitrios Aidonis[a], Margherita Masi[d], Maria Partalidou[b], Martina Francescone[c], Stefanos Nastis[b], Charisios Achillas[a], Luca Bartoli[c], Giuseppe La Rocca[e]

[a]: Department of Supply Chain Management, International Hellenic University, Greece, evagelos@agro.auth.gr, daidonis@ihu.gr, c.achillas@ihu.edu.gr

[b]: Aristotle University of Thessaloniki, School of Agriculture, Department of Agricultural Economics, Greece, chcharat@agro.auth.gr, tassosm@auth.gr, parmar@agro.auth.gr, snastis@agro.auth.gr

[c]: University of Cassino and Southern Lazio, Department of Economics and Law, Italy, mderosa@unicas.it, martina.francescone@unicas.it, bartoli@unicas.it

[d]: Alma Mater Studiorum - University of Bologna, Department of Veterinary Medical Science, Italy, margherita.masi4@unibo.it

[e]: Department of Agriculture, Region Lazio, Italy, larocca_pino@libero.it

Abstract:

Digital platforms are popular tools broadly used in the agricultural sector to connect actors, offer e-commerce opportunities, and allow information and knowledge exchange. However, a pivotal question is whether these platforms have transformative power over users and subsystems operating within the agrifood nexus. In the present work, viewing the topic through a responsible design lens and adopting a mixed research approach, we aimed to offer some preliminary answers to this question, inquiring into the transformative potential of digital platforms for short food supply chains and depicting the competencies needed to help farmers deal with the use of such platforms. Our findings underscore the importance of focusing on a series of ethical and cultural impacts associated with digital platforms, also giving prominence to the potential of such artifacts to create an unwanted uberization of alternative food networks. Furthermore, the results suggest that, to exploit these platforms, farmers need to develop technical and adaptation competencies.

Keywords: digital platforms, agricultural digitalization, short food supply chains, competencies, responsible design, alternative food networks

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Purpose

Digital platforms are technological tools that enable interactions between individuals with the aim of facilitating the performance of different tasks (Bonina et al., 2021). They represent socio-technological systems consisting of technical (software and hardware) and social elements (developers and communities of users) that shape specific and ever-changing organizational structures and associated processes (De Reuver et al., 2018). Hence, the operation of these platforms relies on their technical attributes and the social behavior of their users.

Digital platforms are today widely used in the agrifood sector, offering several benefits, especially to small-scale farmers (Glaros et al., 2023). Such platforms serve different functions, like facilitating transactions among actors (e.g., the platform https://wikifarmer.com/ connects farmers from 17 countries with businesses like restaurants or grocery stores, operating as a digital marketplace), knowledge and information exchange (e.g., https://digitalfarming.eu/ offers a space in which farmers and experts exchange ideas and knowledge on different farming-related problems), equipment and resource sharing (e.g., at https://www.agrishare.app/ farmers can rent or hire their farm equipment and other resources), or innovation diffusion (as the digital descendants of innovation platforms developed in the framework of various EU-funded projects). In all these types of platforms, users' interests and social behavior interplay with the technical attributes of the platform and the prevailing governance structures, shaping complex arrangements (Chen et al., 2022; Bonina et al., 2021).
The experience from various areas of social and economic activity confirms that these platforms can change the ways of doing business or even disrupt industries and sectors. Despite the hype associated with these new socio-technological artifacts, platforms may negatively affect users and other social groups, creating more severe problems than those aiming to address (Cusumano et al., 2019). This observation calls for a responsible design of digital platforms. Responsibly designing involves posing and answering questions on the benefits, risks, and unintended side-effects of new socio-technological artifacts for their users and society (Eggink et al., 2020). To date, research has devoted limited effort to answering these questions for the platforms operating in agrifood systems. In the present study, we sought to provide some preliminary insights into this issue by uncovering the transformative potential of these platforms for users and the open questions that their operation creates.
Our work draws on the experience of developing a digital platform in the framework of an EU-funded project. The platform aims to connect farmers who distribute their products through short food supply chains (SFSCs) with customers using blockchain technology for smart contract management, offer spaces for interaction between users, provide a virtual training environment, and promote business model innovation for SFSCs. Following a responsible design approach, in this study, we aimed to investigate if and how the development of such a platform can transform Greek SFSCs, the risks that may entail, and the competencies that farmers and other actors should possess to exploit the platform.

Design/Methodology/Approach

The study was based on a mixed research design. As a first step, we conducted two workshops with 27 practitioners and experts in SFSCs from Greece to estimate the transformative potential of our platform and the risks that its use may entail for farmers and other participants. To analyze data, we performed a thematic analysis.
In a follow-up phase, drawing on data from a sample of 44 supply chain experts, we added a quantitative component to our study. Participants indicated their general perception of how the platform may affect SFSCs on a five-point scale from 1 (definitely negative) to 5 (definitely positive). To assess the transformative potential of digital platforms, we constructed a list of 10 items referring to different dimensions of SFSCs,

measured on a seven-point scale anchored by -3 (great negative transformation), 0 (no transformation), and 3 (great positive transformation). A principal axis factoring identified three subscales, depicting cultural (example item: alternativeness of SFSCs), relational (example item: social capital between farmers and consumers), and organizational transformation (example item: operational capacity of SFSC farms). We also developed a twelve-item scale to evaluate the importance of farmers' competency needs in dealing with digital platforms. Response options ranged from 1 (not at all important) to 5 (very important). Our factor analysis revealed that the needs represented in the scale can be divided into two categories: those referring to technical competencies (e.g., digitally interacting with consumers) and those reflecting more demanding adaptation-related abilities, like redrafting marketing strategies and business models. After computing new variables for each scale, we analyzed data using descriptive and inferential statistics. Finally, we regressed experts' evaluation of the impacts that digital platforms may have on SFSCs on the scales referring to the transformative potential of these platforms.

Findings

a. Qualitative analysis

Our thematic analysis uncovered that digital platforms do have transformative potential for SFSCs. Remarkably, participants attribute to these platforms both positive and negative impacts. The positive side of digital platforms refers to their ability to facilitate transactions between farmers and consumers and offer geographically marginalized farmers access to relational resources, training, and new markets. Nevertheless, digital platforms seem also to have a dark side. Workshop participants raised several concerns on the potential of transaction platforms to alter the social practices of actors involved in SFSCs, leading alternative food networks to "uberization," where the platform becomes an intermediary, thus disrupting the farmer-consumer relationship and changing the very nature of short supply schemes. Another risk mentioned during data collection concerns the non-benevolent purposes of some users and the emergence of opportunistic behaviors. Finally, platforms seem to promote some new ethics of surveillance associated with questions about the privacy of farmers' data.

Moreover, experts emphasized the need to ensure efficient platform governance by setting rules that allow a fair value distribution within the platform ecosystem. Another essential element determining platforms' value generating capacity is adopting a farmer-first philosophy. Some participants stressed the importance of shifting focus from the emphasis on technical rationality to the needs of users, especially small-scale farmers, by sharpening their competency in absorbing value from the platform through improving their technical, interaction, and organizational skills. The findings also indicate that the viability of such a platform depends on its ability to sustain its value creation activity by attracting farmers, consumers, and complementors and continuously enhancing the knowledge and skills of users.

3.2 Quantitative analysis

The descriptive statistics of the scales used in our quantitative analysis are presented in Table 1. The results indicate that experts believe that digital platforms can negatively transform the cultural ideals of SFSCs and positively change their organizational characteristics, nevertheless to small degrees in both cases. On the other hand, the importance of covering farmers' adaptation-related competencies was significantly higher than that of supplying them with technical competencies ($t=2.10$, $p=0.041$).

Table 1. Summary statistics of the scales used in the quantitative strand of the study

Scale	**Mean**	**S.D.**
Transformative potential		
Cultural transformation	-0.86	1.32
Relational transformation	0.04	1.20
Organizational transformation	0.66	1.09
Competency needs		
Technical competencies	3.17	0.87
Adaptation competencies	3.44	0.93
Evaluation of the impacts that digital platforms can have on SFSCs	2.68	1.20

Our regression revealed that the direction of digital platforms' impacts on SFSCs is positively associated with their perception of the degree to which these platforms can transform the cultural identity of these supply chain systems. On the other hand, the association between organizational transformation and the response variable was marginally non-significant.

Practical Implications

The present study indicates that digital platforms can transform SFSCs positively, negatively, or in both ways. To minimize the risks associated with these technologies, developers should carefully consider the new ethics that such artifacts promote, their impacts on the cultural identity of short supply schemes, and the governance structures that permit equal access to value for all participating actors. Moreover, supplying farmers with adaptation competencies is critical for helping them fully exploit digital platforms. In sum, our results suggest that "platformization" is not a panacea for SFSCs, pointing out the need to carefully consider the externalities of digital platforms when designing such artifacts for the agrifood sector.

Theoretical Implications

Our work confirms the importance of applying a responsible design lens when developing technologies for the agricultural sector and, much more, when focusing on niches operating within agrifood systems. Even the development and utilization of easily adaptable tools, like digital platforms, may be accompanied by several unforeseen uncertainties and risks. Delivering safe-by-design technologies represents a demanding task, requiring researchers to look beyond the functionalities of technologies and understand their transformative potential.

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ENACTING AND NAVIGATING TRANSITIONS: EXPERIENCES AND IMPACTS II

Regulation of nitrogen losses by agroforestry is linked to its association with low inputs farming systems: an assessment in dairy farms from Brittany, France

Romane Mettauer[a], Ambre Yaneli[b], Edith Le Cadre[c], Olivier Godinot[d]*

[a]SAS, Institut Agro, INRAE, 35042 Rennes, France, romane.mettauer@institut-agro.fr

[b]SAS, Institut Agro, INRAE, 35042 Rennes, France

[c]SAS, Institut Agro, INRAE, 35042 Rennes, France, edith.lecadre@institut-agro.fr

[a]SAS, Institut Agro, INRAE, 35042 Rennes, France, olivier.godinot@institut-agro.fr

Abstract:
If recent studies highlighted the regulation of nitrogen (N) losses in the vicinity of trees, the contribution of agroforestry (i.e., combination of trees, crops, and/or livestock) to limit such losses remains ambiguous in temperate areas. This study explores the regulation of N losses by agroforestry (hedges and/or alley cropping) at farm scale through the assessment of the farm-gate N balance in thirty-three dairy farms of Brittany. Clustering of farms on their N balance revealed four clusters associated to a gradient of farming systems from extensive systems with recently planted hedges and alley-cropping agroforestry presenting low N surplus, to intensive systems maintaining old hedges with high N surplus. Analysis through variation partitioning revealed that agroforestry alone had limited impact on the farm-gate N balance, but contributed to the regulation of N losses when considering its association with the management of N inputs and outputs. Discussions with farmers revealed that farmers mostly did not link agroforestry with practices decreasing N inputs. Yet, potential synergies between practices and ecological processes in agroforestry systems (e.g. limitation of N inputs next to the trees) are worthy to be adopted to enhance the impact of agroforestry on the regulation of N losses at farm scale.

Keywords: Silvopastoral systems, Alley-cropping agroforestry, Hedgerow, Farm-gate N balance, Crop-livestock integration

Purpose

Agroforestry, whereby trees are integrated with crops and/or livestock on the same field, is in the spotlight for the development of sustainable farming systems. In Brittany, a region of Northwestern France presenting environmental issues due to high livestock density, two diverse silvopastoral agroforestry systems (i.e., combination of trees and grasslands) are coexisting: (i) the traditional bocage, characterized by the plantation of hedgerows around fields; and (ii) alley-cropping agroforestry, an emerging form characterized by tree rows within fields. In recent years, adoption of silvopastoral systems have been supported by public policies aimed at limiting N losses from livestock systems to water streams (Agreste Bretagne, 2010). Yet, the impact of silvopastoral agroforestry on the regulation of N losses to the environment has been poorly studied under temperate climate (Kim and Isaac, 2022). If recent studies highlight the potential of agroforestry to limit such losses in the very close vicinity of trees (e.g., Zhu et al., 2020; Kim and Isaac, 2022), its contribution remains ambiguous at farm and territory level (Durand et al., 2015).

The aim of this study was to disentangle the relations between silvopastoral agroforestry and the regulation of N losses at farm level. We assessed the farm-gate N balance as a proxy of N losses in a gradient of dairy farms of Brittany that either maintained old hedges, planted hedges recently, and/or developed alley-cropping agroforestry. We hypothesized that the farms which adopted agroforestry systems the most would present lower farm-gate N balance due to (i) direct impact of the presence of hedges and tree rows, and (ii) the adoption of farming systems characterized by lower external N inputs and outputs.

Methodology

Thirty-three farms of the Brittany region (France) were surveyed and modelled in order to assess their N balance. During semi-structured interviews, data on descriptive variables of the farms, crops rotations, management of crops and livestock, and management of hedges and tree rows from alley-cropping agroforestry were collected with closed questions. Further open questions enabled to capture the motivations for the adoption of agroforestry, and the perception of agroforestry as a way to regulate the N cycle. Old hedges (i.e. > 15 years-old), young hedges, and tree rows from alley-cropping agroforestry were mapped with each farmer and reported on QGIS (v3.22.6), and their surface estimated considering 2-m wide hedges and tree rows. Maps of plots for year 2022 were provided by the farmers thanks to their declarations for national and European subsidies.

Farm-gate N balance (kg N ha^{-1} yr^{-1}) was calculated as: *Farm-gate N balance = N inputs – N outputs*.

With N inputs including N from mineral and organic fertilizers, biological N fixation by crops and trees, atmospheric depositions, soil N fixation by free living soil organisms, animal feed, and litter; and N outputs including N from exported crops, animal products, manure, and wood. In accordance with the practices declared by the farmers, hedges and tree rows were considered unfertilized and ungrazed. Results of farm-gate N balance were referred as N surplus when farm-gate N balance was superior to 0 kg N ha^{-1} yr^{-1}.

Farms were classified thanks to hierarchical clustering following a principal component analysis (PCA) on variables of N inputs, outputs, surplus and the surface dedicated to trees. Differences between the clusters were tested through linear models with analysis of variance (when residual normality and homoscedasticity were met) or Kruskal-Wallis tests with Holm adjustment of the p-value.

Motivations for agroforestry practices as well as links between the adoption of agroforestry and regulation of the N cycle expressed by farmers were classified into categories and analyzed in frequency. Finally, variation partitioning of the farm-gate N balance according to N inputs, outputs and tree parameters (i.e., surface dedicated to trees, old and young hedges linear, and surface planted with alley-cropping agroforestry) was performed in order to disentangle the impact of agroforestry as compared to the impact of the management of N inputs and outputs. All statistical analyses were performed using R software (v.4.2.0).

Findings

Dairy farms that planted hedges and alley-cropping agroforestry had lower N surplus

Hierarchical clustering resulted in four clusters with a gradient of farming systems from extensive farming systems with high adoption of agroforestry and low N surplus (clusters 1 and 2) to intensive farming systems based on high external N inputs and maintaining old hedges (cluster 4) (Table 1). Adoption of alley-cropping agroforestry alone was scarce (n=2) and was usually accompanied by plantations of young hedges (n=15). Hence, clusters 1 and 2 are characterized by the plantation of alley-cropping agroforestry and/or hedges, while intermediate clusters 3 is characterized by smaller plantations of hedges. Farmers of cluster 4 did not plant hedges or alley-cropping agroforestry. Alongside, farm-gate N balance increased significantly from cluster 1 to 4, with cluster 1 presenting N surplus on average 5 time lower than cluster 4. The observed relation between high adoption of agroforestry and low N surplus among clusters was supported by a negative correlation between farm gate N balance and the surface dedicated to trees on the first dimension (32.57% of the variability of the dataset) of the PCA used for hierarchical clustering.

Table 1. Mean and standard deviation (±SD) of the farms' characteristics, N inputs, outputs and balance per cluster. Different bold letters indicate significant differences (p < 0.05). R^2 is the adjusted R^2 of each linear model. * indicates when differences were tested thanks to Kruskal-Wallis tests.

Correlation between adoption of agroforestry and low N surplus resulted from the farming systems adopted rather than from the plantation of hedges and tree rows alone

A majority of the farmers (n=30) indicated that animal welfare was a motivation for maintaining and developing hedges and alley-cropping agroforestry. The second most cited motivation was the delimitation of paddocks (n= 19), followed by soil health maintenance (n=12) and biodiversity maintenance (n=11). Ecosystem services linked with

	C1 (n=14)	**C2** (n=8)	**C3** (n=9)	**C4** (n=2)	R^2
Number of organic farms	12	6	1	0	/
Used agricultural area (ha UAA)	99.1 (±46.8)	78.4 (±46.8)	84.1 (±29.1)	151.6 (±32.8)	0.07
Surface planted with trees (ha ha UAA^{-1})	0.018^{a} (±0.005)	0.017^{ab} (±0.009)	0.009^{b} (±0.003)	0.006^{b} (±0.002)	0.28
Forage area (ha ha UAA^{-1})	0.95^{a} (±0.07)	0.96^{a} (±0.06)	0.76^{b} (±0.09)	0.72^{b} (±0.14)	0.54
Old hedges (m ha UAA^{-1})	69.6 (±28.8)	80.8 (±42.3)	79.4 (±24.6)	55.6 (±33.1)	-0.05
Young hedges* (m ha UAA^{-1})	21.0 (±16.9)	24.9 (±27.0)	3.2 (±5.2)	0.0 (±0.0)	0.16
Alley-cropping agroforestry* (ha ha UAA^{-1})	0.18 (±0.16)	0.14 (±0.22)	0.01 (±0.02)	0.00 (±0.00)	0.14
Milk production per cow (L cow^{-1} yr^{-1})	$5{,}516^{c}$ (±1,486)	$6{,}263^{bc}$ (±1,283)	$7{,}244^{ab}$ (±1,567)	$10{,}000^{a}$ (±1414)	0.35
N inputs* (kgN ha^{-1} yr^{-1})	67.5^{d} (±14.3)	107.9^{c} (±43.6)	151.6^{b} (±48.4)	294.6^{a} (±14.8)	0.73
N outputs* (kgN ha^{-1} yr^{-1})	25.5^{d} (±6.5)	35.2^{cd} (±7.3)	43.9^{bc} (±12.3)	65.3^{a} (±33.1)	0.49
Farm-gate N balance* (kgN ha^{-1} yr^{-1})	42.0^{d} (±13.3)	71.9^{cd} (±47.9)	107.7^{bc} (±46.6)	229.3^{a} (±18.3)	0.63

the regulation of the N losses, such as the maintenance of water and air quality (n = 4 and n = 1, respectively) were cited by four farmers only, all belonging to clusters 1 and 2. When asked about links between agroforestry and the regulation of the N cycle, most farmers (14 out of 29) did not identify possible links.

Alongside, the variation partitioning of the farm-gate N balance revealed that tree parameters alone did not explain variations of the farm-gate N balance (Figure 1). Management of N inputs alone accounted for 55.6% of the variability of farm-gate N balance and 18.0% when combined with the management of N outputs. Management of N outputs alone accounted for 2.9% of the variability of the farm-gate N balance. Yet, tree parameters significantly contributed to explain variation of the farm-gate N balance when considering its interaction with the management of N inputs (8.0% of the variability) and with the management of both N inputs and outputs (15.3% of the variability).

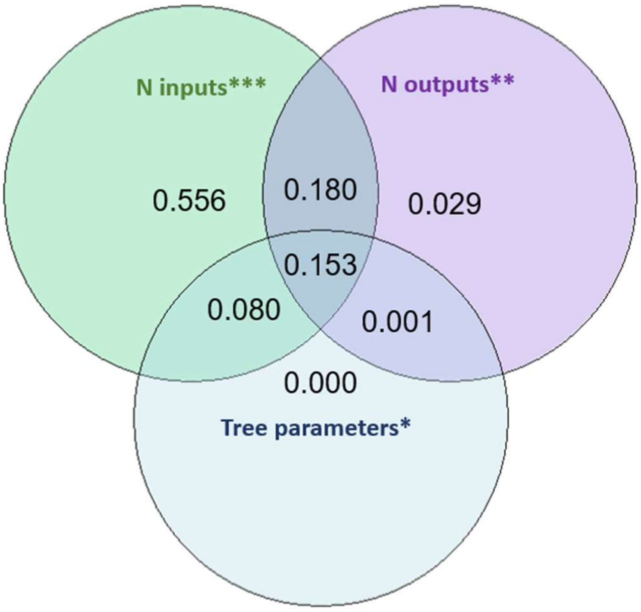

Figure 1. Variation partitioning of the farm gate N balance according to N inputs, outputs, and tree parameters. Significance level: * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Practical implications

Adoption of agroforestry alone has a limited impact on N losses, yet dairy farming systems with more agroforestry present lower risks of N losses

Our results showed that hedges and alley-cropping agroforestry alone did not contribute to decrease N losses at farm scale. In the same territory, Durand et al. (2015) already observed a limited effect of hedges on N losses. Similar to these authors, we identified that lowering N inputs was the main lever to limit N losses at farm scale. Yet, our study highlighted a strong correlation between the adoption of agroforestry systems and low N inputs. Especially, farms that planted hedges and alley-cropping agroforestry the most (clusters 1 and 2) had a low N surplus, similar to other assessed experimental low input dairy systems (Puech and Stark, 2023). Furthermore, Toussaint and Darrot (2021) observed a similar strong correlation between plantation of hedges and the adoption of farming systems with more grasslands and fewer N inputs. Thus, supporting agroforestry supports farming systems that limit N losses, which is line with the objectives of public plantation schemes (Agreste Bretagne, 2010).

Theoretical implications

Adaptation of practices following the adoption of agroforestry can enhance the regulation of N losses by agroforestry systems

Tree parameters had a significant impact on the regulation of the farm-gate N balance when considering their association with the management of N inputs and outputs. This relation can be explained by the introduction of unfertilized areas on farms when planting hedges and tree rows. Hence, synergies between adoption of agroforestry and the management of N inputs can be identified. In this line, Komainda et al. (2023) underlined an interaction between N inputs rates and the distance to the trees on N use efficiency in grassland plots. As a result, they advised not to fertilize grasslands in the

6.5m next to the trees. Moreover, studies on silvopastoral systems highlighted the potential of trees as a feeding resource enabling to limit feed N inputs at farm scale (e.g., Mahieu et al., 2021). The adoption of these practices may enhance the impact of agroforestry on the regulation of N losses. Yet, in our study only one farmer decreased fertilization rates next to the trees and only two farmers used trees as an additional feeding resource. Furthermore, discussions with the farmers revealed that most of them did not see agroforestry as an opportunity to regulate N inputs. Sharing knowledge on practices that can be adapted with the adoption of agroforestry is necessary so that farmers can take full advantage of agroforestry as a way to limit N losses.

Perspectives on agroforestry as a marker of transformation of dairy farming systems

Our study echoes recent sociological studies linking plantation of hedges and alley-cropping agroforestry and the adoption of agroecological farming systems in dairy farms of Brittany (Sachet, 2020; Toussaint and Darrot, 2021). It hence raises questions about the adoption of agroforestry systems as a marker of transformation of dairy farming systems. Sachet (2020) identified three transition pathways which matched our observations: “differed-transition” where agroforestry is a way to gain in efficiency and competitiveness; “invested-transition” where farmers experimented step by step implementation of agroecological practices; and “complete-transition” characterized by the redesign of the farming system and its integration within the social-economic environment. Differed- and invested-transitions were followed by most farmers from clusters 1 to 3. For these pathways, agroforestry is adopted as an adaptation (i.e., changes limited to the scale of a structure or an activity, Moore et al., 2014). On the contrary, complete-transition pathway is transformative (i.e., changes “that recombines existing elements of a system in fundamentally novel ways”, Moore et al., 2014) but was followed by only few farmers from clusters 1 and 2 who modified their practices on N inputs when developing agroforestry.

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Dealing with complexity to reduce pesticides: the case of vineyard cropping systems

MEROT Anne[1], Teo Etchepare[1], Esther Fouillet[1], Audrey Martinez[1]
1 INRAE, CIRAD, Institut Agro, UMR ABsys, Montpellier, France
* Speaker and corresponding author: *anne.merot@inrae.fr*

Abstract:
Pesticide reduction is a key issue to improve sustainability. Progressive changes in winegrowers' practices are observed to engage deeper and deeper in this transition. However, one difficulty often expressed by winegrowers in interviews is the increasing complexity of management and organisation. This work aims at analysing the evolution of technical and organisational complexity during the pesticide reduction process in vineyard systems. In this work, we assessed the evolution of the technical and organisational complexity of the vineyard cropping system by calculating 3 structural and functional indicators. Interviews were performed in 6 French wine-growing regions. The analysis showed that the three indicators evolved with pesticide reduction. Our results revealed that as pesticide use decreased, functional complexity increased while structural complexity decreased.
Key-words: transition, grapevine, labour, trajectory, system, hierarchy

Purpose

To address current climatic, socio-economic, and environmental issues, cropping systems are evolving rapidly. Pesticide reduction is one of these major issues that brings farmers to modify their cropping systems since negative impacts on human health, environment and biodiversity (IPBES, 2016; Jacquet et al., 2022) have been shown these last decades. Until now, research efforts to reduce pesticides have largely focused on the way to gain in efficiency in the use of existing methods and products or on the development of substitutive methods for pest and disease control without necessarily changing the way pest and disease control is reasoning (Fouillet et al., 2022 and 2023). Thus, research studies propose numerous solutions to significantly reduce pesticides until -30 to -40% compared to the average regional use without reported losses in yield or productivity (Jacquet et al., 2022). However, the issue is so important that a limited pesticide reduction associated to a weak ecological process (Jacquet et al., 2022) is not sufficient. Moving from a curative crop protection approach based on the use of synthetic pesticides to a more preventive approach based on prophylaxis, ecological processes and biological control is now required at farm scale. In turn, this can lead to an increase in the complexity of the cropping system. In parallel, more significant modifications in farm structure, farm organization, and crop management may also be necessary (Darnhofer et al. 2005) to allow the implementation of these levers (Merot et al., 2019). The conditions to favour this change of paradigm are largely questioned. It can be hypothesized that farmers have to find the balance between taking the biological advantages of complexity related to biodiversity (Duru et al. 2015) and simplifying the system's structure (e.g., number of fields and number of plants grown) and management (number of field interventions) to optimize production factors. In this work, we propose to analyse the evolution of technical and organisational complexity during the pesticide reduction process in vineyard cropping systems.

Design/Methodology/Approach

Complexity definition and assessment: Complexity refers to a system having many components and interactions that are difficult to define and understand (Flood and Carson 1993). The system's complexity increases with the number of components (i.e., structural complexity) and the number of interactions between these components (i.e., functional complexity) (Cadenasso et al. 2006; Lamanda et al. 2012). Assessing complexity requires assessing both the structural and the functional diversity as proposed by Merot and Wery (2017). In this work, we focused on the technical and organisational complexity of the vineyard system. We calculated six indicators proposed by Merot et Wery (2017) in the case of the conversion towards organic farming (Figure 1 – i) vineyard area, ii) number of plots and iii) difficult plots, iv) number of technical management sequences, v) number of interventions per plot and year, vi) number of management indicators) . The vineyard area informs on the structural complexity and the two others on functional complexity. These three indicators were calculated every year and stepped all over the pesticide reduction process on a minimum period of 10 years.

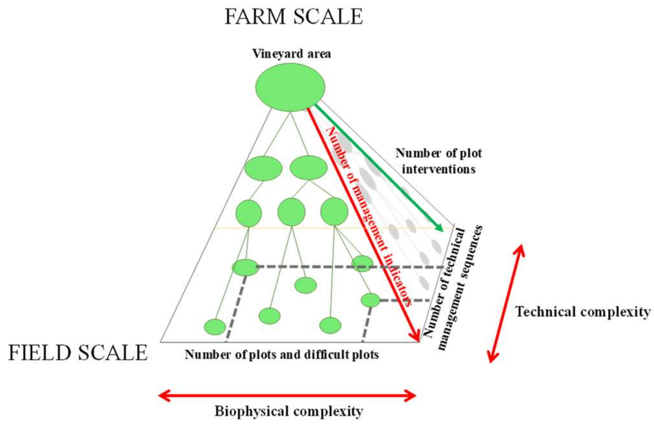

Figure 1: Representation of the vineyard system from plot to farm scale as a hierarchical system combining technical and biophysical components and positioning of the 6 complexity indicators calculated in this work

Data acquisition and farm studied: We interviewed 27 winegrowers in six main wine-growing regions in France spread in various pedoclimatic and production contexts. The winegrowers were more or less advanced in the pesticide reduction process. Each interview consisted in a semi-directive survey (2-3h) on the actual vineyard system completed by a retrospective discussion. The information collected was related to i) the plots' characteristics, ii) the cultural practices and the decision-making process to implement these practices in the various plots in the vineyard. Changes were caught over a period of a minimum of 10 years. We used mapping of the plots and chronologic representation (Figure 2) to collect data during the interviews.

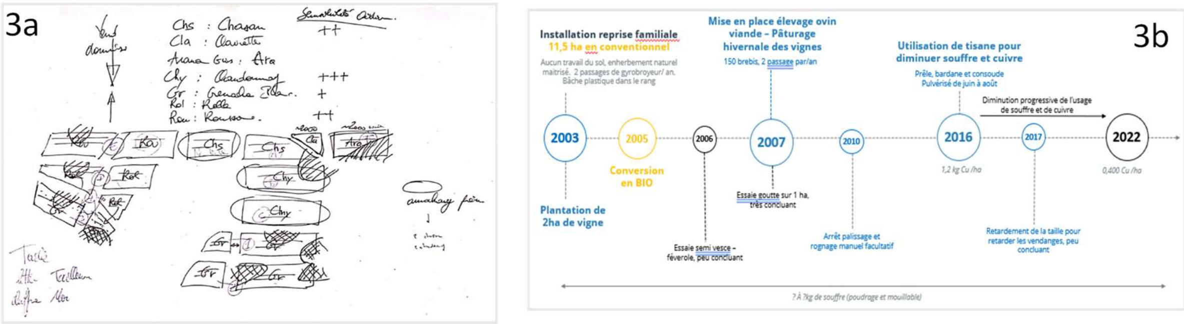

Figure 2: Tools used to synthesise data: 3a) mapping of the plots and 3b) chronologic representation

Indicators calculation: All the data collected let to characterize the intensity of pesticide use and complexity over time. The treatment frequency index was chosen to assess the intensity of pesticide use as it is widely used and accepted in France to assess pesticide reduction (Guichard et al., 2017). TFI was calculated according to the following equation (1):

$$TFI = \sum_{p,t} \left(\frac{Dose_{Sprayed(p,t)}}{Dose_{recommanded(p,t)}}\right)$$

Eq(1): Calculation of the TFI (Fouillet et al., 2023) for a given year at the vineyard scale. The TFI equals the sum of the TFI per treatment t and product p, where one treatment corresponds to one product $_P$ sprayed and one date of application. The TFI per treatment t and product p is calculated as the dose sprayed per product $_P$ ($Dose\_sprayed_{p,t}$) for each treatment divided by the recommended dose for a product p for the targeted pest ($Dose\_recommended_{p,t}$).

The pesticide reduction in a vineyard was calculated as the annual TFI divided by the regional TFI. The regional TFI was provided by the French Ministerial Statistical Service for Agricultural Data. Then we calculate the six complexity indicators from Merot and Wery (2017). The vineyard area was directly available with the survey. A deep analysis of the interactions from plot to farm scale between biophysical and technical components of the vineyard system following an HPD analysis (Merot and Belhouchette, 2019) to calculate the number of technical management sequences and the number of management indicators.

Analysis: Each vineyard studied presented specificities in the vineyard area and plot cutting in the landscape that are more linked to the regional context than the farmers' choices. To compare data from different regions and contexts, we normalized the complexity indicators by the number of plots. Linear mixed modelling was performed to test the significance of the relationship between complexity indicators and pesticide reduction. The analyses were conducted in R (R core team, 2021) using the "lme4" package (Bates et al., 2015).

Findings

In this manuscript, we propose to present only three of the six complexity indicators to give an overview of the results. The choice of the three indicators is not motivated by any scientific reasons except to cover a diversity of indicators in nature and components of the system.

Indicator description: Among the vineyard systems and over the period studied, the vineyard area varied from 1ha to 120ha (Figure 3). The data corresponding to the little areas (around 1-2ha) corresponded to farmers that just beginning their agricultural activities 10-15 years ago and that increased vineyard area during the period studied. The number of technical management sequences varied between 0.1 and 1.16 (Figure 3a). This means that in some vineyards most of the plots are conducted the same way with very low diversity in the technical management sequences. On the opposite, some vineyards presented a strong diversification of the technical sequences between plots with more than one technical sequence per plot. The number of management indicators to implement practices varied from 0.1 to 1.7 indicators per plots (Figure 3b). This important variation showed that some farmers have a dense decision-making process that included largely the plot characteristics.

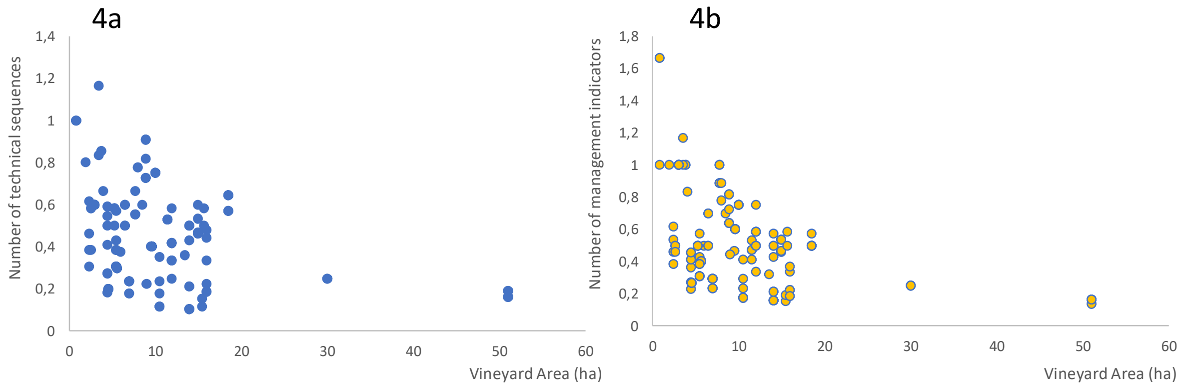

Figure 3: Evolution of two complexity indicators according to vineyard areal 4a) The number of technical management sequences normalized by the number of plots in the farm and 4b) the number of management indicators normalized by the number of plots in the farm. Data for the vineyard area superior to 60ha are not shown (5 situations, a situation is the combination of a vineyard and a year)

Findings on the interactions between complexity indicators: *When* analysing the link between the three indicators studied, we showed that the number of technical management sequences decreased with the increase of the vineyard area (Figure 3a). The evolution of the number of management indicators in the vineyard system followed the same trend as the number of technical management sequences. When the vineyard area increased, the number of management indicators decreased.

***Complexity evolution in vineyard systems in transition to low pesticide used*:** The analysis of the three indicators showed that the complexity evolved with pesticide reduction. The number of technical management sequences and the number of management indicators increased significantly with pesticide reduction (respectively p= 0.09, p=0.08 ; Figure 4) whereas the vineyard area decreased with the pesticide reduction (p = 0.06 ; Results not shown). Our results showed that pesticide reduction is associated to an increase in functional complexity that could be compensated by a reduction in the structural complexity, and reversely.

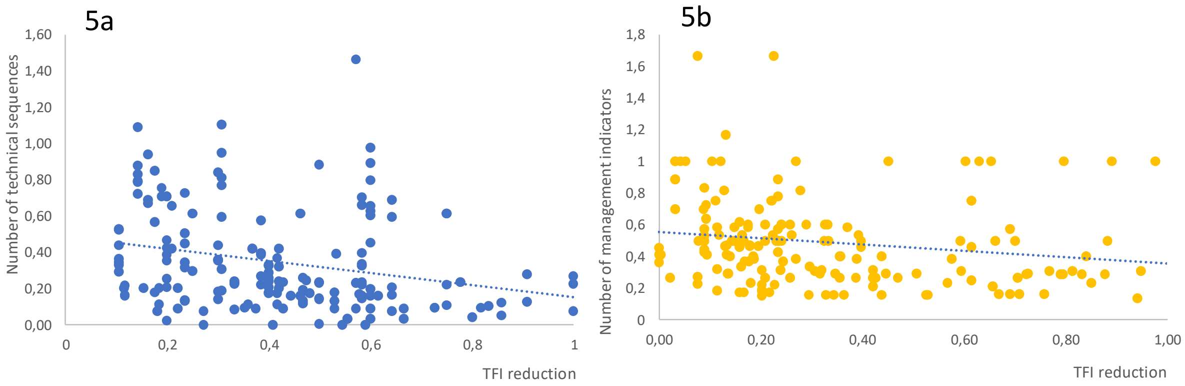

Figure 4 : Evolution of the number of the technical management sequences (5a) and the number of management indicators (5b) in function of the pesticide reduction.

Practical Implications

These results are a step forward in the understanding of the conditions for progressing in the transition towards low pesticide systems. In fact, among the vineyards analysed, some are more advanced than others in pesticide reduction. Our results showed that managing the increase in complexity seemed to be essential to ensure the progression in the transition towards low pesticide systems.

Theoretical Implications

This study contributes to research on the lock-ins and conditions for change implementations from plot to farm scale. Further analyses have to be performed to better understand these results and identify potential compensations and ruptures in the transition. This work must also be completed by the analysis of the other indicators of complexity proposed by Merot and Wery (2017). Anyway, we showed that the transition can be understood as an evolution in the trade-off between the functional complexification and the structural complexity during transition. Farmers have to manage this trade-off during transition adjusting continuously production factors and logic of action when they implement changes.

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Changes in cropping systems associated with biogas plants in French cereal-growing areas

Léa Boros[a,b], Marco Carozzi[b], Sophie Carton[c], Sabine Houot[a], Philippe Martin[b] and Florent Levavasseur[a]

[a] INRAE, AgroParisTech, Université Paris-Saclay, UMR ECOSYS, Palaiseau, France – lea.boros@inrae.fr

[b] INRAE, AgroParisTech, Université Paris-Saclay, UMR SADAPT, Palaiseau, France

[c] AgroParisTech, Ferme de Grignon, Thiverval-Grignon, France

Abstract:
Anaerobic digestion (AD) offers a triple transition opportunity by fostering renewable energy, contributing to a circular economy through waste recycling, and supporting farmer autonomy. In France, AD deployment has recently surged, with an expected rise in energy cover crop (ECC) utilisation, potentially reshaping cropping systems and agricultural practices. However, farming systems linked to AD remain understudied in France, resulting in AD assessments often disconnected from actual farming conditions. Through semi-structured interviews with farmers, we characterised cropping system changes of non-livestock farming systems with AD, focusing on French cereal-growing regions (most impacted by ECC introduction). Key findings reveal barley and rye predominance as winter ECC, and maize and sorghum as summer ECC. These ECC were often treated with pesticides, and irrigated on half of the interviewed farms during summer. Although digestate has the potential to reduce fertiliser use, actual savings varied among farms. This highlights the importance of effective digestate management and the use of agro-industrial waste in AD. AD farming systems may affect water resources, necessitating future AD assessments to consider the impacts of climate change and water scarcity on yields. Our findings underscore the importance of aligning AD deployment with sustainable agricultural practices to ensure a successful energy transition.

Keywords: anaerobic digestion, biogas, cropping system, energy cover crop, fertiliser savings

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Purpose

Anaerobic digestion (AD) can simultaneously contribute to three transition pathways. Firstly, it promotes the energy transition by producing renewable gas as an alternative to fossil fuels. Secondly, it can play a role in the transition towards a circular economy through the recycling of organic waste. Finally, it can support the agricultural transition by enabling farmers to generate new income and enhance their fertilisation autonomy by using digestate, an organic fertiliser generated by AD. The deployment of this technology has increased rapidly in the past five years in France to reach 1705 digesters in 2022 *(MethaFrance, 2023).* This primarily affects farmers, as 90% of the biomass used for AD is expected to be sourced from agriculture by 2030 *(ADEME & Solagro, 2013).*

Energy crops, that can be dedicated crops or energy cover crops (ECC), can be used as AD feedstock. In France, the majority of energy crops used for AD are ECC, as the use of dedicated crops is limited. These ECC are grown between two main crops, and their production is expected to increase by 2050. Various biomethane scenarios suggest that biogas production will increase by 25-30 times at French national scale, and that the share of ECC used as AD feedstock will range from 24 to 48% of the total biomass produced from agriculture by 2050 *(Beline et al., 2023)*.

Incorporating ECC in crop rotation and applying digestate to crops imply changes in farming systems, especially on non-livestock farms relying mainly on ECC for AD. These changes may entail various impacts, including limited greenhouse gas (GHG) emissions or reduced nitrogen leaching *(Bacenetti et al., 2016; Heggenstaller et al., 2008; Hijazi et al., 2016; Malone et al., 2018),* but also potential yield reduction on main crops or increased usage of irrigation or pesticides *(Launay et al., 2022)*. It has been highlighted that current environmental assessments of AD rely on theoretical statements or field trials, neglecting the consideration of actual farming conditions and AD systemic impact on farming systems *(Cadiou, 2023)*. Despite expected environmental consequences, the transformations in cropping systems associated with AD with ECC remain understudied. While *Cadiou (2023)* explored the impact of AD on crop-livestock and livestock systems in Eastern France, there is a notable absence of literature on the impact of AD with ECC on cropping systems in cereal-growing areas, which are potentially the most affected by the ECC introduction, and the agronomical valorisation of digestate.

With this study, our objective is to characterise the farming system changes on non-livestock farms associated with AD in French cereal-growing regions. We hypothesise that their farming practices may deviate from those considered in the environmental assessments of AD. Understanding actual agricultural practices associated with AD can help reassess its impacts in future studies, particularly concerning water resources, food production and GHG emissions.

Design/Methodology/Approach

To characterise cropping system changes on non-livestock farms associated with AD, we conducted semi-structured interviews with 35 farmers associated with 24 biogas plants in French cereal-growing regions, covering a total of 33 farms. For the selection of interviewees, we focused on farmers operating biogas plants for at least one year and located in regions primarily dedicated to field crops. Biogas plants with more than 20% of livestock as feedstock were excluded, as they are usually less dependent on ECC. This resulted in 81 biogas plants among which 24 have been selected for the interviews conducted between December 2020 and March 2023, ensuring a satisfactory sample size and a homogeneous geographic distribution.

Semi-structured interviews were conducted using an interview guide. The interviews covered general information about the farm and the anaerobic digester, the cropping system before and after AD (including specific questions about ECC and their management), the fertilisation practices at the farm scale (focusing on the period before and after the installation of the biogas plant), and the management of digestate.

Descriptive statistical analysis was used to handle quantitative responses of the interviews for general data gathered about the farms and digesters, as well as the level of fertilisation on ECC, and the data about digestate management. An inductive approach was mobilised to manage qualitative responses.

The farms of the interviewees were identified in the French Land Parcel Identification System (LPIS), providing additional and exhaustive information about crop areas per farm and per year. This enabled us to compare the mean land cover changes before and after the installation of the biogas plant. The "before AD period" encompassed the fourth, third, and second years prior to start-up, while the "after AD period" included the start-up year and the two subsequent years, as proposed in *Levavasseur et al. (2023)*. For AD plants that started up in 2020 or 2021, only the one or two years following start-up were included, as LPIS data for 2022 and 2023 were not yet available. Shapiro's test, followed by t-test or Wilcoxon test, were performed in R (v. 5.3.1) to determine whether mean crop surfaces before and after AD were significantly different.

The crop biodiversity index *(Chantrel-Valat et al., 2021)* and the diversity index of crop families *(Hirschy et al., 2015)* were computed for each farm to characterise the crop diversification at the farm level. The crop biodiversity index takes into account the surface area dedicated to each crop. The means of these indexes before and after AD were compared using the same method as described before. Additionally, the number of farms with an increase or a decrease of these indexes before and after AD was determined.

Simplified nitrogen, phosphorous and potassium balances (N, P and K) per hectare at the farm scale before and after AD were calculated, excluding all fertilizers except digestate. This allowed us to determine the potential level of theoretical chemical fertilizer savings achievable through AD. The calculations accounted for nutrient requirements of ECC and the additional nutrient supply from digestate, applicable to both ECC and main crops. Nitrogen imports from biological fixation were excluded, assuming the area covered by leguminous crops remained constant before and after AD, based on interviews and comparison of land cover changes. For example, simplified N balance (ΔN) per hectare after AD was calculated for each farm as follows:

$$\Delta N = \sum(N\ exports\ of\ main\ crops +\ ECC) - N_{efficient}\ from\ digestate$$

With N exports of main crops being determined from crop surfaces, local mean yields, and mean N export of crops from literature. Mean ECC yields were determined from interviews. Efficient nitrogen from digestate was also determined from interviews or from digestate analysis when possible. During the 'before AD' period, ECC surfaces and use of digestate were not considered. Comparing ΔN before and after AD, farms with lower ΔN after AD could theoretically achieve chemical nitrogen fertilizer savings, as it would indicate that their cropping system required less nitrogen than before AD, even after ECC cultivation and with the use of digestate. Similar reasoning was applied to P and K. We conducted linear regression analysis correlating the difference in nutrient balance before and after AD (indicating fertilizer savings achievable through AD) with the amount of agro-industrial waste and by-products in the digester.

Findings

The interviewed farms were involved in AD project for a minimum of 1 year and up to 8 years, with a median experience of 3 years. AD projects involved between 1 to 5 farmers (median = 3) and the size of the interviewed farms ranged from 78 to 750 ha, with a median size of 235 ha. Among the interviewed farms, ECC was grown on 17% to 50% of the total crop surfaces per year (median = 29%). As for the feedstock used in the biogas plants, silage from dedicated energy crops or ECC was the primary input on average, followed by beet pulp, and then by other agro-industrial waste and by-products.

The most prevalent ECC were barley and rye during winter cropping season, maize and sorghum in summer cropping season. The main selection criteria for ECC species by farmer were their sensitivity to drought and their potential biomass productivity, ensuring sufficient input for biogas production and economic returns. ECC were fertilised with a lower amount of nitrogen compared to the same specie cultivated as main crop, with an average fertilisation of 133 kg $N.ha^{-1}$ for winter ECC, and 106 kg $N.ha^{-1}$ for summer ECC. Most farms used pesticides on ECC, especially herbicides. Out of 29 farms growing maize as summer ECC, 20 used pesticides, 4 reported using zero pesticides, and data was missing for 5 farms. Similarly, out of 25 farms cultivating winter barley as winter ECC, 21 used pesticides, 3 reported using zero pesticides, and data was missing for 1 farm. The quantities of pesticides applied on ECC were generally lower than those typically applied to the equivalent main crop. Despite a trend towards prioritising the cultivation of winter ECC to secure AD feedstock production without irrigation, 52% of surveyed farms irrigated summer ECC. Growing more winter ECC shifts the risk of water scarcity to main crops grown during summer. 13 out of 33 farms reported yield losses on the summer crops following winter ECC, with respondents indicating losses ranging from 10% to 40%.

On average, at the farm scale, there has been a significant reduction in the area dedicated to rapeseed and wheat, while the cultivation areas for winter barley, maize, and 'other cereals' (such as rye, oat, or sorghum) with shorter growth periods, have increased. This shift enables farmers to grow two crops in a year. In terms of crop diversity, the crop biodiversity index slightly increased, while the diversity index of crop families slightly decreased. This suggests that the introduction of ECC in rotation helped diversify main crop species at the farm scale, although with crops from the same family, namely "*Poaceae*". Apart from the *Brassicaceae* family, whose cultivated surface decreased on almost every interviewed farm, there was no overall trend of decreasing cultivated areas for a particular family observed; the changes varied from one farm to another.

Regarding digestate management, all farmers used umbilical systems with trailing hoses or shoes to spread digestate on crops in order to limit soil compaction and NH_3 volatilisation. However, a few mentioned the need to use tankers for spreading on small or distant plots. Digestate was primarily spread on winter cereals (main crops or ECC) during February and March, followed by April spreading on spring crops such as sugar beet or potatoes, and in May on maize after winter ECC. Some farmers with limited digestate storage capacity had to spread digestate during autumn on cover crops or winter cereals, when the nitrogen uptake by plants is generally less efficient, potentially leading to more nitrogen leaching and/or ammonia volatilisation. Out of the 33 farms interviewed, 7 had digestate storage for over a year, while 10 had storage for less than 9 months.

Substantial fertiliser savings when using digestate have been mentioned during interviews on 12 farms. However, the amounts saved varied considerably among all interviewed farms, ranging from 0 to 60%. When comparing theoretical simplified nitrogen balances per hectare at the farm scale before and after AD (considering that 50% of the total nitrogen in digestate was available for plant uptake), 17 farms out of 33 demonstrated reduced ΔN after AD, suggesting potential nitrogen fertilizer savings despite ECC cultivation, along with the adoption of effective digestate management practices. On the contrary, 7 farms had increased ΔN after AD, and data was missing for the 9 remaining farms. We also showed that the difference of nutrient balance before and after AD was significantly positively correlated with the agro-industrial waste and by-product level in the biogas plants, suggesting that more fertiliser savings could be achieved when more agro-industrial waste and by-products are used for AD. Indeed, these external inputs are typically nutrient-rich and introduce nutrients from outside the farming system. However, this introduces certain drawbacks, such as increased dependence on resources with fluctuating prices and growing competition, which is contrary to one of the objectives of interviewed farmers, namely to achieve greater autonomy. This dependence could be lowered by cultivating more legumes as ECC, but several barriers have been mentioned during interviews such as legumes susceptibility to drought and limited herbicide options when cultivated legumes mixed with cereals.

Implications for transition pathways

Through the characterisation of non-livestock farming systems associated with AD, we have found that the practices considered in AD assessments can deviate from those observed in French cereal-growing areas. This is especially the case regarding the management of ECC (e.g., fertilisation, pesticide use, irrigation, impact on the yield of the subsequent summer crop, …), and the absence of modification in crop rotation *(Bacenetti et al., 2016; Berger et al., 2022; Esnouf et al., 2021; Malet et al., 2023; Nilsson et al., 2024; Riau et al., 2021)*. Given the anticipated development of these systems with ECC *(Beline et al., 2023 ; Brémond et al., 2021)*, there is a need to re-evaluate anaerobic digestion with ECC, taking into account observed on-farm practices to ensure the sustainable development of this renewable energy supply chain. Our study also emphasises the heavy reliance of cropping systems with ECC on water resources. Therefore, future assessments of AD should focus on the impact of climate change, and potential water scarcity on double-crop systems for AD to mitigate any adverse effects on yields resulting from the energy transition. These findings could inform public policies, facilitating the virtuous development of this renewable energy, enabling the energy transition to be associated with a sustainable agricultural transition.

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Research in precision agriculture: About technologies or about people?

Matteo Belletti[a], Deborah Bentivoglio[a], Thomas Bournaris[b], Chrysanthi Charatsari[b], Giulia Chiaraluce[a], Adele Finco[a], Dimitra Lazaridou[c], Evagelos D. Lioutas[d], Efstratios Loizou[e], Anastasios Michailidis[b] and Aikaterini Paltaki[b]

[a] Polytechnic University of Marche, Department of Agricultural, Food and Environmental Sciences; a.finco@univpm.it; d.bentivoglio@staff.univpm.it; m.belletti@univpm.it; g.chiaraluce@pm.univpm.it

[b] Aristotle University of Thessaloniki, School of Agriculture, Department of Agricultural Economics; tassosm@auth.gr; chcharat@agro.auth.gr; tbournar@agro.auth.gr; apaltaki@agro.auth.gr

[c] Agricultural University of Athens, Department of Forestry and Natural Environment Management; dimitral@for.auth.gr

[d] International Hellenic University, Department of Supply Chain Management; evagelos@agro.auth.gr

[e] University of Western Macedonia, Department of Regional and Cross Border Development; lstratos@agro.auth.gr

Abstract:

Technology-oriented research offers a variety of insights into the potential of precision agriculture technologies to transform current agrifood systems positively. However, little research has been devoted to examining whether researchers studying the technical dimension of precision agriculture technology incorporate social science thinking into their work. In this study, we aimed to uncover if technical researchers integrate societal perspectives into their research and look beyond technologies by emphasizing farmers' needs, considering farming systems' specificities, and understanding how their work affects the future of farmers and farming systems. Following a qualitative approach and using data from two samples of researchers working in Greece and Italy, we found that a positivity bias characterizes technology-oriented research. Participants from both countries conceive of precision agriculture technologies as tools able to solve major environmental and economic problems, attributing limited attention to the cultural appropriateness of these technologies for different types of farming and their social impacts. In both samples, there is a clear focus on the impacts of precision agriculture technologies on farms rather than on farmers or other social groups.

Keywords: precision agriculture, researchers, Greece, Italy, farming, impacts

Purpose

Technical research in precision agriculture continues to grow as new technologies are developed to improve agricultural efficiency, reduce farmer labor, and increase the quality and quantity of agricultural production (Karunathilake et al., 2023; Bhat and Huang, 2021; Erickson and Fausti, 2021). However, doing technology-oriented research, in most instances, means creating, improving, or spreading technology. Of course, user-centered design approaches are often used in the technology development phase (Wang et al., 2024; McCaig et al., 2023). Nevertheless, only a few research projects involve a social science dimension in their designs, thus concentrating their focus on issues referring to social impacts and ethical frontiers of technology utilization or the cultural implications of precision agriculture (Hurst and Spiegal, 2023; Kenny et al., 2021; Stitzlein et al., 2020).

Hence, a critical question is whether the practice of precision agriculture research involves considering the negative impacts that precision agriculture technologies may have on adopters and society. To answer this question, in the present study, we examined if researchers working in the field of precision agriculture consider societal issues when doing technology-oriented research, focus on the needs of farmers and different farming systems, and conceive of their role in the future that new technologies create. In doing so, our research attempted to identify the degree to which technical researchers engage with and potentially contribute to the responsible development of precision agriculture technologies. We conducted our study in two countries where technical research on precision agriculture dominates over social science, and societally responsible research has not yet gained wide popularity: Italy and Greece.

Design/Methodology/Approach

The study was conducted in the framework of the Erasmus+ project "BOOSTing agribusiness acceleration and digital hub networking by an advanced training program on sustainable Precision Agriculture." The study followed a qualitative research approach. We first developed a semi-structured interview guide using inputs from social science research on agricultural digitalization (Charatsari et al., 2022; Fielke et al., 2022; Lioutas and Charatsari, 2020; Vecchio et al., 2022). The guide focused on four dimensions determining researchers' ability to align research on precision agriculture to social needs, namely: understanding farmers' problems and needs; assessing the compatibility of precision agriculture technologies to different types of farming, i.e., the degree to which these technological tools fit the technological infrastructure of farms and the symbolic representations of each type and style of farming (Lioutas and Charatsari, 2020); reflecting on the socio-ethical (Eastwood et al., 2019), economic (Windfeld and Lhermie, 2022), environmental and cultural (Lioutas et al., 2021) impacts of precision agriculture; visioning the future of farming and their roles in shaping it (Regan, 2021).

Data were collected from two researchers' samples (five from Greece and five from Italy). To recruit participants, we first performed a search in bibliographic databases. Greek and Italian researchers with a publication record, including papers focused on topics such as digital or precision agriculture, were considered eligible. Then, we randomly selected and invited 12 potential interviewees. Five researchers from Greece and five from Italy participated in the interviews. All participants perform research on the technical aspects of precision agriculture and the application of precision agriculture technology in farming. Data were analyzed through a critical content analysis.

Findings

The results of our content analysis are summarized in Table 1. The data revealed that, while Greek researchers feel competent in precision agriculture and are confident in their ability to assess the effectiveness of various precision agriculture technologies under different agroecological conditions, they lack field experience. In addition, the multidisciplinary nature of precision agriculture limits their expertise. A notable finding was that researchers pay more attention to the technical features of precision agriculture implementation rather than its cultural or normative aspects. Moreover, the results indicated a limited ability of Greek researchers to understand and predict the interrelations between precision agriculture technologies and socio-economic factors.

On the other hand, Italian researchers tend to emphasize the environmental and economic aspects of precision agriculture. In parallel, as their Greek counterparts, they endorse to a limited extent the need to assess compatibility between precision agriculture technologies and different types of farming. Interestingly, the interviewed researchers tend to see precision agriculture technologies as tools providing several benefits to adopters and agrifood systems and having limited potential negative externalities, such as the high risk and uncertain return of investment in technologies for farmers.

In both countries, researchers seem to understand precision agriculture research as a work focusing on generating, improving, or finding applications for technologies. A social science lens is missing, reducing the ability to see the potential negative impacts of these technologies on farming systems and beyond. According to the interviews, precision agriculture research mainly focuses on farms, farmers, and the agroecosystem. Only some Italian researchers mentioned that consumers could indirectly benefit from the implementation and exploitation of precision agriculture technologies at the farm level (e.g., through the improvement of products' quality).

Table 1. Domains emerged after the content analysis

Domain	**Greek sample**	**Italian sample**
Conceptions of precision agriculture technologies	Technological artifacts able to solve environmental problems and increase farm efficiency	Technological artifacts able to reduce the environmental footprint of agriculture and increase farmers' income
Types of impacts	Positive environmental impacts	Positive economic and environmental impacts
Social sustainability	Limited consideration (emphasis on farmers' well-being)	Limited consideration (emphasis on the quality of products)
Compatibility between technologies and farms	Somewhat limited emphasis (focus on the agroecological conditions)	Limited emphasis (focus on the size of farms and its impacts on technology exploitation)

Nature of precision agriculture research	Technological research (creating and improving technologies)	Technological research (applying precision agriculture technologies)
Impacts of precision agriculture research	Perceived positive impacts: - for farmers, - for farms, - for agroecosystems Perceived negative impacts: - no reference	Perceived positive impacts for: - for farmers, - for the environment, - for consumers Perceived negative impacts: - for farm workers
Anticipation of future	Improvement of precision agriculture technologies by researchers and better targeting of significant challenges faced by farmers; Convenient and sustainable future	Adoption of precision agriculture technologies by a high proportion of farmers; Transition to a technology-enabled (environmentally) sustainable future

Practical Implications

Despite the reliance of the study on two small sample sizes, our results show that researchers working on the technical dimension of precision agriculture emphasize the positive impacts of relevant technologies, paying less attention to their potential (negative) impacts on social sustainability. This finding implies a need to enhance the focus of precision agriculture research on the ways technologies interrelate with society, generating multiple impacts. As Ingram et al. (2022) suggest, a crucial priority for research is to uncover the real benefits of digital (and precision) technologies and how they are distributed across agrifood systems. There is also a need to define the changing roles and responsibilities of researchers and embrace the importance of multi-disciplinarity and public engagement in precision agriculture research (Regan, 2021). Involving farmers in research can offer opportunities to understand their needs and problems and assess in real settings the compatibility of precision agriculture technologies with the specificities of different ways of farming.

Theoretical Implications

In general, the analysis revealed that participants see precision agriculture as a panacea, able to solve problems of any system without contextualizing it based on case-specific attained goals. Finally, the results uncovered that researchers overlook the interrelations between research on precision agriculture technologies (and the technologies themselves) and social sustainability. In addition, researchers from both samples seem to lack the capacity to forecast how precision agriculture technologies can affect the social and cultural aspects of farming.

Notably, the findings are remarkably similar in the two samples. Some minor differences in the perceptions of Greek and Italian researchers (e.g., the reference to the negative impacts of precision agriculture) can be attributed to the prevailing discourse on agricultural digitalization in the two countries. The emphasis put by the Greek agricultural innovation system on overpromoting digital technologies to farmers (Lioutas and Charatsari, 2022) can explain the very positive stance of Greek researchers toward precision agriculture.

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Collective action and participatory knowledge building for Crop-Livestock integration at territory level in Mediterranean areas

Moraine Marc[a], Ryschawy Julie[b], Grillot Myriam[b], Cassagnes Andrea[c], Stark Fabien[d]

[a] UMR 0951 INNOVATION, INRAE, CIRAD, Institut Agro Montpellier, 2 Place Pierre Viala, 34060 MONTPELLIER - *marc.moraine@inrae.fr*

[b] UMR 1248 AGIR, INPT ENSAT INRAE, Chemin de Borderouge F-31324 CASTANET-TOLOSAN - julie.ryschawy@inrae.fr ; myriam.grillot@inrae.fr

[c] BIOCIVAM 11 - Association des producteurs bio de l'Aude, 11 rue de l'Industrie - 11 800 TREBES - andrea.cassagnes@bio-aude.com

[d] UMR SELMET, CIRAD, INRAE, Institut Agro, 34000, Montpellier, France - fabien.stark@inrae.fr

Abstract:
The South of France is exposed to severe climatic hazards and natural resources' depletion, for which farming systems need to innovate to make the best use of water and restore soils and habitats for the biodiversity. In the wine-producing Minervois region, crop-livestock integration at farm and territory level appears to be a model for sustainable farming, allowing agroecological practices and circularity between crops, vineyards and semi-natural areas. We elaborated on the concept of agroecological territory to define under which sociotechnical conditions could crop-livestock integration be developed and reinforced. For this we studied the practices and collective organization of innovative farmers of the territory, and conducted interviews and workshops with farmers and local stakeholders to identify the suitable options for reintroduction of livestock in the territory. On this basis we designed scenarios of change in farming practices and the strategies to secure feed resources for livestock. Landscape mosaics including grazed vineyards, temporary grasslands, cereal cropping and semi-natural areas are desirable and feasible on the territory but require a reinforcement of collective action to support and facilitate the presence and circulation of grazing herds, and the development of shared knowledge and adequate practices.

Purpose

In Mediterranean areas, farming systems are facing multiple sustainability issues including soil erosion, water scarcity and pest invasions, which threaten on the short run the viability of farms, and on the long run the actual possibility to produce agricultural goods in following decades. In the same time, agriculture is more often expected to contribute to the global or local sustainability issues: carbon sequestration in soils and trees, management of habitats for biodiversity, fire risk mitigation. Consequently, building and developing innovative farming systems able to cope with these multiple challenges appears crucial and urgent. *Integrated Crop-Livestock Systems* (ICLS) are promising options for the agroecological transition of farming systems, allowing to increase farm self-sufficiency and nutrient cycling, and to shape diversified landscape patterns. Crop-livestock integration at territory level can address the challenge of specialized systems by opening diversification options, but it faces strong transaction costs and requires adequate combination of knowledge, know-how and cooperation between various stakeholders (Asai et al., 2018).

This article presents an attempt to co-design agroecological farming systems in Mediterranean areas of South-West of France, together with innovative farmers and local stakeholders, within the participatory research project SagiTerres (2021-2025). We studied the Minervois region, a wine-growing area facing numerous sustainability issues, where the reintroduction of livestock systems integrated in vineyards and cereal farming is progressively reconsidered since more than 10 years. We tried to understand the conditions of emergence of ICLS, their potential of development outside of the more innovative actors, and their contribution to local and global challenges.

Methodology

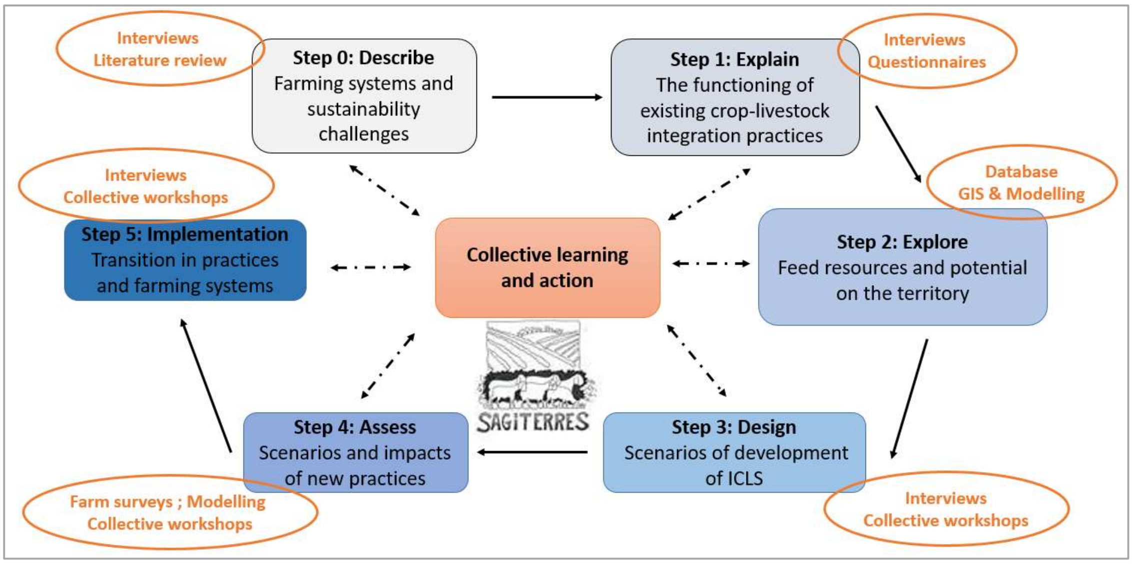
The approach developed in the SagiTerres project consists in 5 methodological steps inspired from Descheemaeker et al. (2019) and presented in Fig. 1. The objective is to integrate the knowledge and priorities of local stakeholders (managers of natural resources, agents of the Natural Regional Park, local authorities, animators of the Territorial Food Project, advisors of the Chamber of Agriculture, local government agents) and innovative farmers to design relevant scenarios for the territory and their conditions of implementation.

- Step 0 is the initial description and diagnosis of current farming systems, and the associated sustainability challenges regarding natural resources, biodiversity, landscape management. This has been done through analysis of existing reports and surveys on the territory, and gathering the visions of local stakeholders through semi-directive interviews at the beginning of the project.
- Step 1 is the characterization of the innovative farming systems already developing crop-livestock integration practices, through farmers' interviews and questionnaires. Farmers were voluntary for participating in this step, and contacted through the organic farmers' association Biocivam 11 in partnership with INRAE for the SagiTerres project.
- Step 2 is the modelling of current feed resources on the territory, based on a Geographical Information System derived from land use map and CAP statement and representing the spatial distribution and surfaces for legume fodder crops, cereals, vineyards, grasslands, fallows, rangelands and woods. An estimation of the potential of feed production through grazing or mowing is done using local data and expertise (technical advisors from Agricultural Chamber and Biocivam 11).
- Step 3 is a participatory step aiming to co-design options for the development of ICLS on the territory. Local stakeholders and voluntary farmers have been interviewed and associated to workshops during which the local knowledge about relevant practices, obstacles and levers to crop-livestock integration in the territory has been shared and discussed.
- Step 4 is a two-level assessment of the potential of ICLS. At farm level we assessed the performances, benefits and impacts of crop-livestock integration practices, through annual farm surveys to collect data, and farmers' interviews to identify their degree of satisfaction regarding the practices and their expectations for following years. At

territory level we estimated the potential of production of crops, fodder and animal products under several hypotheses: i) the impact of climate variations on pastoral resources (dry or humid years), (ii) the increase of the herds' size, (iii) the maximization of the use of biomass for feeding grazing animals. We conducted collective workshops to gather the ideas and visions of local stakeholders on how could the ICLS contribute to other territory issues: fire risk mitigation, water resources protection, biodiversity conservation.

- Step 5 is an investigation of economic, social and political conditions of emergence and development of ICLS practices. Interviews with farmers and local stakeholders and collective workshops have been carried out to identify the relevant animation device, financial support, collective organization and governance rules to frame ICLS and reduce the risk of disengagement.

Figure 1. Synthesis of the methodology of participatory design



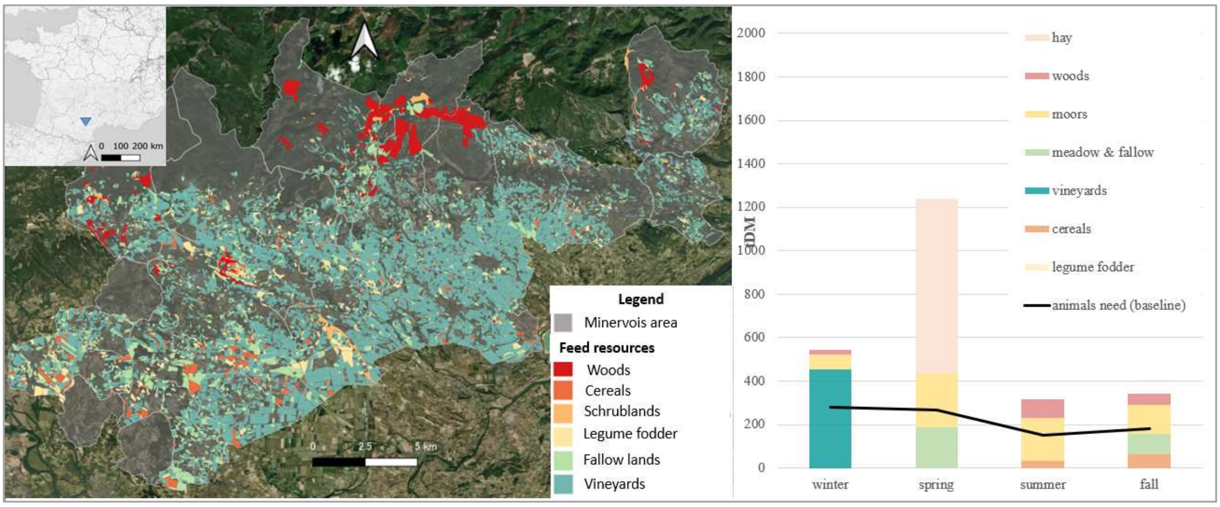
Findings

The *initial step* of diagnosis has stated the importance of restoring a diversity of land use and practices in the Minervois. Wastelands inherited from vineyards grubbing-up should be managed to maintain an open landscape for fauna and flora, and reduce the risk of fire. The use of herbicides and the ploughing of vineyards need to be reduced to preserve the quality of groundwater, to limit soil erosion and restore the soil fertility. The agricultural productions on the territory has to be diversified to contribute to the food production, and to offer more diverse habitats for the biodiversity. Organic diversified cropping systems appears to be good alternatives to the current specialized wine production, but require a coordination with livestock systems to make use of temporary grasslands and supply organic matter.

The *characterization of innovative ICLS* in the Minervois has enlighten the diversity of practices. Cereal farmers and winegrowers collaborate either with livestock breeders from outside the territory or with shepherds grazing across the area. The *Mowing-ICLS* is based on breeders who mow legume fodder crop planted by cereal growers. Organic cereal growers implement legume fodder in their crop rotation in order to improve soil quality and to break the cycles of weeds, diseases and pests. As the first cut of alfalfa and sainfoin cannot be processed into seed because it contains too many impurities, mowing agreements are set up with breeders in order to valorize this biomass. This collaboration give access to a premium on CAP subsidies for cereal farmers, and in return livestock farmers get free hay. The *Grazing-ICLS* is based on sheep herds which graze on vineyards and cereals plots. Shepherds benefit from a good quality and cheap grazing resource, while cereal farmers and winegrowers improve soil quality through animal manure and control their weed without chemical or mechanical intervention. The inter-rows of the vineyards can be sown or covered with spontaneous vegetation and are generally grazed between October after the harvest and March before the vines start to bud. Beyond the agronomic benefits, grazing in vineyards represents an added value in terms of the territory's image.

The *mapping and estimation* of available feed and grazing resources in the Minervois has shown that the availability of such resources is spatially and temporally distributed among the year, with strategic resources that are crucial for some seasons and other more or less plentiful on a very short temporal window (Fig. 2). Feed resources in vineyards, crop residues, temporary grasslands and semi-natural areas could be sufficient to increase the number of animals grazing on the territory, but transhumance may remain necessary in case of long summer droughts.

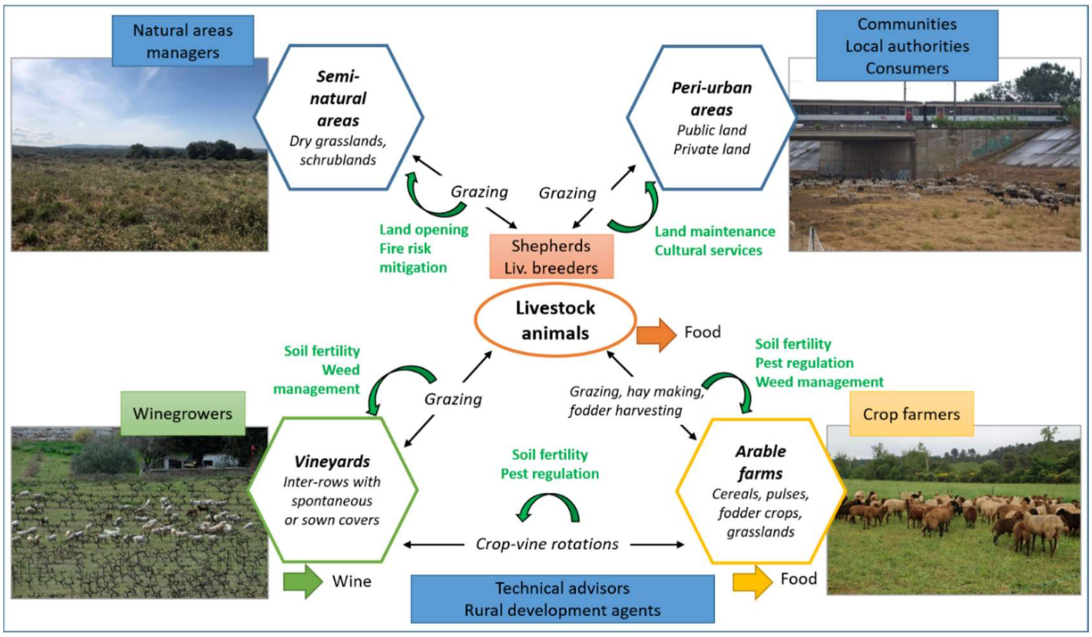
Figure 2: Mapping and seasonal distribution of the potential feed resources in the Minervois.



The *collective scenario* designed for the development of ICLS includes the return of wastelands to cereal production in rotation with grazed or mowed temporary grasslands (Fig. 3). In complementarity, grazing on semi-natural areas appears highly interesting to get feed sources in summer and fall, and to get out of vineyards in winter in case of rain, though avoiding the risk of soil compaction. This requires a coordination with the managers of natural areas, through more or less formalized agreements (grazing conventions, charters, contracts). Hunters and practitioners of open-air sports (hiking, mountain bike) should also be concerted to communicate on the advantages to have animal grazing these areas, and avoid accidents or conflicts in case of lack of communication. Actors of peri-urban areas can also play an important role to allow grazing on additional surfaces (infrastructures such as water retention plains, communal land).

The *assessment of performances, benefits and limits* of ICLS practices has shown that agronomic benefits obtained from grazing of animals in crop plots and vineyards are often very good, according to the observations of farmers. The control of cover crops is better with grazing than with mechanical weeding, and save time, money and fuel consumption. Few damages have been observed (broken wires, dismantled dry-stone walls), and no soil compaction which was a potential problem for winegrowers. A diversity of cooperation has been observed, ranging from large herds on small wine estates to small herds on large estates. Hosting animals on the domain is often considered as a commercial argument, and as a theoretical ideal. A farmer claims that "animals are needed everywhere, they are part of the system".

Figure 3. A scenario for innovative integrated crop-livestock system in the Minervois.



The *factors of transition in practices* towards ICLS development are numerous and require attention and commitment from several stakeholders. The role of technical advisors and rural development agents is very important to make explicit the conditions and requirements of each part of the farmers' partnerships. The emergence of a territorial model of agroecology depends on the network of actors, the existence of common values shared within this network, the development of tools, knowledge and marketing channels, and the construction of a local legitimacy that is more or less formalized in public support policies.

Practical Implications

In the Minervois, the technical and organizational skills of farmers and the specificity of some marketing channels may limit the development of this model to niches. However, intermediaries such as animators of organic farmers' associations can help to elicit the technical knowledge needed to run agroecological systems, as they are already doing through training courses for local farmers. The cooperative of organic farmers “Graines Equitables” has proven that very diverse crop productions can be grown, collected and marketed with an interesting added value for farmers. The question of how to scale up this model of territorial agroecology is the core of a new project driven by the cooperative and gathering many local partners: agricultural land authorities, public authorities, consumers’ associations, etc. The knowledge elaborated within the SagiTerres project will be mobilized to communicate and accompany collective action on the territory, to bring references, guidelines and answers to the main obstacles that have been identified. Our work draws the perspective of an innovative farming model at territory level, in which livestock plays a central role in the valorization of diverse local resources and the supply of a range of ecosystem services. In this respect, it may constitute an alternative to the current predominant farming systems, mainly viticulture and conventional cereal cropping.

Theoretical Implications

Despite being a socio-technical niche, territorial agroecology in the Minervois seems to be well structured and potentially supported by elements of the socio-technical landscape: incentives to reduce inputs in viticulture, motivations from local authorities to relocalize food supply, notably within the framework of Territorial Food Projects, carbon storage issues in soils (4/1000 plan, carbon credits), development of the landscape continuities for biodiversity, etc.

In methodological terms, this analysis seems complementary to the approaches by *Transition Studies*, as it anchors in a territorial reality what appears to be a weakly contextualized theoretical approach. Our approach to territorial agroecology is not focusing on the actors’ networks and controversies, which is nevertheless a determining factor in the ability of agroecological innovations to sustain and develop. Such an analysis, inspired by Multi-Level Perspective approaches, would be a useful convergence. For example, in the Minervois case study, we might consider the ability of organic ICLS to question the currently dominant agricultural models. Identifying the ways in which these models can coexist, and their respective places in a local ecosystem would be a promising line of work.

In return, the framework for reflection proposed by territorial agroecology, inspired by the numerous research on agroecology and territorial approaches to agricultural development, can help to "relocalize" *Transition Studies* theory, which focuses on socio-technical systems and their evolution within a socio-technical landscape, but is rarely linked to territorial contexts with their specific issues and resources.

In proposing to formalize the issues, determinants and territorial resources for the development of a territorial agroecology, we offer a more attentive look at the local specificities of agroecology, while enabling analysis of the dynamics at work and past and future developments in the study area. This analysis can be used to support local stakeholders to find routes for transitions in agricultural and food systems, in the context of climatic and ecological crises.

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METHODOLOGY, METHODS AND TOOLS FOR ANALYSING TRANSITIONS II

What lessons can be learned from the use of two serious games to support the agroecological transition in viticulture and arboriculture?

Annie SIGWALT[a], Arnaud DUFILS[b], Christel RENAUD-GENTIE[c], Blandine ROSIES[d], Aude ALAHILIPPE[d]

[a]Research Unit LARESS, USC INRAE 1507, Ecole Supérieure des Agricultures, 55 rue Rabelais, 49007 Angers, France

[b]INRAE UR Ecodéveloppement, Domaine Saint Paul – Site Agroparc, 228 route de l'aérodrome, CS40509, 84914 Avignon Cedex 9

[c]Research Unit GRAPPE, Ecole Supérieure des Agricultures, USC INRAE 1422, 55 rue Rabelais, 49007 Angers, France

[d]INRAE UERI Gotheron, 460 chemin de Gotheron, 26320 St Marcel-Lès-Valence, France

Abstract:
In France, fruit-growers and winegrowers are facing many regulatory changes and societal injunctions, especially on phytosanitary management. The research program Vitarbae, aims to co-create with sectors' stakeholders' pathways to support the agroecological transition in viticulture and arboriculture, combining environmental and economic assessment tools with serious games, among which "Vitigame", based on viticultural itineraries, and "Design the orchard of future" for orchards' creators. This article aims to present a survey where we evaluated what participation in game sessions may have brought (or not) to respondents. We chose a qualitative sociological approach to interview 15 persons, either game players or facilitators, with an interview guide designed using Kirkpatrick assessment model. The analysis show that the serious game sessions have always been appreciated, both as an original way to study agroecology, and a good support for exchanges among participants. Some respondents made suggestions for improving the games to integrate climate change, economic aspects of the valorization of wines or fruits, or issues related to labor. They also opened avenues for reflection on the content and arrangement of the contributions to be provided during the support pathway to agroecological transition.

Key words: transition pathway, winegrowing, fruit-growing, eco-participatory design, France

Purpose

Due to their perennial status, fruit tree production and viticulture rely on heavy use of pesticides, whereas both sectors are facing growing consumer demand for products that respect the environment and human health, alongside a policy of removal risky pesticides and developing agroecology (Rouault, 2019). Changes in agricultural practices are therefore necessary, and may involve redesigning systems, step by step or *de novo*

(Meynard et al, 2012). The redesign of perennial cropping systems is crucial and includes specific features that can make it complex. Simon et al. (2016) identified some specific elements to be considered to optimize the design of these perennial systems, the evaluation of their impacts and overall performance.

Collective approaches are here considered essential : they allow to benefit from multiple types of knowledge and expertise that can be mobilized, shared and even produced to build an optimal system (Simon et al., 2016; Toffolini, Jeuffroy, et Prost, 2016). Peer-to-peer exchanges enable essential experience sharing to support the agroecological transition of systems (Jeuffroy, 2022). They are notably supported by French public action through support for farmers groups structured around common issues (Girard 2021; Slimi et al. 2022). Indeed, agroecological knowledge are often highly situated, with a lack of references on innovative practices, a need to adopt a global approach, and thus for advisors to move away from a top-down advice. Therefore, this will require specific supporting and facilitating skills, and tools to cope with these major challenges (Faure et Compagnone 2011; Girard 2021). These tools need to be articulated within the entire (re)design process, taking into account their long, non-linear and multi-scale nature (Belmin et al. 2022).

The Vitarbae program research project, funded by the French office for Biodiversity, aims to develop a path to support fruits and grapevine growers in the design of agroecological systems, which should be modular and adaptable to different contexts. This support pathway will be built in close collaboration with end-users, i.e., advisors, farmers, and will combine environmental and economic assessment tools with serious games. Along with assessment tools, serious games are among the tools of great interest in these co-design processes, for renewing exchange, experience, learning, design, and decision-making formats within the framework of collective support. According to Dernat et al. (2021), a serious game is defined as a game whose primary objective is not entertainment.

Two serious games have been pre-identified on the Vitarbae project for certain steps of the support pathway to be built: Vitigame® (Renaud-Gentié et al, 2020) and “Dessinez le verger de demain” (DVD) i.e., “Design the orchard of future”. Vitigame® aims to design viticultural pathways of technical operations combined with Life Cycle Analysis method, to assess their environmental impacts. DVD is a board game which enable the players to design a sustainable orchard, including agroecological levers. For both games, the players’ proposal is discussed at the end of the game to underline its assets and disadvantages.

A reflective analysis of the use of these two serious games and the induced changes for the participants then seemed necessary, to draw useful lessons for the construction of the support pathway and possible adaptations to be made to the two serious games. To do this, we chose to base our work on Donald Kirkpatrick’s evaluation model (Devos and Dumay, 2006), who distinguishes four levels to assess a training given to an enterprise’s employees. These levels encompass i) the participants’ reactions, to see if they enjoyed it, and what were the points that pleased or unpleased them ; ii) the learnings : did participants get knew knowledge through their training ; iii) the way in which they possibly transfer their new knowledge and skills in their professional context

; and iv) the long-term influence of training the employees for the enterprise. This model was tailored to suit our specific needs.

Design/Methodology/Approach

We conducted a survey, aiming to evaluate what participation in game sessions may have brought (or not) to players or facilitators, to draw useful lessons for the following steps. We chose a qualitative sociological approach, to gather the points of view and expectations of the respondents. Our survey was conducted through fifteen semi-directive interviews (with 6 focused on DVD and 9 on Vitigame®), with either face to face or videoconference recorded interviews, spanning the period between August and December 2023. The duration of the interview ranged from one hour to one hour and a half. The interviewees were selected from lists prepared by the games' designers. They all had the experience to use either DVD or Vitigame® in the past three years, either as gamers or facilitators of a game session, sometimes successively in both roles. At that time, some of the interviewees were either students or faculty members, using the game in an educational purpose. In this case, students were either youngsters training for an agricultural degree, or adults aiming to discover a future professional sector. The other interviewees were agricultural advisors in the fruit-production or viticultural sector, or winegrowers. The General Data Protection Regulation was respected, with the signing of an information and consent form by each interviewee.

To follow Kirkpatrick evaluation model, the interview guide was designed with the following parts: i) Presentation of the interviewee, ii) Context in which the interviewee was asked to participate in a game session, iii) Evaluation by the interviewee of the game session, iv) Assessment of learnings, v) Assessment of the level of transfer of learning outcomes into working conditions, vi) Interviewee's opinion on the transition path to be built. A qualitative analysis of content of the collected discourses produced the results, with the aid of NVivo software (version 14) to categorize quotes into the various themes outlined in the interview guide.

Findings

The serious game sessions were primarily conducted during training sessions with agriculture students, or with producers or advisors from the wine or fruit growing sectors. In some cases, the serious games, were initially presented as draft versions, which the respondents tested before subsequent improvement were made. The evaluation of these games also varied based on respondents' individual background: some were enthusiastic "gamers" motivated by winning, while others had a more distanced relationship with games. Nevertheless, all greatly appreciated these sessions. The use of a serious game appears to be an original pedagogical method, which makes it possible to make a synthesis of previously acquired notions, either during the training or from practical field experience. Manipulating the objects in the game proves to be a good way to engage the players' participation, especially when some of them were reluctant to consider agroecology. It also fosters dialogue between players on the decisions to be taken. While discussing, they can exchange about their knowledge and experience, which can help to remove obstacles to changing technical practices. This collective approach is therefore an important lever to keep in mind.

In addition, these games can be used in a wide variety of ways, from raising awareness of agroecology in the context of an all-public fair to working a specific point during a training session when creating an orchard or choosing a winegrowing technical itinerary (e.g., irrigation conditions, biodiversity of the plot). Vitigame® is appreciated for the opening it allows on life cycle analysis approach, considering all the environmental impacts of viticultural techniques, thus not only focusing on pesticide use. DVD is seen as an original serious game, since it allows to think about the creation of an orchard plot, considering different kinds of agroecological levers, in a rather easy and visual way.

Nevertheless, some improvements are still possible on the games. For the DVD game, some respondents deplored the opaque nature of the rules used at the end of the game to rate the ecological nature of the created orchard. They agreed that creativity is the main interest of this game but sometimes feel that the points awarded in the final evaluation as a penalty. For Vitigame®, some respondents reported that the game was rather difficult to understand at first, due to the multiple objects to play with and to combine (cards, booklet on plant production products, weather indications, etc.). Therefore, creating a pathway of technical operations while thinking about less impacting techniques can be a rough task for some. This could advocate for a simplification of the game, or, at the less, for a differentiation between several levels of game. On another hand, initiated players made the wish to be able to play with a software version of the game (still to create). Some respondents also complained about the time needed to calculate the LCA results of the chosen technical itinerary. As a matter of fact, for both games, one of the major survey's results is that the players seemed a bit frustrated not to have been able to play several times to test the games' various possibilities. Furthermore, respondents are asking for an actualization and a regionalization of the games. For Vitigame®, this means including new products in the available list of phytosanitary products such as those used in organic agriculture or being able to use new equipment such as electric tractors. For DVD, the answers mention the need to include new tree species or to be able to specify varieties, some of them being less susceptible to disease. For both games, it seems necessary to offer versions adapted to local farming conditions to promote the spread of the game. Indeed, Vitigame® is designed so far to work on an Anjou vineyard whereas DVD is based on French south-east conditions for fruit production.

The third level of Kirkpatrick's assessment model concentrates on the learning outcomes in real-world working conditions. Teachers and agricultural advisors acknowledge the value of the tested games, and regularly incorporate them into their training programs. Some advisors view them as a potential solution to revitalize recurrent training sessions for farmers, such as those to obtain the certificate authorizing professionals to use pesticides in France. However, for the five winegrowers interviewed, the learning outcomes are not so obvious. Two of them were already evolving towards more environmentally friendly practices, guided by collective advice, when research teams approached them. The remaining three, who were in vocational training when they played the game, are now established winemakers but do not explicitly correlate the game session with their current viticultural practices.

The respondents were also questioned about the establishment of a support pathway for the agroecological transition to be created within of the program. They think that the objective of this course is relevant, given the agroecological orientations to which they are bound both by regulatory pressure and expectations of society. Nevertheless, one respondent on Vitigame® warns that wine is not an essential product for human consumption and that families may tend to purchase cheapest products rather than those produced under better ecological conditions. Therefore, for many respondents, the transition process must consider the economic conditions in which producers operate. This involves knowing both the economic impact of the techniques proposed in each game, but also situating the transition process in relation to the producers' various marketing conditions. Closely related, the issue of the workforce emerges as an obstacle in the design of sustainable fruit production or vine systems. Other propositions are made, such as incorporating visits and demonstrations of new techniques, to broaden producers' perspectives on new possibilities. The respondents also stressed the importance to mix theory and practice, advocating for a balance between indoor sessions and outdoor practical experiences.

Finally, the respondents also provided suggestions about the design of the transition support path. The latter should be designed over several years, involving regular gatherings of participants. The intervals between meetings are crucial, allowing individuals to assimilate or test new ideas or practices. Some respondents advocated for a blend of individual and collective advice. Additionally, one respondent expressed interest in having online resources for self-study between gathering sessions. It's essential to envision the support pathway at a very local level, both to consider the local production conditions and to favor participation. Finally, when asked for the type of actors that could organize and facilitate this transition path in their area, respondents predominantly thought to advisory organizations commonly found in the French agriculture world, and less frequently to advisors in the environment field.

Practical Implications

Vitigame® and DVD are part of the growing collection of serious games in France, contributing to feed thinking about agriculture, food, and territory development, as those listed by Gamaé platform (Dernat et al, 2021). Developed by distinctive research teams, the two studied games cater to diverse audiences and find utility in various contexts. Some of the games' improvements discussed here have already been made, others could soon be discussed within the Vitarbae project. The results also show proposals of training for games' facilitators. Indeed, the interviewees' proposals argue in favor of integrating serious games into a more holistic approach for supporting farmer groups. The broad range of contexts in which these games are employed, the different roles occupied during the game sessions, and the respondents' various positions towards work complicates the analysis of their perceptions. But this, indeed, is also food for thought for the Vitarbae program, which should maybe imagine different scenarios to meet each type of public, including learners in vocational trainings.

Theoretical Implications

A limitation of the study is that respondents were questioned about games they had only played once, during a short session that occurred at least two years ago. Consequently, some participants expressed difficulty recalling specific details, highlighting the challenge of relying on memories. To address this, it is advisable to launch an assessment process that could occur immediately after the game session and be repeated six months later. This could mitigate the impact of fading memories and enhance the accuracy of evaluation.

Moreover, given the limited scientific literature on the integration of serious games within support pathways, considering Etienne recent insights (Etienne, 2023) about local adaptations of support pathways, both at the farm and territory level, and shift in advisors' posture to foster knowledge sharing among farmers, could be relevant.

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Distributed experiments and learnings to support the diversification of cultivated species

Quentin Toffolini[a,c], Maïté De Sainte Agathe[a,b,c], Lorène Prost[b,c] and Chantal Loyce[a,c]

[a]UMR Agronomie, Université Paris-Saclay, AgroParisTech, INRAE, 91120 Palaiseau, France.

[b]UMR SADAPT, Université Paris-Saclay, AgroParisTech, INRAE, 91120 Palaiseau, France.

Abstract:

Transitions towards diversified farming systems directly connect issues regarding knowledge production and sharing, notably concerning little known species (also called minor crops) and agroecological processes occurring in complex farming systems. In this communication, we particularly address the need to renew the ways of generating new knowledge on cropping practices including minor crops by relying on very diverse actors' experiences. System experiments, often implemented on long-term agricultural research sites, are interesting setups to bring out contrasted aspects of this issue. Two different case studies are combined to explore the generation of new knowledge concerning the introduction of minor crops in farming systems that could support transition at the level of cropping practices. We show that this knowledge results from distributed and collective experimentation processes, often remaining invisible in scientific or technical publications. Such experimentation processes require further conceptualization from agricultural scientists for being more appropriately recognized and supported within diversification transition dynamics. Diversification with minor crops can be considered as an illustrative case of connections between epistemic issues and actors' systems organizations within transitions dynamics.

Keywords: diversified farming systems; system experiments; networks of experimentations; collective experimentation; minor crops

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Purpose

Changes in practices as part of agroecological transitions often involve objects little known to research or development, and require situated and systemic approaches (Girard and Magda, 2020; Toffolini et al., 2019). This prompts farmers, agronomists and other actors of agrifood systems to renew their ways of producing relevant knowledge. This is particularly obvious in the case of crop diversification based on minor species, for which knowledge and forms of experimentation are either still deemed inadequate (e.g. scarce knowledge about legume crops concerning pluriannual and landscape effects, as mentioned by Ditzler et al. (2021)), or the subject of methodological developments (Leclère et al., 2023; Reckling et al., 2016). The various forms and configurations of experimental practices, as well as their combinations, are actually called into question. First, multiple actors' experiences are needed to supplement the limited research-produced knowledge on minor species. Second, building ways of cropping and value chains at the same time requires to address new agronomic aspects (e.g. impacts of cropping practices on product qualities required for the dominant processing

technologies). Lastly, the introduction of minor crops requires to redesign cropping systems (Revoyron et al., 2022), implying a particularly strong contextualization of knowledge.
In this research, we thus assume that transition pathways based on the diversification of agrifood systems can be supported by reconfiguring the relations and complementarities of a wide range of experimental situations (i.e. on-farm, in station, explorative, autonomous or within development groups, within collaborative innovation settings) and methods (e.g. system experiments, factorial and randomized trials, exploratory trials), and by acknowledging the various actors' legitimacies and productions in these experimental activities. We initially focused our investigation on system experiments. This type of experiments was proposed for departing from the shortcomings of factorial and annual trials when addressing complex and emergent processes within agroecosystems (Debaeke et al., 2009), such as the cropping systems' performances or their evolution (Borrelli et al., 2014). But very few studies look at the changes in professional skills and practices (Fiorelli et al., 2014) or at the various actors' networks (designers of the systems, experimenters, local farmers) these particular experiments are embedded into (Cardona et al., 2018). Nevertheless, some agronomists have begun to discuss how to organize Long Term System Experiments in the frame of agroecological transitions, notably by encouraging interactions between research stations and on-farm trials, and by involving agrifood system actors in the process of these experiments (Silva and Tchamitchian, 2018).
In this communication, we propose to contribute to recognize and redefine the places and roles of system experiments for agroecological transitions by an analysis of the particular experimental activities performed on diversified cropping systems. We are thus endeavoring to show how system experiments are intertwined in a variety of distributed situations of experimentation and learning that support the construction of particular transformative knowledge.

Methodologies and Approach

We combine insights from two different research projects that comprise system experiments concerned with the diversification of crops. First, we draw on some of the data collected throughout a long-term and longitudinal analysis of the introduction of grazed fodder beets in a mixed livestock farming system experiment (combining interviews, documentary analysis, and activity analysis, led by the first author). Interviews were addressing the main evolutions in the cultivation practices for this new crop, the identified learnings, and the experimenters' coordination along the multi-annual experimentation process. The data analysis relied on the logics of action on fodder beets and their particularities due to its introduction in a long-term system experiment, as well as on their building through knowledge exchanges among local farmers, research and development or other agricultural actors. Second, some findings are based on a set of semi-directive interviews led with the scientists and technical staffs in a network of 7 stations where system experiments were led during 12 years with the constraint of not using any pesticide. Questions and themes addressed during these interviews were primarily aimed at revealing the main learnings that contributed to change

experimenters' practices within diversified systems, only seldom appearing in published papers.
Our intention in combining these studies is to gather arguments supporting the recognition of highly diverse experimental contexts, their interactions, and the learnings they produce. Our aim is to facilitate discussions on relocating them within research and innovation systems to better support transitions.

Findings

System experiments are often defined in opposition with factorial trials, with emphasizes on the aim to unravel processes at the system's level (Debaeke et al., 2009). Questioning what one learns from them concerning specific minor crops may thus seem contradictory. However, we encountered a large diversity of system experiments about diversified cropping systems, based on specific combinations of "patterns of experimental situations" *i.e.* alignments between an intent (e.g. understand a phenomenon, optimize a crop management), a spatial configuration (e.g. plot, strip, margins) and a particular instrumentation of observations (de Sainte Agathe, 2022). Each of these patterns can be associated with particular types of knowledge and learnings, which we do not describe further here. Instead, we present two main findings based on analyzing the interactions among these patterns throughout collective experimentation processes.

Collective building of new knowledge on a diversification fodder crop within a long-term farming system experiment

The first findings concern the progressive building of new knowledge about the introduction of a minor crop in a farming system, resulting both from long-term trials making room for repeated patterns of experimental situations, and from interactions between the experiences of various actors within and outside the research station. This is illustrated with the introduction of fodder beets as a pasture crop in a mixed crop-livestock system experiment on a research station, and the progressive building of knowledge applied for its management thanks to multiple years of trial, farm visits, factorial trials within the system experiment, and to the efforts to combine learnings from scientists, crop and animal managers, visiting farmers and technicians.
At start, in 2014, the idea to introduce fodder beets corresponded to the need for green vegetative feed during hotter and drier summers. What was known by the scientist and the crop or animal managers in charge was based on the basic information provided by technical institutes and advisory services: sowing density (120 000 seeds per hectare), approximate regional sowing date, sowing depth, cultivar choices, types of mechanical weeding tools, digestibility and energy supplies for cattle. First sowings were designed as strips within a plot in order to find the best sowing techniques. Questions mostly concerned the dynamic competition with weeds or cover crops and the quantitative production of dry matter. The fodder beets were impacted by weeds, such as goosefoots, which was first disappointing for the scientist and animal manager. They however noticed that beetroots were growing enough, compensating missing plants, and that goosefoots' dried stems remaining in fields were not preventing cows from grazing.

Questions about weed management still remain today, but rapidly, the identity of this crop and the complexity of its introduction encompassed many other aspects. First, cows needed to learn that roots are edible (and tasty). The animal manager therefore tried many different tricks (e.g. cutting pieces and blending with meslin, adding salt), but finally relied on a local farmer's testimony who insisted that cows learn sometimes by imitation: "*It took my cows three weeks to get used to beets. At first, they only grazed the leaves. Then, little by little, they attacked the roots. Ideally, you should offer them crushed beetroot for the first few days to attract them. Once the first cows are accustomed, the heifers that join the herd adapt more quickly*" (a local farmer). This made the animal manager organize the learning between curious heifers and older cows. Second, new issues appeared such as the proximity of the implanted field with barn, the possibility to rapidly access another pasture next to the beets (cows can stay on beets field only few hours), the necessary room at the border of beets' fields for access and spreading of cows along lines. Later, the repeated observations of the crop manager on various field states and beetroots development dynamics made the identity and function of this crop within the forage system evolve: it consisted as a stock available throughout a longer period of the year. This brought out other aspects of animal health and milk production follow-up: the animal manager progressively fine-tuned the timing of beets pasturing correlated to the observed benefit on milk quality and the climatic conditions impacting the grounds states permitting a pasturing without risking lameness problems. This also connected the crop management techniques (producing enough dry matter) with the herd management: the adaptability of the cows to the beets grazing periods and rapid changes in forage compositions is facilitated by the multi-breed, hardy herd.

The dynamics goes on, but this illustration is enough to show how multiple successive identities of the new crop within the systems were correlated to different and complementary patterns of experimental situations, answering to different elementary questions. These led to mix experiences from actors outside the research station and from the various actors working on the experiment, and finally built a much richer knowledge about a minor crop than what could be known at start from technical and advisory services.

Repeating and sharing patterns of experimental situations among a network of similar system experiments to build new management strategies

We now address the case where several system experiments share the same main objective and are networked over several years. This network gathered experimentations on diversified cropping systems with fertilizers but without any pesticide. The exchange of experiences and data in the network, along with informal interactions with other experiments at each station and interactions between visiting farmers and experimenters, contribute to produce new crop management strategies. These remain often unnoticed and undervalued, yet they represent valuable knowledge for transitioning agricultural practices. We illustrate our finding with the example of a generic management strategy for the *Rumex* perennial weed species. The first technique applied to handle perennial weeds was to repeat mowing on meadows. This worked for *Thistle* but not for *Rumex*. In one site, the experimenter gathered the observations of the other experimenters concerning this species and could interpret processes of *Rumex* development: this nitrophilous weed benefitted from N fertilization and mowing. The experience of a local organic farmer was then mobilized, based on the principle of separating the weeds' vegetative parts from roots reserves by scalping at 7 cm depth after destruction of the meadow. This was then applied first on one site, and progressively shared with the other system experiments confronted with *Rumex*. The repeated observations of similar sequences of practices on several sites confirmed the effectiveness of that strategy. It was also transferred to the other plots of the experimental station. This example shows that beyond the assessment of agronomic performance of the diversified cropping systems, very specific management of agronomic issues appearing with the introduction of minor crop are relying on a distributed experimental work across time, farmers and experimenters and experimental sites. Furthermore, this case-study shows the interest of networking system experiments and supporting specific interactions between patterns of experimental situations at the network level.

Practical Implications

We do not insist on these processes to produce a judgment on what is a good or effective system experiment including minor crops, but rather to show that some descriptors of experimentation practices are necessary to better describe how we know, who knows, and what we know for supporting diversification with minor crops in the frame of agroecological transitions. Transitions in agrifood sectors may require to redefine the roles and types of knowledge that we should collectively recognize and support. Robertson et al. (2008) suggested that Long Term Agricultural Research sites should be organized as networks nodes, referring mostly to common measurements. Our findings support the vision of networks more as complementarities between various experiences that could be organized and shared to build a more collective experimentations (Felt et al., 2016) across sites, actors and ways of learning. However, it remains not straightforward to build the appropriate groups of stakeholders and experimentation settings. Our analyses represent steps toward more accurately identifying specific learnings, collective processes and formalized knowledge, which we aim to highlight and enhance to better support agroecological transitions.

Theoretical Implications

The specific focus on practical aspects of collective dimensions of experimental processes does not primarily intend to refine theories around the Agricultural Knowledge and Innovation Systems. We emphasize the implications concerning theoretical approaches to experimentation, particularly when they are examined in their collective features within transitions frameworks. We think that reflecting on the role of agricultural science within transitions also necessitates the development of suitable theoretical tools for describing more inclusive and collective experimentation processes (Salembier et al., 2023) and to connect these with other research methods (Martin et al., 2018). This requires inputs from agronomists and rural sociologists in redefining paradigms of experimentations, starting by the very organization and recognition of the multiple actors contributing to experimental activities (Toffolini et al., 2021).

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Digitalisation for Agroecology: An indicator-based approach to assess the contribution of digital technologies to agroecology in Europe

Alma Moroder[a d], Karl Reimand[b], Jochen Kantelhardt[b], Andreas Meyer-Aurich[c] and Sonoko Bellingrath-Kimura[a d]

[a] Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany, alma-maria.moroder@zalf.de

[b] University of Natural Resources and Life Sciences (BOKU), Vienna, Austria

[c] Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Potsdam, Germany

[d] Department of Agronomy and Crop Science, Humboldt-University of Berlin, Germany

Abstract:

The transition of agricultural systems towards agroecology is of high importance for a sustainable future. Complying with agroecological principles means ensuring that several aspects within the ecological, economic, and social dimension are taken into consideration. Since agriculture in Europe is becoming increasingly digitalised, we explore the perceived contribution of digital technologies to the transition towards agroecology and particularly, how this contribution can be assessed. Based on a literature review and a small survey, we developed a set of indicators for agroecology under the lens of digitalisation which act as basis upon which digital technologies and their contribution to agroecology can be assessed. Additionally, we conducted a series of semi-structured interviews with agroecology and digitalisation experts to examine the suitability of our understanding of agroecology and our indicators for such an assessment and to further explore the importance of digital technologies for this transition. We find that our indicators are generally suited to achieve our goal and that our understanding of agroecology, however broad, allows for a holistic assessment of complex agricultural systems in Europe. We also find that digital technologies are never inherently "agroecological" but that depending on how they are used, they can contribute to the agroecological transition.

Keywords: Agroecological transition, 10 Elements of Agroecology, FAO, transformation

Purpose

The current agricultural system is still one of the crucial drivers of biodiversity and ecosystem services loss and climate change (Díaz et al. 2019; IPBES 2019; IPCC 2019). This contributes to processes including deforestation, decreasing water availability/disruption of water cycles, and depletion of soils, which exacerbate biodiversity loss and greenhouse gas emissions (FAO, 2018). However, the effects of intensive agriculture can not only be observed on an environmental/ecosystem dimension but on a human and social dimension as well. It has led and still leads to hunger, poverty and other types of inequalities and imbalances (FAO, 2018). A major transition towards a more sustainable or agroecological way of consuming, producing, processing, and distributing food is needed (Wezel et al., 2020).

While several understandings of agroecology exist, the Food and Agriculture Organization of the UN (FAO) has developed its own definition for agroecology, stating that it is "an integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of food and agricultural systems" (Barrios et al. 2020; FAO 2018). Their 10 elements of agroecology encompass a wide range of socio-economic, cultural and political principles (Wezel et al., 2020). Thus, according to this understanding of agroecology, complying with agroecological principles means ensuring that several aspects within the ecological, economic and social dimension are taken into consideration within an agricultural system.

Compliance of agricultural systems with agroecological principles is not only lacking on a global scale but also on a European level. European agriculture is characterized by a particularly intensive use of resources and inputs and by rapidly decreasing levels of biodiversity and ecosystem services. Digital innovations in the agricultural sector are considered to be able to tackle some of these issues (Garske et al., 2021) and help agricultural systems in successfully transitioning towards agroecology. Agricultural practices in Europe are increasingly relying on digital technologies (Bellon-Maurel et al., 2022), and while most technologies used in agriculture primarily aim at increasing productivity and improving efficiency (Ditzler and Driessen 2022; Gandorfer and Meyer-Aurich 2017; Kliem 2022), thus counteracting the principles of agroecology (Bellon-Maurel et al., 2022), evidence exists that it can potentially also contribute e.g. to greenhouse gas emissions mitigation (Balafoutis et al., 2017), thus not only targeting efficiency (as one of the principles of agroecology) but also principles such as diversity, resilience, etc. We consider a variety of digital technologies ranging from farm management information systems, decision support systems, digital information platforms, to sensors, field robots, and drones. With this study, we want to explore how such digital technologies can contribute to agroecology in Europe and how this contribution can be assessed.

Materials and Methods

For the purpose of our study, we developed a set of indicators for agroecology, based on the 10 elements of agroecology by the FAO (2018). The development of indicators aims at representing the concept of agroecology as a whole and thereby allowing for the assessment of digital technologies and their contribution to agroecology. The indicator development was based on an extensive literature review. First, literature from pre-existing knowledge within the project (e.g. Ajena et al. 2020; Meuwissen et al. 2019; Wezel et al. 2020 and others) was gathered and assessed. Subsequently, an exploratory literature review was carried out, for which literature directly related to the FAO's 10 elements of agroecology was analysed. Subsequently, systematic literature research was carried out. Web of Science was used as the primary search engine. 16 publications were found, 6 of which were considered for the development of the indicators after a review (the rest were excluded because they did not include any information related to the assessment of agroecology and did not provide a good basis for the formulation of indicators). All publications were thoroughly analysed, after which relevant indicators for agroecology were gathered through an iterative process, whereby their quality and suitability in the context of digital technologies was estimated. The analysed literature rarely included digitalisation-specific indicators for agroecology. Some of the identified indicators thus had to be adjusted to allow for an assessment under the lens of digital technologies. Furthermore, a small number of indicators was developed based on discussions among ZALF and BOKU and are not directly based on the literature review. During the iterative process of developing indicators based on the literature review, questions such as “is the digital technology related to this indicator of agroecology” or “How compatible is the digital technology with this indicator?” were asked to select or create indicators that would be appropriate for assessing digital tools. After this process, a final list of 62 indicators representing all 10 elements of agroecology was compiled, which was then condensed to 30 final indicators through an online survey among D4AgEcol-members, which this study is embedded in (https://d4agecol.eu/).

In addition, we conducted 17 semi-structured interviews with both agroecology and digitalisation experts. These experts were selected and contacted based on recommendations from D4AgEcol-members. The interviewed agroecology experts were scholars from European institutes and universities, while the interviewed digitalisation experts were both scholars from European institutes and universities, and industry representatives from companies related to the development of digital solutions for agriculture. All interviews were conducted through online-meetings. The interviews were structured into two parts: the first part comprised general questions about the interconnections between agroecology, agriculture, and digitalisation. These questions were aimed at finding why it is important we explore the potential contribution of digital technologies to agroecology. The second part comprised specific questions about our indicators and our concept of agroecology and the feasibility of assessing specific technologies with these indicators. This second part of the interviews aimed at critically assessing our indicators and their suitability for achieving our goal. The interviews were recorded and subsequently transcribed with help of the transcription-tool trint (https://trint.com/). They were then qualitatively analysed according to the qualitative content analysis by Mayring (2014).

Findings and Limitations

Our work resulted in a set of 30 indicators (see Table 1). This list is not intended to be an exhaustive representation of agroecology in its entirety but a selection of agroecology indicators under the lens of digitalisation. In fact, next to general indicators depicting agroecology, it also contains several indicators specifically related to digital technologies.

Table 1. Indicators of agroecology for digitalisation (per element of agroecology (FAO 2018))

Element of Agroecology	**Indicator**
Diversity	Habitat and landscape diversity
	Crop, tree and livestock diversity on the farm
	Diversity of activities, products, and services
Co-Creation and Sharing of Knowledge	Access to data collected by the technology
	Connections among farmers or between farmers and other stakeholders
	Participation of farmers (or other end-users) in the development of the technology
Synergies	Compatibility with other digital and non-digital technologies
	Compatibility with polyculture fields or non-crop plants
	Habitat and landscape connectivity
Efficiency	Farm profitability
	Pesticide use
	Fertiliser use
Recycling	Reusability and reparability of technology
	Water saving or recycling
	Reduction or recycling of waste
Resilience	Protection against extreme weather events
	Protection of farmers against income fluctuations
	Protection against pest and disease attacks
Human and Social Values	Working conditions and wages
	Young people's empowerment and involvement in agriculture
	Data ownership
Culture and Food Traditions	Compatibility with local varieties and breeds
	Preservation of farmers' knowledge, skills and identity
	Integration of local culture into the technology
Responsible Governance	Infrastructure readiness
	Sufficiency of risk assessment related to the use of technology

	Supporting of policymaking and regulation by data provision
Circular and Solidarity Economy	Connecting producers and consumers via local markets and short value chains
	Consumer benefits and fair prices
	Shareability of technology with other farmers

Since agricultural systems in Europe are becoming increasingly digitalised, the question arises in which direction this trend will move agriculture in the future. If we want agricultural systems to transition towards agroecology, thus complying with social, environmental and economic goals at the same time, digital technologies should be developed and used accordingly. Our results show that digitalisation can play an important role in this transition and that it is therefore crucial to understand why certain technologies are adopted over others, how the adopted technologies are used, and how the way they are designed or used impacts agroecological principles. For example, assessing the effect of a technology on efficiency only would merely offer a one-sided estimation of the technology's overall impact on an agricultural system and thus ignore other, possibly opposing effects on other principles. However, our results clearly show that no one digital technology can be considered inherently "agroecological" or compliant with agroecological principles but that whether a technology contributes to agroecology depends on how and to what end it is used. Thus, while it is important that the development process of digital technologies for agriculture be as inclusive as possible (i.e. include developers, researchers, practitioners, and political representatives), and while the intention with which a technology is developed can be a first indication of how it is going to be put into practice, the effect of a technology depends first and foremost on its final users and their goals. Thus, digitalisation can both be an enabler for or a hindrance to agroecology. Given this, the interviewees agree on the importance of digitalisation for the transition pathway towards agroecology. In fact, the results from the interviews confirm that being able to measure the contribution of digitalisation to agroecology and how it impacts agricultural systems generally is important to make consequential decisions at the political level but also at farm level about which technologies are developed, which are adopted and even how they are used. Indicator-based approaches are generally considered to be a good tool for making such assessments. Our proposed indicators were found to be suited for reaching our goal. However, the broadness of our concept of agroecology (FAO, 2018) was mentioned as one of the biggest challenges for developing indicators. In fact, some of our indicators are considered to be relatively vague, which can be ascribed to the broadness of the underlying concept of agroecology. The proposed indicators are intended to be the basis upon which measurements can take place. In their current form, they can offer room for qualitative estimations on the expected effects of digital technologies on agroecology. However, to become a tool for generating robust evidence, scoring and hierarchy systems as well as statistical models will need to underlie the indicators. In fact, another mentioned limitation is their quantifiability. Many interviewees stated that in order to draw significant and robust conclusions from an assessment of a digital technology with our proposed indicators, each of them must be backed up by a different measuring/scoring system. While data availability is not mentioned as a challenge, since most indicators exist similarly in other contexts and data is available on some level for each of them, finding the suitable scoring systems is considered to be the real barrier. Further, establishing a hierarchy among the indicators is found to increase the validity of the results, since the relevance of the indicators for agroecology might depend on the assessed technology and farming system. In general, certain indicators (e.g. efficiency, recycling, diversity, and resilience indicators) are expected to be more easily quantifiable than others (e.g. human and social values, responsible governance).

Our study offers a theoretical basis upon which an assessment of digital technologies and their impact on agriculture in Europe can be carried out. They were developed through a European lens, for European societies, farming systems and technologies used in Europe. At the global scale, our indicators might need to be adapted according to the socio-economic and ecological context they will be used in. However, even within Europe, our indicators might not be suited for every farming system or every digital technology, depending on the context.

Being able to explore whether a technology is an enabling factor for agroecological principles is crucial for supporting certain technologies over others at the governance level if we want to transform agricultural systems towards agroecology, as well as at the farm level, if we want to support farmers in their decision-making and in their individual contribution to agroecology. In fact, we believe that our indicators can serve as a basis upon which practitioners can make sound and informed decisions about the use of digital technologies in agriculture and upon which policy makers can steer the overall direction of agriculture by assessing and promoting certain digital technologies over others, thus paving the way for the agroecological transition.

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Q Methodology Reveals Different Perspectives on Ecosystem Services Among Farmers in the North China Plain

Jiali Cheng [a,b,c,], Yang Zhou [a], Andries Richter [d], Wopke van der Werf [c], Jeroen C.J. Groot [a]*

[a] Farming Systems Ecology, Wageningen University and Research, P.O. Box 430, 6700, AK, Wageningen, the Netherlands

[b] College of Resources and Environmental Sciences, National Academy of Agriculture Green Development, China Agricultural University, Beijing 100193, China

[c] Centre for Crop Systems Analysis, Wageningen University and Research, P.O. Box 430, 6700, AK, Wageningen, the Netherlands

[d] Environmental Economics and Natural Resources Group, Sub-department of Economics, Wageningen University, Netherlands, P.O. Box 430, 6700, AK, Wageningen, the Netherlands

Abstract:

Policymakers across the world demand from farmers to move towards more sustainable systems and more diverse agroecosystems, resulting in the delivery of multiple ecosystem services (ESs). Understanding farmers' diverse perspectives on ESs is crucial for facilitating dialogue, identifying conflicts, and fostering the adoption of improved practices. This study investigates farmers' perspectives on multiple ESs employing Q methodology in Quzhou County, a region characterized by intensively utilized agricultural landscapes in the North China Plain. We find three distinct perspectives of farmers showing preferences for 1) crop production and profit, 2) environment quality, and 3) cultural values. A statistical analysis of how personal, farm and household characteristics relate to farmers' perspectives reveals that age, education, and farm size are the main associating factors. This study offers insights into farmers' ES priorities, highlighting potential trade-offs and decision-making challenges for policy. Recognizing areas of consensus and conflict can guide efforts to promote agroecologically sound practices and policies.

Keywords: agricultural landscape; perception; socio-cultural value; participation; co-design.

Purpose

Global intensive agriculture must transition towards greater sustainability, potentially requiring the restructuring of agricultural landscapes into multifunctional systems (Landis, 2017). Farmer behavior and attitudes, as expressed in their farm management decisions, can significantly influence the delivery of ESs in agricultural landscapes. A comprehensive exploration of farmers' perspectives on the importance of ESs is crucial for the success of landscape management policies (Smith and Sullivan, 2014). However, farmers exhibit diverse and intricate perspectives regarding ESs, influenced by their motivation, knowledge, and interests (Teixeira et al., 2018). Thus, effective policy design and implementation should take into account the variation in ESs perspectives among farmers (Lamarque et al., 2011).

Q methodology is a semi-quantitative method that systematically assesses stakeholder views. It transforms an individual's viewpoint into a set of value positions (McKeown and Thomas, 2013). This study aims to use Q methodology to uncover the variation in farmers' perspectives on the relative importance of multiple ESs. *In this context, a perspective refers to the combination of preferences towards multiple (bundles of) ecosystem services shared by a group of farmers*. Additionally, we investigate which personal, household, and farm characteristics may be associated with farmers' perspectives.

Design/Methodology/Approach

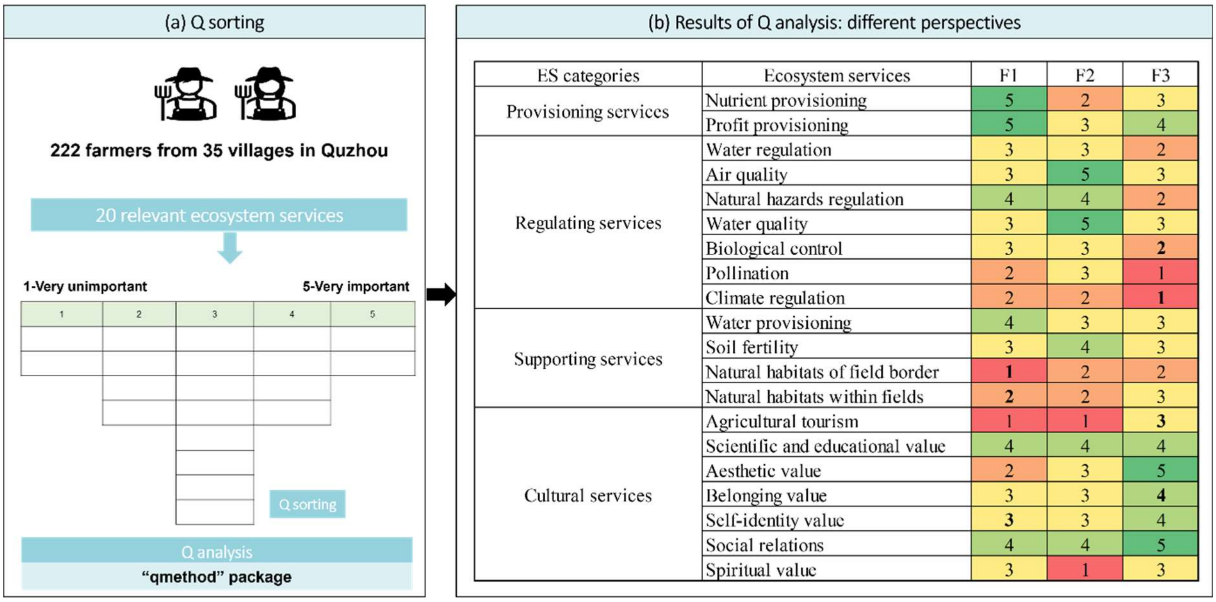
The study area of Quzhou county is located in the south of Hebei province and is part of the North China Plain. It is a major grain-producing area and a representative intensive agricultural area in China. The typical farming system is dominated by the winter wheat–summer maize double cropping system and cotton monoculture system, and most of the population in Quzhou county is rural.

The application of Q methodology proceeded in four steps (adapted from Zabala et al., 2018): (1) We first formulated a Q set of statements based on 20 expert-selected ESs with local relevance. (2) We recruited 222 farmers from 35 villages based on stratified sampling in Quzhou county (Cheng, 2023). (3) Farmers did Q sorting by ranking statements based on importance using a grid system (Fig. 1a.). We asked the participants to give two statements a rank of 1 (very low importance), four a score of 2 (low importance), eight a score of 3 (medium importance), four a score of 4 (high importance) and two a score of 5 (very high importance). We discussed their choices in post-sort interviews. Additional data was collected via structured questionnaires on farm, household, and personal information. (4) Q analysis was utilized to identify different farmers' perspectives on ESs using the 'qmethod' package in R. Associations between perspectives and farmers' characteristics were explored using Kruskal-Wallis and Chi-square tests in R.

Findings

We found that there were three distinct farmers' perspectives on ESs according to the Q analysis, oriented to either profit, environment, or culture. Differences among these three perspectives were interpreted based on four categories of ESs (Fig. 1b.).

Figure 1. Q sorting process (a) and ecosystem services importance scores of different perspectives based on the Q analysis (b).



ES categories	Ecosystem services	F1	F2	F3
Provisioning services	Nutrient provisioning	5	2	3
	Profit provisioning	5	3	4
Regulating services	Water regulation	3	3	2
	Air quality	3	5	3
	Natural hazards regulation	4	4	2
	Water quality	3	5	3
	Biological control	3	3	**2**
	Pollination	2	3	1
	Climate regulation	2	2	**1**
Supporting services	Water provisioning	4	3	3
	Soil fertility	3	4	3
	Natural habitats of field border	**1**	2	2
	Natural habitats within fields	**2**	2	3
Cultural services	Agricultural tourism	1	1	**3**
	Scientific and educational value	4	4	4
	Aesthetic value	2	3	5
	Belonging value	3	3	**4**
	Self-identity value	**3**	3	4
	Social relations	4	4	5
	Spiritual value	3	1	3

Perspective 1: Production-driven perspective. Farmers prioritizing production gave high scores to provisioning services but rated supporting and cultural services lower (Fig.1b.). This perspective was common among farmers (36%), emphasizing crop production and profit. They highly valued "Nutrient Provisioning" and "Profit Provisioning" (+5) but rated "Natural habitats of field border" and "Agricultural tourism" as very low importance (+1). Post-hoc interviews revealed concerns about non-crop habitats impacting yields and scepticism towards tourism.

Perspective 2: Environmental quality-driven perspective. Farmers with an environmental quality-driven perspective emphasized regulating services as the most important, with cultural services ranked lowest (Fig.1b.). Twenty-one percent of farmers shared this view, prioritizing air and water quality (+5). Post-hoc interviews revealed beliefs that high water and air quality benefit both human well-being and crop growth. They assigned low importance (+1) to "Agricultural tourism" and "Spiritual value" cultural services, with reasons such as lack of need for tourism and concerns about land use for graves since it may influence the machinery in the farmlands.

Perspective 3: Cultural value-driven perspective. Farmers prioritizing cultural values assigned high scores to cultural services and low scores to regulating services (Fig.1b.). This minority group (13%) valued "Aesthetic value," "Social relations," "Scientific and educational value," "Belonging value," and "Self-identity value" with scores of +4 or +5. Post-hoc interviews revealed their desire for a more beautiful hometown and emphasis on good neighbourhood relations and happiness. They rated "Pollination" and "Climate regulation" very low (+1), citing a perceived lack of control over these services.

Table 2. Characteristics of farmers with different perspectives.

Characteristic	Perspective				
	1	2	3	Other	p
Age (years)	56.5	53.8	53.6	58.0	0.016**
Education (years)	6.9	9.4	8.6	8.2	0.002**
Farming experience (years)	39.1	33.5	32.3	38.2	0.004**
Farm size (ha)	1.68	2.87	1.93	1.54	0.602
Number of farmers	79 (36%)	46 (21%)	28 (13%)	69 (31%)	

From Table 2, we found that the younger farmers with higher education tended to have an environmental quality-driven perspective (p-value <0.05), and the older farmers with more experience working on agricultural production tended to have a production-driven perspective (p-value <0.05).

Practical Implications

Facilitating farmer participation and open communication among stakeholders is crucial for designing sustainable agricultural landscapes. Q methodology offers an interactive approach to uncover diverse perspectives and aid decision-making by finding common ground. Q methodology helps identify specific objectives favored by different farmer groups and can be integrated with Multi-Criteria Decision Analysis (MCDA) techniques to prioritize indicators based on stakeholder preferences (Groot & Rossing, 2011). Linking ecosystem service preferences with measurable indicators and management options is valuable for future decision-making (Parra-López et al., 2008). Tailoring the incentives for different types of farmers can also be useful in developing ecosystem service payment schemes (Geussens et al., 2019).

Theoretical Implications

This study employed Q methodology to explore farmers' diverse perspectives on ecosystem services (ESs), consistent with prior research (Swagemakers et al., 2017; Teixeira et al., 2018). Factors such as gender, age, and education were significant in shaping perceptions of ESs (Lima and Bastos, 2019). Our findings suggest that younger, higher-educated, and larger-scale farmers often prioritize environmental perspectives, favoring regulating and supporting services (Teixeira et al., 2018). Our study can also provide insights into farmers' values and their willingness to adopt environmentally friendly behaviours (Hammond et al., 2017).

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Innovating in EIP-AGRI operational groups: Beyond good intentions

Chrysanthi Charatsari[a], Eugenia Karamouzi[b], Christos Karras[b], Dimitra Lazaridou[c], Evagelos D. Lioutas[d], Efstratios Loizou[e], Maria Loizou[a], Anastasios Michailidis[a], Anna Michailidou[a], Evangelia Michailidou[a], Abdul M. Mouazen[f], Stefanos A. Nastis[a], Smaragda Nikouli[a], Panagiotis Panopoulos[b], Manuel Perez-Ruiz[g], Dimitrios Tsolis[b], Marco Vieri[h]

[a] Aristotle University of Thessaloniki, School of Agriculture, Department of Agricultural Economics, Greece, chcharat@agro.auth.gr, marialoizou@chem.auth.gr, tassosm@auth.gr, michanna@econ.auth.gr, michevan@plandevel.auth.gr, snastis@agro.auth.gr, smaragda.nik@gmail.com

[b] Rezos Brands S.A., projects@rezosbrands.com

[c] Agricultural University of Athens, Department of Forestry and Natural Environment Management, dimitral@for.auth.gr

[d] International Hellenic University, Department of Supply Chain Management, evagelos@agro.auth.gr

[e] University of Western Macedonia, Department of Regional and Cross Border Development, lstratos@agro.auth.gr

[f] Ghent University, Department of Environment, abdul.mouazen@ugent.be

[g] University of Sevilla, Department of Aerospace Engineering and Fluid Mechanical, manuelperez@us.es

[h] University of Florence, Department of Agriculture, Food, Environmental and Forestry, marco.vieri@unifi.it

Abstract:

Operational groups represent a policy-guided initiative aspiring to facilitate and promote inclusive and interactive innovation in the European Union's agrifood sector. In these groups, farmers, advisors, research organizations, and other actors co-create a pool of (explicit and tacit) knowledge with the aim of collaboratively developing innovative solutions that tackle farmers' problems. However, despite the expansion of operational groups across Europe, research has not yet focused on how the praxis of co-innovating in these constellations evolves. To do so, in the present study, we build upon the ongoing experience of an operational group, attempting to answer four questions. Do operational groups promote inclusive innovation in agrifood systems? What are the obstacles that limit their innovation potential? Why do these obstacles exist? How can we strengthen the innovation capacity of such groups? Combining participatory methods and informal discussions with actors involved in operational groups, we uncovered that vague missions, prioritization of top-down and outside-in innovation approaches, opposite understandings of co-innovation, and a limited blending of actors' knowledges reduce the innovation capacity of operational groups. Our findings suggest that innovating in operational groups is not always an inclusive and efficient process.

Keywords: inclusive innovation, operational groups, co-innovation, EIP-AGRI, sea buckthorn, innovation networks

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Purpose

Aspiring to promote collaborative and inclusive innovation while, in parallel, facilitating the flow of knowledge in rural areas, the European Union has launched a series of initiatives. One of them, the European Innovation Partnership - Agriculture (EIP-AGRI), promotes the formation of groups that collaboratively create, test and exploit innovation (Giarè and Vagnozzi, 2021). These so-called Operational Groups (OGs) comprise a multitude of actors, like farmers, research institutes, advisory organizations, private companies, and societal partners (Bonfiglio, 2023). Combining different types of knowledge (from scientific to practical, and from technical to organizational), OGs co-develop hands-on innovative solutions that are expected to address existing problems (Costantini et al., 2020). This multi-actor nature of OGs aims to include those usually excluded from mainstream innovation in the participatory innovation development process and the knowledge frameworks that govern innovation.
From a theoretical point of view, OGs represent problem-solving initiatives that operate based on the interactive innovation model. Founded on Lundvall's (1988) ideas on the need for direct interaction and cooperation among actors in the process of innovating, the central premise of that model is this research is not an engine generating innovative solutions that other entities adopt but is entangled into a complex web of relations that link actors through knowledge co-creation and sharing (Johannessen, 2009). Forming a constellation consisting of actors with varying backgrounds and diverse foci permits a new institutional environment within which the innovation process progressively and collaboratively grows to emerge (Barras, 1990). The main principles of OGs, as outlined in European Union's Regulation 2021/2115 (2021), involve developing innovations that address the most pressing needs of farmers, focusing on the dynamics of complementary knowledge that group members bring to the OG, and emphasizing collaborative design and production of innovative solutions.
However, despite the good intentions of the initiative, the praxis of co-innovation can face many challenges referring to the different meanings attributed to innovation by initiators of the process and target actors, varying ambitions and intentions of innovators, power relations developed within the OGs, institutions that structure interactions between actors, stakeholders' engagement in the process, difficulties in planning future steps due to the dynamic and continuously evolving nature of co-innovation, and the resourcing behavior adopted by each OG (Opola et al., 2023; Fieldsend et al., 2022; Lioutas et al., 2022; Ingram et al., 2020; Vereijssen et al., 2017). Interestingly, although about 10,000 OGs were, or are going to be, set up in the European Union's member states (EU CAP Network, 2023), little research effort has been made to depict how these issues affect the function and operation of these innovation partnerships.
Our study sought to shed some light on how the innovation process unfolds during the operation of OGs, uncovering the difficulties that emerge while innovating and their antecedents. To do so, we adopted a case study approach, following a Greek OG that innovates in a niche sector of the Greek agrifood system: hippophae production and manufacturing. Hippophae (sea buckthorn) is a genus cultivated in different geographical and temperate zones. Its berries are mainly used as food or as a basis to

produce flavoring ingredients for the food industry, dietary supplements, and skincare products (Ma et al., 2023; Zeb, 2004). In Greece, sea buckthorn is cultivated to a limited extent, mainly in mountainous and marginalized areas where farmers lack support from advisory organizations and innovation services.

The aim of our work was to present the potential of OGs to advance inclusive innovation in agrifood systems, uncover barriers emerging during the innovation process, trace their roots, and propose ways to enhance the innovation capacity of such groups.

Design/Methodology/Approach

The study draws on the ongoing experience of a project involving the creation of an OG aiming to combine the knowledge and expertise of different actors with the purpose of helping sea buckthorn farmers improve the efficiency of their enterprises through adopting and exploiting precision agriculture technologies, improve the quality of the produced berries, connect sea buckthorn growers with the food industry, and create a series of novel functional food products (e.g., cereal bars enriched with sea buckthorn berries). We collected data through participatory techniques and discussions with actors involved in the OG.

Findings

The results indicated that OGs have the potential to generate positive social impacts, enhancing local production, facilitating the stream of knowledge to marginalized farmers, supporting small-scale producers with low-cost technology, and offering consumers new products. Nevertheless, co-innovating in OGs is far from easy since several obstacles appear when actors move from plans to reality (Table 1).

Based on our findings, we can argue that, to meet the set purposes of an OG, a critical first step is to collectively define specific missions and cooperatively draw strategies to achieve them. In this vein, aligning the individual objectives of different OG members is pivotal. However, partners' varying perceptions of innovation, conflicting understandings of what a "proper" innovation strategy (top-down versus bottom-up versus outside-in) is, and the complexity of combining different knowledges put obstacles in the process.

Cultivating collective intentionality, effectively coordinating resource mobilization within OGs, and building new resources based on knowledge pluralism emerged as factors catalyzing effective and inclusive innovation. Finally, the analysis revealed that the overemphasis on the micro-level of interaction among actors participating in OGs does not permit co-innovators to consider inclusion through the lens of resource integration and set up an institutional environment promoting innovation.

Table 1. Issues faced during co-innovation process in Operational Groups

Problem	**Root(s)**	**Outcome(s)**
Ambiguous missions	Varying purposes of actors participating in OGs; Change of priorities during the operation of the group	Confusion and tension among members of the group; Overemphasis on serving individual interests
Ill-defined innovation strategies	Dominance of top-down and outside-in innovation philosophies	Limited emphasis on farmers' role in co-innovation process
Problematic sense-making	Opposite understandings of the process and visions of the ideal state; Sensegiving	Limited progress; Disillusionment
Difficulty in integrating different "knowledges"	Limited appreciation of the need to build on varying levels of expertise; Lack of previous links between some of the actors involved in the group	Dominance of explicit over tacit knowledge
Limited timeframe to co-develop innovations	Bureaucracy; Time-consuming administrative procedures	Shifts from co-creation to promotion of innovation

Practical Implications

Although not generalizable, these results suggest that interactive innovation is not necessarily synonymous with inclusive innovation since, in some instances, the needs of the actors that lack or have limited innovation capacity are not clearly defined and prioritized. To successfully co-innovate, members of OGs should develop a mutual understanding of how the philosophies adopted and practices enacted affect the outcomes of the process and emphasize the need to merge different knowledges while co-designing innovative solutions.

Theoretical Implications

Our work indicates that, despite good intentions, OGs face numerous challenges, which need to be considered when designing policies that foster co-innovation in agrifood systems. Promoting the involvement of all actors in the process of co-creating innovative solutions requires ensuring that interactivity will be maintained throughout projects and monitoring the power dynamics within the groups.

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PATHWAYS TO TRANSITION I

Adoption of cereal-legume intercropping on French Farms: roles of collective dynamics for individual transition pathways

Elodie Yan[a], Marco Carozzi[b] and Philippe Martin[c]

[a]Université Paris-Saclay, INRAE, AgroParisTech, UMR SADAPT, F-91120, Palaiseau, France, elodie.yan@inrae.fr

[b]Université Paris-Saclay, INRAE, AgroParisTech, UMR SADAPT, F-91120, Palaiseau, France, marco.carozzi@inrae.fr

[c]Université Paris-Saclay, AgroParisTech, INRAE, UMR SADAPT, F-91120, Palaiseau, France, philippe.martin@agroparistech.fr

Abstract:

Cereal-legume intercropping is a crop diversification practice with multiple advantages for sustainable agriculture. However, as farmers are facing both technical and economic barriers, the practice remains niche in France. Studies and data suggest that cereal-legume intercropping is more frequent in organic and/or crop-livestock mixed farming systems and in restricted areas. In this study, we aimed to identify the factors that lead farmers to adopt cereal-legume intercropping on their farms. We hypothesised that located professional groups constitute a positive lever for intercropping adoption. In the Centre-West of France, we identified a group of farmers who collectively promote intercropping as a sustainable agricultural practice. We conducted surveys with fifteen farmers of the group and three agricultural advisers connected to the group. Our results showed a collective dynamic built around pivotal events (e.g. group founding, test of wheat varietal mixture, conversion to organic farming). The analysis of individual farm dynamics highlighted three types of pathways: (i) farmers who adopted intercropping through a collective process closely linked to the group's dynamic, (ii) farmers who adopted intercropping in response to difficulties with their initial systems, (iii) farmers who directly included intercropping when establishing their system and now occasionally seek advice from the group.

Keywords: crop mixtures – farm survey – typology of trajectories – group of farmers

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Purpose

Intercropping consists of growing two or more crop species simultaneously on the same field (Willey, 1979). As a crop diversification practice, intercropping has multiple advantages. In particular, in cereal-legume intercrops, the different species protect each other from diseases and pests (e.g. Finckh et al., 2000). Legumes can restore nitrogen to the soil (Rodriguez et al., 2020), and their increased soil covering improves weed control (Corre-Hellou et al., 2011). By relying on these natural processes, farmers can significantly reduce their use of pesticides and fertilisers (Yan et al., 2024). However, intercrops are still not widely grown in France. Farmers are facing both technical (e.g. sowing, harvesting) and economic (e.g. sorting, lack of outlets) barriers (Bedoussac et al., 2015; Mamine & Farès, 2020), which limit the development of intercropping. A number of studies have looked at currently cultivated intercrops with innovation-tracking approaches. For example, Timaeus et al. (2022) and Verret et al. (2020) have provided an overview of existing intercrops in Germany and France respectively. These studies emphasise that the majority of cereal-legume intercrops are found on organic and mixed crop-livestock farms but that even in these favourable systems, the practice remains niche. We hypothesise that organic farming and the presence of livestock are strong factors in adopting the practice but that they are not the only ones to play a role in farmers' decision-making regarding intercropping. Therefore, we wanted to identify the factors that lead farmers to adopt and perpetuate intercropping on their farms.

Design/Methodology/Approach

The French Land-Parcel Identification System data suggests that intercropping in France is diffusing from local hotspots over the years (Yan et al., 2022). Based on this observation, we hypothesise that intercropping can be considered as an innovation diffusing among located professional groups in which farmers and advisers interact with each other and evolve in similar activities (Darré, 1999). In the Centre-West of France, we identified a group of farmers who collectively promote intercropping as a sustainable agricultural practice. To gain a better understanding of how and why this dynamic around intercropping was initiated, we conducted surveys among farmers of the group and agricultural advisers connected to the group. We conducted individual surveys for fifteen farmers, twelve of whom were growing intercrops, two were not, and one of whom was described as a "hybrid" because he was growing intercrops on a farm for which he works as an agricultural contractor, but not on his own farm. In our surveys of farmers, we asked all fifteen of them to describe their farm and its environment (history, crops, livestock, marketing, advice, etc.). Then, for farmers growing intercrops, we asked them why they had started, also asked for details of the different intercrops grown over time, and to detail their objectives, failures and successes with this practice. For those not growing intercrops, we sought to understand why they did not, and whether they planned to test the practice in the future. As for agricultural advisers, we interviewed three of them: one of the group's facilitators, an adviser working for an agricultural cooperative collecting intercrops, and an adviser working at the departmental scale specialised in organic arable farming. The three advisers were asked about intercropping in their areas: the history and dynamics of the practice, what types of intercrops and in which types of farms they are grown, and which existing opportunities for marketing or consumption.

On the basis of these interviews, we first reconstructed the pathway of the group of farmers we studied, focusing on the events that led to the dynamics observed today around intercropping. We were thus able to define different phases of coherence within the collective, punctuated by significant events or decisions that led to a shift to other phases of coherence (Chantre, 2011; Moulin et al., 2008).

Following the same framework, we reconstructed the individual pathways of the twelve farmers growing intercrops, which we compared with the collective pathway in order to understand better the role of the collective for each individual farmer. These trajectories allowed us to identify the combinations of factors that led each farmer to adopt the practice. Then we grouped some pathways together based on combinations of factors, and created a typology of pathways (Chantre, 2011) towards the adoption of cereal-legume intercropping.

Findings

The group of farmers was formally established in 1999 by arable cropping farmers and breeders, all practicing conventional farming. Based on the pathways, we highlighted that the group has been through different phases since its creation. The first phase began at the creation of the group, with the first considerations on low-input cropping and the lowering of costs for crops. Over this phase, farmers began observations on their wheat to stop the systemic treatments, and started growing wheat varietal mixtures, but kept the possibility of using chemical products on their crops.

Then, from 2002 to 2006, the first conversions to organic farming occurred in the group, which led to the second phase: the generalisation of the considerations on autonomous and economical systems for both crops and livestock. In this phase, the group kept on reducing the use of chemical inputs and started to develop more self-sufficiency with farmer seeds, and breeders changed from buying concentrates to growing grains and forage on farms to feed their animals.

After 2006, some of the group's leaders had converted to organic farming and others figured that the less chemical inputs they used, the less they wanted to use, so the third phase began: the elimination of chemical control by redesigning systems. Farmers who had not converted to organic agriculture yet got ideas from organic farmers about restoring nitrogen to the soil, covering the soil to limit weed propagation, and creating natural barriers against pests and diseases – just as they did with wheat varietal mixtures. Therefore, over this third phase, intercropping started to spread widely among the group, up to 2015 when the group took part in a 3-year participatory research project on species and variety mixtures. In this project, eight farmers of the group worked along with researchers. Farmers implemented intercrops that they were already growing before, and together with the researchers, they made observations on biodiversity, pests and diseases, and yields by measuring the Land Equivalent Ratio (Mead & Willey, 1980). Ultimately, the results of the project confirmed the empirical observations of the farmers on the advantages of their intercrops, which encouraged them to continue along their path, and also gave them confidence to provide advice and share their experience on the practice.

With the conclusion of the project, we identified a fourth phase, which is still ongoing: some farmers (mainly among those who took part in participatory research project) of the group have become experts on intercropping and keep on testing new mixtures. Consequently, other farmers both inside and outside the group ask them for advice. There is now a majority of organic farmers in the group (70-80% in 2023), and intercropping has become a base practice in organic farming for the group members. The question of intercropping is no longer central in the group, but still feeds the discussions on other practices, such as farmer seed production or cover crops, in order to limit tillage in organic farming.

Our results show three types of individual pathways. The first (n = 5) concerns the farmers who founded the group in the early 2000s with the aim of achieving greater autonomy and reducing costs on the farm. With support from agricultural advisers, they first adopted wheat varietal mixtures to reduce the spread of disease and thus fungicide use. Then, they eventually converted to organic farming. Convinced by the results obtained with wheat variety mixtures, these farmers naturally turned to cereal-legume intercrops to address problems of crop protection and nitrogen nutrition in organic farming.

The second type of pathway (n = 4) concerns farmers for whom a specific event or problem triggered a willing to transform their systems, but not all of them converted to organic farming. For example, during a heatwave, one farmer realised how dependent on external sources his farm was, so he decided to increase its self-sufficiency. He began with multispecies grasslands for animal grazing. Then arrived a new legislation with incentives to reduce pesticide use, so he extended his reasoning to forage and grain cereal-legume intercrops, also for animal feed. For these farmers, the collective dynamic acted not only as an inspiration to adopt the practice, but also as a source of knowledge, especially for the design of their intercrops (species, proportions).

The third type of pathway (n = 3) concerns farmers who joined the group recently and are less experienced than farmers from the other two types. Like the rest of the group, the introduction of cereal-legume intercrops responded to the desire for an autonomous and economical activity. However, unlike the farmers from other two types of pathways, crop-related issues did not act as a trigger to intercropping as they did not experience any of those before adopting cereal-legume intercropping. By joining the group early on in their establishment, these farmers had occasions to exchange with the group's founders and visit their farms for inspiration. In this third pathway, growing such intercrops was mostly to match the farmers' vision of agriculture, namely a more diversified and environmentally friendly approach, and necessarily in organic farming. Some of them introduced intercrops as soon as they established their farms, along with conversion to organic farming. The farmers in the third type of pathway do not rely on the collective dynamic as much as the farmers in the first or second types when it comes to intercropping. They mainly identified the experts in the group, and went to them individually. However, they do rely on the collective dynamic on other issues (e.g. farmer seed production).

In all three pathways, the adoption and type of intercropping are driven by the outlets. For cereal growers, there are two main outlets: agricultural cooperatives and livestock farmers. Some cooperatives now collect and sort intercrops, but only two-species-intercrops and for organic production, which explains why conversion to organic farming was imperative for cereal growers who mainly sell their harvests to cooperatives. On the contrary, livestock farmers who grow intercrops to feed their own animals, are not bound by the cooperatives' conditions so they do not have to convert to organic farming to use their intercrops. In that sense, they also have more flexibility to design their intercrops and usually use four to five different species to meet the animals' needs. The group's collective empowerment dynamic played a strong role in adoption in all three pathways, especially for the founders who needed approval and support to sustain innovative practices. The founders now provide guidance to other farmers who plan to introduce intercropping on their farms, and one of them even invested in sorting equipment to offer sorting services. As for the farmers who did not grow cereal-legume intercrops when we interviewed them, they confirmed that the main barrier was the lack of outlets in conventional farming. However, they did benefit from the collective dynamic at some point, as they are growing other types of intercrops, such as multispecies grasslands or rapeseed-companion crops.

Implications

This study highlights three pathways leading to the introduction of cereal-legume intercropping on farms, and the importance of collective dynamics for adopting a new practice. The surveyed farmers and advisers are convinced that cereal-legume intercropping is a relevant practice to reduce pesticides and secure production, especially under global change conditions. However, they admit it can take years to master the practice, and some of the farmers might have been discouraged without the help of the group and its leaders. By emphasising the role of a collective dynamic and factors leading to the adoption and perpetuation of cereal-legume intercropping, we believe our work can give insights to support groups of farmers who would like to collectively initiate a transformation of their systems.

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Factors influencing smallholder farmers' willingness to adopt agroecological practices in Huambo province, Angola: a choice experiment study to promote agroecological transition.

José do Rosário[a], Carlos Marques[b] Hycenth Tim Ndah[c], Lívia Madureira[d]

[a] Centre for Transdisciplinary Development Studies (CETRAD), University of Trás-os-Montes e Alto Douro (UTAD), Quinta de Prados, Vila Real/Center for Advanced Studies in Management and Economics, University of Évora, 7000-809 Évora Portugal. Email: josevictorino1@gmail.com

[b] Mediterranean Institute for Agriculture, Environment and Development (MED), Universidade de Évora, Apartado 94, 7006-554 Évora, Portugal. Email: cmarques@uevora.pt

[c] Department of Communication and Advisory Services in Rural Areas, University of Hohenheim, 70599

[d] Centre for Transdisciplinary Development Studies (CETRAD), University of Trás-os-Montes e Alto Douro (UTAD), Quinta de Prados, Vila Real, Portugal. Email: lmadurei@utad.pt

Abstract:
In Africa, agroecology is often limited to agroecological zoning, hindering understanding of its broader socioecological impact and potential. The Global South, including Huambo Province in Angola, exhibits a low adoption rate of agroecological practices. This study aims to investigate the factors influencing farmers' willingness to adopt agroecological practices using a choice experiment. The research utilized conditional logit and mixed logit models to evaluate the effects and trade-offs of various attributes. The findings underscore the significance of factors such as land tenure title, technical assistance, and compensation in influencing farmers' decisions. The study's results highlight the need to provide technical assistance and land tenure security to promote agroecological practices. Policymakers and stakeholders can utilise these findings to design effective policies and programs to enhance the adoption of agroecological practices in Angola. Furthermore, the study emphasizes the necessity for further research to explore the specific dynamics and contextual factors that shape farmers' decision-making processes regarding agroecological practices. Addressing these factors can help create an enabling environment for sustainable agricultural practices and contribute to food security in Angola.

Key words: agroecology, discrete choice experiment, smallholder farmers, willingness to accept, Mixed logit model, Africa.

Purpose

This study aims to investigate factors that influence farmers' willingness to adopt agroecological practices in Huambo Province using a choice experiment (CE). Agroecological transition (Boillat et al., 2022) in Sub-Saharan Africa requires a systemic approach that addresses the current challenges of the region's food security and promotes access to knowledge and secure land tenure. The adoption of agroecological practices is crucial for achieving sustainable agriculture and food security, particularly in developing countries. In Africa, agroecology is mainly mentioned as agroecological zoning which hinders understanding of its broader socioecological impact and its potential as a science and social movement (Sachet et al.2021) However, the adoption rate of such practices remains low in the Global South (Ogundari & Bolarinwa, 2019), including the Huambo Province in Angola. Thus, it is crucial to understand factors that may influence farmer´s Willingness to adopt agroecological practices in order to design a smart AKIS that enhances agroecological transition.

Design/Methodology/Approach

The Choice Experiment (CE) method was used to evaluate individual preferences for sustainable agricultural practices of small farmers in Huambo province of Angola, identifying important decision-making factors. Based on Lancaster's theory of consumer choice and the random utility theory (Lancaster, 1966). The utility of any individual n associated with any alternative i is determined by the attributes of the good and the socio-economic and sociopsychological characteristics of the individual. The Conditional logit model and Mixed logit model are used to estimate the effects and trade-offs between the attributes, with the latter allowing for the relaxation of the IIA assumption and the capture of respondent heterogeneity (Ben-Akiva et al., 2023; Ben-Akiva & Lerman, 1985).

In the first step we defined the research question which was to understand small farmers' preferences for adopting sustainable agricultural practices and which incentives influences farmers' willingness to adopt agroecological practices in Huambo Province.

Second step, we identified the attributes through focus groups and literature review: Determine the attributes of the sustainable agricultural practices that will be included in the choice experiment. After that, for each attribute different levels were defined according to the context of the study area.

In the third step was the design of the choice sets: Create the choice sets, which are the combinations of attributes and levels presented to the participants. In this step we ensured that the choice sets are balanced, and efficient. After that we selected a fractional experimental design according to our research question.

In the Fourth step we consider the context and ensured that the choice experiment is contextually relevant to the small farmers in Huambo and their decision-making processes, by incorporating local knowledge, cultural factors, and socioeconomic considerations. Next, we developed the pilot study to test the choice sets, the experimental design, and the data collection process. Finaly, we analysed the data using and we made interpretations of the results and assessed theoretical and practical implications.

We conducted a choice experiment to estimate smallholder farmer's preferences for different attributes. The attributes included land tenure title, technical assistance, payment, and agroecological practices. We used the Conditional logit model (CLM) and mixed logit model (MLM) to estimate the effects and trade-offs between the attributes. The study is based on Lancaster's theory of consumer choice. The statistical analysis of the collected data is grounded on the random utility theory (McFadden D., 1973), according to which individuals make choices with the aim of maximizing the benefits of their decisions Ben-Akiva et al., 2023; McFadden, 1978; McFadden D., 1973). Employing both conditional and mixed logit models is recommendable for model comparison, flexibility, and robustness (Frontuto et al., 2020). On the other hand, structural equation models (SEM)(Hair et al., 2019) is a statistical technique that combines factor analysis and multiple regression to model complex relationships between variables. In this paper it was used to analyses the relationships between latent variables using the technology acceptance model (TAM) framework (Davis & Venkatesh, 1996). In the context of agroecological transitions, SEM was used to understand the relationships between various factors influencing farmers' decisions to adopt agroecological practices, such as socio-economic factors, institutional support, and sociopsychological variables. Validated scales were adapted to our research context and the results complemented the choice model experiment results.

Data Collection and Analysis

We collected data from 400 smallholder farmers in Angola interviewed face-to face in 2022. The results were used to understand smallholder farmer's preferences and to identify the most important incentives that determines their decision-making process regarding to adoption of biopesticides.

Findings

Our sample comprises smallholder farmers ranging from 18 to 85 years old. Among them, 75.25% are male, and 24.75% are female. Regarding education levels, 41.75% of respondents are illiterate, 52% attended elementary school, 5.25% completed high school, and 0.5% hold a bachelor's degree. The majority (57.5%) of respondents are not part of any farmer-based organization, while 26.25% are members of a farmer field school implemented by FAO. Additionally, 16.25% of smallholders belong to a cooperative. Household family in average comprise 6 members. The main crops cultivated are Maize, cassava, sweet potatoes, been, carrot.

The findings reveal important insights into the willingness of farmers to adopt agroecological practices in Huambo Province. The willingness to accept compensation for agroecological practice uptake by smallholder farmers decreases in the presence of institutional support, such as land tenure title and technical assistance. Sociopsychological variables such as attitude, perceived compatibility and perceived need satisfaction are crucial drivers of adoption in the region as described in figure 1.

Figure1. Estimates of conditional model.

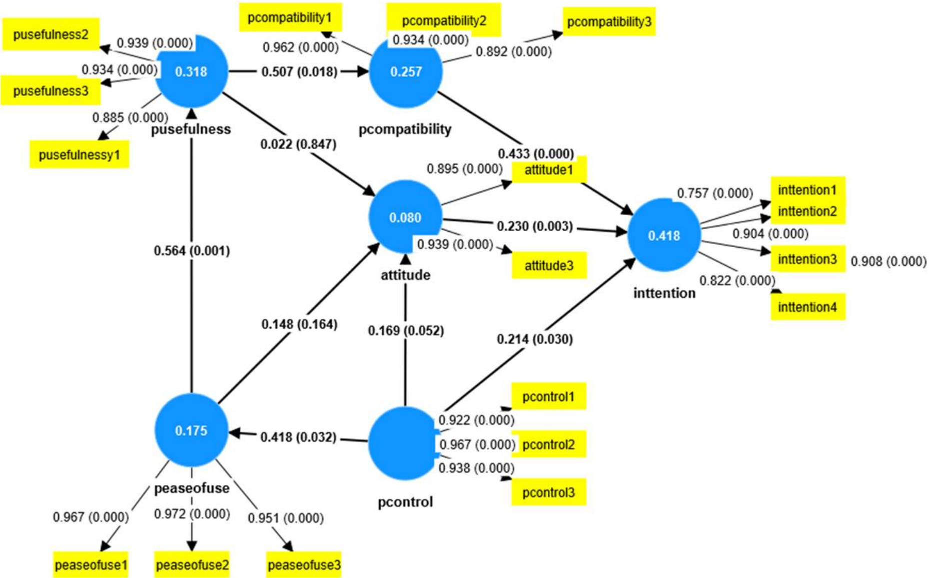
	(1) Conditional logit Base	(2) Conditional logit, ASC	(3) Conditional logit interaction with sociopsychological variables	(4) Conditional Logit Model with ASC
Sustainable practices	0.1532**	-1.111**	-1.554***	-2.149***
	(0.0479)	(0.0493)	(0.578)	(0.622)
Payment	0.0108***	0.00116	0.0110***	0.00118
	(0.0012)	(0.00135)	(0.00121)	(0.00137)
Technical support	0.5102***	0.166***	2.126***	1.610***
	2.1607***	(0.500)	(0.334)	(0.322)
Land concession title	(0.0717)	1.514***	2.020***	1.380***
		(0.0811)	(0.116)	(0.122)
Sustainable practices* need satisfation			0.156**	0.136**
			(0.0626)	(0.0625)
Technical support*need satisfation			-0.363***	-0.325***
			(0.0745)	(0.0715)
Sustainable practice*farm based organisation			0.0494	0.0413
			(0.0524)	(0.0596)
Sustainable practices*household			-0.0277*	-0.0368**
			(0.0154)	(0.0173)
Sustainable practice*age			0.00536*	0.00680**
			(0.00294)	(0.00325)
Land Concession title*totaland			0.0406*	0.0377
			(0.0238)	(0.0238)
Sustainable practices*attitude			0.191*	0.276**
			(0.112)	(0.121)
Constant		-3.796***		-3.830***
		(0.342)		(0.343)
Log-likelihood	-1619.5501	-1525	-1599.374	-1504.544
Numb. Observation	4,800	4,800	4,800	4,800
LR chi2(12)	1724.55	1912	1764.90	1954.56
Prob. > chi2	0.0000	0.0000	0.0000	0.0000
Pseudo R2	0.3474	0.3853	0.3556	0.3938
AIC	3247.1	3061.22	3220.748	3033.09
BIC	3273.0	3093.602	3291.988	3110.81

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The results underscore the importance of providing technical assistance and land tenure security to promote agroecological practices. Policymakers and stakeholders can utilize these findings to design and implement effective policies and programs aimed at increasing the adoption of agroecological practices in Angola. Furthermore, the study highlights the need for further research to explore the specific dynamics and contextual factors that shape farmers' decision-making processes regarding agroecological practices. By addressing these factors, policymakers can create an enabling environment that encourages sustainable agricultural practices and contributes to food security in Angola. Agroecological transitions require a systemic approach that addresses challenges related to food security, access to knowledge, and secure land tenure, which are also factors that can influence the adoption of sustainable agriculture practices. However, to understand the drivers and obstacles for achieving an agroecological transition requires more research and trust between researchers and farmers (Sachet E, et al. 2021). In the Context of Angola, factors such as access to improved seed varieties, quality of leadership among farmers, and resource constraints can also impact the adoption of sustainable agricultural practices.

Regarding to socio-psychological factors, the technology acceptance model (TAM) was used to confirm which behavioural attributes determines the adoption of biopesticides in Huambo. After accessing the measurement model and the structural model reliability, after checking for the content validity and reliability according to the literature (Hair et al., 2019; Sarstedt et al., 2017). The results suggest that attitudes, perceived compatibility, perceived control, and perceived ease of use are important factors influencing intention, with perceived ease of use and perceived usefulness having indirect effects through other variables, as we can see in figure 1.

Figure 1. Indicator and path coefficients of sociopsychological constructs



Practical Implications

By understanding and addressing the sociopsychological dimensions of farmers' decision-making processes, policymakers and development practitioners can create more effective and targeted strategies that resonate with the unique preferences and motivations of smallholder farmers. This will lead to higher levels of adoption and greater success in transitioning towards sustainable agriculture.

Theoretical Implications

From the results, we deduce that the study contributes theoretically by providing further requirements necessary for the agroecological transition to effectively occur in Sub-Saharan Africa. These conditions are related to the role of non-monetary incentives, access to technical knowledge, and the socio-psychological factors of smallholder farmers, such as perceptions, attitude, perceived behavioural control, perceived resources.

Concluding remarks

Choice model experiments and SEM were used together to investigate the factors influencing smallholder farmers' willingness to adopt agroecological practices in Huambo Province, Angola. While choice model experiment was used to estimate farmers' preferences for different attributes, SEM was used to analyse the relationships between these factors and other variables that influence farmers' decision-making processes. By combining these methods, policymakers and stakeholders can design effective policies and programs aimed at increasing the adoption of agroecological practices in Angola and contributing to food security in the region as well as, contribute to agroecological transition.

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Optimizing territorial resources to support agroecological transitions: which levers to adapt to climate change in livestock systems in South of France?

Marc Moraine[a], Guillemette Boiron[b], Xavier Arnaud de Sartre[c], Pierre Gasselin[a]

[a] INRAE, UMR 0951 INNOVATION, CIRAD, INRAE, Montpellier Supagro, 2, Place Viala – 34060 Montpellier, France. marc.moraine@inrae.fr ; pierre.gasselin@inrae.fr

[b]Chamber of Agriculture of Ile-de-France, Le-Mée-sur-Seine, France.

[c]CNRS, UMR 5319 PASSAGES, Avenue du Doyen Poplawski, 64000 Pau, France. xavier.arnauld@cnrs.fr

Abstract:
Agroecological transitions require to foster frameworks and strategies to optimize the identification, access to and activation of territorial resources. Climate change threatens the durability of natural resources and the stability of favorable socioeconomic conditions for transitions. In this paper, we propose a framework to analyze the degree of agroecological transition in farming systems and the sets of territorial resources already available or required to support this transition. We implement this framework on a case study in South Western France, in the Basque region where PDO cheese are produced. After describing ten types of farming systems, we characterize their proximity to agroecology and their potential resilience and adaptation to climate change. The analysis of territorial resources shows that agroecological transition in this territory is possible and would enhance adaptation to climate change, but require further development of territorial resources which depends on economic and political dynamics at local level. This work contributes to the understanding of agroecological transition at territory level, and proposes a framework to bridge existing methods for their analysis.
Keywords: Agroecological transition; Territorial resources; Adaptation; Typology; Coexistence.

Purpose

Agroecological transitions are more and more studied and conceptualized at the territorial level, to deal with the deep embeddedness of technical practices and farmers' strategies in ecological, social, cognitive and economic dynamics which operate beyond farm level. The territory level is also where the combination of natural, cognitive, technical and socioeconomic resources allows or limits the implementation of agroecology (Bergez et al., 2019). Supporting agroecological transitions requires to optimize the identification, access to and activation of territorial resources (Thenard et al., 2021). However, in a context of climate change, the durability of natural resources and the stability of favorable socioeconomic conditions are highly threatened. More probably, tensions, concurrence, conflicts for resources, resulting in affirmations of competing development models for agriculture, could be horizons of future of agriculture of the Anthropocene.

To avoid this and support agroecological transitions on the long run, we analyzed the conditions of agroecological transitions at two levels. At farming systems level, we observe how farmers mobilize territorial resources to engage in agroecology. At territory level, we observe how territorial resources can be managed to facilitate the agroecological transitions of diverse forms of agriculture and their positive coexistence. This article presents this analysis in a case study in South Western France, in the Basque region, where climate change threatens the sustainability of livestock farming systems.

Methodology and analytical framework

This article is based on the historical, technical and economic analysis of the territory of Hasparren, in Pays Basque, South-West of France, following the method of agrarian diagnosis (Boiron, 2017). Hasparren is a mountain area under oceanic climate with mild winters and warm and humid summers, adapted to the growth of crops including maize and grasslands. The topography (mountains, hills, valleys) determines the type of use of the soils: step and rocky slopes are left as moors and ferns lands, hills and slopes with shallow soils are used as permanent grasslands, flatlands with deeper soils are cultivated as temporary grasslands and maize mainly.

Ten types of identified farming systems have been described and analyzed after an historical investigation in local archives, interviews with experts of the territory and a set of around 50 interviews of farmers. Technical and economic data have been collected on farms, as well as the farmers' strategies described by themselves. These actual data on farm illustrate and inform the farming systems described in the typology. On this basis we propose three complementary ways to analyze the farming systems: their dynamics of adaptation to climate change, their proximity to agroecology, and the type and importance of territorial resources that they mobilize. How farming systems implement adaptation measures to climate change has been described using data from a prospective survey conducted in the Pyrenees (OPCC, 2018). Proximity to agroecology has been defined using the historical principles proposed by Altieri (2002).

P1- Reducing external inputs by optimizing the use of natural resources and inputs-services. This principle includes integrated health management for animals.

P2- Favouring biodiversity at agroecosystem level to enhance regulation services.

P3- Optimizing the functioning of production systems to reduce pollutions and environmental impact.

P4- Favouring the diversity and complementarity of resources used in the production system to increase its resilience.

P5- Increasing autonomy and capacity of adaptation through adequate configuration of actors and supply chains.

Each type of farming system is positioned on the two axis of Therond et al. (2017): biodiversity/inputs and territory/globalized, based on the description of farming systems made in Boiron (2017). Mobilization of biodiversity in production systems is assessed through four criteria: 1-Diversity of land types; 2-Diversity of animal species; 3-Management of genetic resources (breed and mode of selection); 4- Contribution to the management of natural areas. Territorial embeddedness of production systems is assessed through four criteria:

1-Diversification of activities: number and nature of enterprises, existence of pluri-activity;

2-Process and commercialization: frequency of direct sales on farm or local supply chains;

3-Local purchase of inputs; 4-Collective dynamics at local level, governance and shared values.

Finally, we assessed qualitatively the type and relative importance of resources available for farmers for their agroecological transitions and adaptation to climate change. For this we used the definition of natural, technical, cognitive, economic and social resources by Thenard et al. (2021).

Findings

The ten types of farming systems in Hasparren present different levels of mobilization of biodiversity and territorial embeddedness (Fig. 1), and of implementation of agroecological principles (Fig. 2). Four farming systems are close to agroecological principles: Dairy Ewes Process. (DEP), Mixed Cows Process. (MCP), and to a smaller extend Dairy Ewes spe. 2 (DE2) and Mixed dairy Ewes and Suckler cows 2 (MES2). The most intensive systems do not mobilize any – or very few – agroecological practices: Dairy Ewes spe. 1 (DE1), Dairy Cows spe. (DC), Mixed dairy Ewes Suckler cows 1 (MES1), and Suckler Cows spe. (SC1).

The mobilization of agroecological principles seems to depend highly on the commercialization channels: high added-value channels such as direct sales or short supply chains favor the development of agroecological practices. Indeed, the two types of farms that process their production (dairy ewes and mixed cows) present more diversified systems, limit their use of inputs using local feed resources from a diversity of areas (schrublands, permanent grasslands, crops). Specialized farming systems selling in globalized markets, in particular DC, are constrained by the necessity to intensify the production per working unit, thus making high use of inputs, especially for maize production.

Coexistence of economic structures and strategies on the territory

Three groups of farming systems can be identified comparing their economic strategies and the resulting income level (Figure 3). Systems processing their products into food products with direct sales or short supply chains obtain high levels of added value per work unit thanks to the commercialization in niche markets: PDO farm cheese, local calf meat, fruit jam, etc., often sold on local markets or through CSA networks.

Figure 1: Biodiversity mobilization and territorial embeddedness in farming systems.

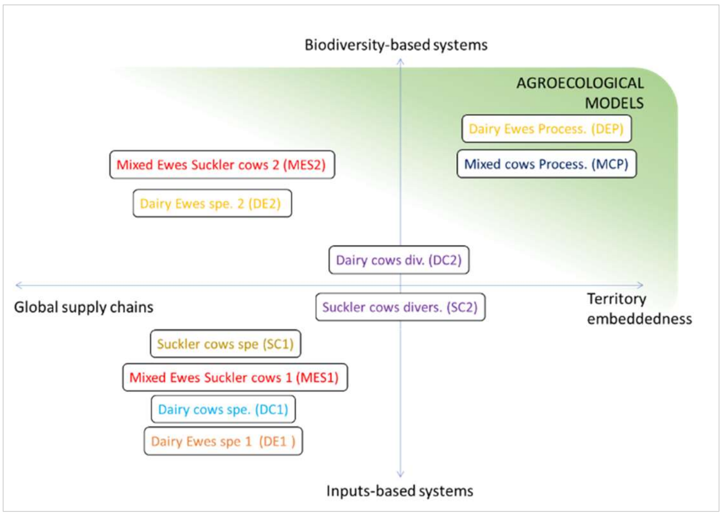


Figure 2: Practices of the farming systems and their proximity to agroecological principles

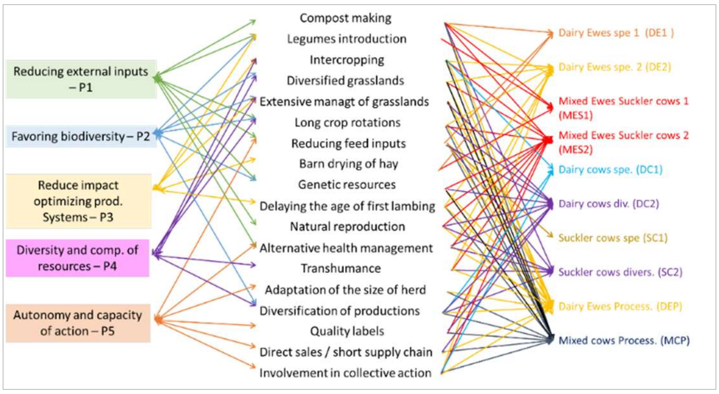
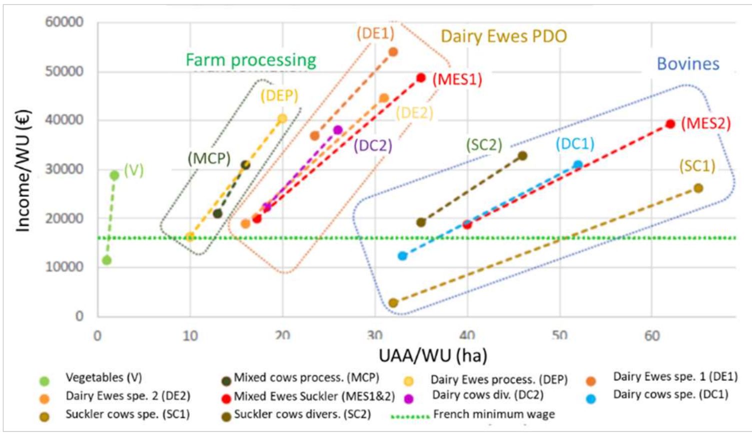


Figure 3: Economic results from land and work for the different farming systems.



Livestock farmers producing ewes' milk for large dairy companies are numerous, and their proximity to agroecology is generally low. Dairy and beef cattle producing generic and standardized food exhibit the lower rate of economic return and need to get larger to reach a satisfying income level.

In these three groups of farming systems, the set of available resources are quite high. Natural resources are high due to the diversity and complementarity of types of lands: croplands for cereal production, high productivity grasslands, valley and mountain pastures, which are spatially distributed and accessible to most of the farming systems. Technical resources such as locally-adapted animal breed, technical advisors (Chamber of Agriculture, farmers' associations), inputs supply companies, are highly present in the territory. The historical structuration of networks for the recognition of the quality of Basque country's products (PDO cheese, vegetables) gives access to economic and social resources. New brands, marketing identities, are developed by alternative farmers (belonging to the DEP and MCP farming systems), to differentiate their products and reinforce their collective identity.

At the territory level, the coexistence of a diversity of farming systems appears to be possible and does not generate strong inequalities, thanks to adequate governance of resources and collective actions for the support and defense of production models in professional institutions (farmer unions, cooperatives, syndicates of products). This coexistence is however challenged by climate change perspectives, which could worsen the competition between farms.

Climate change perspectives and resilience of farming systems

The consequences of climate change will not impact the different farming systems to the same extent. Modification of productivity of mountain pastures will impact farming systems making summer transhumance: DE2, MES2, DEP, MCP. These farming systems will need to adapt their grazing strategies, complete the feed ration with hay and ultimately reduce the number of animals. For the farms having less economic resources, such adaptations could be highly damageable and threaten their survival, especially in MES2 type. Reduction of agricultural productivity, and changes in climate suitable distribution areas for some crops will impact almost every farming system, with a stronger impact on the most intensive, less diversified, using more inputs, cropping systems: DC1, DE1, SC1, MES1. The possible adaptation is to purchase more cereals and protein crops, but this would strongly impact the production costs and profitability of farms.

Practical Implications

Due to climate change, yields and quality of products are more versatile the last years. Agroecological farming systems, more diversified and adapted to local conditions, could represent an alternative for the territory. The agroecological practices already existing could generate technical and cognitive resources for the transition of other farms to agroecology, but other types of resources remain to be developed: valorization of agroecological products on a large scale, in opposition to current niche markets, possibility for young farmers to start their activity on small pieces of land, political and professional support of alternative practices, new productions, evolution of standards and labels. These evolutions are desirable to unlock agroecological transition on a wide scale but they are not the most probable without specific animation structures and supporting communities of citizen.

Theoretical Implications

This study is a methodological attempt to characterize the territorial resources supporting agroecological transitions and their possible evolution in a future shaped by climate change. In the future, climate change could reshuffle the decks of territorial resources, increasing the pressure on feed resources, grasslands and most productive arable lands. The transition to agroecological models, entailing a reduction of animal density and diversification of crops and practices, is jeopardized by the sociotechnical lock-ins that maintain the most intensive farming systems in their path of dependency. If cognitive, technical and socioeconomic resources developed today by agroecological farming systems could be sufficient to trigger largely implemented transitions is difficult to evaluate, as it depends also from factors occurring at the level of sociotechnical landscapes (public policies, global markets, regulations, etc.). The diversity of existing agroecological farming systems and their adaptation to the ecological context of the Hasparren territory could luckily act as “bright spots” to facilitate adaptation to climate change, but only under the condition of adequate social and political dynamics of transition.

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Breaking the pesticide lock-in: insights from the SPRINT project on transition pathways to reduce reliance on synthetic pesticides in agri-food systems

Ana Frelih-Larsen,[1] Jane Mills[2], Antonia Riedel[1], Josselin Rouillard[1], Charlotte Chivers[2], Honor Mackley-Ward[2], Nelson Abrantes[3], Abdallah Alaoui[4], Isabelle Baldi[5], Francisco Alcon[6], Matjaz Glavan[7], Paula Harkes[8], Jakub Hofman[9], Trine Nordgaard[10], Igor Paskovic[11], Marija Polić Pasković[11], Daria Sgargi[12]

[1]Ecologic Institute, ana.frelih-larsen@ecologic.eu

[2]Countryside and Community Research Institute, University of Gloucestershire jmills@glos.ac.uk

[3] University of Averio, njabrantes@ua.pt

[4] University of Bern, abdallah.alaoui@giub.unibe.ch

[5] University of Bordeaux, isabelle.baldi@u-bordeaux.fr

[6] Polytechnic University of Cartagena, francisco.alcon@upct.es

[7] University of Ljubljana, matjaz.glavan@bf.uni-lj.si

[8] Wageningen University & Research, paula.harkes@wur.nl

[9] Masaryk University, jakub.hofman@recetox.muni.cz

[10]Aarhus University, trine.norgaard@agro.au.dk

[11] Institute of Agriculture and Tourism, paskovic@iptpo.hr

[12] Ramazzini Institute, sgargid@ramazzini.it

Abstract:
Plant protection is a key area of contestation for sustainability transition in agri-food systems, where reducing reliance on synthetic pesticides is hindered by the pesticide lock-in. The SPRINT project examined opportunities for breaking this lock-in across 10 European case study areas, focusing on system redesign rather than input efficiency and substitution to achieve transformational change. Combining qualitative research methods (discourse analysis, interviews and workshops), we explored a vision for sustainable plant protection that envisages a pesticide-free future. This paper discusses the method and results of our visioning process to develop effective transition pathways. We identified key lock-in mechanisms and barriers across various dimensions: agronomy & technology; economics; knowledge, awareness & research; political; policy; regulatory; and cognitive, that mutually reinforce each other, impeding a wider transition away from synthetic pesticides. Through 'What If' visioning exercises, we identified tailored transition pathways for different farm systems. Findings highlight the necessity for structural governance changes and integrated strategies to effectively tackle the multifaceted dimensions of the synthetic pesticide lock-in. Practical implications emphasize the significance of integrating knowledge effectively, developing long-term agricultural policies and educating the public. Ultimately, the paper contributes to advancing understanding on cross-sectorial entry points for reducing synthetic pesticides across Europe.

Keywords: pesticides, lock-in, barriers, re-design, transition

Purpose

Plant protection is a key area of contestation and tension for sustainability transition in agri-food systems, where progress towards reduced reliance and dependence on synthetic pesticides is hindered by the pesticide lock-in (Lamine, 2011). Past European efforts to reduce synthetic pesticide use and risks have been unsuccessful in reaching reduction goals (Mohring et al., 2020). The EU Farm to Fork strategy recently set a new target of reducing the use and risk of plant protection products by 50% by 2030. While some research has used a practice theory perspective to explore the transformation process from conventional to non-organic farming (Freyer and Bingen, 2012; Sutherland and Darnhofer, 2012), only recently has research focused on transition in relation to plant protection practices in European countries (Angeon et al., 2024; Jacquet et al., 2020).

Sustainability transformation literature suggests that effective governance for sustainability requires a balance between two approaches: long-term transformational goals and short-term incremental changes (Patterson et al, 2017). The progressive incremental approach prioritises small, yet cumulative steps aimed at creating new pathways towards sustainable futures. Efficiency and substitution strategies, such as those adopted by integrated pest management (IPM) practices, epitomise such an approach. However, we argue that an over-reliance on these incremental approaches can constrain the longer-term planning necessary to break free from the pesticide lock-in. To achieve significant reductions in pesticides will require changes across the whole agri-food system from the field level (Vialette et al, 2021) to the governance level (Patterson et al, 2017). Given the complexity of such change, a system re-design approach that considers changes in agronomy (field/farm/landscape scale), while also addressing the wider system lock-ins across the food system and governance levels might be more effective.

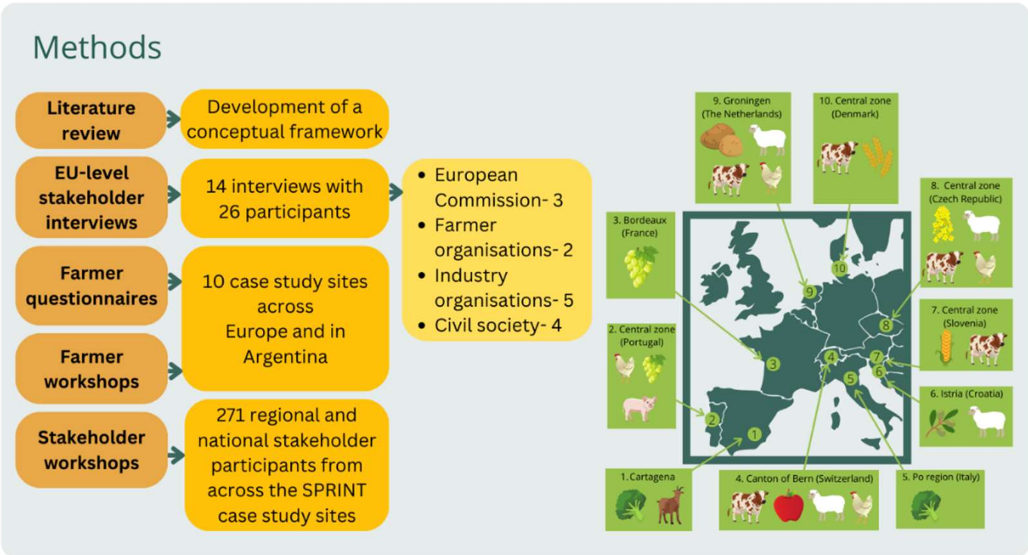
Developing participatory solutions for such a system redesign can be limited by a lack of visionary thinking, making it challenging to envision alternatives beyond the current paradigm. Research on organic farming has predominantly focused on transitioning to organic practices at the farm or field level often overlooking the systemic lock-in of the conventional agricultural paradigm. Our research extends beyond the confines of organic farming per se to encompass a broader spectrum of system redesign alternatives. More specifically, it is focused on system redesign using a 'What if' visioning approach to identify solutions for a pesticide-free agriculture. The aim of this paper, therefore, is to present novel insights into these visions for a pesticide-free agriculture in the future for different sectors and European countries.

Design/Methodology/Approach

Positioning this work in transition studies, this paper aims to examine the key lock-in mechanisms and barriers and identify tailored transition pathways towards synthetic pesticide-free agriculture. It applies concepts based on the multi-level perspective within a socio-technological systems framework developed by Geels (2002). This perspective posits that existing socio-technical systems are stabilised by the alignments between system components (e.g., technologies, policies, user patterns, infrastructures, cultural discourses) that have been created in previous decades (Geels, 2019). In socio-technical systems, change is incremental and path-dependent as perceptions and actions of actors are shaped by dominant power relations, and increasingly entrenched rigid rules and institutions. Changing to another social and technical “regime” is hindered by self-reinforcing feedbacks, where deviation from the dominant path becomes increasingly costly (Pierson, 2000).

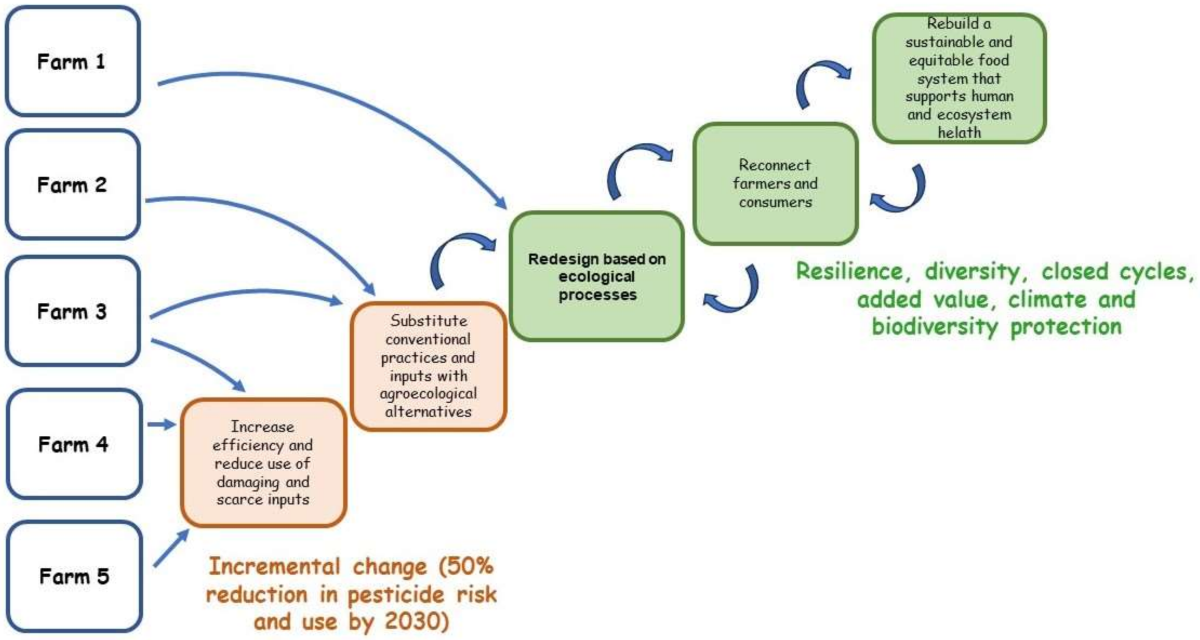
We draw on mixed qualitative methods to explore the different dimensions of the pesticide lock-in situation, i.e., the barriers and the underlying mechanisms that are holding back the transition towards sustainable plant protection in the European Union. A literature review, interviews with 14 EU level stakeholders and a survey of 174 farmers were employed to identify a wide range of barriers and lock-in mechanisms across different agricultural sectors in 10 different European countries. Workshops in each of the 10 SPRINT case study sites were then undertaken to identify transition pathways for specific contexts (see Fig 1).

Figure 1 Research methods employed and case study areas



SPRINT conceptualises the transition to a pesticide-free farming system as a process with five levels adapted from Gliessman (2015) and Jones et al (2022). The first three levels are based on the Hill and MacRae (1995) framework: 1) input efficiency 2) input substation; and 3) system redesign. Level 4 reconnects farmers and consumers through alternative networks and the final level is the rebuilding of a sustainable and equitable food system (see Fig 2).

Figure 2. Transition pathways to synthetic pesticide-free farming



It is recognised that farms will start from different starting points on the transition pathway. The work of Padel et al. (2019) when exploring transition pathways towards agroecological farm redesign found that input efficiency and input substitution measures generally did not lead to a system redesign, although sometimes they might run in parallel. They found no clear indication that efficiency or substitution measures were encouraging farmers to redesign their system. They argue that what leads farmers to move towards system redesign needs to be better understood. The aim of this paper, therefore, is to develop transition pathways for different food production systems across Europe that focus on system redesign.

To identify transition pathways to pesticide-free farming the project adopted a "What if" visioning approach with backcasting to identify different entry points to overcome barriers to achieving system redesign. In participatory workshops with a range of stakeholders including, farmers, farm advisers, technical authorities, researchers, policy-makers, breeders, civil society and retailers who are committed to a transition to reduce dependency on synthetic pesticides, two questions were explored: What does a system redesign that enables a future without synthetic pesticides look like? and What kind of enabling environment would be needed to get there?

Findings

The results confirmed that progress towards reduced reliance and dependence on synthetic pesticides is very much hindered by the pesticide lock-in situation. We identified the key lock-in mechanisms and barriers across different dimensions including agronomy and research, economics, knowledge, policy, regulation and cognition. The results highlighted the extent of changes required across the whole agri-food socio-technological system to break the pesticide-lock-in.

Future food production system visions for synthetic pesticide-free farming were produced for a range of farm types across the different case study countries. For example, in Slovenia the vision for a future arable farm comprised a system where crop varieties are selected based on criteria such as hardiness, disease resistance, and drought tolerance, with adjustments made for changing climate conditions. Irrigation is considered important to reduce plant stress and enhance productivity, while nutrient management involved using a wider range of sources including food residues and other organic materials. Livestock are also integral to the farm system, serving as a source of both meat and milk as well as providing fertilisation for the crops. Marketing strategies include cooperative partnerships, risk-sharing with organized consumers, and consumer education on the value of food production. In Switzerland a pesticide-free vision for apple orchards would entail international collaboration between farmers, researchers and government to find alternatives to pesticide to avoid reduced yields and a narrower range of available varieties. Additional fruit species or even non-speciality crops could mitigate yield reductions. Agroforestry systems, supported by appropriate subsidies could also enhance the economic viability of these approaches.

Potential steps on the transition pathway to achieving future a pesticide-free food production system in Slovenia and apple orchards in Switzerland are presented in Table 1.

Table 1. Steps on the transition pathways to pesticide food production in Slovenia and Switzerland

Slovenia	
Dimension	**Steps on the transition path**
Agronomy & Research	**Knowledge and science integration** that moves from pest and disease treatment to prevention as the basis of plant protection. Research is focused on the plants nutrition and water needs to increase their resilience to pests. Adoption of a holistic approach to research that does not just focus on a single element.
Knowledge	**Engagement Platforms and Knowledge Exchange** through the utilization of platforms like EIP (European Innovation Partnership), study circles, and demonstration farms to bridge the gap between research and practice, ensuring that valuable knowledge reaches farmers effectively.
Knowledge	**Training of specialist advisers** who meet professional criteria standards.
Policy	**Long-term agricultural policies** that consider societal needs, environmental sustainability, and economic viability. Establishment of national councils composed of experts and stakeholders to develop comprehensive, forward-thinking agricultural strategies.
Knowledge	**Education of the public**, including children through school nutrition programmes and farm visits, about the importance of sustainable agriculture, healthy food choices, and the value of local farming communities.

Switzerland	
Economics	**Offer subsidies** that favour agro-ecological methods and provide financial support for investments in new equipment and technologies.
Agronomy & Research	**Investment in research on alternatives** prioritising international collaboration to find sustainable solutions for yield losses without increasing imports. Explore both traditional and exotic fruit cultures; recognising some fruits may not be available in the future due to the shift in practices. Develop and distribute forecast models for diseases like apple scab and fire blight, provided free of cost.
Knowledge	**Investment in education and strengthen farmer consultation**, such as integrating sustainable farming knowledge into apprenticeship curriculums and encouraging creative and innovative thinking. Incorporate new theories and demonstrate reduced pesticide use possibilities. Integrate the IPM decision pyramid (prevention instead of curation) into the curriculum.
Knowledge	**Raise consumer awareness** about the environmental and health risks associated with pesticides. Demonstrate to consumers their influence within apple production. Highlight the impact of risks on health and the environment and explain the importance of eliminating synthetic pesticide use. Utilize tools like environmental and health monitoring, including maps for communication.
Policy & Regulatory	**Incorporate ecotoxicology considerations into decision-making processes**, imposing taxes on the most toxic substances while also simplifying the authorization process for alternatives

Practical Implications

The findings identified that there are many interrelated processes and direct barriers that mutually reinforce each other to limit or substantially slow down the possibility of a wider transition away from reliance on synthetic pesticides. The transition to reduced pesticide use cannot be solved simply by providing technical efficiency or substitution solutions but instead requires support for structural change. In particular, the insights point to the need for changes in governance mechanisms and to develop integrated strategies for sustainability in agri-food systems, that simultaneously address the multiple dimensions of the pesticide lock-in identified in this paper.

Theoretical Implications

The paper shows that realising transformative change in synthetic pesticide use through system redesign is contingent upon policy design embracing a socio-technological systems perspective. This perspective is essential for considering the multifaceted nature of the synthetic pesticide lock-in and simultaneously addressing its diverse components.

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Bucking the trend: crop farmers' motivations for reintegrating livestock

Clémentine Meunier[a], Guillaume Martin[a], Cécile Barnaud[b] and Julie Ryschawy[c]

[a] AGIR, Univ Toulouse, INRAE, 31326 Castanet-Tolosan, France

[b] UMR Dynafor, Univ Toulouse, INRAE, 31326 Castanet-Tolosan, France

[c] AGIR, Univ Toulouse, INPT, INRAE, 31320 Auzeville, France

Abstract:

Bucking the trend of specialisation, a few pioneering farmers have reintegrated livestock onto crop farms. These systems have been neglected by research to date. We identified French farmers' motivations for reintegrating livestock into specialised crop farms and crop-producing regions. Following innovation-tracking principles, we interviewed 18 crop farmers having reintegrated livestock in various systems in two regions dominated by crop farming. The semi-directed interviews focused on farmers' motivations for reintegrating livestock and were completed by farmers' ranking of 10/36 cards representing their main agronomic, economic, social and environmental motivations for crop-livestock farming. Seven categories of motivations for reintegrating livestock emerged from inductive content analysis: following personal ethical and moral values, increasing and stabilising income, promoting ecosystem services, increasing self-sufficiency and traceability, connecting to the local community, decreasing pollution and keeping the landscape open. Agricultural motivations, particularly related to soil quality, dominated both discourse analysis and motivation card rankings. Economic and social motivations were closely ranked, with income stability and social connections being primary drivers. Environmental motivation cards were less selected. This study is the first to provide a ranked summary of crop farmers' motivations for reintegrating livestock. Understanding this diversity is an initial step in supporting the development of this practice.

Keywords: Crop-livestock integration, Mixed systems, Sustainability, Farmers' motivations, Innovation tracking, Inductive content analysis

Purpose

Over the past few decades, the trend towards agricultural specialisation has spatially disconnected crop and livestock farming systems in Europe, and in France in particular, contributing to generate environmental externalities (Garrett et al., 2020). Specialised crop regions, while productive, heavily rely on nutrient inputs and consume substantial energy (Harchaoui and Chatzimpiros, 2018). Conversely, specialised livestock regions face challenges such as dependence on external animal feed and the generation of excess manure, leading to storage, disposal, and pollution issues (Lassaletta et al., 2009; Peterson et al., 2020). In spite of these acknowledged impacts, input-intensive segregated crop and livestock systems go on being developed.

Bucking this trend, a few pioneering farmers in France are reintegrating (i.e. intentionally organising the return of) livestock onto crop farms and into crop regions. These systems can contribute to decreasing environmental externalities thanks to crop and livestock reconnection at the farm (e.g. rearing livestock on the farm) or regional level (e.g. partnership between a crop farmer and livestock farmer, with the former hosting the latter's livestock for a specific period, for example to graze a winter cover crop). In spite of the potential advantages of these systems for transition towards sustainable farming, livestock reintegration is rare and understudied to date. Few studies have focused on the conditions that support or impede persistence of mixed systems or reconnection of crops and livestock due to farmer cooperation beyond the farm level in regions where both types of farms still exist (Martin et al., 2016). To date, no study has specifically sought in-depth understanding of the motivation toward reintegrating livestock onto specialised crop farms and into crop-producing regions.
The objective of this study was to identify and analyse French farmers' motivations for reintegrating livestock onto crop farms and into regions. Understanding the motivations that drive farmers to reintegrate livestock in such a challenging context is a necessary first step to assess performances of these systems in light of farmers' objectives and to incentivise, promote and/or support transition pathways towards sustainability through adoption of this sustainable practice (Paut et al., 2021; Ryschawy et al., 2021).

Methodology

We conducted 18 semi-directed interviews with crop farmers who had reintegrated livestock in order to analyse their motivations for having done so.

Case-study regions and farmers

We selected two regions where crops currently predominate but which differed in their history of livestock production: Occitanie (where traditional livestock and crop-livestock farms have strongly declined to be replaced with specialised grain crop farms, and where services such as slaughterhouses or technical advisors have remained but have been reduced greatly) ; and the Parisian Basin (where specialised cash crop farms have dominated for decades).
Following innovation tracking principles (Salembier et al., 2021), we aimed at identifying a wide variety of crop farmers' motivations for reintegrating livestock, rather than at obtaining statistical representativeness. As reintegrating livestock is uncommon, we included all crop farmers we could identify in the two regions, i.e. organic or conventional farmers who produced any type of crop and had reintegrated any type of livestock at the farm or regional level. We relied on farm advisors from our network to identify farmers who had reintegrated livestock onto crop farms and into regions, and increased the sample size using the snowball approach.
We interviewed 10 farmers in Occitanie and 8 farmers in the Parisian Basin (total: 18), who had diverse profiles in production mode (15 in organic farming or in conversion, 3 conventional), utilized agricultural area (5-2000 ha), crop production (grain crops, vegetables, orchard, vineyard), livestock production (meat sheep, meat cattle, laying hens, broilers, pigs), number of animals (e.g. from 200 laying hens to 1200 ewes plus 15 000 fattening lambs), as well as the type (farm level, regional level or both) and

duration of livestock reintegration (1-24 years, but most farmers had reintegrated livestock recently (mean of 5.6 years and median of 4 years)).

Data collection

Following Ajzen's Theory of Planned Behaviour (1991), the interview guide included questions targeting all the factors that may have motivated crop farmers to reintegrate livestock, such as i) beliefs about livestock reintegration, ii) overall objectives for the farm, iii) values and their influence on livestock reintegration, iv) perception of the risks involved in reintegrating livestock and v) internalised subjective norms. We also mentioned other topics to understand the overall functioning of the farm and identify some motivations for reintegrating livestock the farmer might have omitted when asked specifically.

At the end of the interview, to confirm whether we had identified all the motivations for livestock reintegration and to establish their priority, we provided farmers with 36 cards, encompassing the primary benefits of mixed farming and livestock reintegration as identified in existing literature, supplemented by us with additional advantages associated with farmers adopting sustainable practices. The cards were categorised into four categories: agronomic (13 cards, including 5 for soil-related benefits such as improving soil fertility and 8 for other aspects), environmental (4 cards), economic (12 cards), and social (7 cards). We asked farmers to choose and rank approximately 10 cards, irrespective of the category, that resonated with their own motivations for reintegrating livestock into their crop farms. Farmers were also given the option to add cards if they felt that a significant motivation was missing. We engaged in a brief discussion to explore their rankings, align them with the motivations identified during the interview, and incorporated any overlooked points.

Data analysis

To identify farmers' motivations for reintegrating livestock, we transcribed the 18 interviews completely and performed inductive content analysis. To rank crop farmers' motivations, we analysed their 18 rankings of the motivation cards, using the number of times each card had been selected, and the weighted sum of points attributed to each card (from 10 points for rank 1 to 1 point for rank 10). We triangulated the results obtained through qualitative and quantitative data analysis to increase their robustness. For each farmer, we compared the motivations identified through discourse analysis to the ranking of each motivation card and classified the comparison into four classes: i) the same ; ii) nearly the same (he card could be easily associated with something the farmer mentioned, albeit expressed in different term.); iii) ambiguous or unclear (e.g. the motivation was mentioned by the farmer only after seeing it on the card, or was not specific to livestock reintegration) ; iv) different (the motivation was identified in only one of the methods). We computed the percentage of motivations within each category by aggregating responses from all 18 farmers. We also performed multivariate analysis to characterize the differences in farmers' motivations rankings according to characteristics of the farming system (i.e. Region, Crops, Livestock reintegrated, Level of reintegration, Years reintegrated, farm size, type of housing) and farmer's profile (Age and Prior connection to livestock farming).

Findings

Discourse analysis

Seven categories of motivations for reintegrating livestock emerged from the inductive analysis of the interviews: following personal ethical and moral values, increasing and stabilising income, promoting ecosystem services, connecting to the local community, increasing self-sufficiency and traceability, decreasing pollution and keeping the landscape open.

Almost all farmers (17) identified livestock reintegration as a means to follow their diverse personal ethical and moral values, either to i) respond to their desire to have a meaningful job (as animals helped derive value from crops that were difficult to sell) (3 farmers) ; ii) matching their value of environmental stewardship (10); iii) undertaking a technical challenge through implementing a not well-known agricultural practice (8) ; iv) connecting to family or regional heritage of mixed farming (6) ; v) insuring the transmission of the farm by increasing its financial value (6); vi) improving the balance between personal and personal life by reducing workload (e.g. mechanization avoided through grazing) (5) and vii) improving their satisfaction at work thanks to animals' presence (11).

Fourteen farmers reintegrated livestock to *increase their income* through i) selling new products (6 farmers) ; ii) using "lost" crops or land, such as between orchard or vineyard rows or growing pasture where crop production was costly (7) ; iii) decreasing production costs by promoting ecosystem services and increasing self-sufficiency (6). Another motivation was to stabilise income (10), by i) increasing farm self-sufficiency and diversifying production to lessen dependence on market prices and climate events (10) and ii) using livestock to derive value from crops that did not grow well (1).

Another motivation for reintegrating livestock was to *promote ecosystem services* (16 farmers), especially regarding soils (life, fertility, structure, and carbon storage thanks to substituting mechanization with grazing thereby reducing greenhouse gas emissions). Five farmers mentioned grazing (sometimes associated with introducing pasture in the crop rotation) as a way to manage weeds and cover crops. Three farmers identified livestock as helping increase fields biodiversity.

Twelve farmers reintegrated livestock as a way to *strengthen their connections to the local community*, either within the agricultural sector (e.g. having someone working on the farm yearlong to tend the livestock, partnering with a livestock farmer) or outside (e.g. improving the image of the system towards customers (5 farmers) or citizens (3)).

Eight farmers also identified reintegrating livestock as a way to improve *farm self-sufficiency*, especially regarding nitrogen thanks to high-quality livestock manure. Fours farmers mentioned an increased traceability of farm products thanks to direct selling initiated with livestock reintegration.

In fewer cases, farmers mentioned reintegrating livestock to *decrease pollution* (through promotion of ecosystem services, decrease of input and energy use) (3 farmers) or to *maintain the landscape* (e.g. renovating an abandoned orchard) (3).

Motivation card rankings analysis and triangulation of the results

Through the analysis of farmers' ranking of motivation cards, we showed that farmers' main category of motivations for reintegrating livestock was agronomy (43% of the points), especially regarding soils (25% of the points) and biodiversity, consistently with

the high number of farmers mentioning ecosystem services promotion in their discourse.
Cards from economic and social categories were selected nearly as much by farmers (25% and 22% of the points respectively). The highest-ranked economic motivations were increasing and stabilising income, and increasing self-sufficiency, also identified as important motivations in farmers' discourse. Social motivations included creating social connections as mentioned by 17 farmers in their discourse, then responding to a desire/preference/belief, that could be linked to the motivation to follow personal moral and ethical values. Farmers attribute few points to the pollution cards in the environmental category (9% of the points in total). The most selected card was environmental stewardship, consistently with farmers' motivation to follow ethical values identified in their discourse.
Overall, results from the discourse analysis and motivation cards analysis were similar, with 82% of motivations that were the same or nearly the same, and mismatches appearing low in farmers' rankings. The motivations classified as different were mainly those identified through discourse analysis but not selected in the cards.
Main difference between farmers' motivations to reintegrate livestock regarding farming systems' characteristics was linked to the type of housing, as farmers reintegrating livestock in fully outdoor systems tended to favour agronomic motivations whereas farmers with at least partly indoor systems (e.g. free-range poultry, mixed indoors/outdoors for other livestock) tended to select more economic motivations.

Practical implications

In the current climate of escalating energy, feed, and nitrogen fertilizer prices, livestock reintegration seems to be a promising lifeline for crop farmers. Understanding the diversity of crop farmers' motivations for reintegrating livestock is the first step in sustaining the development of this innovative practice under favourable conditions and farmers' transition towards more sustainable farming systems. Building on the motivations for reintegrating livestock identified among crop farmers, decision-makers could align their communication on the benefits of these systems accordingly. They could also promote the development of this practice by developing payments for the ecosystem services provided.

Theoretical implications

Motivations for reintegrating livestock identified in this study are consistent with the benefits of crop-livestock integration documented in the literature, especially regarding promotion of ecosystem services through livestock manure and diversification of the crop rotation (Brewer and Gaudin, 2020) and income stabilisation through increased resilience regarding climate and market events (Bell and Moore, 2012). Social motivations highlighted in our study have not been reported as an advantage of crop-livestock integration so far. Benefits of crop-livestock integrated systems in pollution reduction have been widely documented, especially regarding closing carbon and nitrogen cycles (Ryschawy et al., 2021), but have not stood out as a major motivation in our sample.
Farmers' motivations for reintegrating livestock were consistent with those mentioned in other studies for engaging in sustainable transition pathways. Ecosystem services

promotion was identified as a motivation for adopting conservation agricultural practices (Casagrande et al., 2016). Increasing income was also identified in studies on adoption of conservation practices in organic farming, reducing pesticide use or grazing orchards (Casagrande et al., 2016; Paut et al., 2021; Pergner and Lippert, 2023). Social motivations identified in our study, such as the desire to undertake a technical challenge and to strengthen connections to the local community, were mentioned as triggering conversion to organic farming (Bouttes et al., 2019). Similarly, increased work satisfaction and caring about future generations were other motivations for adopting sustainable practices other than reintegrating livestock.

Our study focused on identifying a wide variety of crop farmers' motivations for reintegrating livestock. Following Lalani et al. (2021), future studies may focus on the interlinkages between those motivations, and how those motivations may vary according to farmers' profiles and farm characteristics. Similarly, motivations are one of the many factors triggering farmers' adoption of a sustainable practice or transition pathway. If the development of this practice is to be sustained, other elements should be in-depth studied such as the conditions that facilitate or hinder livestock reintegration, the trajectories followed by crop farmers to reintegrate livestock, or the impacts of reintegrating livestock on the sustainability of crop farms.

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PATHWAYS TO TRANSITION II

Transition levels to agroecology and factors supporting and discouraging its adoption – a case study from Northern Burkina Faso

Yasmina Tega [a,b], Hycenth Tim Ndah [c,d], Eveline Sawadogo/Compaore [b], Hamado Sawadogo [b] and Johannes Schuler [c]

[a] Joseph Ki-Zerbo University (UJKZ), Ouagadougou, Burkina Faso, tegayasmina@yahoo.com

[b] Institut de l'Environnement et de la Recherches Agricoles (INERA), Ouagadougou, Burkina Faso

[c] Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany

[d] University of Hohenheim, Research Center Global Food Security and Ecosystems (GFE)

Abstract:

Agriculture in West African countries faces significant challenges stemming from climate instability and socio-economic shifts, necessitating sustainable strategies for ecosystem preservation. Agroecology emerges as a promising solution in Burkina Faso farming systems, though obstacles hinder its widespread transition and adoption. The present study evaluates this transition (focusing mainly on the 10 elements of FAO) and the facilitating or inhibiting factors to adoption, utilising two assessment tools: the Tool of Agroecology Performance Evaluation (TAPE) and the Qualitative Assessment TOolset for Fostering an Agroecological Intensification to improve farmers' Resilience (QATOFAIR). Conducted in three communities of Northern Burkina Faso (Arbollé, Korsimoro, and Nagréongo), the study was based on a multi-stakeholder workshop and farmer interviews. Results indicate a strong commitment to agroecology, particularly in principles like circular economy and knowledge sharing. However, challenges persist in terms of efficiency and market conditions. While the communities show a high adoption potential, barriers to adoption and scaling include limited institutional support, short project durations leading to project dependent adoption, financial and inadequate infrastructure constraints. Addressing these challenges is crucial for scaling up agroecology in Burkina Faso and beyond, which will lead to sustainable agricultural development in the face of climate change pressures and land degradation. Moreso, the need for context-specific indicators to agroecology was recognised to bridge the gap between general statements and farmers' practical experiences

Keywords: Agroecology, Transition, Adoption, QAToCA, West Africa, Burkina Faso

Purpose

The agricultural landscape of Burkina Faso is confronted with many challenges arising from climatic unpredictability and evolving socio-economic dynamics. Tackling these challenges necessitates the co-creation of resilient strategies to ensure the sustainable utilization and safeguarding of ecosystems. In response, agroecology has emerged as a promising alternative. This multifaceted approach is perceived as a scientific discipline, a suite of practices, and a bottom-up social movement aimed at reshaping the food system (Wezel et al., 2009; Côte, Poirrier-Magona, 2018). This study aimed at i) accessing the levels of agro-ecological transition, ii) characterising the agroecological innovation chronology with focus on support services and actors, and iii) assessing pivotal factors influencing the adoption and scaling of site specific agroecological practices.

Design/Methodology/Approach

To fulfil the objectives of this study, two distinct approaches were employed: The Tool for Agroecological Performance Evaluation (TAPE) (FAO (2019) was utilized to gauge the extent of agroecological transition across the 10 Agroecology elements defined by FAO. Based on a set of statements grouped along the 10 elements, respondents evaluated their communities' level of transition for each element. Additionally, the Qualitative Assessment TOolset for Fostering an Agroecological Intensification to improve farmers' Resilience (QATOFAIR), informed by the methodologies of Ndah, Schuler (2015), Ndah et al. (2020), first developed for the assessment of conservation agriculture (QATOCA), was employed. Both methods were applied in a two-day multi-stakeholder focus group workshop with 30 participants consisting of farmers, service providers and representatives of the local administration. The participants worked on printed statement forms (one per community) for both tools. After joint discussions, they consensually identified and agreed on most fitting statements, which i) illustrate the levels of transition for each agroecological element (for the case of TAPE), and ii) best describe the state of adoption conditions (for case of QATOFAIR).

This was followed by an analysis of the timeline for agroecological practices highlighting observed support actors, corresponding activities, and effects on the agroecological innovation process. The study site for this investigation was in northern region of Burkina Faso, focusing on three specific communities: Korsimoro, Arbollé, and Nagréongo.

Findings

Findings on agro-ecological transition

The Agroecological Performance Assessment Tool (TAPE) has provided diverse insights into the transition for each AE element in Northern Burkina Faso. Notably, in the three communities examined, there is a marked advancement along the AE elements such as circular and solidarity economy, co-creation and knowledge sharing, and the preservation of food culture and traditions, with transition levels surpassing 60% on average (Figure 1). On the element "circular & solidarity economy" farmers state that the community is almost completely self-sufficient for agricultural and food production and there is a high level of exchange/trade of products and services between producers in the solidarity economy. There are functioning platforms available for the "co-creation and transfer of knowledge" in the field of agroecology, including women. These platforms facilitate the sharing of knowledge and promote collaboration in the development of agricultural practices. The preservation of "food culture and traditions" involves good awareness of local or traditional identity and respect for traditions or rituals overall.

In sum, elements, such as 'food culture and traditions' and 'co-creation and knowledge sharing', were consistently rated positively stakeholders, while difficulties arose in elements of 'recycling' and 'resilience', which were consistently rated low in all villages.

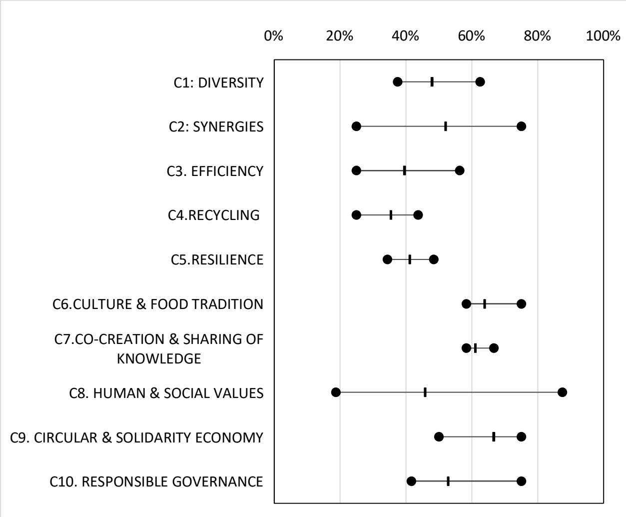

Figure 1: Transition level for agroecological elements in Northern Burkina Faso; average, minimum and maximum values per element of agroecology transition

Findings on timelines of agroecological innovation

While some observed practices have been part of the farming communities for the last 20 years, participants' reports on past agroecology promotion activities in the communities show that support for agriculture and agroecology has evolved over this period. As a result, agroecology is not completely new in the communities although new practices are being introduced through field trials and the redesign of existing ones. Initially, there were fewer players involved in support actions, but the number increased between 2010 and 2023 predominantly by public organisations and NGOs. Support service activities have mainly focused on building capacity (e.g. soil conservation methods and other agro-ecological practices) and improving access to resources (e.g. agricultural equipment).

These efforts have led to significant results, including the acquisition of knowledge on soil conservation techniques, land reclamation, composting practices, reforestation, and improved farming skills. As a result, farmers have seen their yields and incomes rise, and their environment improve thanks to reduced dependence on fertilisers and improved soil fertility. Nevertheless, following support service activities were noticed to be completely missing along the agroecological innovation process, beckoning a need for more attention: advice and consultation visits, awareness creation and knowledge sharing, empowering farmers to clearly express their needs, facilitating networking and brokering.

Adoption likelihood and factors influencing scaling of agroecology in northern Burkina Faso

The evaluation results reveal a varied influence within the thematic categories on the likelihood of adoption in the different villages. Categories with a significant influence (i.e. over 85% in two villages) include attributes of the dissemination and scaling strategy and Knowledge of agroecology's role on climate change and other ecological benefits. In addition, the villages of Korsimoro and Arbollé show high influence (80% or more) in 2 or

3 thematic categories. In contrast, categories such as market conditions for products and inputs, technical characteristics of agroecology as an object of adoption, and farm-household characteristics have a lower influence on adoption potential and are ranked lower in the assessment.

Factors supporting the adoption of agroecology in the communities.

For a successful agroecology dissemination strategy, a number of factors need to be taken into account. Examples are the selection of lead farmers, giving them the means to defend and promote innovative practices. It also involves setting clear objectives with defined indicators for monitoring and evaluation, supported by frequent data collection mechanisms. A crucial aspect is the establishment of a realistic and comprehensive timetable for the dissemination activities, including an effective exit strategy. In addition, it is essential to foster a strong and communicative relationship between the promoting organisation and the farmers, to ensure a reliable feedback mechanism. The role of the promoting organisation is to enable farmers to support themselves independently once the project has ended. In the agricultural landscape, the accessibility of farm-to-market routes throughout the year has a major influence on marketing conditions for agricultural products and inputs. The capacity of the implementing institution is also crucial, as it emphasises a clear vision and a common strategy for achieving the objectives set. It is important to note that the implementation of innovations in farming practices does not impose a minimum plot size, which makes it possible to accommodate farms of different sizes. Raising farmers' awareness of the benefits of agroecology in terms of climate change and ecological gains plays a crucial role in the adoption of these practices. Surprisingly, given the current security issues in many parts of Burkina Faso, farmers in their responses do not seem to see the political and institutional framework in the project region as conflicting with update of agroecology. At village level, local customs are not an obstacle to the introduction of innovative practices, ensuring their smooth integration into existing societal norms.

Factors limiting the adoption of agroecology in the communities.

The participants report a lack of interest from other support service providers in supporting the adoption of these practices, indicating potential barriers to their implementation. Farmers' access to markets for agroecological products throughout the year seems problematic. In addition, the promoting organisation lacks a long-term experience working in the targeted case study communities. Farmers face obstacles in accessing the inputs and machinery needed for the innovation, which is likely to hamper its adoption. Especially the absence of mechanisation leads to an increased labour burden which eventually discourages potential adopters. In addition, the complexity of the innovation requires more than two training sessions to apply it correctly. Short term observable benefits, such as increased yields from agroecology, are not evident, and there appears to be no local government authorities in the communities directly committed to rural development objectives. In addition, the settlement structure does not make it easy for extension workers to reach farmers, which is a further obstacle to effective implementation.

Practical Implications

An examination of the timelines of AE transition in different regions has demonstrated the evolution of support for agriculture and agroecology. Positive results were observed, including the acquisition of knowledge, increased production and income, land recovery and improved soil fertility. While support for agroecology has evolved over the years, some practices were deeply rooted in traditional farming systems. Public organisations and NGOs have played a leading role in bringing about these changes.
The identification of supporting and hindering factors highlighted the many challenges involved in adopting agroecology. A comprehensive dissemination strategy, empowerment of lead farmers, clear objectives, reliable feedback mechanisms and attention to local customs were identified as crucial elements. In addition, the importance of a supportive policy and institutional environment, accessible farm-to-market routes and capacity building within implementing institutions was highlighted for the successful adoption of agroecological practices.

Theoretical Implications

The evaluation of the TAPE results revealed significant variability in farmers' perceptions of the FAO's 10 elements of agroecology in different villages. While some elements, such as 'food culture and traditions' and 'co-creation and knowledge sharing', were consistently rated positively, difficulties arose in elements such as 'recycling' and 'resilience', which were consistently rated low in all villages. The need for context-specific indicators was recognised to bridge the gap between general statements and farmers' practical experiences. Overall, the results suggest that a holistic and collaborative approach, tailored to the specific context and needs of farmers, is essential to successfully promote sustainable farming practices in northern Burkina Faso.

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Testing the ground: barriers and stakeholders in the pathways to sustainable business models for soil health

Greta Winkler[a], *Fabio Bartolini*[a], *Lisette Phelan*[b], *Alexandra Langlais-Hesse*[c], *Liesbeth Dries*[d], *Insa Thiermann*[d], *Eriselda Canaj*[e], *Francisco Jose Blanco Velazquez*[f], *Francesco Riccioli*[g], *Ekatherina Tzvetanova-Georgieva*[h], *Dimitre Nikolov*[h], *Ana Iglesias*[i], *Gloria Minarelli*[j]

[a] University of Ferrara, greta.winkler@unife.it, fabio.bartolini@unife.it

[b] University of Leeds, l.phelan@leeds.ac.uk

[c] University of Rennes, alexandra.langlais@univ-rennes.fr

[d] Wageningen University, liesbeth.dries@wur.nl, insa.thiermann@wur.nl,

[e] Assembly of European Horticultural Regions, euprojects@areflh.org

[f] Evenor tech, fj.blanco@evenor-tech.com

[g] University of Pisa, francesco.riccioli@unipi.it,

[h] New Bulgarian University, ecvetanova@nbu.bg, dnik_sp@yahoo.com

[i] Iastituto Delta Ecologia Applicata, loriaminarelli@istitutodelta.com,

[j] Universidad Politecnica de Madrid, aiglesias@gmail.com

Abstract:

Increasing evidence of soil degradation has brought the topic to the policy arena; at European Union level, the Soil Strategy aims to restore soil health by improving the delivery of soil-related ecosystem services. Yet, how to better regulate and incentivize soil health between public and private actors is still a contested matter. Business models with greater social sustainability should result in soil management that delivers ecosystem services, including e.g. biodiversity and cultural heritage, and balances individual gains from property rights on land with the broader societal need for environmental conservation. Applying a system-oriented approach and the pentagonal problem approach to identifying key barriers in the implementation of sustainable business models for soil health, this study maps stakeholders' ability to influence the adoption of business models across 12 European case studies and the practical and policy implications of this influence for transitions towards soil health at a local scale. Results suggest lack of governmental (e.g., a regulative framework, and insufficient political commitment) and technological (e.g., tools for monitoring and mapping) as barriers exist. Farmers, the supply chain, policy makers and advisory services emerged as key actors for a transition towards soil health. This reflects the needs for greater coordination between societal sectors to guarantee that soil health is pursued not only as a policy objective but constitutes an implementable strategy in practice.

Keywords: soil health, sustainable business models, system innovation approach, stakeholder map, transition pathways

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Purpose

Soil is a natural resource of importance for several sectors, ranging from food and energy production to habitat conservation, but is threatened by various degradation processes and is difficult to govern and conserve as it is a (mostly) privately owned asset and is capable of delivering ES in the form of both private and public goods but lacks a property rights definition that ensures a public goods interests (Ronchi et al., 2019; Bartkowski et al., 2018; Juerges & Hansjürgens, 2018). Soil protection has been on the policy agenda for several decades, albeit with priorities, focus and narratives changing (Lehmann et al., 2020). The current European Union (EU)-adopted definition of soil health reflects the view that soils can deliver many ecosystem services (ES), being it the ability of soils to sustain and improve the biological, chemical and physical properties that support plant growth and other ecosystem functions (Lehmann et al, 2020). However, insufficient provision and inadequate remuneration of ES related to soil is a challenge to promoting sustainable soil management (SSM); this is particularly evident in the case of public goods delivery in the context of agricultural production (Bartowski et al, 2018). While agricultural activities can adversely impact and reduce soil health, SSM can contribute to less input intensive agricultural production by restoring soil health, biodiversity, and organic matter content (Lehmann et al, 2020).

The kind of soil governance necessary to guarantee soil health is complex and multilayered, encompassing regulating and incentivizing instruments. Regulatory instruments are used to set legally binding standards for soil management practices. In the EU, the lack of a shared regulatory framework has resulted in overlapping and conflicting policies between agriculture and other land uses (Heuser, 2022) as well as differing approaches to and objectives of SSM between and within member states (Ronchi et al, 2019). Economic instruments financially incentivize certain soil management practices, often voluntary in their character, and are based for instance on subsidies, taxes, or tradable permits (Juerges & Hansjürgens, 2016). The implementation and combination of those instruments is under-explored, but highly relevant in light of the ongoing EU Soil Mission and proposal for a Directive on Soil Monitoring and Resilience. Juerges & Hansjürgens (2016) found that successful soil governance depends on the combination of formal and informal institutions, soft and hard instruments, and multi-level decision-making. Thus, a shift towards greater soil health could be approached as a transition that requires systemic change, encompassing interdependencies of actors, institutions and technologies and targeting normative goals (Scoones, 2015).

Both public and private sectors are looking to identify organizational, technological and financial pathways that can contribute to achieving sustainable business models (SBM) for improved soil health. The term SBM refers to organizations' delivery of goods and services in a profitable manner, as well as their contribution to improved environmental and social conditions resulting from sustainable management (Barth et al, 2017). Different stakeholders' understandings of the soil health issue, as well as the desirable solutions, may constitute important success factors for SBM (Ulvenblad et al, 2018). Diverse stakeholders – e.g. landowners and land workers, advisory services, local administrators – are affected by their participation, as beneficiaries or providers of soil ES, in SBM and their participation is key to ensuring legitimacy of the governance process (Juerges & Hansjürgens, 2016; Bartowski et al, 2018) and thriving successful adoption of SBM (da Rocha Oliveira Teixeira et al., 2023)

This study aims to (i) identifying key barriers in the implementation of SBM for soil health across 12 European case studies and (ii) mapping stakeholders' ability to influence the adoption of SBM. It also outlines the practical and policy implications of this influence for transitions towards soil health at a local scale.

Approach and methodology

Data was collected across 12 case studies by research partners in 7 European countries as part of the EU-funded Horizon Europe project NOVASOIL (grant agreement: 101091268) which aims to promote SSM through SBM for soil health. These case studies were categorized as: (i) individual, i.e. SBM depended on farmers', landowners', or consumers' participation; and (ii) network, i.e. multiple actors' participation was key to SBM adoption (Table 1). The case study-centered approach facilitated the collection of context-specific data related to the barriers to SBM and stakeholders' needs to implement SBM for soil health (da Rocha Oliveira Teixeira et al., 2023), whilst providing a broader understanding of ongoing processes in socio-ecological systems (Guimarães et al., 2018).

Table 1. Overview of individual and network-based case studies in each of the case studies

Categories	Case study[7]	Key features of SBM
INDIVIDUAL-BASED	DE_1	Private marketplace for certificates of nature conservation projects
	DE_2	Private fund to compensate farmers for sustainable soil management
	NL_1	Bank for carbon credits generated from regenerative agricultural practices
	IT_1	Certificates of conservation and organic agriculture, coupled with long term experiment and technical advice
	LV_1	Public funding (CAP, I pillar, eco-schemes) to farmers for minimum tillage coupled with accessible mapping of local soil conditions
	LV_2	Civil society compensation to farmers for agroforestry, i.e. alley cropping
NETWORK - BASED	UK_1	Private sector-led investment scheme to thrive soil health at landscape level
	ES_1	Public sector-led monitoring, mapping and digitalization for soil health in municipal park
	BG_1	Public financial support and vertical integration for supply chain on agriculture and rural tourism

	DE_3	Private marketplace for carbon certificates of farmers' groups
	IT_2	Public financial support for supply chain over multifunctional agriculture and rural tourism
	IT_3	Territorial level organization of farmers to access public and private funds and certificates

Similar to previous studies relating to the governance of threatened environments, sustainability transitions, and science-stakeholder interfaces (Alamanos et al, 2022; Scoones, 2015), this study adopted a system innovation approach to identifying key barriers in the implementation of SBM for soil health and stakeholders' influence over the adoption of SBM. The 'pentagonal problem approach' (De Vincente Lopez and Matti, 2016) was used to describe the case studies according to (i) challenges related to soil health, (ii) impact of climate change, (iii) socio-economic barriers, iv) socio-technological solutions in the form of SBM, (v) barriers and (vi) needs to adoption of SBM. Thereafter, research partners compiled an online survey, selecting 5 – 10 stakeholders in each case study and assessing their level of influence according to a Likert scale. Following the example of De Vincente Lopez and Matti (2016), the survey elicited data on stakeholders' perceptions of: a) their relevance for SSM, i.e. to influence the adoption of SBM and the design of soil-related policy and regulation; b) their interest, i.e. engagement and commitment towards soil health; and c) their expertise, i.e. knowledge of technical issues related to soil health. Content analysis was conducted on the textual results with the software MAXQDA Analytics Pro (VERBI GmbH 2022). Deductive coding was based on pre-defined codes from the review on internal and external barriers to sustainable innovation of business models (Ulvenblad et at., 2018).

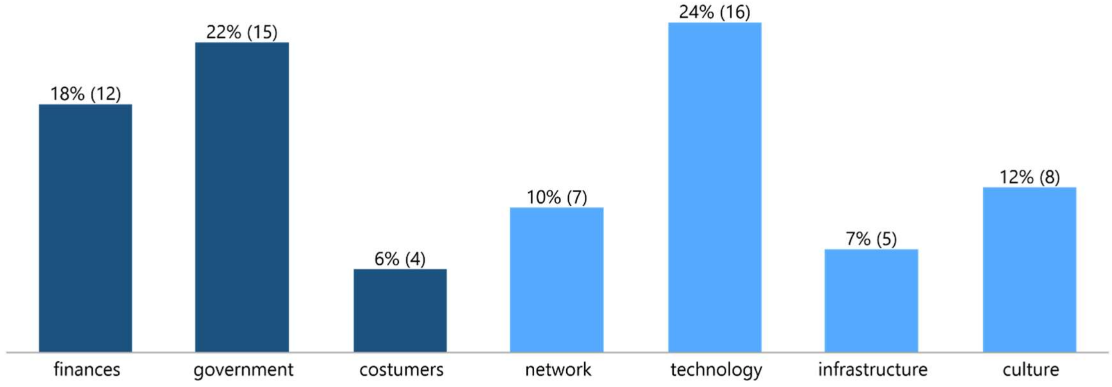
Findings

Barriers to SBM for soil health

Ulvenblad et at. (2018) define external barriers as relating to (a) a lack of support by strategic actors, e.g. governments and costumers, or access to finance and (b) a restrictive macro-environment (underdeveloped networks, technology, infrastructure, local culture).

A total of 67 external barriers were found across the case studies (Figure 2). The main barrier to adoption of SBM was a lack of access to appropriate technology, e.g. for long-term monitoring of soil carbon stocks; mapping and digitalization of soil data; and measurement of soil-related ES. However, a lack of government support (i.e., enabling regulatory frameworks, political commitment, and planning) was also mentioned as important barriers. The main financial limitations were decreasing public resources availability as well as the low market value of carbon credits and ES.

Figure 2. External barriers to adoption of SBM; the colors refer to the external barriers: a) lack of support (dark blue) and b) restrictive macro-economic environments (light blue)



Internal barriers considered by this study, also classified according to Ulvenblad et al. (2018), include: (a) individual (i.e. mindset, perceptions, values, behaviour); (b) lack of competency (discovery, incubation, acceleration); (c) insufficient resources (internal finances, leadership, tools, experience, information); d) organizational structure (hierarchies, communication, roles and responsibilities, planning, management). However, (b) and (c) were excluded from the analysis for this study as the data collected were too specific to each case study to draw generalized insights regarding and research partners did not have access to such level of detailed information on the case studies.

Organizational barriers identified by this study reflected missing networks and collaboration with other actors, i.e. supply-chain, government, private sector, research. Barriers to competencies were not to be detected or were assimilated to information and experience, i.e. resources. Of the remaining internal barriers (n=40), individual barriers (38%) reflected attitudes toward risk, distrust in long term results and future perspectives for the agricultural sector, and change of mindset. Insufficient resources (63%) mostly related to profitability and cost of innovation, access to reliable knowledge and access to information and training regarding SBM.

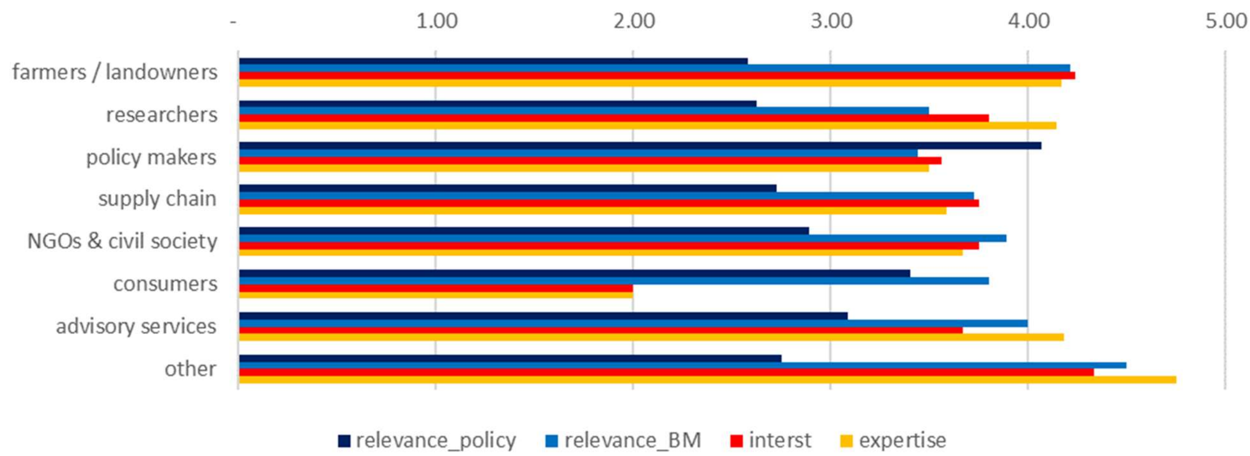
Stakeholder mapping

Stakeholders, grouped into broader categories, see a majority of farmers, supply chain, advisory services and policy makers among the key actors (Figure 3).

Figure 3: Stakeholders categories in individual SBM (left) and network SBM (right)

Stakeholders' influence over the implementation of SBM for soil health is shown in Figure 4. All stakeholders scored highly in terms of their expertise and interest (>3.5.) in implementing SBM for soil health, with the exception of consumers. As technology was previously found to be the highest barrier facing stakeholders, the results suggest that knowledge should be disseminated by stakeholders in so-called expert categories, e.g. researchers, advisers, and farmers, to other stakeholders in order to increase the interest in and knowledge about SBM. The results of this study are in line with those of other studies, such as da Rocha Oliveira Teixeira et al. (2023) who assert that SBM requires a coordinated effort of actors along supply chains. As owners and workers of their land, farmers were regarded as highly relevant stakeholders to involve in SBM; they had high levels of interest and expertise related to the development of SBM. Civil society and supply chain actors signalled high interested in SBM. Consumers, civil society and technical advisers were perceived as playing a key role in influencing the success of the SBM, while policy makers, and consumers were perceived as having the most influence over policies. Researchers and advisory services were seen as having expertise that could play a role in the implementation of SBM.

Figure 4 - Lickert scale on stakeholders' level of influence



Theoretical and practical implications

As the policy landscape is rapidly changing and the policy agenda for increased sustainability pursued by the EU and marked by the Green Deal strategy is increasingly being challenged by economic and political crises, key policy questions are emerging related to the governance of natural resources, including soil. For instance, in the case of soil, how to ensure the flows of knowledge and information between stakeholders that facilitate the conservation of these resources? And how to enable policy acceptability and trustworthiness from the side of soil users, e.g. farmers and landowners? How to create an SBM where increased participation of consumers and civil society reward for improved soil health? These questions should be addressed to guarantee that SBM are socially sustainable.

This study contributes to answering such questions by exploring SBM for soil health across 7 EU countries, and provides insight into the roles that a diverse set of stakeholders could play in adopting SBM if barriers currently faced were addressed and there was an enabling policy and governance environment. It demonstrates how the system innovation approach and the pentagonal problem approach (and the theories associated with both approaches) can be applied to gain insight into the internal and external barriers faced by stakeholders implementing SBM and determine the stakeholders that might play an important role in realising an effective transition towards soil health at a local scale. Moreover, the study highlights the extent to which recognising and valuing the public goods value of soil is a contested matter and implies trade-offs between contrasting interests, values and priorities among stakeholders at different scales of action and governance. Building on the results of this study, follow-up research currently being conducted by the NOVASOIL research partners will further explore these trade-offs and the institutional framework and soil governance (e.g. contracts and innovations) that exist to support the establishment SBM in each of the case studies. Research partners have established Policy Innovation Labs to further explore stakeholders needs and barriers identified for the case studies as well as to discuss and reformulate underlying values embedded in establishing SBM for soil health.

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Requirements for adopting and supporting agrivoltaics – Perspectives from agriculture and policy

Felix Zoll[a], Alexandra Doernberg[b] and Rosemarie Siebert[c]

[a]Leibniz Centre for Agricultural Landscape Research (ZALF), zoll@zalf.de

[b]Leibniz Centre for Agricultural Landscape Research (ZALF), doernberg@zalf.de

[c]Leibniz Centre for Agricultural Landscape Research (ZALF), rsiebert@zalf.de

Abstract:

This study investigates agrivoltaics (AV), integrating agriculture with solar power generation, as a solution for food security, climate change adaption, and for ecosystem preservation. Based on qualitative interviews in Germany, the research examines farmers', policymakers', and administrative stakeholders' perceptions of AV and the conditions under which these stakeholders would adopt or support AV. Key findings indicate that farmers' and farmers' organizations' willingness to adopt AV depends on the economic viability and sustainability of projects, with a preference for implementing AV on less valuable soils. From a farmer's perspective community engagement and local benefits are vital for acceptance, while concerns about landscape aesthetics, legal complexities, and policy frameworks pose barriers. Interviewed policymakers and administrative stakeholders highlight the need for AV to align with agricultural preservation, community welfare, and landscape integrity, emphasizing the use of lower-value lands and efficient energy grid integration. Addressing these stakeholder conditions could make AV a socially sustainable farming practice, enhancing social equity and economic resilience in rural areas. The study's implications suggest the importance of power grid infrastructure, policy support, and community-centred approaches for successful AV integration. Overall, our study contributes empirical results to theories on rural innovation, behavioral economics, and sustainable transitions.

Keywords: photovoltaics, energy transition, social acceptability, socio-technical innovation

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Purpose

Agrivoltaics (AV), the practice of combining agricultural and photovoltaic power production, offers a promising solution to the trilemma of preserving ecosystems, achieving food security, and addressing climate change. AV potentially maximizes land-use efficiency and mitigates land use competition, making it particularly relevant amid transitions to tackle global food and energy crises (Ketzer et al., 2020; Feuerbacher et al., 2022).

Investigating public perceptions of AV is crucial due to their potential to influence adoption rates and policy decisions. Studies indicate that public acceptance of renewable energy technologies like AV can be influenced by factors such as the perceptions of landscape aesthetics and land-use changes (Ketzer et al., 2020; Moore et al., 2022). Research on stakeholder perceptions and attitudes towards AV is essential for informing policymaking, technology development, and societal acceptance of AV systems. Especially farmers and agricultural associations are critical stakeholders in the successful diffusion of AV, as their adoption of AV systems is primarily driven by environmental and economic considerations (Pascaris et al., 2020; Moore et al., 2022). Moreover, policymakers' perspectives on AV need to be considered, as government policies and regulations play a crucial role in promoting the adoption and acceptance of sustainable energy and agricultural practices like AV (Moore et al., 2022; Torma et al., 2023). Therefore, we conducted a study that considers farmers', policymakers' and administrative staff's perceptions to answer the following research questions:

(1) What are farmers' adoption criteria for AV?
(2) Under which conditions will policymakers and administration support AV?

Design/Methodology/Approach

In our study, we opted for Northeastern Germany (comprising the states of Brandenburg and Mecklenburg-Vorpommern) and Southern Germany (including the states Bavaria and Baden-Württemberg) as areas of investigation. These regions were selected due to their significant differences in agricultural structure. With the Northeastern region consisting of large field plots and Southern region being characterized by small-scale agriculture. To answer our research objectives, we employed an exploratory qualitative research methodology. We conducted semi-structured interviews to gather data, as they offer firsthand insights into real-life phenomena and associated aspects such as AV (Brinkmann, 2018). Interviewees were selected following a stakeholder analysis. Selection criteria for farmers where that they were already familiar with the concept of AV and thought about building AV on their farm. We contacted the agricultural organizations of the four states involved in the study and asked for representatives who were knowledgeable of the AV approach. Where possible, we interviewed policymakers and administrative employees familiar with the topic of AV in the regions where the interviewed farmers were from. If this was not possible, we interviewed policymakers and administrative employees in regions where AV is planned or already implemented. Overall, 24 people belonging to two stakeholder groups were interviewed. Stakeholder group 1, representing farmers' perceptions: 16 interviews captured farmers' perspectives, eight interviewees were farmers and eight interviewees worked for agricultural associations but in all cases were farmers as well. Stakeholder group 2, representing perceptions of policy and administration: Eight interviewees were active in public administration and policy. Due to the explorative character of our study and the number of interviews especially of the stakeholder group policy and administration, our findings should not be generalized.

Findings

Adoption criteria among farmers and farmers' association representatives

The willingness of the interviewed farmers and farmers' association representatives to adopt AV hinges on specific requirements that ensure the sustainability and economic viability of such projects. Their openness to photovoltaic technology is primarily motivated by the potential for generating additional income, with a preference for installations that do not compromise valuable agricultural land. This includes a strong inclination towards first utilizing rooftops and less fertile lands for photovoltaic systems, while firmly opposing the use of high-quality farmlands for ground-mounted PV installations.

The success of AV projects in the farming community is also contingent upon effective community involvement. Interviewed farmers and farmers' association representatives emphasize the importance of engaging local citizens and ensuring that the benefits of such projects, including financial gains, remain within the local community. This community-centric approach is crucial for garnering local support and acceptance of AV initiatives.

However, there are significant barriers that need to be addressed for farmers to fully embrace AV. These include concerns about the impact of installations on the landscape, the complexity of legal and tax issues, the need for adjustments in land-use policies, and cautious handling of investors. Clear and supportive regulatory frameworks are deemed essential for the adoption of AV. The interviewed farmers and farmers' association representatives included in this study are calling for policies that specifically facilitate AV projects and allow for the use of non-arable lands for photovoltaic purposes, ensuring that AV initiatives are both economically attractive and compatible with existing agricultural practices.

Policy makers' and administrative stakeholders' conditions for supporting AV

To garner support for the adoption of AV, policymakers and administrative stakeholders underscore the necessity of meeting specific conditions that ensure a harmonious balance between the benefits of solar energy and the preservation of agricultural practices, community welfare, and landscape integrity. According to the interviewees, the support hinges on ensuring planning flexibility and streamlined permitting processes that favor solar energy, particularly AV, for its ease of integration and profitability. However, this support is contingent upon the prioritization of lower-value lands, conversion areas, and spaces along existing infrastructures (e. g. transportation) for solar projects to safeguard prime agricultural lands, reflecting a clear stance against the use of high-quality agricultural soils for photovoltaic installations.

The integration of AV into the energy grid is perceived as another critical condition, with both policy and administrative stakeholders highlighting the need to address grid capacity challenges and competition for feed-in points, which are often saturated by existing photovoltaic systems. Community acceptance and benefits are pivotal; projects that fail to extend benefits beyond landowners to local communities and the public, or to integrate visually and minimize resistance, are less likely to be supported.

The development of framework concepts for photovoltaic use within communities is encouraged by almost all interviewees of the policy and administration stakeholder group, aiming for a structured approach that is coordinated collectively. This indicates a preference for projects that align with such frameworks. Political and regulatory support is considered essential for the diffusion of AV. Yet it is highlighted that authorities' have to build capacities to efficiently process applications, suggesting a need for regulatory efficiency to ensure quick decision making and planning security for people who want to install AV.

Moreover, there is an explicit call by all interviewees of this stakeholder group for prioritizing the expansion of photovoltaic installations on existing roof and already sealed surfaces before considering new/ additional land use, aiming to minimize land consumption. The significance of land for agricultural production is considered a critical consideration. Proposals that risk impairing agricultural production due to inappropriate land use for photovoltaics are less likely to be supported. Hence, AV, which combines energy generation with agricultural use, is only favored by the interviewed policymakers and administrative stakeholders if it ensures the multifunctionality of farmland without compromising their agricultural productivity.

Practical Implications

If the conditions that farmers, policy makers and administrative stakeholders expressed are applied for a rollout of AV, there is potential that it contributes to a transition towards more sustainable and equitable farming and energy production benefitting both farmers and society.

Socially, the condition that projects should benefit local communities highlight the potential for AV to foster social equity. By ensuring that renewable energy projects extend benefits beyond landowners to local communities, AV can contribute to rural development and improve community infrastructure, thereby addressing social inequalities. However, the interviewed farmers' fear of (non-agricultural) investors shows that there is also risks that large corporations are the main beneficiaries of an unregulated development of AV.

Economically, the interviewed farmers and their representatives perceive AV as an opportunity to diversify their income sources through energy production, potentially reducing economic vulnerability to volatile agricultural markets and climatic uncertainties. The implementation of AV projects can stimulate rural economies by creating jobs, fostering local entrepreneurship, and keeping value creation within local communities, contributing to rural revitalization.

However, the basis for a development of AV must be laid first. The concern over grid capacities and the competition for feed-in points highlight the need for infrastructure investments and innovative solutions to integrate renewable energy into existing grids. Similarly, the careful consideration of land use underscores the necessity for strategic planning and technological advancements in AV to ensure that agricultural productivity is not compromised, thereby maintaining food security while expanding renewable energy production. The results also suggest that effective policy measures, incentives, and streamlined permitting processes are crucial for the successful integration of AV into the energy and agricultural sectors. Such policy support can facilitate the transition towards viable farming, aligning with national and international goals for renewable energy and climate adaptation.

Theoretical Implications

The research sheds light on innovation adoption in rural areas, particularly how local cultural, economic, and environmental factors influence the acceptance of new technologies. This can contribute to theories on rural innovation systems, emphasizing the role of local context and stakeholder engagement in the diffusion of innovation. Farmers' skepticism towards large external investors and preference for community cooperatives gives insights into behavioral economics, particularly regarding risk aversion, trust, and the perceived fairness of economic transactions. This can enrich theoretical understanding of decision-making processes and social preferences in the agricultural sector under conditions of uncertainty. Lastly, the conditional support for AV aligns with transition theory, which examines how societal systems evolve from one state to another, particularly towards more sustainable practices. The findings underscore the role of policy, community acceptance, and technological innovation in facilitating transitions within energy and agricultural systems, highlighting the importance of multi-actor engagement and the interplay between local actions and broader policy frameworks.

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A reflexive collaborative workshop on agroecology narratives and researcher's postures

Lola Richelle[a], Alain Brauman[a], Bruno Romagny[b], Jean-Phillipe Venot[d], Dominique Masse[a], Laurent Cournac[a], Eric Leonard[d], Amar Imache[e], Davide Rizzo[f]

[a] Eco&Sols, Univ. Montpellier, CIRAD, INRAE, IRD, Institut Agro, Montpellier, France, {name.surname}@ird.fr

[b] LPED, UMR 151AMU-IRD, IRD, Aix-Marseille University, Marseille, France, bruno.romagny@ird.fr

[c] G-EAU, Univ. Montpellier, AgroParisTech, BRGM, CIRAD, INRAE, Institut Agro, IRD, Montpellier, France, jean-philippe.venot@ird.fr

[d] SENS, IRD, CIRAD, Univ Paul Valery Montpellier 3, Univ Montpellier, Montpellier, France, eric.leonard@ird.fr

[e] LISODE, Montpellier, France, amar.imache@lisode.com

[f] LISAH, Univ Montpellier, AgroParisTech, INRAE, Institut Agro, IRD, Montpellier, France, davide.rizzo@ird.fr

Abstract:

Agroecological principles and transitions can create tensions between initiatives rooted in social movements and institutionalisation processes. This pulls researchers between two potentially conflicting tasks: (i) advising policymakers and (ii) supporting farmers and stakeholders in their endogenous trajectories. This paper addresses this tension by focusing on the role of academics in transdisciplinary long-term collaborations. The study reviews a two-day transdisciplinary workshop organised by the "Lands and Soils'' knowledge community (CoSav Terresol) hosted by the French National Research Institute for Sustainable Development (IRD). Forty participants, including researchers, NGOs, farmers and policymakers' representatives, engaged in reflexive activities to explore various agroecology narratives and the issue of researchers' postures in agroecological transitions. The findings highlight the need for transversal skills and facilitators to support researchers in dialoguing with different stakeholders. This includes the importance of deconstructing narratives and considering ethical implications of long-term partnerships in the production of agroecological knowledge. In this way, it is crucial to engage in a transdisciplinary dialogue that recognises farmers' knowledge and to consider farmers as research actors and partners.

Keywords: Agroecology, Sustainability science, Transdisciplinarity, CoSav, Knowledge Community

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Purpose

Agroecology, drawing from ecology and social movements, promotes sustainable agriculture (FAO, 2018; López-García et al., 2021). While gaining traction in science and media, its political and policy inclusion varies across regions. Furthermore, contextual social and political dynamics can weaken farmer-led transitions. Depending on the national context or the actors' position in society, various agroecology narratives meet and/or confront. Altogether, stakeholders are caught between an activist/militant approach rooted in agroecology as a social movement, and pathways for institutionalising its principles, similarly to organic farming (Van Dam and Nizet, 2014). This creates tension between calls for a radical transformation and those for a more cautious, evidence-based approach. Scientists supporting agroecology face a credibility challenge to bridge the gap between policymakers needing evidence and farmers experimenting with new practices. Such a dual role is key to legitimize agroecology in policy and strengthen sustainable agriculture through research methods suited for such collaborations.

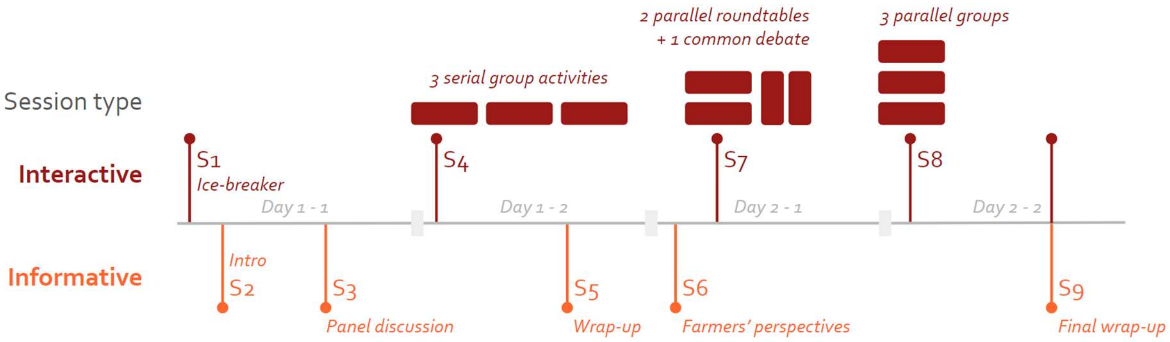
We focus here on the need for scientists to support farmers in agroecological transitions, while acknowledging the broader challenge of research navigating between policy and local needs. Sustainable science demands a shift towards co-creation of knowledge with farmers, valuing their expertise and incorporating collaborative research methods (Dangles and Fréour, 2023; Kates et al., 2001). In the case of agroecological transitions, it is important to engage in a transdisciplinary dialogue that recognises the relevance and credibility of farmers' knowledge. Furthermore, it is crucial to consider farmers as research actors and partners. Collaborative and action-oriented research are essential dimensions in sustainable agriculture transition processes. They allow farmers to anchor their transition pathway in an enriching and rigorous knowledge dialogue (Méndez et al., 2013). In this context, platforms fostering dialogue and workshops can bridge the gap between scientific and farmer knowledge, enriching the transition to sustainable agriculture. This paper reviews a reflexive collaborative workshop on agroecology narratives and researcher's roles organised by the "Lands and Soils" knowledge community (called in French "CoSav Terres et Sols": https://terresetsols.ird.fr/en/). This knowledge community is part of the French National Research Institute for Sustainable Development (IRD) commitment to more sustainable and inclusive research through nine key societal challenges, including land, climate, sustainable cities, and biodiversity. Established in 2022, this community fosters dialogue on sustainable land management with researchers worldwide. It exemplifies a shift towards a collaborative and inclusive approach to research.

Approach and methods

The "Lands and Soils" community holds yearly a thematic workshop. In 2023, it focused on agroecology narratives and questioned the political positioning and epistemological posture of researchers in agroecological transitions. The topic was selected considering the growing diversity of ways in which agroecology is integrated into the agenda by public policies and social movements in Southern and Northern countries. Accordingly, the workshop addressed the following questions: what are the missions expected from research in the context of agroecological transitions? How do researchers reconcile their commitment to agroecology with their research goals? How do researchers commit to finding solutions with people? One of its goals was to share and compare the narratives and experiences of agroecology within the cultural context of the members of the knowledge community. It was attended by 40 participants, which included a variety of actors such as farmers, NGOs and public policy representatives, even though researchers were in the majority.

The two-day workshop alternated interactive and informative sessions for a total of nine slots (Fig 1). Four interactive sessions rhythmed the workshop with gradually increasing engagement of individuals in different group activities. Participants rotated through group activities and lectures from diverse backgrounds, with a focus on building common background. A professional cooperative consultancy in participatory approaches (LISODE, https://www.lisode.com/home/) helped in designing the interactive sessions. Group composition shifted to encourage exchange of personal perspectives and formulate shared answers to the introductory questions. Day one opened with diverse speakers highlighting agroecology across regions: West Africa, Maghreb, Latin America, South-East Asia, and France. Interactive sessions followed, with participants defining agroecology, reflecting on personal experiences, and identifying stakeholders in a simulated project based on a description of a generic rural context and community. This allowed for the comparison of narratives without reference to any specific geographical framework. Day two began with farmer perspectives on research, featuring testimonies from a European Coordination Via Campesina member (https://www.eurovia.org) and a farmer involved in the Tarassac onion breeding (De Bon, 2022). Split-group discussions explored researcher-farmer interaction, prerequisites for collaboration, and societal/policymaker expectations. An afternoon simulation saw participants role-play project teams presenting a five-year agroecology plan to a local community, using top-down, fully collaborative, and open-ended approaches. The workshop concluded with anonymous feedback and final discussions on key takeaways.

Figure 1. Diagram of sessions (S1 to S9) and activities of the two-day workshop.



Findings

The international panel of the opening session highlighted some regional variations:

- *West Africa*: Senegal's DyTAES network (https://dytaes.sn/) promotes agroecology, but national policy shows limited support, as outlined in the "Dakar 2" Declaration (Africa Food Summit, 2023).

- *Maghreb*: Despite notable interest from farmers and pioneering initiatives such as the living lab implemented by the NATAE European project in Algeria (https://www.natae-agroecology.eu/), agroecology remains conspicuously absent from the regional agricultural framework. Agroecology even faces challenges, such in the case of new farming practices threatening traditional oasis knowledge.
- *Southeast Asia*: Public interest exists, but practical application lags, as reported for Cambodia.
- *Brazil*: Agroecology policies are vulnerable to political shifts.

Agroecology is a polysemic term, as confirmed by the group activity on its collective definition. The resulting three distinct definitions emphasise: (1) the importance of the social and farmer components, (2) the scientific and multidisciplinary aspects of agroecology, and (3) the need for sustainable farming practices. These definitions are complementary but also reveal a potential conflict arising from the plurality of understanding and priorities. Only two keywords were consistently present in all three definitions: diversity (used alone or in combination with 'bio' or 'socio') and systems (used alone or in combination with 'agro', 'eco' or 'socio-eco'). This underscores the need for context-specific approaches in agroecology transitions, considering diverse actors and experiences. Sharing knowledge promotes learning from successes and failures. Heterogeneity in agroecological transition pathways also operates at both local and individual scales. At the farm level, the farming system defined as the starting point (Tittonell, 2020) of the transition processes (e.g. industrialised or peasant systems) induces specificities and requires adaptations in the adopted transition pathway. Doing research in agroecology involves dealing with complexity and heterogeneity and considering socio-agroecosystems as a whole.

To support and assess transition pathways, it is important to consider not only ecological and physical contexts but also socio-political and cultural contexts. Individuals also bring diverse experiences to agroecology. A workshop session explored these variations, focusing on how participants from different backgrounds (scientists, farmers, policymakers) navigate implementing agroecology. The discussion categorized these trajectories into four stages: fertile grounds, barriers, actions taken, and future paths (Table 1).

Table 1. Stages in the agroecology individual trajectory (source: authors' elaboration).

Stage in the trajectory	Description by the participant
Fertile grounds	*Initial interests in ecology and "nature"* *Interdisciplinary experiences face complex questions* *Discrepancies between personal and institutional visions* *Teaching experiences*
Barriers	*Complex systems at different spatial and temporal levels* *Political issues (agroecology is not neutral)* *Diversity of knowledge* *Access to funds*
Actions	*Reflexivity and personal transformations* *Transforming practices and paradigms (e.g., research posture)* *Individual resistance* *Counter reductionism* *Assume ethical positions and engaged values* *Forms teams to work collectively* *Changing teaching programs*
Paths	*Adopting more sustainable lifestyles* *Communicate a more attractive vision of agroecology* *Consider political dimensions in agroecological research* *Co-design research project focused on actors' concerns* *Formations to inter/transdisciplinarity methodologies* *Contribute to more inclusive narratives* *Give time and places for expressing and sharing agroecological experiences* *Lobbying funders*

This session provided an opportunity for actors involved in agroecological research and transition to share and discuss about the uncomfortable position their experiences of being caught on the edge of socio-political engagement and scientific requirements. The session emphasized the importance of consolidating networks and working collectively to break down feelings of isolation. When addressing agroecological transitions, a researcher is expected to collaborate with farmers to find solutions to practical problems but also to respond to scientific evaluation standards and publication requirements. This can result in conflicting and sometimes incompatible timeframes and objectives, calling for an adaptation of research frameworks and valorisation criteria to reflect the specificities of collaborative transdisciplinary research.

Transforming practices and paradigms with a transdisciplinary posture can be challenging. Therefore, experience sharing is necessary to foster a reflexive approach and consolidate experimental methodologies. Transdisciplinarity goes beyond academic issues and resonates with the needs and concerns of society. Assessing the risks and impacts of transitioning towards agroecology and sustainable farming practices presents an opportunity to explore multiple pathways for scientific experimentation with field actors (Cuéllar-Padilla and Calle-Collado, 2011). Working with local actors allows researchers to explore diverse pathways and re-evaluate indicators used to measure success.

The second day of the workshop was dedicated to collaborative research and postures included two parallel sessions. Farmer presentations on sensitive topics like seed rights emphasized their desire to be knowledge partners, valuing their experience beyond technical expertise. During the last session on research posture and methodologies based on a simulation exercise, it was challenging to avoid caricatures, such as an extreme top-down academic approach or an overly inclusive participatory approach. Nonetheless, it was a valuable exercise to practise humorous self-criticism and collectively imagine alternatives, concluding on the need for fundamental science and participatory and cooperative approaches to complement each other to varying degrees throughout long-term research partnerships. In the individual evaluation at the end of the workshop, Participants identified social sciences as key to integrating field knowledge with sustainable development strategies, emphasizing living labs and long-term partnerships

Practical implications

This open and reflexive workshop provided a platform to identify shared concerns and recommendations within the "Lands and Soils" knowledge community. The findings will inform institutional strategy but require consideration of funding, wider expertise, and practical implications. Here are the key takeaways:

- Create new researcher profiles with transversal skills to facilitate transdisciplinarity
- Include a facilitator profile in transdisciplinary long-term research projects and partnerships
- Clarify prerequisites and warnings to elicit formal commitment in collaborative research
- Create "third places" to ease multi-actor meetings and co-construct research questions and projects
- Boost qualitative changes in research and researcher assessment framework to improve the inter- and trans-disciplinary considerations

These practical implications suggest the relevance of articulating short and long-term projects, on the one hand, to generate practical knowledge and impact assessments and, on the other hand, monitoring and supporting agroecological practices and system transitions. Multidisciplinary research institutes like IRD are well-positioned to facilitate dialogue between agroecological research and local stakeholders. This opportunity requires stable means and long-term partnerships to be deployed as far as possible.

Theoretical Implications

The present study contributes to transdisciplinary thought on the role of researchers in the knowledge production processes of agroecological transition. The urgency to design sustainable pathways for agricultural production must include the consideration of the complex local socio-technical systems. Long-term partnerships built on mutual respect are key to successful transdisciplinary projects. The study also highlights the need to balance short-term projects (providing evidence) with long-term ones (fostering knowledge co-creation). Researchers need a broader skillset encompassing ecology, agronomy, social sciences, and complexity thinking. This requires addressing epistemological challenges like deconstructing narratives, partner ethics, collective governance, and interdisciplinary methodologies. Sustainable science demands versatility from researchers, who navigate multiple tasks and evaluation metrics. Partnering with social actors generates relevant local knowledge and ensures stakeholder concerns inform policy advice. Ultimately, these efforts represent two sides of the same coin: using science for a more sustainable and equitable future.

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