UNISECO

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

Deliverable 2.3: Report on Practice-Validated SES Framework for Sustainability Assessments of Farming Systems and Recommendations for Future Applications

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ACRONYMS

A	Actors
AEFS	Agro-ecological farming system
CPR	Common Pool Resources
CS	Case study
DST	Decision support tools
EC	European Commission
ECO	Related ecosystems
ES	Ecosystem Services
FADN	Farm Accountancy Data Network
GS	Governance system
I	Interactions
IAD	Institutional Analysis and Development
MAP	Multi-Actor platform
O	Outcomes
P	Products
PAG	Project Advisory Group
PDO	Protected designation of origin
RS	Resource system
RU	Resource Units
S	Social, economic and political settings
SES	Social-Ecological System
SLA	Sustainable Livelihoods Approach
SNA	System Network Analysis
SRG	Stakeholders Reference Group
TS	Transformation system
UNISECO	Understanding and Improving the Sustainability of Agro-ecological Farming Systems in the EU
WP	Work Package

EXECUTIVE SUMMARY

In UNISECO, a Social-Ecological Systems approach was used in transdisciplinary action science (Irvine *et al*., 2019; D7.2) for the analysis of how interacting sub-systems influence a given situation ("Focal Action Situation"). It provided a common structure for the analysis of the case studies, identification of drivers and barriers towards agro-ecology transitions, identification of individual agro-ecological practices, and the establishment of a candidate list of innovative market and policy incentives.

The Social-Ecological System and each of the component sub-systems provided the structure for characterising the case studies and their analysis. It was operationalised in the 15 case studies across Europe, covering a wide range of farming systems, socio-economic contexts and stages of agro-ecological transitions. It's validation was based on the experiences gained by the project case study teams it that operationalisation, which were captured in a questionnaire.

Key findings from the survey of case study partners concluded:

i) The Social-Ecological Systems framework provided a value tool with which to set out the overall roadmap of the UNISECO project, and to summarise and visualise the complexity of the farming systems being studied. In turn, this aided in narrowing the high level issues to discussion of the local context of individual case studies.
ii) It was relevant for the analysis of the diversity of sub-systems and variables in which agriculture is embedded. However, that analysis is more of an approach to understanding the mechanisms of a system, and a qualitative picture of the different dimensions of sustainability, than a quantitative assessment of the sustainability of the farming systems.
iii) The approach was useful to frame discussions with stakeholders about drivers and barriers to transitions, and to formalise a desired future towards a more agro-ecological agriculture. In turn, that engagement with the Multi-Actor Platforms played an important role in increasing the robustness of the results of the assessments of the Social-Ecological Systems.
iv) It provided a common method across all case studies for the completion of a status quo assessment, but one gap identified was the link between the systems approach and the dynamics of transitions, reported by Landert *et al.* (2019; D3.1).
v) The results of the application of the framework enabled an understanding to be gained of the current governance and sustainability performance of the farming systems, reported by Vanni *et al*. (2019; D5.2).
vi) The Social-Ecological Systems framework provided materials for use in the wider communication of the farming systems being studied and the transitions towards agro-ecological practices and systems. These materials included inputs to the two sets of story maps (Prazan *et al*., 2019, D3.3; Landert *et al*., 2021, D3.6); and the Spatially Explicit Spatially Explicit Interactive Online Tool (SESSIT) (Helin *et al*., 2021; D6.3).

In its operationalisation, the case study partners noted some challenges for its use, most notably:

i) the need for a level of understanding of the concept to enable its application to be effective;
ii) the number of variables in the systems and sub-systems was high, and some of the data difficult to collect.

However, despite overall the case study partners acknowledge they did not encounter any major difficulties in adopting the approach, considerably aided by the good design of detailed guidelines, and their explanation at project partner meetings and in webinars.

The team responsible for designing and sharing the approach with other partners (ISARA, UZEI, HUT) noted challenges of obtaining the balance between sharing knowledge and raising capabilities in the use of the framework to the same level across all partner teams. This was of particular significance when drawing conclusions about the assessments of the systems.

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Case study partners identified considerable potential for the use of the Social-Ecological Systems approach in future research. One condition for much of those uses is the need to share a common understanding of both Social-Ecological Systems theory and an operational framework, especially for projects with high numbers of teams and a diversity of expertise.

Overall, the structure and logic of the Social-Ecological Systems were found to be well suited to the use of story telling approaches for communicating narratives about agro-ecological transitions across Europe, for which UNISECO used Story maps, made accessible through a map-based interface. Combined, these tools provide flexible and practical tools for explaining farming systems and agro-ecological transitions.

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1. OBJECTIVES AND CONTENT OF DELIVERABLE D2.3

The aim of this deliverable is to assess the uses of the adapted SES framework, and to propose practical recommendations for future applications of this framework. In this deliverable the following questions are addressed:

- What were the strengths and weaknesses of the approach to assess the sustainability of EU farming systems?
- Were there specific difficulties in its application? (e.g. data, synthesis challenges, reliability of conclusions).
- How could the approach be taken forward in other research topics, and what should be taken into account for its use?

The deliverable is organised as follows:

- Recap of the role of the SES framework in UNISECO
- Method for assessing the relevance of the framework
- Results of the evaluation of the framework
- Conclusions.

The application of the Social-ecological System framework for analysing the transition of agro-ecological farming systems was assessed through its use in the case studies. Each case study partner completed a questionnaire to report on various aspects of the use of the framework, strengths and weakne4sses, and prospective uses in future research. A copy of the questionnaire used is provided in Annex 1.

2. THE ADAPTED SOCIAL-ECOLOGICAL SYSTEMS FRAMEWORK AND USES IN UNISECO

2.1. Objectives of the Social-ecological System Framework in UNISECO

UNISECO aims at enhancing the understanding of socio-economic and policy drivers and barriers for further development and implementation of agro-ecological approaches in EU farming systems. In order to achieve this, the main objective of Work Package 2 (Social-ecological system for the sustainability assessment of Agro-Ecological Farming System) was to develop a conceptual framework suitable for:

- the sustainability assessment of farming systems in Europe;
- the identification and the analysis of barriers and drivers towards agro-ecological transitions;
- providing an umbrella framework for establishing linkages between Work Packages.

The background and concepts of Social-Ecological Systems, and their applicability in the analysis of the transition of agro-ecological farming systems, are set out in Guisepelli *et al*. (2018; D2.1), and Its relationship to typologies of agro-ecological farming systems and practices in Prazan and Aalders (2019; D2.2). In UNISECO it was used as a unifying approach between the partners to guide in-depth analysis of action situations in case studies to overcome weaknesses of agro-ecological farming systems (Work Packages 3 and 5) and to understand drivers and barriers towards agro-ecological transition.

A consistent framework to guide the indicator-based assessments of changes in the economic, social and environmental performance and trade-off assessments at farm and territorial levels (Work Packages 3 and 4) (sustainability assessment), and the design of end-user tools and recommendations (Work Package 6).

2.2. Social-Ecological Systems Concept and its Objectives

To recap, a Social-Ecological Systems can be defined as "*an integrated complex system that includes social (human) and ecological (biophysical) sub-systems in a two-way feedback relationsh*ip" (Ostrom, 2009; Berkes

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et al., 2011). Such a Social-Ecological Systems framework can be used to address wicked problems (for which there is no optimal solution; Duckett *et al.,* 2016), and understand why some exploitations of nature are sustainable whereas others collapse.

The Social-Ecological Systems framework provides a theoretical framework relevant to understanding the drivers and barriers to agro-ecological transition both at individual and collective scales. Its properties represent:

- a coherent system of biophysical and social factors that regularly interact;
- a system defined at several spatial, temporal, and organizational scales;
- a set of critical resources (natural, socio-economic, and cultural) the uses of which are regulated by a combination of ecological and social systems;
- a dynamic, complex system with continuous adaptations.

Ostrom's framework (2007) of Social-Ecological Systems was selected for use in UNISECO (Figure 1). It introduces the products and transformation sub-systems, and enables links to be established between the technical, environmental, social and economic and political dimensions of agro-ecological transitions within a complex set of interactions. This was modified following the work of Marshall (2015) to consider the transformation and products sub-systems rather than only considering the parts relating to agricultural production. Those sub-systems are top or first tier attributes of Social-Ecological Systems. Each sub-system is described by a set of second-tier variables, which in turn can be described in more detail by third-tier variables or indicators (quantitative or qualitative) (Del Mar Delgado, 2015).

The limitations of a Social-Ecological Systems approach have been reported by authors studying the contcept, and its application in different transitions (e.g. Baron *et al.,* 2011; Barreteau *et al*., 2016; Binder *et al*., 2013; Clément, 2013; Del Mar Delgado Serrano and Ramos, 2015; MacCarthy, 2006; Ollivier *et al*., 2018). Duru *et al*. (2015) identify limitations of Social-Ecological Systems that reflect gaps in their original design, notably in rel;ation to "agronomic and organisational reasoning and constraints in farming systems", and changes that are necessary in agricultural supply chains.

In UNISECO, the Social-Ecological System framework used was that proposed by Marshall (2015), adapted to enable better account to be taken of transformation activities "where it is inappropriate to define all such activities as exogenous to the SES of focal concern". The modification was made for application of the system in food system research in which the food systems are described with two subsystems: transformation system and products. This model has some inherent challenges. These include:

i) risks of overlaps between sub-systems, such as where actors in transformation systems could be analysed both in terms of their governance or transformation systems;
ii) difficulties in tackling "post-farm gate" issues in case studies where the relationships between farmers and food supply chain actor are very weak and fragmented, with products being exported globally but no information as to their ultimate destinations;
iii) many farms selling their products into different types of supply chains, but the choices of these supply chains varying over time.

The choice between the framework of Ostrom (2007) or the adapted version of Marshall (2015) was informed by consideration of whether processing and marketing issues would influence the system, and in particular the actions and decisions which are made at the farm level, and thus how the boundaries of the Social-Ecological Systems would be defined. For use in UNISECO, the sub-systems were revised to reflect the specificities of agriculture, with resource systems being aligned to the farming systems being studied. Some of the variables in each sub-system were modified and simplified, and the details of each variable defined to avoid different interpretations across partners (Guisepelli *et al*., 2018; D2.1).

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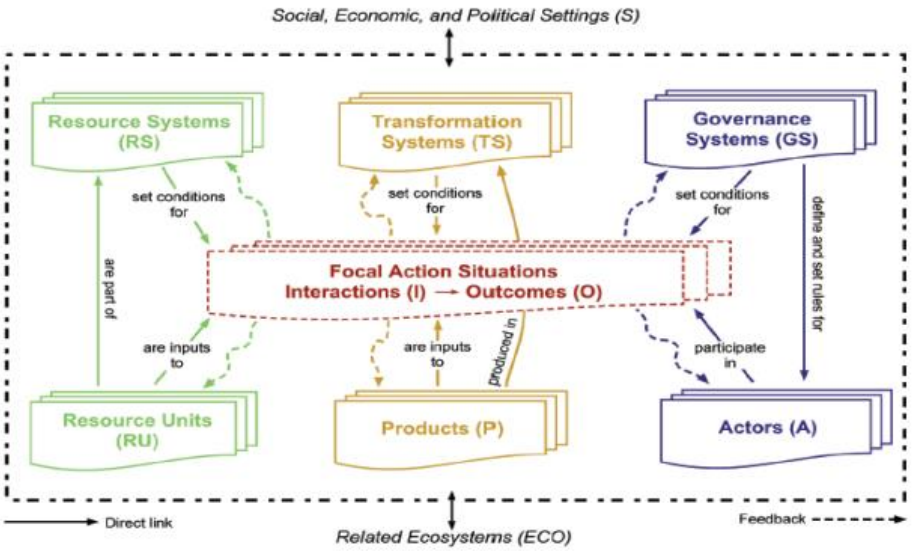

Figure 1. Adapted Social-Ecological Systems framework for UNISECO, showing relationships between the sub-systems (Source: McGinnis Ostrom, 2010, revised by Marshall, 2015).

2.1. Operationalisation of Social-Ecological Systems Concept

In UNISECO, the Social-Ecological Systems approach has been used in transdisciplinary action science (Irvine *et al*., 2019; D7.2) for the analysis of how interacting sub-systems[1] influence a given situation ("Focal Action Situation").

The framework provided a structure for the selection, analysis and reporting of the work in the 15 case studies, and links between relevant components of the Work Packages if the project. Its initial use was to inform the processes of the initial identification and selection of the candidate farming systems to be studied in the case studies and their presentation to the Project Advisory Group (Venice, Italy, November 2018). The case studies were distributed across Europe, covering a wide range of farming systems, socio-economic contexts and stages of agro-ecological transition (e.g. Schwarz *et al*., 2021; D3.4).

Its operationalisation was designed around addressing two core questions:

- What are the most influential variables in each sub-system and how do these variables influence agro-ecological transition in focal action situations?
- How to overcome these barriers and design strategic pathways?

The Social-Ecological System and each of the component sub-systems provided the structure for characterising the case studies and their analysis, including identification of relevant actors (Vanni *et al*., 2019; D5.2), drivers and barriers of transitions towards agro-ecological farming practices in each case study (Schwarz *et al*., 2021; D3.4), and policy and instruments (Galioto *et al*., 2021; D5.4). The outputs from those analyses of the case studies were then reflected in the content of the first and second iteration of the storymaps (Prazan *et al*., 2019, D3.3; Landert *et al*., 2021, D3.6), and presented at in the case study sessions of the UNISECO Final Conference. Several of the explanations of the agro-ecological farming systems in the case studies which explicitly used the structures and sub-systems of the SES framework to explain the transitions (e.g. the drivers and barriers mapped onto the stages of transition and relevant sub-systems (e.g. UK case study).

[1] A sub-system is a secondary system defined as a set of processes, organized practices, intended to ensure a defined function.

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The operationalization of the Social-Ecological Systems framework required working through the set of sub-systems. The sub-systems are the first tier attributes of a Social-ecological System, shown in Figure 1 and listed in Table 1. Understanding the interactions of those sub-systems provides insight to what is happening in the focal action situation. For UNISECO, eight sub-systems were identified (Table 1). Specific questions were developed for enquiring into the characteristics, operation and functions of the sub-systems (Table 1).

Table 1. The sub-systems of the Social-Ecological System, and the associated questions addressed by UNISECO.

Social-Ecological Systems Sub-system	Questions of the Sub-systems Addressed in UNISECO
Focal Action situation, Interactions (I) and Outcomes (0) (environmental, social and economic performances and impacts)	What are the agro-ecological performances of the farming systems concerned? What are their transition 'patterns' and their drivers and barriers?
Resource systems (RS), farming systems (from conventional to agro-ecological)	How are farming systems organized and managed? (RS can concern all types of agriculture, conventional or agro-ecological)
Resource units (RU), agricultural production of the resource systems (RS)	What are the different factors of production and agricultural productions (at the farm gate)
Actors (A), Farmers; Agri-food value chain; Consumers; Science, innovation, advisory, capacity building; NGOs, civic society organisations, local community representatives; Authorities and Administration (Vanni *et al*., 2019; D5.2)	Who are the actors involved in agriculture governance? Who are the major actors able to influence?
Governance (GS), strategic decision-making bodies	What are the main governance systems (from state regulations to collective rules)? What are the main decision-making processes?
Transformation system (TS), secondary and tertiary transformation processes	How do the food systems work? Are the farmers the main beneficiaries of the added value?
Products (P), generated by processes in TS	What are the final marketed products?
Social, economic, and political settings (S)	The general context: economic development; demographic, social and cultural settings; political context and stability; markets, media, environment, etc.

The sub-systems were identified and reported for each case study, compiling a set of Social-Ecological Systems that characterise the 15 case studies. The detailed descriptions of each of the Tier 1 and 2 attributes of these sub-systems are provided in Guisepelli *et al*. (2018; D2.1; Section 3.2), and the list of variables (Section 3.4).

Overviews of the systems in the case studies, and their component sub-systems, are reported in Schwartz *et al*. (2021; D3.4). Examples are shown in Figure 2 of two the Social-Ecological Systems, that of the Chianti Biodistrict in the Italian case study (Figure 2a), and the organic dairy farming system in the Latvian case study (Figure 2b).

The two illustrations provide a short description of the Focal Action Situation, each of the sub-systems listed in Table 1, plus the Focal Action Situation, Interactions between sub-systems, and Outcomes. In the example of the Chianti biodistrict the interactions at the core of the system indicate the need, identified by the actors, of a new model of territorial governance to increase the provision of ecosystem services, and guide the diffusion of management practices and changes on institutional settings at the territorial level. In Latvia, the example focuses on the economic fragility of organic dairy farms, the weak position of dairy farmers in the value chain, of ensuring that more of the organic milk produced on farms is processed as organic dairy products.

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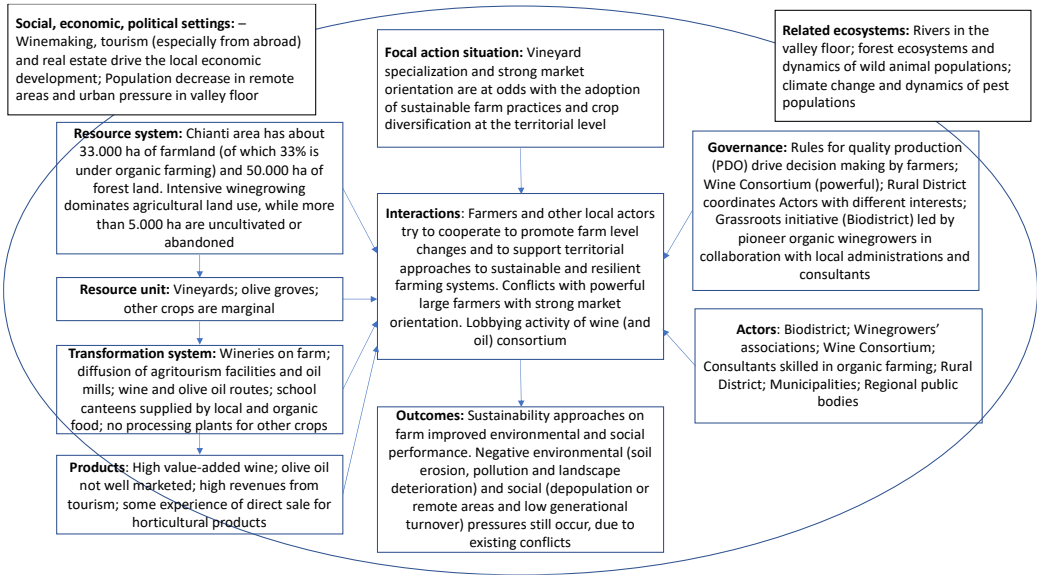

Figure 2(a). Overview of the social-ecological system – Italian case study (Source: own figure based on Ostrom and Cox, 2010; McGinniss and Ostrom, 2014). (Schwarz et al., 2021; D3.4).

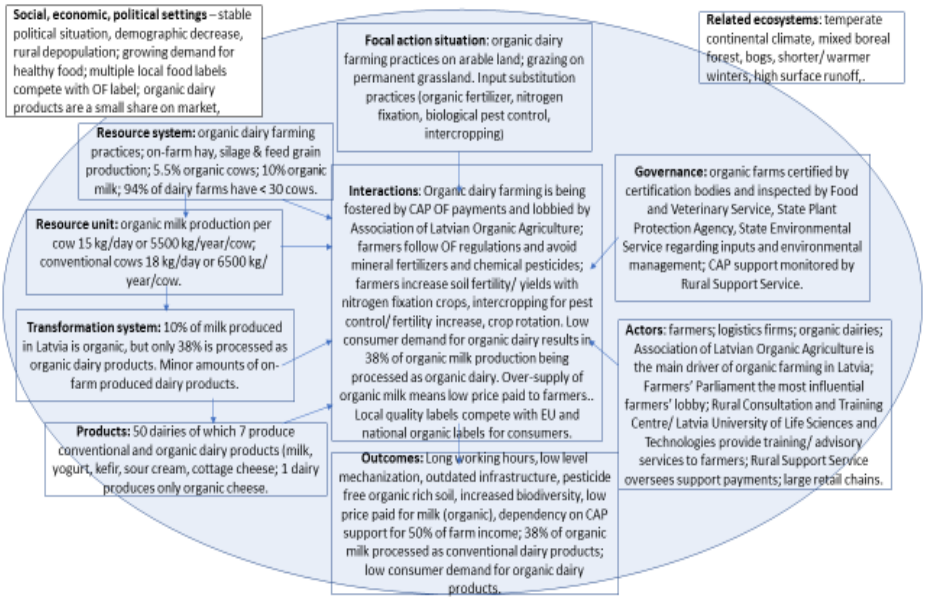

Figure 2(b). Overview of the social-ecological system – Latvian case study (Source: own figure based on Ostrom and Cox, 2010; McGinniss and Ostrom, 2014). (Schwarz et al., 2021; D3.4).

Informed by the guidance and briefing sessions on implementation of the approach, and the case study teams gained experience in the use of the Social-Ecological Systems approach. The process of developing the models of the Social-Ecological Systems of the farming systems in the case studies necessitated reviews of scientific and technical literature, policies and practices, relevant to the farming systems being studied and key dilemma to be tackled. These data provided materials for engagement with actors at case study levels in activities in Work Packages 3 to 6.

At a project level the approach provided an umbrella framework for linking Work Packages, particularly those focusing on the case studies: the indicator-based assessments of changes in the economic, social and environmental performance and assessment of trade-offs at farm and territorial levels (Work Package 3 and Work Package 4); governance and policy assessment, and characterising aspects of the actors and governance

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sub-systems informed by the social network analysis (Work Package 5); and the integrated sustainability assessment, and recommendations (Work Package 6).

Based on the experiences gained from use of the framework in the case studies, the relevant project partners provided feedback on the roles of, issues arising with and opportunities for its future use.

3. APPROACH TO PRACTICE VALIDATION OF THE ADAPTED SES FRAMEWORK

3.1. Uses of the Social-ecological Systems Framework in UNISECO

3.2. Capturing Experiences of Uses of Social-Ecological Systems Framework

The process used to capture feedback on the use of the Social-ecological Systems framework was based on a questionnaire to each case study partner and the relevant Work Package and Task Leaders, and a workshop with the the EU level Multi-Actor Platform and Stakeholder Reference Group (February 2021)from which lessons learnt and recommendations were derived.

The questionnaire was designed to assess the main uses of SES framework, with questions to gain insight to the experiences of the project partners on:

i) the advantages and limitations of the approach to:
   a. identification of the drivers and barriers towards agro-ecological transitions;
   b. assessing the sustainability of EU farming systems;
   c. providing an umbrella framework (e.g. linking the Work Packages, and links between a systems and a transition approach);
   d. uses of Social-ecological Systems in discussions with local Multi-Actor Platforms
ii) specific difficulties encountered in applying the SES framework (e.g. data, synthesis challenges, reliability of conclusions, exchanges and debates with local stakeholders, etc.);
iii) how the approach could be taken forward in other research topics, and what should be taken into account (e.g. including opportunities and limitations to its use).

The questionnaire comprised a set of 27 closed (Likert Scale) and open questions. A copy of the questionnaire content is provided in Annex 1. The questionnaire and guidelines were developed by the Work Package team (ISARA, UZEI, HUT and LUKE), and discussed with the project partners at the online partner meeting held in November 2020, with refinements made in the content and wording. The questionnaire was distributed to all project case study teams, through an online portal, with responses received from all case study partners and relevant Work Package and Task Leaders (total of 18 responses).

The findings were used in a workshop (16th February 2021) with the Project Advisory Group, Stakeholder Reference Group, and the EU level Multi-Actor Platform, run in collaboration with Task 6.2. The output was a set of recommendations for future applications. The workshop represented achievement of Milestone MS9 (Review of adapted SES framework carried out with Project Advisory Group, Stakeholder Refeence Group, and the EU level Multi-Actor Platform).

Responses were received from Work Package and Task Leaders, and partners responsible for each case study or the local Multi-Actor Platforms. The results were collated and reviewed, and key findings used in a workshop with the EU level Multi-Actor Platform and Stakeholder Reference Group in February 2021. Feedback on the draft findings was used to inform the final recommendations and components of presentations at the UNISECO Final Conference.

The results of the survey of users of the Social-ecological Systems framework are summarised in the following Section.

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4. PRACTICE VALIDATION OF THE ADAPTED SES FRAMEWORK IN CASE STUDIES

4.1. Relevance of the Social-Ecological Framework

The users of the Social-ecological Systems framework were asked for their assessment of its relevance in applications relating to the types of agricultural farming systems and the dilemmas tackled in the case studies. They were asked three questions, to which the following responses were received.

i) Question: What is your overall assessment of the relevance of the SES framework to identify and analyse the dynamics of agriculture of your case study?

Table 2. Responses to question on overall assessment of relevance of SES framework relating to analyse the dynamics of agriculture

Response	Number	Percentage
Excellent	3	16.7%
Good	13	72.2%
Average	2	11.1%

The majority of respondents assessed the framework as good or excellent for analysing the dynamics of agriculture in their case study. The responses to the economic, environmental and social challenges of the sustainability issues and dilemma being faced in the case study provided evidence of the transition towards agro-ecological farming systems of those studies.

The framework provided a means of structured approach to describing how agriculture, and wider land uses, has evolved in the case studies, and was considered to provide a valuable common structure to apply across all case studies in preparing a status quo picture of the farming systems studied in the case studies, reporting in Landert *et al*. (2019; D3.1). It also provided a good basis for workgin through the relationships of various components of the agricultural system (e.g. actors, regulations) and the environment, and broader issues of relevance outwith the local system being studied.

However, it was noted that the sequence of application of the SES framework meant that some sub-systems were analysed in greater depth than others, an outcome of which could have been an influence on some results.

ii) Question: What is the relevance of the SES framework to identifying the main drivers and barriers towards agro-ecological transition?

Table 3. Responses to question on relevance of SES framework relating to identifying the main drivers and barriers to agro-ecological transition

Response	Number	Percentage
Excellent	7	38.9%
Good	7	38.9%
Average	2	11.1%
Poor	2	11.1%

The majority of respondents assessed the framework as being good (38.9%) or excellent (38.9%) for analysing the main drivers and barriers to agro-ecological transition, although 2 respondents reported it as poor and 2 as average.

The framework informed a broad reflection on the barriers and drivers of agro-ecological transitions, and separating barriers and drivers that are internal to the system compared to those that are external (noting that establishing a clear distinction can be difficult). Its use provided evidence of progress being made to

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overcome barriers to transition, through a portfolio of policies and actions. Examples are of: i) policy instruments providing financial support for tackling barriers of a lack of local processing capability, stepping in where other sources of funding have been insufficient; ii) significant investments made by the private sector, including cooperatives, in infrastructure for improving the quality and efficiency of supply chains for crops and cattle, contributing to economic and environmental sustainability.

Feedback also noted that barriers can differ between individual farms (e.g. breed of cattle unsitable for organic farmimg systems; debt, negative experiences), as can drivers (e.g. motivations, financial opportunity) and thus the identification and repoirting of sets of barriers or drivers could be influenced by the composition of the Multi-Actor Platform. There was also recognition of alternative approaches which could be used to that of the SES framework.

iii) Question: What is the relevance of the SES framework to assess the impacts of policies in your case study (on key dilemma and on agroecological transition)?

Table 4. Responses to question on the the relevance of the SES framework to assess the impacts of policies in case studies

Response	Number	Percentage
Excellent	4	22.2%
Good	7	38.9%
Average	7	38.9%

The opinions of respondents on the relevance of the framework to assessing the impacts of policies in case studies was split with 11 reporting it as good or excellent, and 7 as average.

The framework was reported as enabling the articulation of arguments relating to policies in ways relevant to different types of policy interests (i.e. national compared to local; officials compared to elected representatives). It support the gaoing of insights of the role of policies in influencing complex systems studied. The populated components of the local social-ecological systems showed the extent to which policy has a significant impact on the transition to agro-ecological farming systems. However, in the definition of the local social-ecological system, it was the influences of the actors and governance factors that was particularly apparent through the influence they in making specific changes within case studies (e.g. individual farmers or cooperatives).

Overall, the feedback reflected the observation that the governance dimension of the SES framework was valuable for describing previous and existing policies, however a complemetary approach was required to provide deeper insights of their impacts (e.g. its use in workshops with domain and policy experts). One such tool was the Social Network Analysis (see Vanni *et al*., 2019; D5.2), which provided a broader perspective on the political environment.

Respondents also noted that variables used would require refinement to improve insight to the impacts of policies on addressing the dilemma, and that some of the "standard" variables are less relevant to this particular task.

4.2. Issues with Use of the Social-Ecological Systems Framework

The users of the Social-ecological Systems framework were asked a set of questions to identify types of issues they encountered, and how they could be addressed. The types of issues covered: i) the guidance for use of the framework; ii) the number of variables in the framework; iii) issues associated with collecting relevant data; iv) establishing links between varibales; iv) reliability of the conclusionjs that can be drawn; v) the potential to provide a synthesis of drivers, barriers, key dilemma and sustainability. The responses to the associated questions follow.

Question: Are the guidelines to undertake the diagnosis well designed?

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Table 5. Responses to question on whether the guidelines to undertake the diagnosis are well designed

Response	Number	Percentage
Excellent	1	**5.6%**
Good	15	**83.3%**
Average	2	**11.1%**

Statement: The number of variables to be assessed is too high

Table 6. Responses to the statement on whether there were too many variables to be assessed

Response	Number	Percentage
Strongly Agree	4	22.2%
Agree	6	33.3%
Disagree	8	44.4%

Statement: I faced difficulties collecting the relevant data

Table 7. Responses to the statement on whether the user faced difficulties collecting the relevant data

Response	Number	Percentage
Strongly Agree	2	11.1%
Agree	8	44.4%
Disagree	6	33.3%
Strongly Disagree	2	11.1%

Statement: Establishing the links between variables is difficult

Table 8. Responses to the statement on whether establishing links between variables was difficult

Response	Number	Percentage
Strongly Agree	4	22.25
Agree	9	50.0%
Disagree	5	27.8%
Strongly Disagree	0	0%

Statement: The reliability of conclusions is low

Table 9. Responses to statement of whether the reliability of the conclusions is low

Response	Number	Percentage
Strongly Agree	1	5.6%
Agree	5	27.8%
Disagree	11	61.1%
Strongly Disagree	1	5.6%

Statement: A SES characterization provides a synthesis of drivers, barriers, key dilemma and sustainability

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Table 10. Responses to the statement that a SES characterization provides a synthesis of drivers, barriers, key dilemma and sustainability

Response	Number	Percentage
Strongly Agree	6	33.3%
Agree	8	44.4%
Disagree	3	16.7%
Strongly Disagree	1	5.6%

The majority of respondents (88.9%; Table 4) reported the guidelines for undertaking the daignosis of the social-ecological system in the case study to have been well designed (i.e. scored good or excellent).

The SES framework enabled complex information to be captured in a structured way. Its overall presentation, following the model illustrated in Figure 1, aided summarising and visualising the complexity of the farming systems being studied. In turn, this aided in narrowing the high level issues to discussion of the local context of individual case studies.

However, understanding its theoretical basis requires some level of capability in several disciplines (e.g. natural sciences, institutional economics and social sciences, system theory). Therefore, guidelines alone are likely to be insuficient to provide a strong grounding in the background of the framework for project teams which do not have the relevant backgrounds or sufficient time for learning. However, the guidelines themeselves set out the methodology clearly and enabled the implementation of the framework in case studies.

Over 55% of respondents reported there were too many variables (55.5%, Table 5), requiring a commensurate amount of time to collect the data required. However, potentially more significant was that some respondents noted that the relative importance of each variable would not be equal, which required consideration when interpreting the details in the sub-systems.

Some users reported difficulties in collecting, or in synthesising the data collected (55.5%, Table 6). Amongst the issues identified are that too much information was required, much of which was not directly relevant to some of the dilemmas, and took too long to collect.

A high proportion of respondents also considered that establishing links between variables was difficult (72.24%, Table 7). However, positive reflections were received on the use of the framework for establishing links relating to the sub-systems on Governance and Actors. This may reflect the in-depth consideration of those sub-systems in workshops with a specific focus to those topics, and thus greater opportunity to understand the links with the aid of the members of the Multi-Actor Platforms.

Overall, 33.3% of respondents considered the reliabilty of the conclusions to be low (Table 8), however 66.6% disagreed or strongly disagreed with that statement. The exact reasons for the opinions that reliability was low were not clear. They may relate to the confidence of the case study partners or challenges faced with the respective case study.

4.3. Use of Social-Ecological Systems Framework with Multi-Actor Platforms

The users of the Social-Ecological Systems framework were asked about its use in engagement with the Multi-Actor Platforms.

Question: Did you present the SES framework (principle and concept) in discussions with your local MAP

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Table 11. Responses to question on whether the the SES framework was used in discussions with the local Multi-Actor Platforms

Response	Number	Percentage
Yes	6	33.3%
No	9	50.0%
No Answer	3	16.7%

Question: In the form of a figure or a table characterising the different sub-systems and their variables (or some of them)

Table 12. Responses to question on whether presentation of the SES framework was in the form of a figure or table characterising the sub-systems and variables

Response	Number	Percentage
Yes	7	38.9%
No	8	44.4%
No Answer	3	16.7%

A third of respondents used the Social-ecological System framework directly in discusisons with the local Multi-Actor Platforms (6 respondents, 33.3%; Table 10). One more partner used the system in a diagrammatic or tabular form (Table 11, 38.9%; Table 11).

In general, those who did use the framework to provide a structured approach to formal engagement with local actors, and a terminology under which topics could be discussed with the actors and organise the discussion. Uses included: i) helping members of the Platforms grasp the concept of the "system"; ii) a mechanism for providing an overview of the context and local realities of the case study, and the interplay of social and ecological changes taking place in the area; iii) to create a common understanding of the context and boundaries of what was to be assessed in discussing barriers and drivers.

In other case studies, project teams used elements of the framework and sub-systems where they were relevant to the case study dilemma, challenges, or barriers, but presented as a Social-Ecoogical System or its sub-systems. Some uses were more tailored to the running of workshops, such as materials for a preliminary exercise prior to the in-depth discussion of the workshop.

In turn, that understanding was used with members of the Multi-Actor Platforms to provide a roadmap which helped with understanding the project as a whole. Linked to such an overview, some respondents also reported that a 1 page summary of the Social-Ecological Systems framework would have been useful in supporting discussion with certain types of stakeholder.

4.4. Use of the Social-Ecological Framework as an Umbrella framework

Question: What is your assessment of the relevance of the SES framework as an umbrella framework for UNISECO

Table 13. Responses to question on the relevance of the SES framework as an umbrella framework for UNISECO

Response	Number	Percentage
Excellent	4	22.2%
Good	9	50.0%
Average	5	27.8%
Poor	0	0%

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The majority of respondents rated the relevance of the Social-ecological System framework as good or excellent as an umbrella framework for the work of UNISECO (72.2% rating good or excellent, Table 12). The Social-Ecological System approach enabled links to be established between Work Packages within a common theoretical framework. Certain sub-systems could be related to specific sub-systems or variables of the framework (e.g. Actors, Task 5.2, Vanni *et al*., 2019; D5.2; Governance intersecting with Tasks across WP5).

Question: What is your assessment of the relevance of the SES diagnosis for this specific use?

Table 14. Responses to question on the relevance of the SES diagnosis for the specific uses in UNSECO

Response	Number	Percentage
Excellent	3	16.7%
Good	4	22.2%
Average	1	5.6%
Poor	0	0%
No answer	10	55.7%

Fewer than half of respondents answered this question (8 of 18; Table 13). However, almost all of those who did respond rated the relevance of the Social-ecological System framework as good or excellent for spceific uses in the work of UNISECO. The data and analysis required for some of the sub-systems of the framework helped inform specific Tasks in the programme of work in UNISECO, and development of subsequent deliverables. So, in some case studies, the results obtained for different sub-systems were presented to the Multi-Actor Platforms in workshops. Examples of those Tasks and deliverables are: i) Task 3.1, description and assessment of the SES in the case studies (Landert *et al*., 2019; D3.1); ii) Task 3.4, understanding of drivers and barriers, and co-constructing agro-ecological transitions (Schwarz *et al*., 2021; D3.4); iii) Task 5.2, identifying the governance networks supporting agro-ecoogical farming systems (Vanni *et al*., 2019; D5.2); iv) Task 5.3, the evaluation of policy instruments (Linares Quero *et al*., 2020; D5.3); v) Task 3.5, lessons learnt from the case study assessments and the associated stroymaps (Landert *et al*., 2021; D3.6).

Question: What is your assessment of the relevance of the SES framework to contribute to an integrated sustainability assessment?

Table 15. Responses to question on the relevance of the SES framework to contribute to an integrated sustainability assessment?

Response	Number	Percentage
Excellent	3	16.7%
Good	10	55.6%
Average	3	16.7%
Poor	2	11.1%

The majority of respondents (72.3%, Table 14) rated the Social-Ecological System framework as relevant to conducting an integrated sustainability assessment. Accompanying comments noted that the approach provided a complete overall synthesis of a farming system situation without having to undertake a detailed assessment in all the dimensions of sustainability, and of dealing with the complexity of data and interdependencies and links within the system. When accompanied by interviews with stakeholders, the Social-Ecological Systems framework helped with the prioritisation of the policies that would aid overcoming barriers to transitions, and promotion of the drivers.

However, a weakness of the application of the approach is that much of the use of the framework uses subjective information. That increases the requirement for good quality standards and guidance to ensure consistency in approach. One respondent noted that considered the Social-Ecological System as lacking key tools to carry out an integrated sustainability assessment. Instead, the assessment could be an input to a model, used to define the outcomes of sub-systems at different stages of the transition.

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The principal strengths and weaknesses of the Social-ecological System framework for the analysis of agro-ecological transitions are summarised in Figure 3.

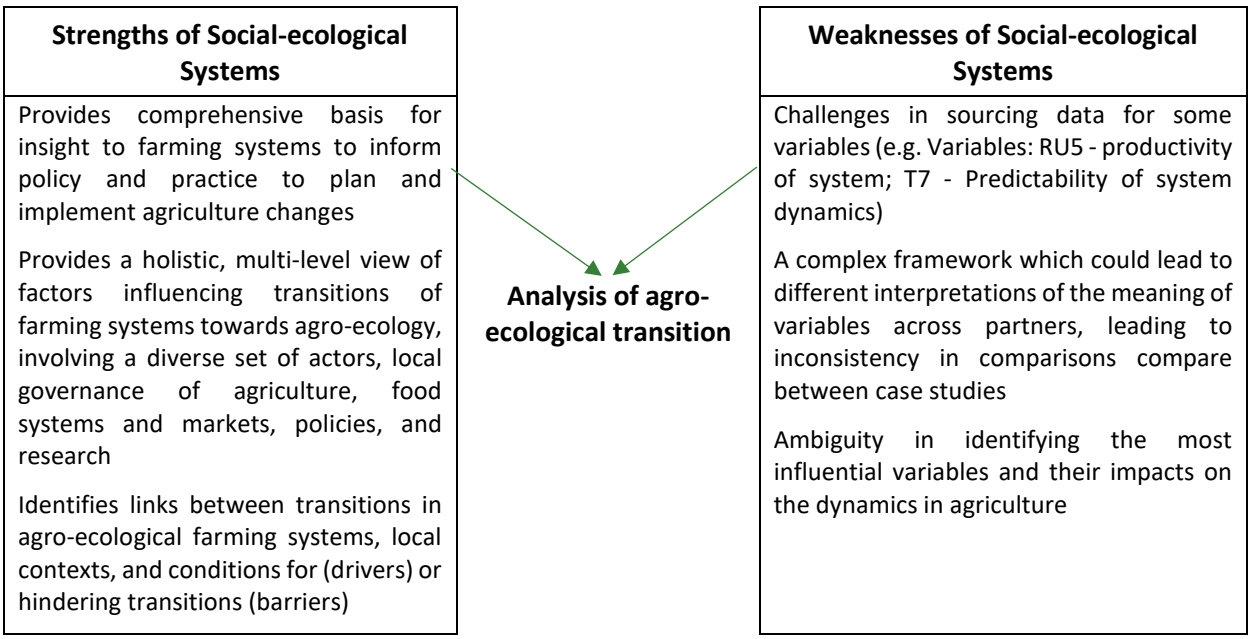

Figure 3. Strengths and weaknesses of SES framework for the study of agro-ecological transition.

It was not considered possible to draw a conclusion on the use of the framework at a European level.

5. DISCUSSION

5.1. Social-Ecological Systems as a Theory and a Tool

Ostrom (2007) noted that a Social-Ecological Systems framework, that is to say a set of variables organised in sub-systems, "enables scholars to organize analyses of how attributes of: i) a resource system (e.g. fishery, lake, grazing area); ii) the resource units generated by that system (e.g. fish, water, fodder); iii) the users of that system; and iv) the governance system jointly affect and are indirectly affected by interactions and resulting outcomes achieved at a particular time and place. The framework also enables us to organize how these attributes may affect and be affected by larger socio-economic, political, and ecological settings in which they are embedded, as well as smaller ones."

For these types of uses, the Social-Ecological Systems framework helps with the identification of variables relevant to the study of a single Social-Ecological System, and provides a common set of variables for organising and comparing studies of similar Social-Ecological Systems in different locations and biophysical and socio-economic contexts.

Ostrom (2007) argues that developing such a Social-Ecological; System can be a step towards building a strong interdisciplinary science of complex and multi-level systems to:

"… develop cumulative, coherent, and empirically supported answers to three broad questions:

i) What patterns of interactions and outcomes, such as overuse, conflict, collapse, stability, and increasing returns, are likely to result from using a particular set of rules for the governance, ownership, and use of a resource system and specific resource units in a specific technological, socio-economic, and political environment?
ii) What is the likely endogenous development of different governance arrangements, use patterns, and outcomes with or without external financial inducements or imposed rules?

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iii) How robust and sustainable is a particular configuration of users, resource system, resource units, and governance system to external and internal disturbances?"

The Social-Ecological Systems concept is a flexible, but complex, approach that requires to be adapted to the specific question being addressed, and to the contexts of the relevant case study. It enables the incorporation of changes in governance internal to the Social-Ecoogical System, property rights regimes, the role of free riders, and the role of social capital (trust and its role in the capacity of actors to cooperate or agree to institutional change), collective action, and common pool resources.

In UNISECO, the adapted Social-Ecological Systems approach was chosen and designed for use as an operational framework for the collection, analysis and comparison of data from across disciplines at the case study level. It was a core element for identifying the principal drivers and barriers to agro-ecology, and how to overcome these barriers and co-construct strategic pathways to transitions (Schwarz *et al*., 2021; D3.4).

Implementing the Social-Ecological Systems concept benefits from a transdisciplinary research approach (Irvine *et al*., 2019; D7.2). However, its use requires good knowledge and understanding of the concepts and theoretical basis of Social-ecological Systems and Institutional Analysis and Development (IAD) theories. In support of this, dedicated information and guidance sessions were run at project partner meetings at an early stage of the project (e.g. 2nd project Meeting, Venice, Italy, November 2018; 3rd partner meeting Helsinki, Finland, May 2019).

Feedback received from the case study research partners implementing the Social-Ecological System framework reported the need for a greater level of understanding of the underlying theory, and sufficient time for learning, (Section 4.2; Tables 5 and 6). The need for local knowledge for the effective application of the approach is consistent with those reported by Del Mar Delgado-Serrano *et al*. (2015).

However, one weakness is that contributors from all sectors (research, practice, policy) need a shared support for the approach. In UNISECO, almost all participants and stakeholders committed to the approach, but a rapid increase in capabilities for understanding the concepts and then its application has significant demands on individuals for whom the research may be a relatively small component of their portfolio of tasks or responsibilities. For example, in the evaluation of the stakeholder activities, Smyrniotopoulou and Vlahos (2021, D7.3) noted feedback about the complexity of some topics discussed at those events, and the "tight schedule for complex topics". Case study teams also reported challenges collecting relevant data and the relatively high number of variables to be populated, providing empirical evidence in support of the findings of Partelow (2018) and Del Mar Delgado-Serrano *et al*. (2015).

The Multi-Actor Approach (Irvine *et al*., 2019; D7.2) played a key role in increasing the robustness and reliability of the results obtained for the case studies. A suite of tools applied in the project were deployed in those forums of engagement with stakeholders. One such tool was the Social-Ecological Systems framework, used to structure aspects of the discussion with the members of the case study Multi-Actor Platforms, and gain insights to and understanding of factors leading to the implementation of agro-ecological practices and transition of systems (Figure 4).

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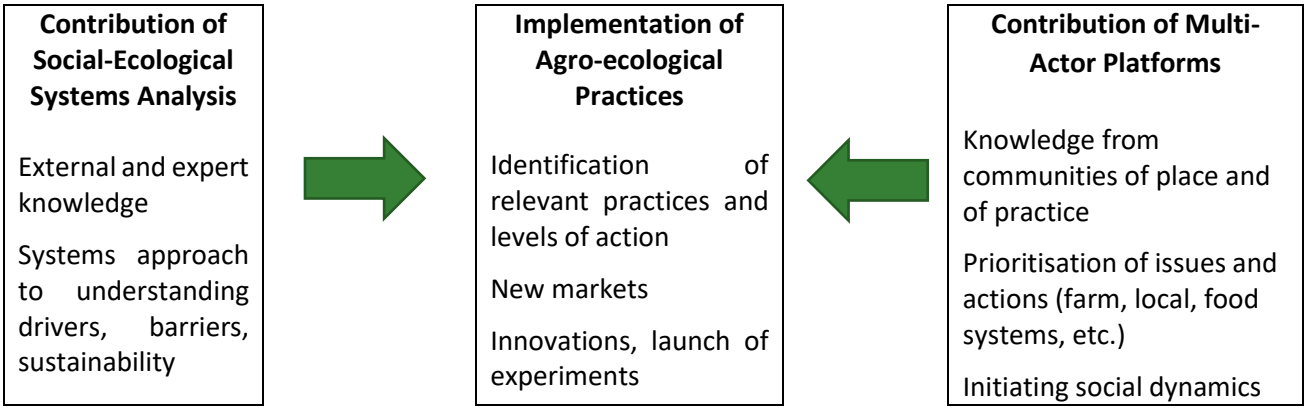

Figure 4. Linking contributions of the Social-ecological Systems framework and the Multi-Actor Platforms for the identifying key characteristics for supporting implementation of agro-ecological practices.

Project activities with the Multi-Actor Platforms identified in the Project Management Plan (Schwarz *et al*., 2018; D1.1) and guide to transdisciplinary working (Irvine *et al*., 2019; D7.2) included three in which the Social-Ecological Systems framework formed an explicit part**:**

- Activity 2.4.3, Discuss and evaluate the advantages, limits, difficulties in applying the SES framework for sustainability assessment of farming systems (Work Package 2);
- Activity 3.1.5, Provide information about the SES defined in the case studies (e.g. resource management, outputs of production, actors, interactions between actors, rules agreed and their enforcement, governance, change of arrangements over time) (Work Package 3);
- Activities 3.3.4 and 5.2.6 address policy framework and market mechanisms, and drivers of and barriers to agro-ecological transitions, including how existing market and policy instruments are used in different SES (Work Packages 3 and 5).

Other activities for which specific aspects of the Social-Ecological Systems framework were identified for use were in the co-creation of management strategy solutions (Activity 3.3.5), reported in Schwarz *et al*. (2021; D3.4), and in assessing innovative market and policy incentives (Activity 5.4.5), as reported in Galioto *et al*. (2021, D5.4). It also contributed inputs to modelling at a European level through Work Package 4.

The approach was combined with two in-depth analyses of the case studies, and an overarching transdisciplinary Multi-Actor approach, as summarised below.

- **Set of farm level Decision Support Tools**: A status quo assessment of the sustainability performance of farming systems using a set of three Decision Support Tools (DST) (Landert *et al*., 2019; D3.1). The three Decision Support Tools COMPAS, Cool Farm Tool and SMART were applied across farms in the 15 countries to provide information on the environmental, economic and social performance of current agro-ecological farming systems. This enabled the quantitative assessments of indicators of sustainability outputs from the Decision Support Tools to be combined with the qualitative assessments from the Social-Ecological Systems approach.

- **Social Network Analysis:** A Social Network Analysis was undertaken to obtain insight to the governance structures which characterise the different transition "patterns" in the context of the 15 UNISECO case studies (Vanni *et al*., 2019; D5.2). The experience gained from the Social Network Analysis showed how effective it is for assessing the sub-systems of governance and actors. However, on its own, it provides an incomplete picture of some variables of the governance sub-system.

- **Transdisciplinary Multi-Actor Approach:** Irvine *et al*. (2019; D7.2) explain the importance of, and benefits gained from, sharing knowledge from different disciplines, research and practice to address the key objectives of UNISECO. They set out the importance of taking account of the 'rules of engagement' in this approach, including the ethical issues such that factors such as relative positions of power within the subject systems can be studied using a forum in which all members are equal.

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Embedded in the approach are the social leanring processes knowledge and power distributions identified by Ollivier *et al*. (2018) for inter- and transdisciplinary dialogue into agro-ecological transitions.

Explaining the theory and concept of the Social-Ecological Systems framework was not an explicit objective, but it was of interest to the actors in some case studies, reflecting their composition of researcher, practice and policy. As such, overviews of the concept were used by several case study partners to engender confidence and trust of the members of the Multi-Actor Platforms that the results would be based on a structured and robust scientific approach. It also provided a framework that:

- organised the collection of the in-depth knowledge of specific dynamics of the Social-Ecological System in a local context;
- supported a step-by-step discussion of the drivers of agro-ecological farming systems, and barriers to its uptake;
- structured the development of visions of transitions towards agro-ecological farming practices and systems;
- helped to create a common understanding of the farming systems, within and between the case studies.

However, evidence from its use in the case studies suggests that the operation of the Social-Ecological System was most applicable at a case study level, and that tests would be required to understand its applicability at higher levels (e.g. Europe-wide).

5.2. Analysis of Barriers, Drivers and Sustainability Assessment of Farming Systems

The Social-Ecological System framework was subsequently implemented for use in analysing the drivers and barriers that may not directly concern agricultural practices and farming system but can be influences upon them (e.g. market, local dynamics, interactions between farmers and environmental NGOs).

The project case study teams reviewed the barriers and drivers of agro-ecological transitions and validated them with the local Multi-Actor Platforms. Analysis of the barriers and drivers included their relationship with the sub-systems of the Social-Ecological System, actors in the Social Network Analysis (Vanni *et al*., 2019; D5.2), transition stage, and how the barrier or driver relate to existing market or policy incentives. Based upon the Social-Ecological Systems assessment, the analysis how the barrier was overcome or driver enhanced, or why that did not happen. The synthesis of the findings were then the subject of a project level workshop with the Stakeholder Reference Group and EU level Multi-Actor Platform (February 2021).

The framework was implemented for use in analysing the main drivers and barriers to agro-ecological transitions which may not directly concern agricultural practices and farming system but can be influences upon them (e.g. market, local dynamics, interactions between farmers and environmental NGOs). The application of the framework increased the understanding of why, in some cases, particular barriers could be overcome while in other cases such barriers persisted. Key actors and their influence and role in addressing barriers and drivers were identified.

The framework enabled recognition that, whilst governance changes inside a social-ecological system could significantly change the capacity of the farming system to undergo a transition, changes in the external governance contribute to creating a supportive environment, which in turn can enable such changes inside the social-ecological system.

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5.3. Boundaries of the Social-Ecological System

A clear lesson learnt was the need for a robust definition of the boundaries of a Social-Ecological System being studied. The definition of an appropriate boundary will constrain the scope of the study to a manageable level, avoiding an unnecessary level of complexity.

Studying factors of the case study beyond the boundaries of the Social-Ecological System can lead to a mixing of the subject of analysis inside the System with actors and other factors in the wider environment within which the system operates, and of confusing the roles of the actors within and outwith the system. For example, actions could be sought from actors who are outside the Social-Ecological System who do not have organisational means, remit or mandate for their actions to function within the System.

The boundaries of the Social-Ecological System are determined by factors such as the geographic location of the resource system and the boundaries of the areas within which the same challenges are being faced. This is particularly relevant for spatially (regionally) defined case studies. However, the definition is more problematic with network-based case studies for which the boundaries of the resource system may not be clear. In such a case the resource system still plays a role in defining the boundary, but the definition should also take account of the common issue or dilemma faced by the management of the resource system (e.g. arable land managed in a way that leads to a water deficit) and the actors relevant to the Social-Ecological System.

The conclusion drawn is that the definition of the boundary should stem from answering the questions:

i) "What land/farms deal with the same issue in the resource system management?",
ii) "Which actors are inside and which are outside the Social-Ecological System?"

If there is no close cooperation between farmers and other actors (e.g. the only governance structure is the market), the resource system management could be sufficient to make the distinction of the system boundary, and the farmers are taken as the key actors of the Social-Ecological System.

If there is some additional form of governance between farmers, or between farmers and other types of actors, then the boundary would be defined by the actors (e.g. those actors who commonly deal with the issue in the resource system management). For example, farmers could come together and regularly share knowledge and experiences of the management of the resource system (e.g. how to deal with drought in vineyards; Italian case study), or to create informal or formal institutions govern some common actions such as processing or marketing (e.g. Czech case study).

All of the actors who participate in such agreements can be interpreted as being within the Social-Ecological System. However, those actors who have contracts with farmers for the wholesale purchase of products, and their relationship with the actors is governed by the market, should be regarded as being outwith the Social-Ecological System being studied.

However, the experience with implementing the Social-Ecological System approach showed that the distinction is not always clear. The lesson learnt from that experience is that the key characteristics to inform the definition of the boundary of the system are a combination of the resource system, closeness of cooperation, common formal or informal institutions, and sharing costs and benefits during cooperation. The experience in the UNISECO case studies also highlighted the importance of recognising that boundaries are subject to change during a transition with new, or formerly external, actors becoming part of the system, e.g. due to new forms of collaboration between farmers and value chain actors.

5.4. Handling Transitions

A Social-Ecological System approach is principally a systems approach and not a transition approach, even if in theory it has the capacity to analyse changes over time (Ostrom, 2007). Consistent with the findings of Ollivier *et al.* (2018), UNISECO faced limitations with the use of Social-Ecological Systems for fully explaining

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the complex processes and phases of agro-ecological transitions. Re-running the analysis at a different moment in time would enable discussion about change in the sub-systems to be more accurately aligned to how the dilemma is being tackled and the transition of the system. However, conducting a Social-Ecological System analysis at two (or more) different points of time in each case study was not feasible in its application in UNISECO.

To overcome this limitation, while remaining consistent with the objectives and resources of UNISECO, strategic pathways to initiate or enhance agro-ecological transitions were co-constructed that combine the perspectives and knowledge of actors from science, society and policy and propose concrete actions and changes to the governance of the farming systems (Schwarz *et al.*, 2021; D3.4). The "Story telling" approach of the story maps (Landert *et al.*, 2021; D3.6) was used to provide information about processes in the case study that enabled barriers to be overcome, or processes and actions needed to overcome barriers in the future, based on the application of the Social-Ecological Systems framework. In practice, this part of the framework was implemented at different levels of detail across the case studies. The process was judged to be complex and in some case studies too resource intensive.

6. ISSUES FOR FUTURE USE OF SOCIAL-ECOLOGICAL SYSTEMS APPROACH

The use of the Social-ecological Systems framework in UNISECO enabled a broad analysis of a diverse set of examples of agricultural activities in Europe, within a broad range of socio-economic contexts. In reflecting on the uses, strengths and weaknesses of the framework the project case study teams identified opportunities for its use in future research.

Respondents proposed opportunities for use of the Social-ecological Systems framework in structuring the analysis and interpretation of systems, complemented by other tools with which to analysis sub-systems or components in greater detail. Although the framework is not restricted to uses in agricultural and environmental land uses, it was in these subject domains that most applications were identified.

Examples of those uses are summarised in Table 16, organised according to four overall themes.

Table 16. Topics and issue for research using the Social-ecological Systems approach.

Topic	Issues for Research
i) Farming systems and types of agriculture	• comparisons between specific farming systems and types of agriculture, such as dairy, fruit, and pig farming • sustainability assessments and identifying opportunities for the expansion of: agro-ecological farming; permaculture practices; agroforestry; social farming; uses of biochar in farming; dairy organic farms; potato cultivation; conversions of low fertility land to biomass production; production of hardy seeds • investigation of processes and new technologies to create opportunities for accelerating pathways of transition, and of the interactions between biophysical and social processes in the fields of new technologies applied to agriculture
ii) Forms of governance and related drivers and barriers	• understanding the roles of private and public advisory services, and the impacts of political and market initiatives • understanding the impacts of political and market initiatives on the agro-ecological transition and the role of different categories of actors • understanding the behaviours of different types of actors in relation to farming systems

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	• understanding constraints on pathways of transitions through mapping of scenarios into the framework • socio and economic aspects behind use of pesticides • conditions required for successful institutional change in common pool resources management in the context of low social capital • improving farmer cooperation in the management of biodiversity in protected areas
iii) Environmental issues and related policies	• approaches to reversing the loss of biodiversity, improving water quality, reducing greenhouse gas emissions • understanding the risks of losses of biodiversity due to agriculture • identifying the strengths and weaknesses of water governance arrangements for river basin management in the context of implementation of the EU Water Framework Directive • understanding interactions between social and environmental processes, and between public and private goods • assessing the impacts of farming in biodiversity protected areas • in-depth exploration of local ecosystems to understand how relationships between people and nature is changing, and what this means for the future of the region • understanding the roles of multi-level governance on environmental issues (e.g. governance of water catchments)
iv) Policy design and implementation	• analysis and assessment of the process of implementation of local projects • understanding processes of innovation at local levels • requirements and approaches to creating a bioregion (e.g. involvement of actors, local sales, circular economy) • assessment of the role of policies aiming at increasing the capacities of farming systems to organise themselves under collective actions for common purposes
v)Outside the field of agriculture	• Systems related to natural resource exploitation (e.g. fishing, mining, forestry) particularly in creating sustainable outcomes

Based upon their experience of the use of Social-ecological Systems approach in UNISECO, a set of opportunities were identified for the application of the approach in practice-oriented research. These areas of research reflect a need to understand the context provided by socio-economic dynamics, the identification of new opportunities for farming systems, and the design of local or regional action plans taking into account place specific circumstances. These topics are summarised in Table 18.

Table 18. Practice oriented topics identified for use of the Social-ecological Systems approach.

Topic	Issues for Research
i) Understanding context	• identification of factors that inhibit the implementation of policies at a local level (e.g. results based agro-environmental measures, landscape level policies) • identification of the social, economic and cultural factors to consider when fostering cooperation amongst farmers • understanding factors behind the successful design and operation of short supply chains within a region • approaches to identifying actors relevant to the agro-ecological farming systems at the outset of stakeholder-based projects, approaches to

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	inform their involvement, and awareness of potential conflicts that could arise • assessment of the capacity of farming systems to improve the nature and levels of cooperation • understanding how to create links between spatial planning programmes and environmental protection tools
ii)Identifying new opportunities	• design of innovative measures of policy or practice • identification of windows of opportunity for market initiatives • identifying approaches for overcoming barriers, and motivating farmers, to switching to organic farming in the areas of protection of drinking water resources • understanding approaches to introducing new practices into farming (e.g. precision agriculture, no-till systems) • how to stimulate markets in organic seeds • how to create opportunities to share information about agro-ecological transitions, at local level
iii) Design and implementation of local or regional action plans	• creation of transition strategies (e.g. for local waste management; development of sustainable tourism) • approaches to improving farming practices to mitigate greenhouse gas emissions and improve water quality • approaches to introduce organic food into schools and public sector catering • approaches to stimulating transitions to carbon or biodiversity positive farming • designing local nature conservation areas that takes into account the values of local people from ecological and historical perspectives • understanding the compromises required in the provision of public and private goods linked to enhanced cooperation between the private and public sectors • creation of water protection cooperatives (e.g. by farmers) at the level of a water basin • approaches to planning agro-ecological transitions at the local level

The design of the approaches to understanding the farming systems and the drivers and barriers to their transitions recognised the limitations of using any one approach, and that there is no 'ready made framework (Ollivier *et al.*, 2018). They note the risks associated with 'mixing or integrating' frameworks due to issues such as mismatches in the underlying ontologies and conceptual units. Amongst the issues they identify an potential weaknesses in approaches is that of the delineation of systems, and the types of social, ecological, and technological entities studied.

The experience of using the Social-Ecological System approach in the 15 case studies of UNISECO provided insights to how it can be used in combination with other approaches to provide a more comprehensive understanding of the farming systems being studied. The structure and logic of the Social-Ecological Systems are well suited to the use of the story telling approach implemented in the Story Maps (Landert *et al.*, 2021; D3.6). For communicating the narratives about agro-ecological transitions across Europe, the approach in UNISECO of bringing together the set of story maps within a single map-based interface, in the Socio-Ecological System Interaction Tool (SESSIT; Helin *et al.*, 2021; D6.3) was shown to offer considerable promise. Combined, these tools provide flexible and practical tools for explaining farming systems and agro-ecological transitions.

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Future research using these complementary approaches could provide insights to other farming systems, not studied in UNISECO, or changes in systems through time with feedback loops between the outcomes and new updated inputs to specific variables in sub-systems.

7. CONCLUSIONS

Overall, the Social-Ecological Systems framework provided a value tool with which to set out the roadmap of the UNISECO project, and to summarise and visualise the complexity of the farming systems being studied. In turn, this aided in narrowing the high level issues to discussion of the local context of individual case studies.

The experience gained in UNISECO shows that numerous further uses of Social-Ecological Systems framework are possible. Conceptually, it was most effective at capturing and representing the status quo. Its application was most effective at local and regional levels. Its use aids dealing with high levels of complexity in the assessment of farming systems at the level of case studies (Landert *et al*., 2019; D3.1) and their governance (Vanni *et al*., 2019; D5.2).

It can be very effectively applied in specific farming systems and types of agriculture, with aims of understanding drivers and barriers mainly related to specific actors and forms of governance, environmental issues and related policies, and policy design and implementation. However, the experience of its use at local and regional levels suggests that the Social-Ecological Systems framework would not have been practical to use at a European level, or would have risked being superficial in its content and thus the value of the interpretation.

The practice validation identified limitations of the framework. It is static rather than dynamic nature meant it was less effective at adjusting to reflect changes and impacts of drivers and barriers on the system as a whole. The links between this systems approach and the dynamics of the transition are limited, with a challenge to identify and represent the barriers and drivers at different stages of transition.

Other characteristics which were considered to be weaknesses were the relatively high number of variables for which to colect data, creating complexity with its application, and the difficulties in distinguishing between some variables.

A level of understanding of the concept by the research teams was found to be highly beneficial, reflecting the complexity of the variables and their interpretation. That understanding helps in articulating the concept of the farming system, and the agro-ecological transition. Its core sub-systems and their connectivity lend themselves to explanation by narratives, using tools such as story maps (e.g. Landert *et al*., 2021; D3.6), and more broadly across the different biophysical and socio-economic contexts of Europe by providing a set of story maps within a suitable spatially explicit interface (Helin *et al*., 2021; D6.3).

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10. APPENDIX: QUESTIONNAIRE ON THE SOCIAL-ECOLOGICAL SYSTEMS FRAMEWORK

10.1. Presentation of the Questionnaire

Survey URL:

https://enquete.isara.fr/index.php/763672/lang-en

Practical validation of the SES conceptual framework and recommendations for future applications.

The following survey comprises a set of closed (Likert Scale) and open questions.

Please ensure that you provide complete answers to the open questions.

Responses required from: Work Package xx Leader, Task xx Leader (and co-leaders), in charge of the case study, in charge of leading the local Multi-Actor Platform (inside or outside your institution according to your specific organisation for UNISECO project)

Depending on the organisation several questionnaires may be completed by each partner.

Reminder of the objectives of the Social-ecological System framework:

- Identification and analysis of barriers and drivers towards agro-ecological transition (SES diagnosis in each case study)
- Establishing linkages between Work Packages under the umbrella SES framework
- The SES framework has been used in several Work Packages
    - Work Package 3 (assessment at farm level);
    - Work Package 5 (governance and policy assessment) SNA (social network analysis);
    - Work Package 6 (integrated sustainability assessment, end-user tools and recommendations);
    - Work Package 7 (multi-actor engagement)
- Contribution to the sustainability assessment of farming systems in Europe (with other Work Packages, especially Work Package 6)

Completing the questionnaire takes around 1h:30mins; a little longer for Work Package and Task leaders.

There are 27 questions in this survey.

10.2. Copy of the Questionnaire Circulated to UNISECO Partners

1. Respondent

1.1 Name:

Please write your answer here:

1.2 Institution and Case Study

Please write your answer here:

1.3 Function in UNISECO for which you are completing this questionnaire:

Please write your answer here:

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Possible responses: Work Package xx Leader, Task xx Leader (and co-leaders), in charge of the case study, in charge of leading the local Multi-Actor Platform (inside or outside your institution according to your organisation), other. If you perform more than one function please state here.

NB:

- Depending on your function, some questions are less important than others, this is specified at the beginning of each part of the survey.
- If you are the leader of more than one task or if you have several functions in UNISECO, consider your different responsibilities when responding to the question. Please specify for which responsibility you are providing the answer.

PART 1: DIAGNOSIS OF THE SES OF YOUR CASE STUDY (FOR ALL TYPES OF RESPONDENTS)

1. What is your overall assessment of the relevance of the SES framework to identify and analyse the dynamics of agriculture of your case study?

Please choose only one of the following:

○ Excellent

○ Good

○ Average

○ Poor

Comment on your choice here:

NB: The SES framework refers to Guisepelli *et al*. (2018; D2.1) practical use of SES framework is detailed in Milestone (MS10): Guidelines for data collection/outlines for assessments in SES (xx reference xx)

2. What is your assessment of the relevance to use the SES framework to identify the main drivers and barriers towards agro-ecological transition?

Please choose only one of the following:

○ Excellent

○ Good

○ Average

○ Poor

Comment on your choice here:

3. What is your assessment of the relevance of the SES framework to assess the impacts of policies in your case study (to addressing the key dilemma and the agro-ecological transition)?

Please choose only one of the following:

○ Excellent

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○ Good

○ Average

○ Poor

Comment on your choice here:

4. What is your assessment of the relevance of the SES framework to characterize the sustainability of the farming systems (in your case study)?

Please choose only one of the following:

○ Excellent

○ Good

○ Average

○ Poor

Comment on your choice here:

5. What specific difficulties were encountered in applying SES framework?

Please choose the appropriate response for each item:

	Strongly agree	Agree	Disagree	Strongly disagree
The guidelines to undertake the diagnosis are well designed (Milestone MS10)	○	○	○	○
The number of variables to assess is too high	○	○	○	○
I faced difficulties in collecting the relevant data	○	○	○	○
Establishing the links between variables is difficult	○	○	○	○
The reliability of conclusions is low	○	○	○	○
A SES characterization provides a synthesis of drivers, barriers, key dilemma, sustainability	○	○	○	○

In the table above, for each statement specify your level of agreement

6. Here refer to the other difficulties not mentioned in the table, and comment on your answers to the questions above

Please write your answer here:

7. Explain how to improve the limits mentioned above

Please write your answer here:

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PART 2: EXCHANGES AND DEBATES WITH STAKEHOLDERS IN THE LOCAL MULTI-ACTOR PLATFORM

(respondents: only person in charge of the local map)

1. Did you present the SES framework (principle and concept) in discussions with your local MAP?

Please choose only one of the following:

○ Yes

○ No

Comment on your choice here:

2. Did you present the results of the SES analysis in discussions with your local MAP? (e.g. in the form of a figure or table characterising all or some of the sub-systems and their variables)

Please choose only one of the following:

○ Yes

○ No

Comment on your choice here:

If you answered 'No' to the two previous questions go to Part 3, on the use of using SES as an umbrella framework

if you answered 'Yes' to one of the two previous then please also complete the three following questions.

3. In a few sentences. explain when, how and for what purpose you used the SES framework and/or the results of the SES diagnosis (e.g. to discuss drivers and/or barriers)

Please write your answer here:

Only answer this question if you answered 'Yes' to one of the two previous questions, then please also complete the three following questions.

4. What is your assessment of the relevance of such use for discussions?

Please choose only one of the following:

○ Excellent

○ Good

○ Average

○ Poor

Comment on your choice here:

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Explain in a few sentences the strengths, weaknesses and difficulties of the SES for such use and the type of use to which it was put can be improved.

PART 3: USING SES FRAMEWORK AS AN UMBRELLA FRAMEWORK TO ESTABLISH LINKAGES BETWEEN WORK PACKAGES

Respondents: All types of respondents should answer question 1 to 3. WORK PACKAGE and Task Leaders only answer Questions 4 to 7.

In Part 3, if you are Leader of more than one Work Packages or Task, please specify your response for each of your responsibilities

1. What is your assessment of the relevance to use the SES framework as an umbrella framework for UNISECO?

Please choose only one of the following:

○ Excellent

○ Good

○ Average

○ Poor

2. What were the strengths, weaknesses and difficulties in the use of the SES framework? (please write your response below in one or two sentences)

Please write your answer here:

3. In a few sentences explain how what improvements can be made to the type of use to which the SES framework was put.

Please write your answer here:

If you are not Work Package or Task Leader go directly to Part 4

4. Did you use SES framework as an umbrella framework in the Work Package or Task for which you were responsible (or co-responsible)?

Please choose only one of the following:

○ Yes

○ No

If you answered 'No' to Question 4, go to Part 4 on the use of the SES framework to contribute to an integrated sustainability assessment at European level

If you answered 'Yes', then please also complete the three following questions.

5. Explain in a few sentences why and for what purpose it was used? (Please cross-reference the relevant Deliverable or output and specify the relevant page)

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Please write your answer here:

6. What is your assessment of the relevance of the SES diagnosis for this specific use?

Please choose only one of the following:

○ Excellent

○ Good

○ Average

○ Poor

7. What were the strengths, weaknesses and difficulties of the SES framework for such a use?

Explain in a few sentences how the type of use to which it was put can be improved.

Please write your answer here:

PART 4: USING SES TO CONTRIBUTE TO AN INTEGRATED SUSTAINABILITY ASSESSMENT AT EUROPEAN LEVEL (ALL TYPES OF RESPONDENTS)

1. What is your assessment of the relevance of the use of the SES framework to contribute to an integrated sustainability assessment? (This question relates to Task 3.5 and mainly Task 6.2)

Please choose only one of the following:

○ Excellent

○ Good

○ Average

○ Poor

Comment on your choice here:

Please comment on the strengths, weaknesses and difficulties of the SES framework for such a use and how can it can be improved for such a use.

PART 5: HOW SHOULD THE SES APPROACH BE TAKEN FORWARD IN OTHER RESEARCH TOPICS, AND WHAT SHOULD BE TAKEN INTO ACCOUNT?

1. List three to five research topics for which the SES framework could be used and, if possible, specify the adaptations that would be necessary or useful for those applications.

Please write your answer here:

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Example response: identification and analysis of factors explaining the success or the failure of local projects to reduce water pollution.

2. List three to five practice oriented topics (e.g. to design and implement a local development project) for which the SES framework could be used and, if possible, specify the adaptations that would be required for such use.

Please write your answer here:

Example response: design of an action plan to improve water quality on a sensitive area.

PART 6: ADDITIONAL COMMENTS (ALL TYPES OF RESPONDENTS)

1. Please add any additional comment you wish to make:

Please write your answer here:

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