UNISECO

UNDERSTANDING & IMPROVING THE SUSTAINABILITY OF AGRO-ECOLOGICAL FARMING SYSTEMS IN THE EU

Deliverable Report D6.2: Integrated Sustainability Assessment in a Transdisciplinary Perspective

AUTHORS	Francesco Vanni (CREA) Gerald Schwarz (Thünen Institute) David Miller (James Hutton Institute) Janne Helin (Luke) Jaroslav Prazan (UZEI)
APPROVED BY WORK PACKAGE MANAGER OF WP6	Janne Helin (LUKE)
DATE OF APPROVAL:	30.06.2021
APPROVED BY PROJECT COORDINATOR:	Gerald Schwarz (Thünen Institute)
DATE OF APPROVAL:	30.06.2021
CALL H2020-SFS-2017-2	Sustainable Food Security-Resilient and Resource-Efficient Value Chains
WORK PROGRAMME Topic SFS-29-2017	Socio-eco-economics - socio-economics in ecological approaches
PROJECT WEBSITE:	www.uniseco-project.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

This page is left blank deliberately.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

TABLE OF CONTENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

EXECUTIVE SUMMARY

This document is Deliverable D6.2 in Work package 6 "Integrated sustainability assessment, end-user tools and recommendations" of the H2020 project UNISECO. This report integrates the results of the case studies on agro-ecological transitions with the territorial level assessments and explores the potential contributions of the strategies for agro-ecological transitions to the Sustainability Development Goals (SDGs). The review of the potential contributions to the SDGs pays particular attention to the role of the transdisciplinary research approach in UNISECO, and the strengths and weaknesses of the co-construction of strategies for agro-ecological transitions in strengthening the sustainability of farming systems in Europe.

The review builds on the main results of the UNISECO project, including: i) co-constructed strategies for agro-ecological transitions in the case studies (Schwarz *et al.*, 2021, D3.4; Galioto *et al*., 2021, D5.4); ii) assessments of the implementation of agro-ecological practices at farm level (Landert *et al.*, 2019, D3.1; Albanito *et al.*, 2021, D3.5); iii) territorial level assessments of large-scale implementations of agro-ecological practices in the context of different food scenarios (Mayer *et al.*, 2021, D4.3; Röös *et al*., 2021, D4.2); iv evaluation of the transdisciplinary approach and the engagement of actors in Multi-Actor Platforms (Smyrniotopoulou and Vlahos, 2021; D7.3).

The environmental and socio-economic sustainability of agro-ecological strategies adopted at the local level are highly influenced by contextual factors such as the type of farming system, socio-economic and institutional contexts where farms operate, and the dilemmas and objectives characterising the agricultural decision-making context in each case study. Some common implications for sustainability, especially in relation to SDG 4 (Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all), SDG 12 (Ensure sustainable consumption and production patterns), and SDG 15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss) can be identified. The sustainability implications discussed for the agro-ecological scenarios at territorial level allow additional SDGs to be addressed, such as SDG 2 (End hunger, achieve food security and improved nutrition, and promote sustainable agriculture), and SDG 13 (Take urgent action to combat climate change and its impacts).

This report also enabled the bringing together of more general insights into the roles of the transdisciplinary research approach in EU agricultural research and innovation, as well as on how a process of co-construction improved and practice-validated strategies with Multi-Actor Platforms. Key lessons and recommendations emerging from UNISECO are:

- to advise the design of Platforms in a structured way, aiming to create and strengthen long term relationships and networks. This includes considering synergies with relevant current and future projects with remits in policy, science and society dialogues on topics relevant for agro-ecological transitions and sustainability of farming and food systems and rural areas (e.g. use of UNISECO case study Multi-Actor Platforms in H2020 Coordination and Support Actions SHERPA and ALL-Ready), and integration in wider relevant networks. e.g. partnerships on agro-ecology.
- to guide the co-development of the remit and implementation of Platforms with their members, and with 'rules of engagement' sensitive to local contexts, following ethical process, power relationships between members, and considering actors who are hard to reach to ensure Multi-Actor Platforms reflect the principals of just transitions;
- to promote the evolution of Platform membership in response to their evaluation and changes in context;
- to make use strategic use of EIP-AGRI mechanisms to communicate with its 'innovation actors' (farmers, advisers, researchers, businesses, NGOs) by: i) providing practice abstracts to the EIP-Agri database of key results of the case studies, the territorial level analysis, and agro-ecological strategies; ii) looking for collaboration and synergies with EIP-AGRI Operational Groups and other innovative projects and networks that are exploring ways to develop agro-ecological practices and strategies.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

1. INTRODUCTION

Current food systems have led to the depletion of resources and negative environmental impacts (Rockström *et al*., 2020; Willett *et al*., 2019). The heavy use of agro-chemicals, heavy machinery, water, and the increasing reliance on fossil fuels in general has contributed to destabilizing the ecosystem processes which are the basis of agricultural production. Furthermore, the intensification and homogenization of agro-ecosystems has led to an increasing dependence on external inputs, which in healthy agro-ecosystems could mainly be done by the optimization of internal ecological processes. Thus, several experts and high-level commissions in international organizations have concluded that a transformation is necessary (Brunori *et al*., 2020; Eyhorn *et al*., 2019; Theurl *et al*., 2020; Willett *et al*., 2019).

Agro-ecological approaches have gained prominence in this scientific, agricultural and political discourse in recent years, suggesting pathways to transform farming and food systems that address these issues (Wezel *et al*., 2020). A key question raised in that discourse is, 'How can the full production potential of agro-ecological systems be utilised to provide a varying diet without increasing the inputs from fossil fuel economy?'

Agro-ecological production is considered to play a key role in sustainable food production by many organisations, such as the FAO (Food and Agriculture Organisation of the United Nations). The concept connects the understanding of ecological systems to productivity growth, and also the dietary choices of people to farmers and rural development (Wezel *et al*., 2009).

The main ambition and objective of the UNISECO project was to provide recommendations on how the sustainability of agro-ecological farming systems (AEFS) in Europe can be strengthened, through co-constructing improved and practice-validated strategies for agro-ecological transitions. The project focussed on analysing and understanding how socio-economic and policy drivers of, and barriers to, further development and implementation of agro-ecological approaches in EU farming systems can be addressed in a set of diverse contexts of case studies in 15 European countries. In each case study a set of farms were used to investigate the potential economic, environmental and social implications of agro-ecological practices at farm level. The findings were used to showcase the practices, with an aim of fostering co-learning amongst different local actors with different roles and influences on the decision-making of farmers to implement such practices. In addition, the impacts of large-scale implementation of selected innovative agro-ecological practices were analysed at territorial level within the context of different scenarios of European food systems.

The project applied a transdisciplinary approach using Multi-Actor Platforms to construct context-specific strategies to initiate and enhance agro-ecological transition (Irvine *et al*., 2019; D7.2). The purpose of the Multi-Actor Platforms was to provide a continuous and transparent exchange of information and knowledge between actors from society, policy and science as a basis to develop shared strategies for agro-ecological transitions. In addition, an EU-level Multi-Actor Platform was set up to enable co-learning across multiple levels and for consultations as part of the development of agro-ecological scenarios and related uncertainties (Budniok *et al*., 2018; D7.1). The engagement in the Multi-Actor Platforms was monitored and evaluated to assess potential benefits and challenges both for the project team and the involved actors, providing insights into observed evidence of co-learning and knowledge sharing and generation within the context of just transitions and promoting opportunities for lifelong learning (Smyrniotopoulou and Vlahos, 2021; D7.3).

A major consensus building process moderated by the United Nations led to an international agreement on a set of 17 Sustainable Development Goals (SDGs) (UN, 2015). The aim of the UNISECO project was to explore how the promotion of initiating and enhancing agro-ecological transitions contributes to particular SDGs, including: SDG2 (End hunger, achieve food security and improved nutrition, and promote sustainable agriculture), SDG 4 (Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all), SDG12 (Ensure sustainable consumption and production patterns), SDG13 (Take urgent action to combat climate change and its impacts) and SDG15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

This report integrates the results of the case studies on agro-ecological transitions with the territorial level assessments and explores the potential contributions of the strategies for agro-ecological transitions to the SDGs and the gaps that need to be addressed in future research. The review of the potential contributions to the SDGs pays particular attention to the role of the transdisciplinary research approach in UNISECO, and the strengths and weaknesses of the co-construction of strategies for agro-ecological transitions in strengthening the sustainability of farming systems in Europe.

The review builds on the main results of the UNISECO project, principally those of the: i) co-constructed strategies for agro-ecological transitions in the case studies (Schwarz *et al.*, 2021, D3.4; Galioto *et al.*, 2021, D5.4); ii) assessments of the implementation of agro-ecological practices at farm level (Landert *et al.*, 2019, D3.1; Albanito *et al.*, 2021, D3.5); iii) territorial level assessments of large-scale implementations of agro-ecological practices in the context of different food scenarios (Mayer *et al.*, 2021, D4.3; Röös *et al*., 2021, D4.2); iv evaluation of the transdisciplinary approach and the engagement of actors in Multi-Actor Platforms (Smyrniotopoulou and Vlahos, 2021; D7.3).

The following Section provides an overview of the transdisciplinary approach adopted in UNISECO, together with a short description of the project case studies. Section 3 details the methodology and the data collection process used for this deliverable. Section 4 presents the key results, and Section 5 provides a synthesis of sustainability implications. Finally, key lessons and recommendations for further research using a transdisciplinary approach for agro-ecological transition are included in Section 6.

2. THE TRANSDISCIPLINARY APPROACH IN UNISECO

A transdisciplinary approach is increasingly advocated by funders and end users of research, as well as scientists. Such an approach has been identified as particularly fruitful for investigating complex, 'wicked' problems, often with a 'real world' dimension such as those under consideration within the UNISECO project. Frequently, these problems involve: i) uncertainties in scientific knowledge; ii) human activities and interactions; and iii) political, economic and cultural dimensions of knowledge that can influence research and its impact (Aslin and Blackstock, 2010; Brown *et al*., 2010). The combination of perspectives and skills that can be brought together through a transdisciplinary process has the potential to generate novel insight and solutions to address societal challenges (Pohl, 2008; Polk, 2015).

The main objective of the UNISECO project was to provide recommendations on how the sustainability of agro-ecological farming systems (AEFS) in Europe can be strengthened. Successfully initiating and enhancing transitions to agro-ecological farming systems and practices requires shared understanding of the barriers and drivers of transitions, the actions required by actors in practice, policy, science and society to address those barriers and drivers, and the sustainability implications at farm and territorial level. Bringing together complementary perspectives of key actors of the social-ecological systems (SES) in transdisciplinary Multi-Actor Platforms provides forums to enable co-learning and co-construct strategies for agro-ecological transitions, and their implementation.

Combinations of suitable agro-ecological practices are context-specific and agro-ecological transitions need to be adapted to the local context (Barrios *et al.*, 2020). If applied in an unsuitable context. agro-ecological practises can also lead to detrimental effects, e.g. on water quality and quantity issues. Some specific measures, such as no-tillage, can involve trade-offs between different measures of water quality depending on the chosen metric of quality or the environmental circumstances in which it is applied (Skaalsveen *et al*., 2019; Uusitalo *et al*., 2018). In-depth discussions with farmers, advisors and other practitioners in the UNISECO case studies were aimed at ensuring that practices were selected which were suitable for the particular biophysical and socioeconomic context of the farms (Landert *et al.*, 2020; Albanito *et al*., 2021, D3.5).

There is a lack of consistency in definitions of agro-ecology, ranging from an academic discipline to a movement for the socio-economic as well as ecological transformation of agriculture (Lampkin *et al.*, 2020). For UNISECO the definition followed was that of Agroecology for Europe (Wezel *et al*., 2018), considering agro-

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

ecology jointly as a science, a practice and a social movement, in which agro-ecological practises are interpreted to emphasise the use of local resources in a sustainable manner (Prazan and Alders, 2019). To cover the breadth of different barriers and drivers in early and more advanced stages of agro-ecological transitions, UNISECO analysed how to initiate transitions of conventional farming systems, and how to enhance transitions of farming systems that already apply (to some extent) agro-ecological principles.

However, for many local actors the concept of agro-ecology is not sufficiently concrete and results in different interpretations and expectations. More concrete key dilemma and sustainability issues were defined in the case studies (for example biodiversity loss or poor water quality) to act as boundary objects and shared references that are meaningful for actors with different backgrounds to facilitate a common and shared understanding of the concrete goals of the strategies. Key sustainability issues (see section 4 of Schwarz *et al.*, 2021a).

The transdisciplinary framework was implemented at two levels including Multi-Actor Platforms at case study and at European levels. This two-level approach created a structure to enable timely engagement with relevant actors across the various steps of the analysis of agro-ecological farming systems providing insights into: i) the development of strategies and incentives for agro-ecological transitions in participatory case studies in 15 European countries (AT, CH, CZ, DE, ES, FI, FR, GR, HU, IT, LT, LV, RO, SE, UK); ii) storylines and scenarios of the large-scale implementation of agro-ecological practices in the EU; iii) and the environmental, social and economic sustainability implications at territorial level under different future food systems contexts.

The pool of individuals invited to join the Multi-Actor Platforms, both in the partner countries and at EU level, were identified through existing vocational networks, screening for relevant actors in the case study areas and recommendations of the stakeholder champions and other actors. These individuals were reviewed against a set of criteria including the relevance to the case study, commitment, appropriateness, representativeness, willingness as well as gender, age and geographical spread (Budniok *et al.*, 2018; D7.1), and following the guidance on transdisciplinarity for partners (Irvine *et al.*, 2019; D7.2) (Step 1 in Figure 2 , Section 3). The processes and impacts of interactions with the MAPs and relevant actors involved in the participatory activities during the project at the EU and case study levels were monitored and evaluated applying different sets of criteria for preparation, implementation, post-implementation (Smyrniotopoulou and Vlahos, 2021).

Case study Multi-Actor Platforms (MAPs)

A key element and requirement of the research call to which UNISECO responded was to cover the diversity of European farming systems as much as would feasible within such a 3-year research project. Table 1 provides an overview of the different types of actors involved in the case study MAPs, and Figure 1 shows the areas (NUTS3) with farm data collection for the UNISECO case studies.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

Table 1. Overview of different types of actors of the members of the case study Multi-Actor Platforms (legend of the types of actors provided at the foot of the table.)

Country Code	Case Studies						
AT	Mitigation of climate change by humus formation in arable farming (Ökoregion Kaindorf)	5 [5]	(2)		3		
CH	Intensive animal farming (Lucerne Central Lakes Region)	11 [8]	2		2	1	7
CZ	Arable land management on organic dairy farms (Vysočina Region)	6 [6]		1	2		3
DE	Developing strategies for agro-ecological transition in arable farming systems (Nienburg County, Lower Saxony)	10 [9]	1		4	4	5
ES	Agro-ecological farming systems (Basque Country and Navarra)	13 [10]	1	1	2	2	3
FI	Planning a dairy sector driven bio-product plant (Nivala)	10 [9]	3		3		3
FR	Connecting CUMAs to foster adoption of agro-ecological practices for viticulture (Auvergne Rhône Alpes)	9 [9]			10	2	1
GR	Collective implementation of alternative plant protection practices in peach trees (Imathia)	10 [8]	1		2		1
HU	Soil conservation farming	10 [8]	2	1	4		7
IT	Diversifying specialised winegrowing areas (Chianti Biodistrict)	16 [12]	3		5	2	7
LT	Small scale dairy farmers and cheesemakers	8 [7]		(1)	3	1	5
LV	Organic dairy farming	9 [7]			4	2	4
RO	Hotspot of biodiversity and healthy food (Transylvania)	10 [10]	1		3	5	4
SE	More food from ruminant farms	10 [10]	12		3	3	
UK	Mixed farming and general cropping (North-east Scotland)	16 [9]	2		1	1	1

[] – number of farms for which the on-farm sustainability assessments were undertaken.

() - the number of farmers who are also directly involved in value chain activities (e.g. AT) or joint producer-consumer organisations (e.g. LT).

The legend of the icons and types of actors from Vanni *et al.* (2019) is:

Farmers

Agri-food value chain

Consumers

Science, innovation, advisory, capacity building

NGOs, civic society organisations, local community representatives

Authorities and Administration

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

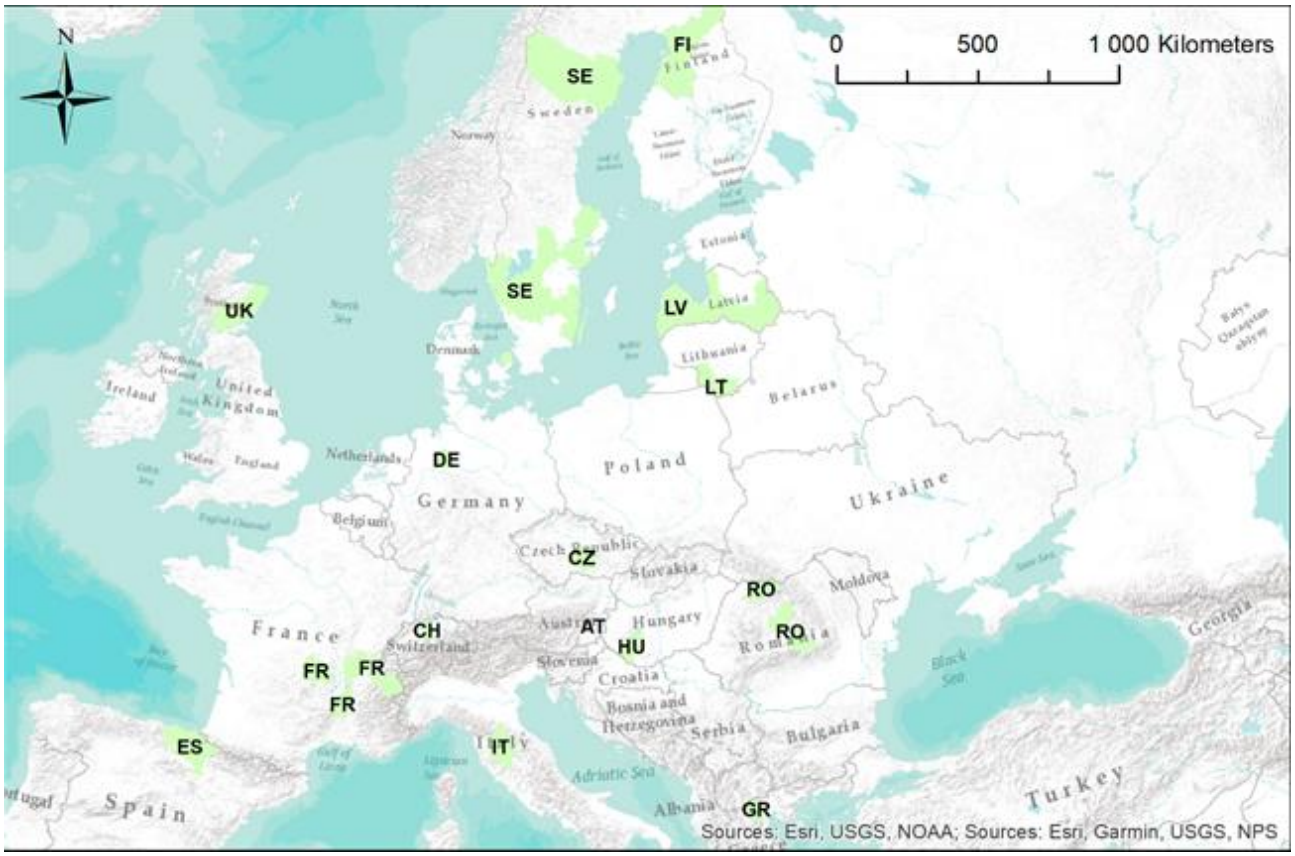

Figure 1. Areas (NUTS3) with farm data collection for the UNISECO case studies

Three candidate case studies were identified in each country. Following a stakeholder consultation a final selection of one case study was done in each country, considering the overall diversity of main EU production systems, different stages of agro-ecological transitions and socio-economic and socio-cultural contexts (Prazan and Alders, 2019). The choice of a case study, i.e. a specific decision situation to analyse (known as focal action situation in the social-ecological system literature) defined the specific farming systems for which the SES assessment was done and strategies to initiate or enhance agro-ecological transitions co-constructed.

Based on the adapted social-ecological systems framework developed by Guisepelli *et al*. (2018; D2.1) each case study carried out a status quo assessment to understand the: i) current sustainability performance of the farming systems (Step 2 in Figure 2, Section 3); ii) barriers which make the transformation towards agro-ecological farming systems difficult or impossible. The sustainability performance of the farms was assessed using three different decision support tools, SMART, CoolFarmTool and COMPAS (Landert *et al*., 2020; Groot *et al.,* 2012). The data were collected by interviewing both conventional and agro-ecological farmers in all case study countries to give a point of reference for the different sustainability indicators produced by the tools. This informed the discussion and understanding of the main sustainability issues and performance of the farming systems in the case study Multi-Actor Platforms. Further data for the social-ecological systems assessment were collected through interviews and workshops with farmers and other members of the Multi-Actor Platforms, from existing databases (e.g. FADN data), projects, and publicly available data for the regions concerned (Prazan *et al*., 2019, D3.3; Landert *et al*., 2019, D3.1).

Participatory social network analysis was used in the case study Multi-Actor Platforms to create network maps to identify key actors who have an influence on the decision-making of farmers to implement agro-ecological practices, and to analyse the current governance of the farming system (governance sub-system of the SES) (Vanni *et al.*, 2019; D5.2). In addition, policies considered as innovative locally were identified and published in an inventory (Zilans *et al.*, 2019; D5.1).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

The work on the status quo assessment and identification of actors and policies laid the foundation for the analysis of barriers and drivers of agro-ecological transitions. The social-ecological systems assessment structured the discussions in workshops with members of the case study Multi-Actor Platforms of: i) why certain barriers and drivers could be addressed; ii) why in other systems certain barriers and drivers could not be overcome; iii) and how to improve understanding of the interdependencies between different barriers and drivers (Step 3 in Figure 2, Section 3). The analysis of barriers and drivers was also informed by the participatory assessment of existing policy instruments with the case study MAPs, and how these impact on agro-ecological transitions (Linares *et al*., 2020; D5.3).

The strategies to support the adoption of agro-ecological practices were co-constructed in each country through a combination of interviews and workshops with members of the case study Multi-Actor Platforms. These engagement activities were informed by the knowledge gained from the previous steps. For a more detailed description of the approach of co-constructing the local strategies see Schwarz *et al.* (2021a; D3.4).

The practices covered by strategies were used to deepen the knowledge of trade-offs and synergies that the strategies would enable, using the results of the decision support tools obtained from Step 1 (Albanito *et al*., 2021; D3.5). Then, the local stakeholders (drawn from the local Multi-Actor Platform, supplemented with policy-oriented stakeholders) evaluated the policy measures implied by the strategies (Galioto *et al*., 2021; D5.4) (Step 4 in Figure 2, Section 3).

EU level Multi-Actor Platform (MAP) and Stakeholder Reference Group (SRG)

In addition to the case study MAPs, an EU level MAP consisting of 15 actors was set up using the same set of selection criteria as described for the case study MAPs. Contact was made through the networks of the practice partners and research organisations in the consortium. The EU level MAP engaged in knowledge exchange and co-learning activities with the Stakeholder Reference Group (consisting of representatives of each case study MAP) to build capacity for collaborative working at stakeholder workshops organised in six-monthly intervals (e.g. knowledge sharing in group discussions on barriers and drivers of agro-ecological transitions at the stakeholder workshop in Basel, Switzerland, in November 2019).

The EU level MAP and Stakeholder Reference Group were involved in the participatory scenario development and consultations on the modelling framework and results at a territorial level. Two biophysical models, BioBaM and SOLm (Erb *et al*., 2016, Müller *et al*., 2020), in combination with a partial equilibrium model of trade, were used to assess the impacts of selected agro-ecological practises derived from the case study strategies in combination with various scenarios considering different levels of implementation, localisation of food system and dietary changes in Europe (Mayer *et al*., 2021, Röös *et al*., 2021) (Step 5 in Figure 2, Section 3).

The principal sustainability implications based on the modelled strategies and assumptions were subject to a literature review reported here. In the final step of co-construction, the uncertainties and drivers affecting sustainability were discussed with the members of the Stakeholder Reference Group, the EU level Multi-Actor Platform, and the Project Advisory Group (Step 6 in Figure 2, Section 3).

3. METHODS AND DATA

The data collection process used for this deliverable can be simplified into the seven steps illustrated in Figure 2. This logic model was developed for achieving Milestone 24 (Helin *et al*., 2021). This was an internal project report of Task 6.2 that aimed at providing a template to collect the main evidence and results from the project tasks and related deliverables. Milestone 24 provides a more comprehensive overview of the logic model adopted, in which each step is further divided into several sub-steps. The logic model has also been used to structure and link the different methodological briefs to the various steps (Schwarz *et al*., 2021b).

The aim of the logic model was to categorise, structure and link project outcomes in order to enhance understanding of how the co-construction of strategies for promoting agro-ecological practices can strengthen

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

the sustainability of farming systems. The types of analysis and outcomes of UNISECO are organised in seven hierarchical steps according to their focus: (1) setting up and monitoring the transdisciplinary framework; (2) status quo assessment of the farming systems; (3) analysis of barriers and drivers; (4) co-construction of local agri-ecological strategies; (5) development of agro-ecological scenarios at territorial level. The key outcomes are then linked to a sixth Step (6) in which sustainability implications are discussed in the context of uncertainties of future settings and drivers, and to the final Step (7) on lessons and recommendations for future research using a transdisciplinary approach.

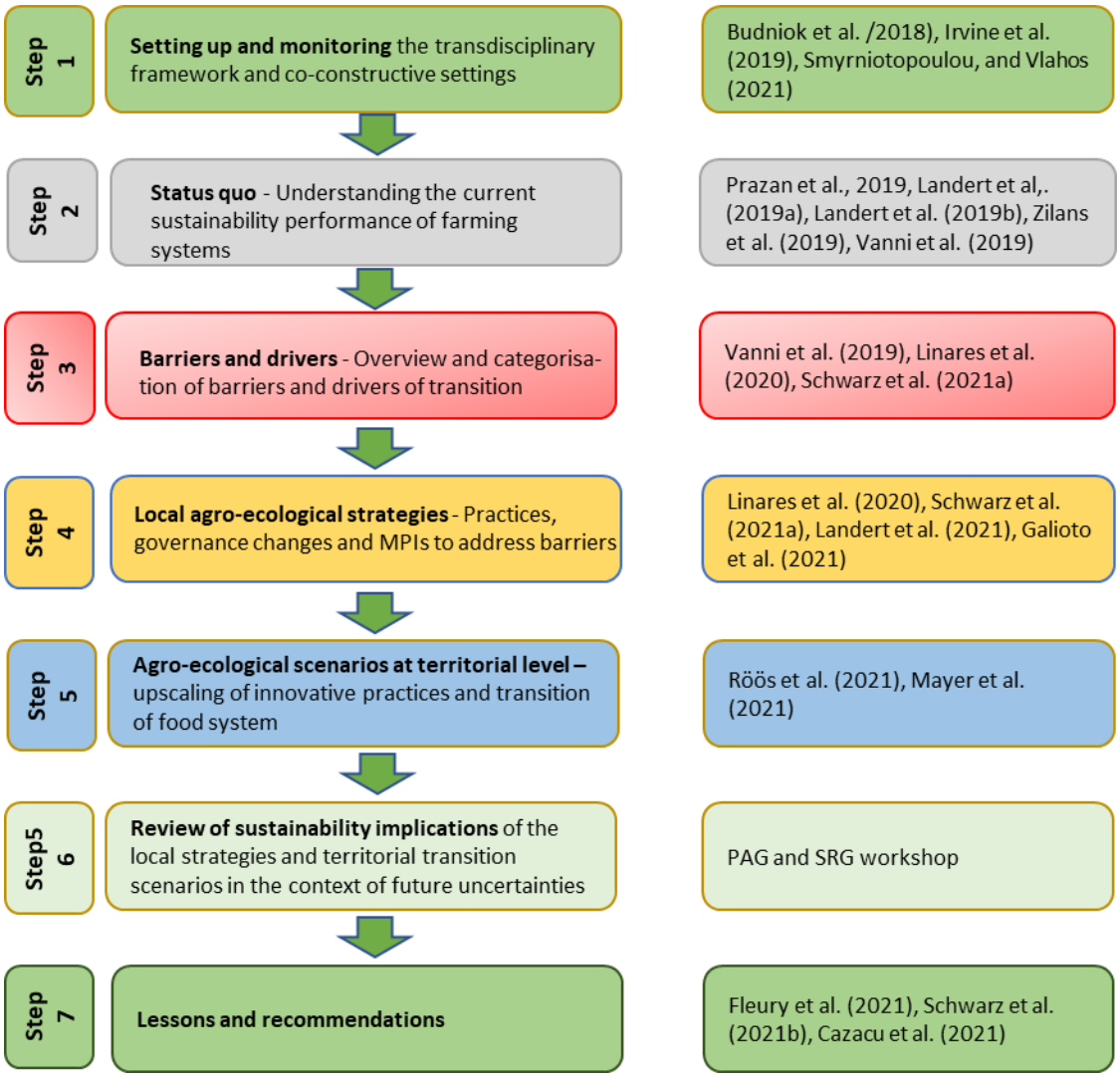

Figure 2. Simplified logic model for the analysis of agro-ecological farming systems in the UNISECO project

To carry out an Integrated Synthesis Assessment of the project and to provide a review of the key project results, the methods were combined as follows:

- **Steps 1, 2, 3, 4 and 5**: a critical review of relevant project deliverables (see references in Figure 1) was combined with open ended questions to be addressed by the main authors of the deliverables and Task Leaders.
- **Step 6:** the key sustainability implications of the local strategies and territorial transition scenarios, synthesised in the preceding Steps, were discussed in a workshop with members of the EU Multi-Actor Platform (EU-MAP), Stakeholder Reference Group (SRG) and Project Advisory Group (PAG), held online on 16th February 2021. This workshop was organised to discuss the sustainability implications of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

UNISECO findings, and to develop recommendations for future research needs and actions. The workshop involved 23 participants (7 from the EU-MAP, 12 from the SRG and 4 from the PAG).

- The discussion with participants was based around addressing the following 3 questions:
  - By 2050, which driver would increase, decrease or have no or little impact on the transition to agro-ecological production in Europe?
  - Which farming systems will be impacted in particular by this driver and how?
  - How can policy and practice respond to uncertainties associated with these drivers?
- **Step 7:** lessons and recommendations for future research using a transdisciplinary approach for agro-ecological transition were developed on the basis of key findings of Steps 1 to 5.

The Results are presented according to the categories based on the synthesis concept, corresponding to Steps 1 to 5. The key sustainability implications (Step 6) and lessons and recommendations (Step 7) are discussed sections 5 and 6.

4. RESULTS

4.1 Status Quo - Understanding Current Sustainability Performance

In the case studies, the main sustainability issues were identified when addressing the research question discussed with the local actor groups specific to each case study (Prazàn *et al*., 2019).

All of the 15 UNISECO case studies were structured towards understanding a key dilemma to be addressed by the transition to agro-ecological farming systems. The most common sustainability concern was the economic viability of the farming system. The most frequent environmental concern related to water, although biodiversity was also mentioned frequently.

The performance of 131 farms in 15 farming systems was assessed by applying the three decision support tools, SMART, Cool Farm Tool, and COMPAS. The combined sustainability assessment indicated that agro-ecological practices lead to generally higher scores for water quality and biodiversity indicators compared to their non agro-ecological counterparts, whereas no clear pattern was observed regarding their impacts on soil quality. With regard to greenhouse gas emissions, in some cases, agro-ecological farms have lower N-fertiliser application rates, which contributes to a reduction of emissions. The most notable environmental trade-off was between the greenhouse gas emissions of agro-ecological practices and biodiversity. such as in the French case with the use of mechanical weeding instead of pesticides. In terms of economic performance, the results from the decision support tools showed no clear pattern on farm income between more agro-ecologically oriented and more conventional farms (Landert *et al.*, 2020).

Members of the case study Multi-Actor Platforms were selected based on their relevance and potential influence on the decision-making by farmers to implement agro-ecological practices. The members of the case study Multi-Actor Platforms represent a set of different interests that can affect the sustainability of the farming practices. The experience of engagement in the case studies showed the importance of commonly identifying and acknowledging the main sustainability issues to encourage working towards a common goal. This process was also facilitated by the Social Network Analysis. The results of the Social Network Analysis (which mapped the relations of 261 actors across the 15 case studies) showed that the duration of cooperation among individual network actors, including their previous experience with rural development projects, and the strength of actor-actor relationships, are more important for characterising the network structures than the stage in the transition pathway of single case studies.

In those case studies which were characterised by weaker actor-actor relationships, and at an initial stage of transition (initiating), Authorities (e.g. Ministries of Agriculture) are the key actors in the Governance Networks. These actors are in the position to initiate, manage and direct Governance Networks towards the agro-ecological transition. In case studies at a more advanced stage of transition (enhancing), often characterised by long-lasting

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

collaborations amongst civil society partners in the decision-making process, the interactions between public and private actors are more important to balance the power relations in the Governance Networks.

The policy analysis of the status quo (Zilans *et al.,* 2019) was targeted on the market and policy initiatives that extend beyond the scope of agri-environmental measures of CAP (2014-2020). A large number of such incentives were identified across Europe. Out of the 289 incentives, 20% were information measures (measures based on creating and distributing knowledge), 33% were economic instruments (mainly based on the existing CAP measures) and 47% were other policies. In the interviews and workshops arranged in the case study countries, the local stakeholders acknowledged the importance of CAP Pillar II instruments, especially agri-environment measures, organic farming, farm modernization and investments as being important for encouraging the adoption of agro-ecological farming practices.

4.2 Barriers and Drivers

Across the 15 case studies, more than 100 barriers and drivers of agro-ecological transitions were identified in the interviews and workshops with the members of the case study MAPs (see Schwarz *et al.,* 2021a for more details). Reasons for why these barriers could not be overcome or had already been addressed were analysed in the assessment of the social-ecological systems.

Three broad themes of clusters of barriers and drivers were derived from analysis of the inventory of barriers and drivers: i) lack of knowledge and social capital; ii) lack of added value, processing and market access; iii) ineffective policy design. The analysis focussed on barriers that hinder a transition to agro-ecological farming, with consideration also given to the drivers which are discussed in the section on uncertainties. The three themes are summarized below.

Lack of knowledge and social capital: The most commonly identified barrier is the lack of knowledge of specific agro-ecological practices and their sustainability benefits, and the economic opportunities and associated uncertainties for creating added value from agro-ecologically produced goods. Such barriers were reported for most of the case studies, and reflects the knowledge-intensive character of agro-ecological farming. These barriers relate mainly to a lack of knowledge amongst farmers, and highlight the need for specialised knowledge for advisors and teachers working in vocational schools. Two main constraints for farm advisory services need to be considered; they can be underfinanced or they have difficulties in recruiting qualified advisors. A related weakness is one of limited coordination amongst AKIS actors, and the lack of networks for knowledge sharing involving farmers, advisors and researchers.

In many case studies there was evidence of barriers to agro-ecological transitions due to a low capacity and willingness to cooperate which, in turn, was due to weak social capital and individualism of, and rivalry between, farmers. For case studies in Eastern Europe, reluctance to cooperate can be explained by the negative experience of nationalised collective agricultural systems imposed by the communist regime. In these contexts, the term 'cooperation' has a negative connotation. The lack of confidence and trust in agricultural cooperatives, and resulting low willingness to cooperate, is closely linked to economic barriers. For example, a lack of willingness to cooperate may inhibit options for shared purchasing of storage and processing infrastructure, or direct marketing.

Lack of added value, processing and market access: Barriers which were commonly identified across several case studies related to the economic sustainability of agro-ecological farming within the framework of the current conventional food systems. A lack of access to finance and other issues related to investments were the most common barriers. A diverse set of issues relating to the lack of value-added by agro-ecological production was identified in most of the case study countries, including low demand and productivity was expressed by low prices rather than production costs, which led to issues in logistics of storing, processing, and selling the agro-ecological products. The availability of labour and market concentration were also identified as significant issues.

Ineffective policy design: Specific barriers due to policies covered the unsustainable prescriptions and lack of flexibility in implementation and monitoring. This cluster included the bureaucracy of the policy support, and lack of targeting or public procurement, present in only a few case studies each.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

The clustering provided a means of viewing the challenges to agro-ecological transition from specific angles that inform the identification of specific actions in the strategic pathways, as well as the analysis of market and policy instruments that can foster transition processes. However, the different barriers and drivers do not occur in isolation. The existence of some barriers reinforces the pace at which other barriers develop over time. The case studies demonstrate the interconnectedness and interdependencies between different barriers, and that the issues of information, economy and policy are intimately linked in the European agro-ecological landscape and making progress from one perspective requires dealing with the other two (Schwarz *et al.*, 2021a).

Addressing these different barriers requires the involvement of actors with different roles and representing multiple interests (multi-stakeholder networks) and innovative forms of coordination and cooperation. While charismatic actors, especially NGOs and Farmers, are more important when the network is new or less mature, and subject to change, multi-stakeholder hubs are the core of more mature and stable networks (a set of influential actors can be clearly identified). Despite the diversity of actors, barriers are also linked to actors who are missing from the identified networks. The most common missing actors are Consumers, Tourism associations and Farmer's unions (Vanni *et al.*, 2019; D5.2).

The potential of existing policy instruments in addressing the key barriers and to act as important drivers for the agro-ecological transition has been assessed (Linares *et al.*, 2020; D5.3). From this assessment, it may be argued that the key Market and Policy Incentives to be considered in the co-construction of strategies of agro-ecological transitions are:

- **Networking instruments**. Such instruments contribute to the creation of synergies amongst local actors. When adopted at the value chain level, these market and policy incentives may enable a fairer distribution of added value, thereby supporting local rural development. Examples of such incentives could be the creation of collective post-harvest models for small farms to carry out joint transformations, purchase of equipment and machinery, and mechanisms for sales. Networks also improve the governance capacity of local farmers, by promoting the participation of the local population in planning, decision-making and implementation of the strategies necessary for territorial development. Existing instruments could be improved by changing eligibility criteria, such as prioritising projects involving small farms.
- **Knowledge promotion instruments.** The advisory, information, training and experimentation initiatives were generally considered as one of the key instruments to facilitate the agro-ecological transition. These services can encourage farmers to initiate the transition to agro-ecological farming systems and experiment with approaches. They also raise awareness of farmers about environmental problems, and explain the reasons behind new practices which have proven effective when used by other farmers, and so aid in their promotion and uptake. Such services can significantly change attitudes towards agricultural approaches, especially if economic profitability is clearly explained. They enable the exchange of knowledge and know-how between farmers, as well as between farmers, technicians and researchers. Peer-to-peer learning encourages farmers to explore solutions in real-life situations. In addition, the existence of these services is associated with the generation of more innovative public projects. Priority, funding and accessibility are the main issues around which stakeholders recommended improvements.

4.3 Local Agro-ecological Strategies

Each case study resulted in one co-constructed strategy consisting of strategic pathways to address the key barriers and drivers for initiating or enhancing agro-ecological transitions. Table 2 provides an overview of the strategic pathways co-constructed to address key dilemmas in the 15 case studies and indicates the main themes of barriers and drivers to which these respond. Most of the case studies identified strategic pathways that respond to at least two of the three key themes which reflects the interdependencies of barriers and drivers across the three main themes.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

Table 2. Overview of the case study dilemmas and the co-constructed strategic pathways (Main themes of barriers and drivers: KNO – Knowledge and social capital; VAL - Value added, processing and market access; POL – Policy design).

Case Study	Case Study Dilemma	Co-constructed Strategic Pathways	Main Themes
AT	How to tackle impacts from climate change (e.g. water stress), increase carbon sequestration in soils, prevent soil degradation and reduce soil fertility loss while maintaining or improving the farm's social and economic sustainability and contributing to climate change mitigation.	• Strengthening knowledge networks and cooperation • Supporting humus formation at systems level urban waste management • Improved action research	KNO
CH	How to reduce the high animal densities and at the same time remaining profitable against the backdrop of important path dependencies (barn constructions, depths, up- and downstream market, knowledge system).	• Conversion to organic farming • Diversification with new farm enterprises • Increase in direct marketing	KNO VAL
CZ	How to maintain the good performance of arable land management in organic dairy farms in the Vysočina region to reduce arable soil degradation and water pollution by pesticides while ensuring economic viability.	• Improving market access and added value • Enhancing knowledge and cooperation • Improving access to land	KNO VAL
DE	How to integrate agro-ecological practices on arable land in market-oriented farming systems to reduce biodiversity loss and water pollution without significant negative impacts on the economic viability of farms.	• Setting up and strengthening knowledge networks • Engaging landowners in agro-ecological transitions • Creating markets and generating added value • Increasing the effectiveness of policy support	KNO VAL POL
ES	How to reduce the fragility of agro-ecological farms while maintaining the social, economic and environmental sustainability.	• Strengthening farmer cooperation and networks • Supporting collectivization of services and infrastructures • Improving conditions of access to land	KNO VAL
FI	How to reduce harmful impacts of dairy farming in the Nivala region on climate, soil and water without sacrificing economic viability of the dairy sector, by means of envisioning and implementing a multipurpose bio-product plant along the lines of a circular bioeconomy, with the aim of producing bioenergy and organic fertilizers from manure.	• Improving economic valuation of manure input • Supporting valorization of biogas digestates • Creating a supportive and consistent policy framework for investments in biogas plants	VAL
FR	How to reduce dependency on external fertilisers and to reduce pesticides use (especially glyphosate) through agro-ecological practices increasing soil ecological services (soil biology) while maintaining the economic profitability of farms.	• Fostering local cooperation of pesticide free farming • Creating partnerships at a food system level for values based supply chains • Collective actions for landscape management	KNO VAL

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

GR	How to sustain the long-term economic viability of farms whilst protecting the natural resources. How to protect biodiversity and water quality in orchards whilst improving competitiveness and market access.	• Increasing the social capital of local actors • Addressing knowledge gaps on agro-ecological practices • Improving market access and value added	KNO VAL
HU	How to integrate agro-ecological practices on arable land in highly market-oriented arable farming systems to maintain and improve soil quality without significant negative impacts on the economic viability of farms.	• Increasing cooperation at national level • Fostering a shift in mindsets and improving cooperation • Enabling the application of new technologies • Increasing consumer awareness	KNO VAL
IT	How to promote cropping system diversification in a highly specialised and market-oriented winegrowing area via the adoption of agro-ecological practices, to increase biodiversity and improve landscape management while maintaining the profitability of farming through local value chains.	• Empowering regional and local knowledge networks • Promoting cooperation on the implementation of agro-ecological practices • Promoting coordination of farmers and other local food chain actors	KNO VAL
LT	How to maintain and encourage extensive management (grazing) of grassland habitats. How to become (or remain) competitive in the market without intensifying the farming practice.	• Enhancing cooperation for improved value chains and consumer awareness • Improving access to, and sharing of, knowledge	KNO VAL
LV	How to increase the economic viability of conventional and organic, largely grass-based, dairy farms while preserving biodiversity in grasslands and water resource quality. How to ensure that all organic milk is processed into organic dairy products.	• Creating dairy cooperatives to increase market access • Increasing public awareness and demand • Improving policy support for agro-ecological transitions	VAL POL
RO	How to increase the economic viability of small-scale farming while preserving the cultural landscape and biodiversity.	• Enhancing knowledge sharing on agro-ecological practices • Increasing market access through cooperation • Improving targeting of, and access to, policy support	KNO VAL POL
SE	What are the challenges and possibilities to diversify specialised ruminant farms to include more crops for direct human consumption, while simultaneously integrating more agro-ecological principles to enhance sustainability performance in an economically strained production sector?	• Fostering knowledge exchange and cooperation • Enhancing cooperation in the value chain and market access	KNO VAL
UK	Producing public goods whilst maintaining viable production of private goods, and securing economic and social sustainability at a farm level.	• Enhancing knowledge and changing culture and mindsets • Increasing cooperation and diversity in the value chain	KNO VAL

Source: Schwarz *et al.* (2021a)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

A first key lesson from the co-construction relates to the importance of mature social capital and improved farmer knowledge of the benefits of agro-ecological practices and economic opportunities for successful agro-ecological transitions. Mature social capital is critical for the institutional changes proposed such as new knowledge networks. Case studies identified the important role of intermediaries to facilitate the generation of social capital and the institutional changes, e.g. trusted advisors reaching out to farmers and bringing actors together. In cases where agro-ecological transitions are initiated in conventional farming systems, the institutional changes proposed need to recognise traditional values and attitudes of farmers to avoid incompatibility with views about a 'good farmer' (Runhaar, 2021). However, improving social capital is a long-term process that requires an enabling policy environment through support for capacity building and for investments to normalize or institutionalise new forms of cooperation.

A second key lesson of the co-construction of the strategies across the case studies is the need for strengthened collaborative actions and collective institutions to increase negotiating power within the value-chain. This would enable higher prices to be obtained for agro-ecological products and realise the potential of agro-ecological farming to be economically viable. Such processes need to be supported by policy and the public sector, to address issues of economic exploitation and power relations, as well as tackling problems of overconsumption and food waste in food chains with their implications for public health, social justice and food security (Lampkin *et al*., 2020).

A third key lesson of the co-construction of the strategies is the importance of changes in consumer behaviour and diets, in particular if transformative change is the main objective of the agro-ecological transitions. Trends of increased demand of consumers for food labelled as healthy, sustainable and local have been further accelerated by the COVID-19 pandemic (Vittuari *et al.*, 2021). Higher demand for local products and short value chains has been observed in several countries (Hobbs, 2020). If sustained after the end of the pandemic, these trends in consumer behaviour could be reinforced by consumer awareness campaigns and public procurement programmes in schools and canteens, as proposed in the co-constructed transition strategies. This would help overcome barriers such as market saturation of organic products. However, reorientation to direct consumer sales is not always possible, or can often only be done with significant financial implications, particularly for small-scale farmers (Hingley, 2005).

Finally, with regard to the innovative market and policy instruments to promote the agro-ecological transition strategies at a case study level (Galioto *et al.*, 2021), local actors emphasized that agro-ecology is knowledge-intensive and that different combinations of market and policy incentives are important to be able to tackle the knowledge-related challenges of the transition pathway. Three forms of those knowledge-related challenges are:

- **Knowledge creation:** this challenge refers to the need for developing research, demonstration fields and advisory services around agro-ecological issues, accompanied by incentives and information for value chain actors and consumers. Key market and policy incentives to face this challenge are agri-environment payments and knowledge promotion.
- **Knowledge diffusion:** this challenge refers to the need for facilitating the introduction of agroecological approaches and practices in value chains. Key market and policy incentives are certification schemes and food policies.
- **Capacity building:** this challenge refers to the promotion of collective action, peer-to-peer learning and networking to re-design the food system. Key market and policy incentives are networking and cooperation. The objective of knowledge promotion can be achieved through dedicated policy measures and a broad range of market and policy incentives. Agro-ecological transition is a knowledge intensive process, evidence of the challenges to which was identified in case studies in relation to knowledge, starting from knowledge creation to knowledge diffusion through to capacity building. While practice-based payments and advisory services were recognized as very important for knowledge creation, certification schemes and food policy are crucial for the knowledge diffusion

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

at value chain level. The capacity building needed to re-design the local food system can be only achieved through a mix of local interventions such as regional policies and networking instruments.

4.4 Agro-ecological Scenarios at Territorial Level

In the UNISECO project, the co-construction of local agro-ecological strategies was combined with the assessment of 432 scenarios for the EU in the year 2050 in which different combinations of conventional and agro-ecological farming and food consumption practices were modelled (Mayer *et al.,* 2021; D4.3). The overall objective was on the feasibility of the scenarios and their socio-economic and environmental impacts, not to assess how these scenarios could come about. The main results show that a range of future agro-ecological scenarios are feasible and that many environmental benefits can be realised if agricultural systems adopt wide-ranging changes that include several innovations from the plot to the food-systems level. An increase in land under agro-ecological practices and a reduction of GHG emissions is possible within the EU in the year 2050. A particular potential for climate change mitigation can be realized with agroforestry and the related carbon sequestration in woody biomass, which can amount to compensation of significant shares of GHG emissions of future agriculture. Agro-ecological practices such as undersowing cereals with leys and clover allows to reduce synthetic nitrogen fertilizers and provide roughage for ruminant livestock and also reduces grazing intensities on grasslands (Mayer *et al*., 2021).

Human diets also play a crucial role since they determine the total size of the food system. Changes in diets are feasible in all of the agro-ecological scenarios, and may provide enough food and feed biomass if EU-wide diets follow a business-as-usual trajectory. This is an important insight since a paradigm shift within the European Union could be evident in, for example, the EU Farm to Fork Strategy which aims to transform the focus from solely food production towards securing ecosystem services and maintaining cultural landscapes.

The territorial model results (Mayer *et al.,* 2021) show that up-scaling selected agro-practices (a subset of practices from the case studies that could conveniently modelled) to the European level, would reduce exports of both crops and animal products from the EU significantly, if dietary preferences do not change. Reduced productivity in the results of the model is based on an assumption that yields will be reduced, which is supported by the literature on organic farming (Connor, 2008; Seufert *et al*. 2012; Knapp and van der Heiden, 2018). Yield losses from conservation farming practices vary depending on the practice. One of the common practices in the case study strategies was direct drilling or no tillage (AT, DE, HU, UK), which has been estimated to reduce the yields by 5.7% (Ponisio *et al.,* 2015; Pittelkow *et al.,* 2015).

To circumvent the negative effect on food supply and security, the agro-ecological scenarios co-constructed (Röös *et al.*, 2021; D4.2) with the European level stakeholders adopt dietary changes that significantly reduce the consumption of animal products following, for example, the so-called Lancet diet (Willet *et al.,* 2019). The efficiency gain (more calories for human consumption can be produced by land area when the energy is not lost in animal metabolism) is enough to offset the reduced productivity of agro-ecological practices.

Embedding wider food systems changes (including the dietary change of consumers) into agro-ecological transition ensures that many agro-ecological futures with improvements along a number of sustainability indicators (e.g. biodiversity and water quality in relation to SDG 15) are possible in the EU without compromising food security. Healthy low-meat diets, less food wastes and reduced export-production allow for several important measures, including increasing self-sufficiency, nature-based climate solutions (i.e. re-/afforestation), general extensification of crop yields and implementation of soil- and biodiversity-friendly farming practices (e.g. hedgerows, undersowing, lower grazing intensities), and establishing agro-forestry systems with a large potential for carbon sequestration in woody biomass and other sustainability benefits (reduced water use, pesticide inputs, N and P runoff).

The importance of changes in consumer preferences and diets is also reflected in the co-constructed transitions strategies in the case studies, e.g. in proposed actions such as consumer awareness campaigns and public procurement programmes in schools and canteens. Farm level assessments in the case study in Sweden focussing on a shift from production for feed to a production for food show more diversified farms

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

with the potential for synergies between various environmental indicators (e.g. habitat diversity and greenhouse gas emission) and improvements in net value added and farm income (Albanito *et al.*, 2021).

5. REVIEW OF SUSTAINABILITY IMPLICATIONS

In this section the key results outlined above are synthesised and discussed, considering the potential implications for sustainability that may arise from the adoption of the co-constructed strategies at the local level, as well from the agro-ecological scenarios at territorial level.

The key sustainability implications were identified (Table 3) using the selected SDGs as references to which the UNISECO project aims at contributing.

The environmental and socio-economic sustainability of agro-ecological strategies adopted at the local level are highly influenced by contextual factors such as the type of farming system, socio-economic and institutional contexts where farms operate, farm type and size, and the dilemmas and objectives characterising the agricultural decision-making context in each case study. It is also possible to identify some implications for common sustainability, especially in relation to SDG 4 (Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all), SDG 12 (Ensure sustainable consumption and production patterns), and SDG 15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss).

In general, it may be argued that in many cases unique combinations of agro-ecological practices are able to release relevant synergies (e.g. biodiversity-friendly and climate-friendly farming practices), that may ensure farm viability as well as contributing to the provision of environmental and social public goods associated to farming. From a social perspective, the local adoption of agro-ecological strategies involve different types of cooperation actions that imply sharing information, and developing common investments in research and education, the outcome of which is the provision of learning opportunities for farmers and for the other categories of actors (public authorities, value chain, NGOs, consumers, etc.). The co-constructed transition strategies highlight the importance of advice, research, innovation and training in the social networks of farming systems, as means of achieving Sustainable Development Goal 4 on education and life-long learning. This includes, in particular: i) on-farm peer-to-peer learning; ii) actor-led knowledge and innovation and active sharing of place-based knowledge; iii) principles and practices of agro-ecology in school curricula covering principles of food production and consumption, agricultural practices, and social responsibility.

The sustainability implications discussed for the agro-ecological scenarios at territorial level allow additional SDGs to be addressed, such as SDG 2 (End hunger, achieve food security and improved nutrition, and promote sustainable agriculture), and SDG 13 (Take urgent action to combat climate change and its impacts). The main results gained from the territorial modelling scenarios show that a range of future agro-ecological scenarios are feasible, and that many social and environmental benefits can be released if agricultural systems adopt wide-ranging changes that include innovations from the plot to the food-systems level. The key findings related to agro-ecological scenarios at a territorial level point to the need for a wider food system perspective in agro-ecological transitions. The analysis at territorial level mirrors the that of the social-ecological systems of the case studies, in which changes in food consumption, and especially the consumption of animal products, is a major factor impacting on the feasibility of agro-ecological transitions. More sustainable human diets which contain less animal products enable large-scale implementation of agro-ecological practices without overstretching domestic agricultural land and avoiding deforestation (Mayer *et al.*, 2021; D4.3).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

Table 3. Key sustainability implications of agro-ecological strategies and scenarios

SDG	Local Agro-ecological Strategies	Agro-ecological Scenarios at Territorial Level
SDG2 – End hunger, achieve food security and improved nutrition, and promote sustainable agriculture		• Diets play a crucial role since they determine the total size of the food system, but are feasible in all agro-ecological scenarios, and provide enough food and feed biomass to cover EU-wide demand for food, feed, fibre and fuel. • Reduced production levels in the EU due to the adoption of agro-ecological practices would lead to higher prices for many goods.
SDG 4 – Ensure inclusive and equitable quality education and promote lifelong learning opport-unities for all	• Local agro-ecological transition strategies imply different levels and forms of cooperation that enhance learning opportunities for farmers, and for the other categories of actors (public authorities, value chain, NGOs, consumers, etc.).	
SDG12 – Ensure sustainable consumption and production patterns	• In several cases the introduction of agro-ecological farming practices could reduce the economic sustainability of the farming system in the short term. This is a typical economic barrier to transition which requires the creation of added value and design of effective policy support to improve economic sustainability. • Agro-ecological practices ensure reductions in the use of external inputs and simultaneous improvement in the quality and use-efficiency of input at farm level. • The transition from mineral to organic fertilization may generate trade-offs between increases in biodiversity benefits and yield, and between the carbon footprint and yield at farm level.	• In agro-ecological scenarios the economic welfare for consumers and producers would decrease for some commodities but increase for others, with a small reduction in economic welfare on average. • The current amount of livestock production needs to be reduced in order to remain within current agricultural land endowment in the future. • Livestock production needs to be linked to the potential uses of agricultural land within the EU. In combination with innovative livestock diets balance nutrient supply and demand can be rebalanced at the sub-national scale.
SDG13 – Take urgent action to combat climate change and its impacts		• An increase in land under agro-ecological practices would lead to a consistent reduction of GHG emissions: this is possible within the EU by 2050 but would require substantial dietary changes and the reduction of production for exports. • A particular potential for climate change mitigation can be realized with agroforestry and the related carbon sequestration in woody biomass, which can amount to compensation of significant shares of GHG emissions of future agriculture.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

SDG15 – Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	• Agro-ecological practices such as undersowing cereals with leys and clover allows reductions in the use of synthetic nitrogen fertilizers, provision of roughage for ruminant livestock, and reduced grazing intensities on grasslands. • Crop diversification, reduced tillage, permanent soil cover through cover crops or mulching, intercropping with nitrogen fixing crops, the extensification of mixed crop-livestock systems, etc. are all agro-ecological practices that ensure a more sustainable management of natural resources.	• Reducing grazing intensities on high natural value farmland is possible without the risk of shortages in grass supply for domestic ruminant livestock. • Freeing up agricultural areas through an overall reduction in the size of the food system would allow for a range of positive effects on the environment, including the protection of habitats and establishment of habitat corridors.

As reported in the sections on methods and data (Section 3), some of the sustainability implications identified for the co-constructed strategies at the local level and the agro-ecological scenarios at territorial level were discussed during a workshop with EU level Multi-Actor Platform members (EU-MAPs), Stakeholder Reference Group (SRGs) and Project Advisory Group (PAGs). The objective of this workshop was to review the sustainability implications in the context of future uncertainties of settings and drivers. Table 4 below shows the key results of this workshop.

The participants confirmed the relevance of some drivers and settings identified in previous activities of the UNISECO project, identifying some additional important implications of sustainability the tackling of which would require additional research. In particular, participants emphasised the need to consider social disparity and inequality (including gender and equity issues), as well as generation renewal in assessing the sustainability of agro-ecological strategies. The concept of "just transition" is emerging in international policy discourses, as in the recent EU strategy on "A long-term Vision for the EU's Rural Areas" (European Commission, 2021), that highlights the "need for ensuring rights and responsibilities of all actors in just transitions to farming systems". The concept is increasingly relevant in the debate regarding food system transformation based on agro-ecology principles (Anderson *et al*., 2019). Further study is merited into the role of marginalisation and inequality occurring at the EU level during the development and adoption of agro-ecological strategies, and on the design and development of sustainable food systems.

At EU level there is recognition of the problem of generation renewal in agriculture and on the related policy needs (Coopmans *et al*., 2020). However, greater attention should be directed towards the relations between generational renewal and agro-ecological transition to understand the attitudes, values and behaviours of young farmers in relation to agro-ecological approaches and principles.

Participants in the workshop also identified the need expressed to take a global perspective when analysing the sustainability implications of agroecological transitions. In particular, they highlighted the need to understand the effect of the adopted agro-ecological strategies and practices within the EU and beyond, so that global trade flows do not outsource environmental damage to other countries, while taking the credit for green policies at home (Fuchs *et al.,* 2020). As in the other sectors of the economy, corrective policies should be put in place for significant negative spill overs, and future research projects emphasise knowledge creation about this key topic.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

Table 4. Sustainability implications in the context of future uncertainties of settings and drivers: key results from of workshop with stakeholders

Questions	Answers
By 2050, which driver increased/decreased/had no or little impact on the transition to agro-ecological production in Europe?	Key environmental drivers and settings: • Soil degradation: erosion, carbon losses, biodiversity losses, soil structure (compaction) • Availability of agricultural land Key socio-economic drivers and settings: • Social disparity and inequality (including gender and equity issues) • Generation renewal • Dichotomy between staple food and quality markets/niche markets will be exacerbated
What farming systems will be particularly impacted on by this driver and how?	• Participants did not identify any farming system that, in their view, will be particularly impacted by future drivers and settings since all EU farming systems are highly interconnected • Participants highlighted the need to consider jointly the institutional and technological drivers that potentially may influence the transition to agro-ecological production in Europe. Technical and agronomic perspectives should not continue to be dominant, with social, political and legal perspectives better taken into account
How can policy and practice respond to uncertainties associated with these drivers?	• Need to raise the awareness of farmers through peer-to peer learning and training provided by advisors • Raise awareness amongst the general public • Strengthening urban-rural linkages and attitudes of urban inhabitants towards rural areas • Ensuring the effectiveness of EU Green Deal and Post-COVID-19 Green Recovery • Exploring the potential of taxes and of other corrective policies to reduce spill overs effects in non-EU countries

6. LESSONS AND RECOMMENDATIONS

Participatory transdisciplinary research engages heterogeneous stakeholders, across disciplines and beyond academia, in an ongoing process to discuss, research, and problem-solve issues of common interest (Prell *et al.,* 2021). In UNISECO, the issue of common interest was the understanding of socio-economic and policy drivers and barriers for the further development and implementation of agro-ecological practices in EU farming systems.

Stimulating agro-ecological transition across EU farming systems means addressing the 'wicked problems' that combine environmental, economic and social challenges. To address this challenge, the project aimed at combing robust, integrative science that 'cuts across' disciplines with participatory processes that facilitated the involvement of actors from non-academic organisations in the development of new knowledge (Irvine *et al.*, 2019).

This deliverable (D6.2) was primarily intended to explore the potential contributions of the strategies for agro-ecological transitions to the SDGs, and the gaps that need to be addressed in future research. However, it also enabled the bringing together of more general insights into the roles of the transdisciplinary research

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

approach in EU agricultural research and innovation, as well as on how a process of co-construction improved and practice-validated strategies with Multi-Actor Platforms.

Research in agriculture is increasingly oriented towards stronger levels of interaction and integration across disciplines (from multidisciplinary to transdisciplinary) and across the science-society divide. However, in many cases researchers and practitioners continue to struggle with the complexities involved in this collaborative, multi-party, and transdisciplinary approach (Kirchhoff *et al.,* 2013). Indeed, transdisciplinary research goes beyond the bringing together teams of specialists from different disciplines to guiding scientific inquiry, pushing scientists to work beyond scientific boundaries and at integrating knowledge across organisations, that can be even more challenging than across disciplines (Tomich *et al*., 2007). Although this approach may be considered vague and ambiguous, especially when lacking empirical implementation strategies (Thompson *et al.,* 2017), the research process and findings of UNISECO project demonstrate how an open science transdisciplinary approach using Multi-Actor Platforms can be successfully adopted for the co-construction of the strategies for agro-ecological transitions.

Agriculture is a challenging field for co-construction approaches due to the heterogeneity of the production systems. In UNISECO the diverse set of farming systems and sustainability dilemma investigated in the case studies could have, to some extent, reduced the direct opportunities to be gained from stakeholder-to-stakeholder interaction, and to reduce the cross-pollination of ideas between countries. However, project results demonstrate that adopting a case study approach, based on a variety of farming systems and socio-economic contexts, can promote learning amongst country specific actor platforms and between them.

Additional strengths of the transdisciplinary research approach adopted in UNISECO were:

- A good fit between the research questions and the needs of the organisations involved. In UNISECO the specific sustainability dilemma and the agro-ecological scenarios were co-constructed with local and EU Multi-Actor Platforms, facilitating the co-production of knowledge in later steps of the project.
- Stakeholders were involved in multiple stages of the research, including the definition of the problem, development of the research question, research design, data collection, and interpretation. However, in the final year of the research, there were constraints on the nature of involvement in data analysis, testing of findings and dissemination due to circumstances relating to COVID-19.

The Multi-Actor Platforms at case study and EU levels have provided the key forums for the development of transdisciplinary understanding of the overall project dilemma and those of the case studies. The project's Methodological briefs provide guidance on setting up and monitoring Multi-Actor Platforms in future projects (Schwarz *et al*., 2021b). A key part of the legacy of the project is to leave the members of the Platforms with increased insight to the working of each of the domains represented. Findings from the evaluation of the transdisciplinary tools and methods suggests that over 50% of members of the Multi-Actor Platforms recognised benefits such as expansion of networks, learning something new, the use of new information and changes in attitudes towards agro-ecological farming systems. The experiences of some members suggest a positive basis for further development of Multi-Actor Platforms as a forum for co-constructing evidence and advancement of the Open Science agenda.

> *"I had the opportunity to meet specialists in the field of agroecology and to participate in network activities, and this is the biggest benefit of participating in the UNISECO project for my organization" (member, Romanian Multi-Actor Platform)*
>
> *"one of the main contributions of this project was the very good and open exchange of views in the various workshops. This is an important trust-building measure and maybe this is even the main impact of the project." (member, DE Multi-Actor Platform)*
>
> *"the engagement between the different actors and open and constructive exchange was an important contribution of the project that increased the trust within the group" (member, UK Multi-Actor Platform)*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

As in other projects using participatory transdisciplinary research, some participants faced challenges of committing the time required for collaborative research, with some mis-matches in expectations between researchers and practitioners (Polk, 2015). However, overall, participants expressed clear desire for a continuation of the science-policy-society dialogue on agro-ecological transitions after the end of the project. This was particularly important at case studies level where, in many cases, local stakeholders expected specific and additional support for further developing and adopting the co-constructed agro-ecological strategies. A similar desire was expressed for operation at the national and EU levels, especially regarding updating recommendations for practice and policy in a rapidly evolving contexts (e.g. in relation to the National Strategic Plans for the CAP currently under development in all Member States). In this regard some key lessons and recommendations emerging from UNISECO are:

- to advise the design of Platforms in a structured way, aiming to create and strengthen long term relationships and networks. This includes considering synergies with relevant current and future projects with remits in policy, science and society dialogues on topics relevant for agro-ecological transitions and sustainability of farming and food systems and rural areas (e.g. use of UNISECO case study Multi-Actor Platforms in H2020 Coordination and Support Actions SHERPA and ALL-Ready), and integration in wider relevant networks. e.g. partnerships on agro-ecology.
- to guide the co-development of the remit and implementation of Platforms with their members, and with 'rules of engagement' sensitive to local contexts, following ethical process, power relationships between members, and considering actors who are hard to reach to ensure Multi-Actor Platforms reflect the principals of just transitions;
- to promote the evolution of Platform membership in response to their evaluation and changes in context;
- to make use strategic use of EIP-AGRI mechanisms to communicate with its 'innovation actors' (farmers, advisers, researchers, businesses, NGOs) by: i) providing practice abstracts to the EIP-Agri database of key results of the case studies, the territorial level analysis, and agro-ecological strategies; ii) looking for collaboration and synergies with EIP-AGRI Operational Groups and other innovative projects and networks that are exploring ways to develop agro-ecological practices and strategies.

Implementation of these recommendations should help in addressing one of the key limitations when co-constructing strategies with local actors, as in the 15 case studies of UNISECO, namely the potential of scaling up good practices and influencing policy actions at EU and Member State levels. Since direct interaction with actors in the co-construction process seems the most effective ways in which the co-construction can promote transition, it may be argued that to create broader and larger impacts requires a wider social and policy movement.

There is a need for multi-national networks that crate spaces for long-term and multi-stakeholder interactions that define the direction for research activities on agro-ecology at the EU and national levels. Single research projects may not have the resources and the potential to create the conditions to scale-up the transition processes.

The candidate partnership on agro-ecology living labs and research infrastructures, and that on food systems, recently proposed by the European Commission, are significant initiatives that could structure and further support the transition towards agro-ecology throughout Europe.

The construction of agro-ecological strategies at the local level could be viewed as a communication channel or a governance measure facilitating policy changes already agreed. Thus, key to understanding the significance of the strategies might be the perceptions of the local stakeholders towards the agro-ecological transition are evolving, rather than how the strategies are implemented.

Given the interest in evaluating the outcomes of co-constructed strategies, follow-up studies enabling *ex post* assessment are needed. The lack of *ex ante* observations on the structure of the strategies developed, such

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

as on timetables or monitoring procedures, could cast doubt as to whether strategies will lead to actions. The risk of a lack of follow-up may be greatest when the process of developing a strategy is initiated by research instead of being driven by the local actors or national policy dialogues. Evaluating strategies *ex post* would verify which actions were actually implemented and provide further lessons on how co-construction can promote agro-ecology and sustainability. Therefore, the development of agro-ecological initiatives such as the European partnerships, would benefit from monitoring the impacts of the adopted farming practices, and from the monitoring of social mechanisms with respect to their success in the adoption of the agro-ecological practices.

7. ACKNOWLEDGEMENTS

This report is compiled for the H2020 UNISECO project (Grant Agreement No. 773901). We would like to thank members of the Case Study MAPs, the Stakeholder Reference Group, the members of the EU level MAP and the Project Advisory Group for participating in the various project events and for their valuable input to the discussion of the sustainability implications of UNISECO findings reported in this Deliverable.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

8. REFERENCES

Albanito, F., Landert, J., Carolus, J., Smith, P., Schwarz, G., Pfeifer, C.,…, Sanders. J. (2021). Assessment of sustainability trade-offs and synergies among agro-ecological practices at farm level. Deliverable D3.5. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO), Report to the European Union, pp. 108.

Anderson, C.R., Bruil, J., Chappell, M.J., Kiss, C., Pimbert, M. (2021). Agroecology Now! Transformations Towards More Just and Sustainable Food Systems. Palgrave Macmillan. DoI: 10.1007/978-3-030-61315-0

Anderson, C. R., Bruil, J., Chappell, M. J., Kiss, C., Pimbert, M. P. (2019). From transition to domains of transformation: Getting to sustainable and just food systems through agroecology. *Sustainability*, 11(19), 5272.

Aslin, H. and Blackstock, K. (2010). 'Now I'm not an expert in anything': challenges in undertaking transdisciplinary inquiries across the social and biophysical sciences', in Brown, V.A., Harris, J.A., Russell, J.Y. (eds) Tackling wicked problems through the transdisciplinary imagination, Earthscan, London, pp. 117-130.

Brown, V.A., Harris, J.A. and Russell, J.Y. (eds) (2010). Tackling wicked problems through the transdisciplinary imagination, Earthscan, London, pp. 117-130.

Brunori, G., Branca, G., Cembalo, L., D'Haese, M., Dries, L., (2020). Agricultural and Food Economics: the challenge of sustainability. *Agric. Food Econ*. 8, 12. https://doi.org/10.1186/s40100-020-00156-2

Cazacu, M., Balazs, K., Schwarz, G. and Miller, D. (2021). Issue Briefs for Practitioners and Policy-Makers. Deliverable D6.5. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO).

Connor, D. J. (2008). Organic agriculture cannot feed the world. *Field Crops Research*, 106(2), 187.

Coopmans, I., Dessein, J., Accatino, F., Antonioli, F., Gavrilescu, C., Gradziuk, P., … Wauters, E. (2020). Policy directions to support generational renewal in European farming systems. *EuroChoices*, 19(2), 30–36. doi:10.1111/1746-692x.12282

Erb, K. H., Lauk, C., Kastner, T., Mayer, A., Theurl, M. C., & Haberl, H. (2016). Exploring the biophysical option space for feeding the world without deforestation. *Nature communications*, 7(1), 1-9.

European Commission (2021) A long-term Vision for the EU's Rural Areas - Towards stronger, connected, resilient and prosperous rural areas by 2040, {SWD(2021) 166 final} - {SWD(2021) 167 final}. Brussels, 30.6.2021, COM(2021) 345 final.

Eyhorn, F., Muller, A., Reganold, J. P., Frison, E., Herren, H. R., Luttikholt, L., ... & Smith, P. (2019). Sustainability in global agriculture driven by organic farming. *Nature Sustainability*, 2(4), 253-255.

Fleury, P., Guisepelli, E., Vincent, A., Prazan, J., Miller, D. (2021). Report on Practice-Validated SES Framework for Sustainability Assessments of Farming Systems and Recommendations for Future Applications. Deliverable D2.3. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO).

Fuchs, R., Brown, C., & Rounsevell, M. (2020). Europe's Green Deal offshores environmental damage to other nations. *Nature*, Vol 586, 671-673.

Galioto, F., Gava, Oriana, Povellato, A. and Vanni, F. (2021). Innovative market and policy instruments to promote the agro-ecological transition strategies. Deliverable D5.4. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO).

Groot, J., Rossing, W., Dogliotti, S., Tittonell, P. (2012). The COMPASS framework – navigating agricultural landscapes for science-based innovation. Conference of the European Society of Agronomy, 20–24 August 2012, Helsinki, Finland.

Helin, J., Prazan, J. Vanni, F., Schwarz, G. (2021). Template to collect the main evidence and results from the project tasks and related deliverables. Milestone MS24. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

Hingley, M.K. (2005). Power to all our friends? Living with imbalance in supplier-retailer relationships. *Industrial Marketing Management*, 34, 848–858.

Hobbs, J. E. (2020). Food supply chains during the COVID-19 pandemic. *Canadian Journal of Agricultural Economics*, 68, 171–176. DoI: 10.1111/cjag.12237

Irvine, K. N., Miller, D., Schwarz, G., Smyrniotopoulou, A. and Vlahos, G. (2019). A Guide to Transdisciplinarity for Partners. Deliverable D7.2. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO), Report to the European Union, pp. 48. DoI: 10.5281/zenodo.3625677

Kirchhoff, C. J., Carmen Lemos, M., Dessai, S. (2013). Actionable knowledge for environmental decision making: broadening the usability of climate science. *Annual review of environment and resources*, 38, 393-414.

Knapp, S. and van der Heiden, M. (2018). A global meta-analysis of yield stability in organic and conservation agriculture. *Nature Communications*, 9.

Lampkin, N., Schwarz, G. and Bellon, S. (2020). Policies for agroecology in Europe, building on experiences in France, Germany and the United Kingdom. *Landbauforschung Journal of Sustainable Organic Agricultural Systems*, 70(2), 103–112. DoI: 10.3220/LBF1611684471000

Landert, J., Pfeiffer, C., Carolus, J., Albanito, F., Mueller, A., Baumgart, L., Blockeel, J., Schwarz, G., Waisshaidinger, R., Bartel-Kratochvil, R., Hollaus, A., Hrabalová, A., Helin, J., Aakkula, J., Svels, K., Guisepelli, E., Fleury, P., Vincent, A., Smyrniotopoulou, A., … Smith, P. (2019a). Report on Environmental, Economic and Social Performance of Current AEFS, and Comparison to Conventional Baseline. Deliverable D3.1. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO), Report to the European Union, pp. 234. DoI: 10.5281/zenodo.3625681

Landert, J., Schwarz, G., Cazacu, M., Pražan, J., Helin, J., Weisshaidinger, R., Bartel-Kratochvil, R., Mayer, A., Hrabalova, A., Guisepelli, E., Fleury, P, Vincent, A., Carolus, J. Smyrniotopoulou, A....and Christie, A. (2021). Updated Story Maps on Lessons Learnt from each Case Study. Deliverable D3.6. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO).

Landert, J., Pfeifer, C., Carolus, J., Schwarz, G., Albanito, F., Muller, A., Smith, P., Sanders, J., Schader, C., Vanni, F., Prazan, J., Baumgart,L., Blockeel, J., Weisshaidinger, R., Bartel-Kratochvil, R., Hollaus, A., Mayer, A., Hrabalova, A., Helin, J., Aakkula, J., Svels, K., Guisepelli, E., Smyrniotopoulou, A., Vlahos, G., Iordanidis, Y., Szilágyi, A., Podmaniczky, L., Balázs, K., Galioto, F., Longhitano, D., Rossignolo, L., Povellato, A., Zilans, A., Jegelevicius, G., Fratila, M., Yoldi, U.I., Massa, C., Adrián, J.B., Sahlin, K.R., Röös, E., Frick, R., Bircher, R., Aalders, I.H., Irvine, K.N., Kyle, C. and Miller, D.R. (2020). Assessing agro-ecological practices using a combination of three sustainability assessment tools. *Landbauforschung Journal of Sustainable Organic Agricultural Systems*, 70, 129-144. DoI: 10.3220/LBF1612794225000

Linares Quero, A., Gava, O., Povellato, A., Schwarz, G., Iragui Yoldi, U., Astrain Massa, C., Galioto, F. and Vanni, F. (2020). Participatory Analysis of Market and Policy Instruments for Agro-ecological Transition. Deliverable D5.3. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO).

Mayer, A., Muller, A., Kalt, G., Roux, N., Weisshaidinger, R., Röös, E., Kaufmann, L., Matej, S., Theurl, M., Ferguson, S., Hart, R., Smith, P. and Erb, KH. (2021). Report on territorial impacts and lessons learnt of the diffusion of agro-ecological food systems (AEFS) in the European Union. Deliverable D4.3. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO).

Muller, A., Mayer, A., Erb, KH., Kalt, G., Lauk, C., Theurl, M., Kaufmann, L., Frehner, A., Pfeiffer, C., Moakes, S., Schader, C. (2020). Report on the methodological specification of the spatially-explicit modelling framework. Deliverable D4.1. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO).

Pittelkow, C. M., Liang, X., Linquist, B. A., Van Groenigen, K. J., Lee, J., Lundy, M. E., ... & Van Kessel, C. (2015). Productivity limits and potentials of the principles of conservation agriculture. *Nature*, 517(7534), 365-368.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

Pohl, C., Hadorn, G. (2008). Methodological challenges of transdisciplinary research. *Natures Sciences Sociétés*, 16: 111-121. https://doi.org/10.1051/nss:2008035

Polk, M. (2015). Transdisciplinary co-production: Designing and testing a transdisciplinary research framework for societal problem solving. *Futures*, 65, 110-122.

Ponisio, L. C. et al. 2015. Diversification practices reduce organic to conventional yield gap. *Proc. R. Soc. Lond. B: Biol. Sci.,* 282

Prazan, J., Helin, J., Gulbinas, J., Vanni, F., Landert, J., Schwarz, G., Weisshaidinger, R., Bartel-Kratochvil, R., Hollaus, A., Kučera, J., Mrnusík-Konečná, M., Hrabalova, A., Pyysiäinen, J., Aakkula, J., Rikkonen, P., Guisepelli, E., Fleury, P., Vincent, A., Carolus, J., … Smith, P. (2019). Story Maps of the SES of the Case Studies. Deliverable D3.3. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO), Report to the European Union, pp. 6. DoI: 10.5281/zenodo.4765621

Prazan, J. and Aalders, I. (2019). Typology of Agro-Ecological Farming Systems and Practices in the EU and the Selection of Case Studies. Deliverable D2.2. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO), Report to the European Union, pp. 57. DoI: 10.5281/zenodo.4116344

Prell, C., Hesed, C. D. M., Johnson, K., Paolisso, M., Teodoro, J. D., & Van Dolah, E. (2021). Transdisciplinarity and Shifting Network Boundaries: The Challenges of Studying an Evolving Stakeholder Network in Participatory Settings. *Field Methods*, DOI: 1525822X20983984.

Rockström, J., Edenhofer, O., Gaertner, J., DeClerck, F., (2020). Planet-proofing the global food system. Nat. Food 1, 3–5. https://doi.org/10.1038/s43016-019-0010-4

Röös, E., Mayer, A., Erb, K.H., Kalt, G., Kaufmann, L., Matej, S., Theurl, M., Lauk, C., Muller, A., Ferguson, S., Hart, R., Smith, P. (2021). Report on Participatory Scenario Development of Agro-ecological Farming Systems. Deliverable D4.2. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO), Report to the European Union, pp. 54.

Runhaar, H. (2021). Four critical conditions for agroecological transitions in Europe, *International Journal of Agricultural Sustainability*, DoI: 10.1080/14735903.2021.1906055

Schmidhuber, J., Tubiello, F. N. (2007). Global food security under climate change. *Proceedings of the National Academy of Sciences*, 104(50), 19703-19708.

Schwarz, G., Prazan, J., Landert, J., Miller, D., Vanni, F., Carolus, J., Weisshaidinger, R., Bartel-Kratochvil, R., Mayer, A., Frick, R., Hrabalová, A.,…, Smith, P. (2021a). Report on Key Barriers of AEFS in Europe and Co-constructed Strategies to Address Them. Deliverable D3.4. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO), Report to the European Union, pp. 128.

Schwarz, G., Carolus, J., Irvine, K., Miller, D., Smyrniotopoulou, A., Vlahos, G., Povellato, A., Vanni, F., Fleury, P., Guisepelli, E., Vincent, A., Pražan, J., Landert, J., Albanito, F., Röös, E., Cazacu, M., Fratila, M.(2021b). Methodological Briefs. Deliverable D6.4. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO), Report to the European Union.

Seufert, V., Ramankutty, N. and Foley, J. (2012). Comparing the yields of organic and conventional agriculture. *Nature*, 485: 29-232.

Skaalsveen, K., Ingram, J. Clarke, L. (2019). The effect of no-till farming on the soil functions of water purification and retention in north-western Europe: A literature review. *Soil and Tillage Research*, 189: 98-109 https://doi.org/10.1016/j.still.2019.01.004.

Smyrniotopoulou, A., and Vlahos, G. (2021). Report on assessment of transdisciplinary tools and methods. Deliverable D7.3. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO), Report to the European Union.

Theurl, M. C., Lauk, C., Kalt, G., Mayer, A., Kaltenegger, K., Morais, T. G., ... & Haberl, H. (2020). Food systems in a zero-deforestation world: Dietary change is more important than intensification for climate targets in 2050. *Science of the Total Environment*, 735, 139353.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.

Thompson, M. A., Owen, S., Lindsay, J. M., Leonard, G. S., Cronin, S. J. (2017). Scientist and stakeholder perspectives of transdisciplinary research: Early attitudes, expectations, and tensions. *Environmental Science & Policy,* 74, 30-39.

Tomich, T. P., Timmer, D. W., Velarde, S. J., Alegre, J., Areskoug, V., Cash, D. W., ... & White, D. (2007). Integrative science in practice: Process perspectives from ASB, the Partnership for the Tropical Forest Margins. *Agriculture, Ecosystems & Environment*, 121(3), 269-286.

Uusitalo, R. Lemola. R. and Turtola, E. 2018. Surface and Subsurface Phosphorus Discharge from a Clay Soil in a Nine-Year Study Comparing No-Till and Plowing. Journal of Environmental Quality, 47 https://acsess.onlinelibrary.wiley.com/doi/10.2134/jeq2018.06.0242

Uusitalo, R., Lemola, R., Turtola, E. (2018). Surface and subsurface phosphorus discharge from a clay soil in a nine-year study comparing no-till and plowing. *Journal of Environmental Quality*, 47(6), 1478-1486.

Vanni, F., Gava, O., Povellato, A., Guisepelli, E., Fleury, P., Vincent, A., Prazan, J., Schwarz, G., Bartel-Kratochvil, R., Hollaus, A., Weisshaidinger, R., Frick, R., Hrabalová, A., Carolus, J., Iragui Yoldi, U., Elía Hurtado, S., Pyysiäinen, J., Aakkula, J., Helin, J., Rikkonen, P., Smyrniotopoulou, A., Vlahos, G., Balázs, K., Szilágyi, A., Jegelevičius, G., Mikšyte, E., Zilans, A., Veidemane, K., Frățilă, M., Röös, E., Resare Sahlin, K., Miller, D., Kyle, C., Irvine, K. and Aalders, I. (2019). Governance Networks Supporting AEFS. Deliverable D5.2. Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU (UNISECO), Report to the European Commission, pp.65. DoI: 10.5281/zenodo.4568422

Vittuari, M., Bazzocchi, G., Blasioli, S., Cirone, F., Maggio, A., Orsini, F., Penca, J., Petruzzelli, M., Specht, K., Amghar, S., Atanasov, A-M., Bastia, T., Bertocchi, I., Coudard, A., Crepaldi, A., Curtis, A., Fox-Kämper, R., Gheorghica, A.E., Lelièvre, A., Muñoz, P., Nolde, E., Pascual-Fernández, J., Pennisi, G., Pölling, B., Reynaud-Desmet, L., Righini, I., Rouphael, Y., Saint-Ges, V., Samoggia, A., Shaystej, S., da Silva, M., Toboso Chavero, S., Tonini, P., Trušnovec, G., Vidmar, BL.., Villalba, G. and De Menna, F. (2021). Envisioning the Future of European Food Systems: Approaches and Research Priorities After COVID-19. *Frontiers in Sustainable Food Systems*, 5:642787. DoI: 10.3389/fsufs.2021.642787

Wezel, A., Herren, B.G., Kerr, R.B., Barrios, E., Gonçalves, A.L.R. and Sinclair, F. (2020). Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. *Agronomy for Sustainable Development* 40(6), 1-13

Wezel, A., Goris, M., Bruil, J., Félix, G., Peeters, A., Bàrberi, P., Bellon, S., Migliorini, P. (2018) Challenges and action points to amplify agroecology in Europe. *Sustainability* 10(5):1598, doi:10.3390/su10051598

Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., & David, C. (2009). Agroecology as a science, a movement and a practice. A review. *Agronomy for sustainable development*, 29(4), 503-515. https://doi.org/10.1051/agro/2009004

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., et al. 2019. Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet*, 393: 447–492

Zilans, A., Vanni, F., Povellato, A. (2019) Inventory of market and policy Incentives supporting AEFS. Deliverable D5.1. Understanding and improving the sustainability of agro-ecological farming systems in the EU: UNISECO Project Report, DoI:10.5281/zenodo.4453259 Project Report, doi:10.5281/zenodo.4453259

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773901.