LIFT

Low-Input Farming and Territories – Integrating knowledge for improving ecosystem based farming

Research and Innovation action: H2020 – 770747
Call: H2020-SFS-2016-2017
Type of action: Research and Innovation Action (RIA)
Work programme topic: SFS-29-2017
Duration of the project: 01 May 2018 – 30 April 2022

Territorial sustainability of ecological farming

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DELIVERABLE D5.2

Workpackage N°5

Due date: M48

Actual delivery date: 29/04/2022

Dissemination level: Public

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770747

About the LIFT research project

Ecological approaches to farming practices are gaining interest across Europe. As this interest grows there is a pressing need to assess the potential contributions these practices may make, the contexts in which they function and their attractiveness to farmers as potential adopters. In particular, ecological agriculture must be assessed against the aim of promoting the improved performance and sustainability of farms, rural environment, rural societies and economies, together.

The overall goal of LIFT is to identify the potential benefits of the adoption of ecological farming in the European Union (EU) and to understand how socio-economic and policy factors impact the adoption, performance and sustainability of ecological farming at various scales, from the level of the single farm to that of a territory.

To meet this goal, LIFT will assess the determinants of adoption of ecological approaches, and evaluate the performance and overall sustainability of these approaches in comparison to more conventional agriculture across a range of farm systems and geographic scales. LIFT will also develop new private arrangements and policy instruments that could improve the adoption and subsequent performance and sustainability of the rural nexus. For this, LIFT will suggest an innovative framework for multi-scale sustainability assessment aimed at identifying critical paths toward the adoption of ecological approaches to enhance public goods and ecosystem services delivery. This will be achieved through the integration of transdisciplinary scientific knowledge and stakeholder expertise to co-develop innovative decision-support tools.

The project will inform and support EU priorities relating to agriculture and the environment in order to promote the performance and sustainability of the combined rural system. At least 30 case studies will be performed in order to reflect the enormous variety in the socio-economic and bio-physical conditions for agriculture across the EU.

Project consortium

No.	Participant organisation name	Country
1	**INRAE – Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement**	**FR**
2	VetAgro Sup – Institut d'enseignement supérieur et de recherche en alimentation, santé animale, sciences agronomiques et de l'environnement	FR
3	SRUC – Scotland's Rural College	UK
4	Teagasc – Agriculture and Food Development Authority	IE
5	KU Leuven – Katholieke Universiteit Leuven	BE
6	SLU – Sveriges Lantbruksuniversitet	SE
7	UNIBO – Alma Mater Studiorum – Universita di Bologna	IT
8	BOKU – Universitaet fuer Bodenkultur Wien	AT
9	UBO – Rheinische Friedrich-Wilhelms – Universitat Bonn	DE
10	JRC – Joint Research Centre – European Commission	BE
11	IAE-AR – Institute of Agricultural Economics	RO
12	KRTK – Közgazdaság – és Regionális Tudományi Kutatóközpont	HU
13	IRWiR PAN – Instytut Rozwoju Wsi i Rolnictwa Polskiej Akademii Nauk	PL
14	DEMETER – Hellinikos Georgikos Organismos – DIMITRA	GR
15	UNIKENT – University of Kent	UK
16	IT – INRAE Transfert S.A.	FR
17	ECOZEPT Deutschland	DE

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1. Summary

This Deliverable 5.2 of the LIFT project presents a territorial level sustainability assessment of alternative scenarios for the adoption of ecological farming approaches for 16 case study areas across Europe. Given that there are many approaches to sustainability assessment depending on the theoretical framework, the assessment's aims, and data used, this deliverable begins with a review of the sustainability assessment literature in relation to agriculture and territorial scale issues, to identify the most appropriate methodology for this deliverable. The limited availability of landscape-scale data, the use of scenarios, and the need to rapidly apply a straightforward methodology across diverse case study areas, favoured a qualitative assessment of each adoption scenario in terms of their impacts against a set of regionally-specific sustainability objectives. Moreover, because territorial impacts can reflect many interacting cause-effect relationships, network analysis formed an optional extension to the assessment, to explore the patterns of influence underpinning scenario performance.

In order to define the sustainability objectives for assessment, an initial long list of possible objectives was created through a review of the academic literature and relevant regional policy documents, followed by a round of stakeholder consultation to produce a final short list of objectives for each case study area. Performance against these objectives was assessed for four ecological farming adoption scenarios that differed in terms of the rate (either high or low) and distribution (clustered or dispersed) of adoption in 10 years' time. The ecological practices being adopted in these scenarios were identified based on the output of Delphi exercises with stakeholder panels for each case study area, conducted as part of previous research in LIFT.

Drawing on results from LIFT, local literature, and expert knowledge, each scenario was described as the product of a set of drivers of change. The drivers of change were tabulated against the objectives to produce an assessment matrix for each scenario. Groups of experts and stakeholders completed these matrices by deciding whether the state of each driver in each scenario had a positive or negative, strong or weak, impact on each objective. The different driver impacts on each objective were aggregated to show the scenario's overall performance against each objective. For the High Weald case study area in England, the assessment matrices were also used to create network graphs to show the interacting cause-effect relationships between drivers and impacts, and network analysis was used to identify features of the system that were especially influential in determining overall sustainability performance.

Based on this qualitative mapping of impacts against sustainability objectives, across case study areas, territorial sustainability performance was assessed to be strongest when the ecological farming adoption rate was high, and when adoption occurred in a clustered distribution (although the impact of adoption distribution was typically smaller than the impact of adoption rate). The same overall pattern was also reported when considering only the environmental and social dimensions of sustainability, but economic sustainability performance was only impacted by the rate, and typically not the distribution, of adoption.

These results suggest that the practices identified by stakeholders as relevant to future ecological adoption scenarios for a given case study area tend to be appropriate for achieving the area's specific sustainability objectives, and that the spread of ecological farming approaches, at least in some areas, has the potential to deliver 'win-win-win' outcomes that reconcile performance across different sustainability dimensions. However, no one scenario was best for every objective in a case study area, so even if high clustered adoption of ecological farming makes an overall positive contribution to sustainability at the territorial level, realising this scenario in practice will still involve navigating some trade-offs between objectives.

By extending the methodology to include network analysis, the sustainability assessment for the High Weald highlighted pathways and barriers that could be important in accounting for differences in scenario performance. In particular, information exchange among farmers on the benefits of ecological practices (facilitated by strong organisational and advisory support, and the use of technology) was a key contributor to the strong territorial sustainability performance of a high clustered adoption scenario. The network graphs produced for the High Weald also provided some indication as to how the territorial sustainability performance of ecological farming is due to a combination of farm-level and landscape-level processes, and suggested areas of interaction between these farm and landscape-level processes. As an example, strong interpersonal relationships among farmers could enhance information exchange that promotes ecological practice uptake on individual farms, but also encourage greater coordination of land management and collaboration between farmers.

While the combination of scenario analysis, qualitative impact mapping and network analysis has been used for sustainability assessment before, in this case scenario development was built around alternative outcomes for the spread of agricultural land management practices, rather than starting with particular philosophies about the direction of society or policy. A key challenge, and priority area for further innovation, could be to reconcile the approach presented here with farm-level sustainability assessments, helping to identify areas of alignment or disconnect between farm and territorial level performance.

2. Introduction

Different approaches to farming are associated with different types of positive and negative impacts (Abler 2004; Renting et al. 2009; Jespersen et al. 2017). The concept of sustainability provides a framework that can be applied to comprehensively evaluate and compare the performance of different farming approaches, accounting for the full variety of social, economic, and environmental costs and benefits (Smith & McDonald 1998; Pretty 2008; Gerrard et al. 2012). However, the performance of different farming approaches is typically closely linked to the wider landscape and territory where they are implemented, and so impacts may be influenced by the spatial configuration as well as rate of adoption (Smith & Mcdonald 1997; Gabriel et al. 2010; Winqvist et al. 2011; Batáry et al. 2011; Tuck et al. 2014). Therefore, the sustainability performance of ecological farming approaches[1] must account for their impacts at the regional or territorial scale, as well as at the farm level (Smith & Mcdonald 1997; Graymore et al. 2008).

Research in LIFT addresses this problem by conducting a sustainability assessment of the adoption of ecological approaches to farming at the territorial level. To assess how adoption impacts play out at this level, the methodology used here combines a qualitative sustainability assessment framework with scenario and network analysis tools. Territorial scenarios for the adoption of ecological approaches are assessed in terms of their performance against a set of regionally specific sustainability objectives. The interacting cause-effect relationships that produce the differences in sustainability

[1] Ecological practices are understood in LIFT as low-input practices and/or practices that are environmentally friendly. The originality of LIFT in this view is not to focus on a specific type of ecological approaches, but to cover the whole continuum of farming approaches, from the most conventional to the most ecological, including the widest range of ecological approaches. This comprises the existing nomenclatures such as organic farming, low-input farming, agroecological farming, etc. It also encompasses approaches that are not yet part of a nomenclature, but that can be identified with various criteria such as management practices, on-farm diversification etc.

performance are mapped using network graphs, and these networks are then analysed using graph theory tools to identify critical paths and possible barriers for sustainability performance. This methodology draws upon diverse multidisciplinary information from LIFT, combined with stakeholder input at multiple stages throughout the assessment. This deliverable is based on the collaborative work in the LIFT project, involving most LIFT partners, led by UNIKENT (UK).

The deliverable is structured as follows. In section 3, we review the relevant literature on sustainability assessment approaches, considering their suitability for a territorial assessment of ecological farming under different adoption scenarios, to provide a justification for our approach. In section 4, we describe the steps that make up the chosen methodology for this assessment. In section 5, we present the results of the assessments from each case study area. Finally, in section 6, we discuss some key findings and insights generated by interpreting the assessment results across the different territories and consider further implications of the methodology used here.

3. Review of sustainability assessment methods

3.1. Introduction to sustainability assessment

Sustainability has been subject to a range of definitions and interpretations that have made it challenging to define in a sufficiently meaningful or practical way that it allows it to be operationalised and measured (Pope et al. 2004). However, the sustainability literature does identify some consistent recurring themes associated with the use and discussion of the sustainability concept. Most definitions of sustainable development tend to place an emphasis on the need for maintaining resilience and robustness in environmental and social systems through meeting a set of interdependent environmental, social and economic conditions (Swart et al. 2004). Different conceptualisations of sustainability represent these conditions in different ways: for example, the ‘triple bottom line’ concept frames sustainability in terms of interrelated ‘pillars’ that support a sustainable state, while the ‘deep green’ approach frames sustainability in terms of a set of nested circles, where the economic domain is nested inside the circle of society, which in turn lies within the circle of environment (Gibson 2001; Swart et al. 2004).

The application of sustainability concepts to impact assessment has led to the development of a range of approaches for sustainability assessment, in which the implications for sustainability associated with an initiative are evaluated (Pope et al. 2004). In this context, ‘sustainability assessment’ can be considered an umbrella term that encompasses a variety of processes that aim to integrate sustainability concepts into decision-making processes (Pope et al. 2004; Pope 2006). Although a lack of a clear, precise methodological definition has been cited as a weakness of the sustainability assessment framework, this vagueness also acknowledges the importance of context and pluralism when considering sustainability, so that sustainability assessment can be designed to fit the relevant decision context for the system being assessed (Bond et al. 2012). There is no one overarching framework for sustainability assessments in the academic literature, with publications reflecting divergent approaches, techniques and terminologies (Büyüközkan & Karabulut 2018). A diverse range of methods and tools for sustainability assessment have therefore been developed, that make it possible to compare progress towards sustainability under different projects or policies (Gasparatos & Scolobig 2012; Fauré et al. 2017). While the choice between sustainability assessment tools is usually decided by practical considerations, tools differ in their assumptions about what needs to be measured and how, and what are the relevant and legitimate perspectives on sustainability, so the theoretical basis of different tools should not be neglected when selecting an assessment technique (Gasparatos & Scolobig 2012).

Broad distinctions can be made between different groups of sustainability assessment tools and frameworks according to their purpose. Some are designed for evaluating the current sustainability of an existing system, and may be used to compare sustainability performance within specific systems, or compare progress against reference points or baseline values (Bockstaller et al. 2015; Inwood et al. 2018). Sustainability assessment is also applied to the comparison of possible alternative future scenarios, and in this context, can be used as a tool in planning or policy development, or simply as an exploratory approach to guide decision-makers (Gasparatos & Scolobig 2012; Bockstaller et al. 2015; Inwood et al. 2018). This review gives an overview of the different methods that can be used for sustainability assessment, and based on this, considers which of the available methods are best suited for a scenario-based sustainability assessment of ecological farming conducted at a territorial scale.

3.2. Indicator-based approaches

Sustainability indicators represent quantifiable and measurable attributes of a system that are related to specific aspects of its sustainability, and are the basis for a range of index-based assessment tools for measuring a system's overall sustainability (Pannell & Schilizzi 1999; Ness et al. 2007; Dillon et al. 2016). Indicator-based assessments have seen widespread adoption, being a useful means of understanding the current state of a system, and measuring progress towards (or away from) a goal (Bausch et al. 2014). In particular, a range of indicator-based tools have been developed to assess the sustainability performance of agricultural systems (Dillon et al. 2016). These tools deliver a holistic evaluation of farm sustainability performance (accounting for environmental, social, and economic aspects of sustainability), to support farmers in improving management, and help policy makers analyse policy impacts (Meul et al. 2008; Gaviglio et al. 2017; Stylianou et al. 2020). The tools therefore tend to comprise a set of environmental, social, and economic indicators, typically developed through some combination of literature review and expert consultation (Paracchini et al. 2015; Gaviglio et al. 2017).

Depending on the tool, indicator values representing the current state of the system can be calculated using quantitative data, qualitative data, or a combination of the two. A mixed-methods approach is therefore often necessary, and data collection may draw on both primary and secondary data sources, and involve a mix of farm survey or census information, direct field observations, spatial analysis, sampling, model estimates, farmer records, and farmer or other declarations in interviews or focus groups (Meul et al. 2008; Bausch et al. 2014; Antwi et al. 2017; Soldi et al. 2019; Stylianou et al. 2020).

The results of an indicator-based assessment may take the form of the set of sustainability indicators presented individually, or one or a few composite indicators may be generated by combining individual indicators into aggregated indices (Büyüközkan & Karabulut 2018). Tools using composite indicators must synthesise diverse types of data and therefore tend to use aggregation techniques to remove indicator-specific units and visualise sustainability at the thematic or dimensional level (Inwood et al. 2018). The data collected are converted into (typically weighted) scores for individual indicators that are then aggregated to generate scores for composite indicators (Paracchini et al. 2015; de Olde et al. 2017; Trivino-Tarradas et al. 2019; Soldi et al. 2019; Paraskevopoulou et al. 2020).

The aggregated overall indicator score (or set of scores) can be used to monitor progress on individual farms (Meul et al. 2008; Dillon et al. 2016), or for comparing the performance of different farms (Gaviglio et al. 2017; Soldi et al. 2019). If the assessment is conducted across a sample of farms that are representative of a particular sector, then assessment results could be used to draw conclusions about the sustainability of this sector or farming system (Curran et al. 2020). If the assessment is conducted across multiple farms representing a range of farming systems, then as well as comparing individual farms, assessment tools can compare the performance of different farming systems (Berbeć et al. 2018; Landert et al. 2020; Paraskevopoulou et al. 2020; Stylianou et al. 2020).

Although composite sustainability indices have been widely used for agricultural assessments, owing to their ease of use, and their suitability for clearly communicating results to a non-technical audience, their usage has also come under some criticism. The methods used to create composite indices often assume that low performance in one indicator can be offset by higher performance in another indicator, so the resulting composite index may overlook trade-offs and compromises, generating arbitrary and misleading results, and distorting assessment outcomes (Böhringer & Jochem 2007; Morrison-Saunders & Pope 2013). The process of aggregating indicators can also be associated with information loss, and may fail to account for complexities due to interdependencies among indicators (Büyüközkan & Karabulut 2018). The validity of composite indicators is therefore heavily dependent on the methods used to weight and aggregate their component indicators (Gan et al. 2017).

Moreover, while dozens of indicator-based assessment frameworks have been developed for use in the agricultural sector, they tend not to be applicable to the patterns and processes in agricultural landscapes, which currently have to be assessed using a distinct type of tool compared to that used at the farm level (Inwood et al. 2018). There is little published literature concerning applying sustainability metrics at the territorial level, especially when compared to indices for sustainability at a local or site level (Nogués et al. 2019). Many indicator-based tools for agricultural sustainability are specifically targeted towards individual farm systems, and would be difficult to apply at a larger scale because the data collection methods focus on farmer records that are unlikely to include landscape parameters (Inwood et al. 2018). However, there is considerable potential to develop landscape-scale performance indicators for use in sustainability assessments. In particular, environmental performance of agriculture at the landscape level has already been extensively studied through the use of ecosystem service mapping and modelling tools, allowing policy makers and land managers to assess the outcomes of different management approaches or land use changes in terms of ecosystem service delivery (Daily et al. 2009; Malinga et al. 2015; Tomlinson et al. 2018). Geo-referenced databases for environmental, social, and economic impacts of agriculture could be combined and linked to spatial modelling approaches, as a way to calculate input data for sustainability indicators relevant to agricultural landscapes, although the associated increase in data complexity may require further assessor training and support (Inwood et al. 2018).

3.3. Sustainability assessment and scenarios - modelling

Ex ante sustainability assessments of alternative scenarios have been widely used to inform planning and policy, but there is no single tool in the literature that can be universally applied to these types of assessment (Fauré et al. 2017). The aims of the assessment, and the nature of the scenarios being developed, determine the most appropriate approach in each case (Fauré et al. 2017).

When evaluating the sustainability of alternative futures or proposals, rather than the current state of a system, an indicator-based assessment requires future values of indicators to be estimated. Using sustainability indicators to assess proposed projects or strategies could be achieved through the use of expert knowledge to suggest plausible changes under different scenarios, which can be used to calculate or estimate future indicator values associated with each scenario (Kuzdas et al. 2016; Nogués et al. 2019; Shah et al. 2020; Barron et al. 2021). Assumptions made for different scenarios can be applied to models that quantify future values of key system parameters, and subsequent model simulations can be used to generate future indicator values that reflect sustainability performance under each scenario (Oudshoorn et al. 2011). Model simulations have therefore been used to support the sustainability assessment of alternative scenarios. Once the problem and the boundaries of the system have been defined, and a hypothesis has been formulated, simulations can be run to test the performance of each scenario (Timma et al. 2020).

Combining modelling and quantitative scenario analysis, with projections of change drawing on information from past trends and different economic forecasts, has been used to assess the environmental performance of alternative futures for agriculture (Rega et al. 2019), and plays a central role in impact assessment to inform European agricultural policy (Britz & Witzke 2014; European Commission 2021). There is therefore considerable opportunity for quantitative indicator-based sustainability assessment tools to be developed for use with scenario research (Fauré et al. 2017). However, the nature of scenario analysis also makes it well suited for integration with qualitative methods. Some researchers have expressed concern over the use of quantitative data to assess long-term scenarios associated with more transformational change, given that the resulting quantitative outcome could give a misleading impression of accuracy and precision in our understanding of future performance (Höjer et al. 2008). The purpose of scenario analysis is not to precisely quantify the future performance of a given option, but to illustrate the range of possibilities for a given system, and therefore provide decision makers with a better understanding of the space for manoeuvring within (Peterson et al. 2003; Aligica 2005). Therefore, qualitative methods can be especially appropriate for assessing scenarios, particularly when considering longer-term, transformative scenarios, and more generally, the inherent uncertainties involved in discussing futures mean that qualitative approaches tend to better reflect the basic premise of most scenario-based research (Höjer et al. 2008; Arushanyan et al. 2017).

3.4. Sustainability assessment and scenarios – objective-led assessments

The evaluation of alternative futures has therefore involved a range of assessment methods that are not based on the calculation of quantitative sustainability indicators (Ness et al. 2007). Scenario-based assessments may rely on the qualitative ‘mapping’ of impacts on different aspects of sustainability (Fauré et al. 2017). The qualitative evaluation of sustainability impacts under a given scenario can be used to assess alternative scenarios in terms of their potential to contribute towards or prevent the achievement of sustainability objectives (Sheate et al. 2008; Baard et al. 2012).

Under this approach, each scenario can be framed as a set of causal links between drivers of change and impacts on sustainability objectives. The use of objectives distinguishes this approach from other ‘baseline-led’ sustainability assessment methodologies: a sustainability assessment requires a metric for sustainability performance to be assessed against, which can take the form of baseline standards or aspirational objectives (Pope et al. 2004). Baseline-led approaches have been criticised by sustainability researchers as being directionless, simply extrapolating from past trends without a clearly defined vision of what a sustainable future should look like (Pope et al. 2004; Hacking & Guthrie 2006). The alternative is for assessments to be performed against aspirational objectives that target positive change, reflecting a view of sustainability as a goal, or series of goals, to which society is aspiring (Pope et al. 2004). This objective-led approach, as well as providing a direction to the assessment, can simplify the process of communicating assessment results to stakeholders and policy makers, succinctly demonstrating how to achieve policy targets and minimise trade-offs (Pope et al. 2004; Olsson et al. 2009). However, while the baseline-led approach to sustainability assessment has seen widespread application in research and policy, the objective-led approach has little representation in current sustainability assessment practice outside of policy-making in England, which has been dominated by objective-led sustainability appraisal for decades (Smith & Sheate 2001a; Pope et al. 2017).

An objective-led sustainability assessment depends on establishing well-defined environmental, social, and economic objectives, against which the assessment can be performed (Pope et al. 2004). Moreover, given increasing acknowledgement that sustainability is a 'normative' concept that lacks a universal definition, and is subject to individual value judgements, when considering sustainability performance, what objectives are associated with sustainability must be identified on a case-by-case basis (Bond et al. 2012). Therefore, the assessment process must begin by defining the objectives that must be achieved to create a sustainable system, according to the assessment context (Girardin et al. 2000; Gibson 2001; Pope et al. 2004; Payraudeau & Van Der Werf 2005).

Various commentators have highlighted desirable features for sustainability objectives: such objectives should be context-specific, and as concrete, meaningful, practical, comprehensive and credible as possible (Gibson 2001; Pope et al. 2004). However, there may be difficulties in reconciling these different requirements. Comprehensive objectives may be all-encompassing and holistic, but this can make them less concrete and therefore harder to assess (Hacking & Guthrie 2006). On the other hand, an objective-led approach may be more likely to identify possible synergies and 'win-win-win' outcomes between the different pillars of sustainability, helping to navigate around undesirable conflicts and trade-offs (Pope et al. 2004). However, in order to ensure this, the objectives agreed upon should be designed, as far as possible, to reflect stakeholder needs (Pope et al. 2004).

Canvassing stakeholder opinion is widely used as a means of generating a list of relevant sustainability objectives. The normative nature of the sustainability concept means that some form of stakeholder engagement is needed at the start of the sustainability assessment process, to identify what a sustainable future will look like (Bond et al. 2012). However, the sustainability assessment literature has also highlighted some challenges that must be addressed if sustainability objectives are to be defined with stakeholder input. Stakeholder consultation should account for people's self-interest and tendency to overlook the long-term consequences of their decisions: the concerns of future generations may not always be fully acknowledged by stakeholders, and yet are key to sustainable development, and should not be neglected (Hacking & Guthrie 2006). Even when stakeholder consultations emphasise the need to target sustainable development, the contributions of stakeholders can be frustrated by knowledge gaps or ulterior motives (Hacking & Guthrie 2006).

Alongside stakeholder consultation, sustainability objectives are frequently derived directly from conceptualisations of sustainability, particularly the 'three-pillar' or 'triple bottom line' models, which generate objectives that are grouped into separate environmental, social, and economic categories (Gibson 2001; Pope et al. 2004). The use of these models to guide selection of objectives has been criticised for being divisive and reductionist, emphasising competition and conflicts between objectives, rather than on the potential to accommodate interconnected human and environmental interests simultaneously (Gibson 2001; Pope et al. 2004). This has led some authors to call for an alternative approach to defining objectives, beginning instead with a set of principles for sustainability, that encompass key societal changes needed for progress towards sustainability (Gibson 2001; Pope et al. 2004). However, although sustainability principles may help guide selection of objectives at a general level, determining more specific and targeted objectives that are meaningful for an assessment tends to require reference to environmental and socio-economic components of sustainability, making a compartmentalised approach, such as the three pillar format, unavoidable (Hacking & Guthrie 2006).

Designing sustainability objectives by starting with general principles and then applying further refinement as the objectives become increasingly specific also underpins the idea of 'tiering' in the design of sustainability objectives. This involves 'trickling down' objectives from higher to lower levels of planning: for instance, in the United Kingdom (UK), where the use of sustainability appraisal is widespread in planning and policy, regional sustainability objectives are developed with reference to national and international sustainability strategy (Smith & Sheate 2001b, 2001a). Under a tiered approach, higher level assessments set the context for appropriate objectives for assessments at lower levels in the planning hierarchy (Noble 2002; Pope et al. 2004). Ideally, in a tiered or 'vertically integrated' approach to assessment design, the sustainability objectives should be defined so that they are consistent and compatible with the objectives for assessing decisions made at both higher and lower organisational levels (Pope et al. 2004). However, tiering has also been criticised as being unrepresentative of reality, and carries a risk of being overly reliant on centralised planning, where centralised authorities end up imposing a single vision on different contexts (Hacking & Guthrie 2006).

3.5. Sustainability assessment and scenarios – mapping impacts on objectives

An approach to sustainability assessment that involves the qualitative mapping of impacts on bespoke sustainability objectives also requires the identification of the factors that produce these impacts: the drivers of change (Sheate et al. 2008; Partidário et al. 2009). Determining how drivers of change relate to sustainability objectives can be done initially through expert judgement: previous objective-based sustainability assessments have used group interdisciplinary meetings where experts decide whether each driver would make a positive or negative contribution to the objectives, and how these contributions could differ under different scenarios (Sheate et al. 2008; Partidário et al. 2009; Baard et al. 2012). Where possible, a basic assessment of the magnitude of each driver's positive or negative contribution, even in the form of simple ordinal measures (for example, whether the magnitude is large or small), can increase the usefulness of the assessment for decision-making over trade-offs and enhance transparency (Baard et al. 2012). The output from such a discussion consists of checklists or matrices mapping the sustainability impacts: an assessment matrix for each scenario showing how each driver relates to each objective, and a matrix comparing the scenarios, showing whether objectives are met under different scenarios (Sheate et al. 2008; Baard et al. 2012).

In order to show how each scenario contributes to sustainability objectives, the combined impact of multiple drivers on each objective under each scenario must be assessed. In some instances, particularly for qualitative assessments, this is based on consistently applied rules determined by expert judgement, according to assumptions about the ways impacts act in combination on the objectives (Sheate et al. 2008; Partidário et al. 2009). In other cases, primarily qualitative results from checklist- or matrix-based approaches to mapping sustainability impacts can be made semi-quantitative by rating impacts according to their magnitude and direction, so that they can be used as input for aggregation tools (Fauré et al. 2017).

The preliminary results from an objective-based assessment of alternative scenarios, in the form of assessment and scenario comparison matrices, can then be refined based on stakeholder input, through group discussions focusing on areas of uncertainty over impacts, preferences for different scenarios, and approaches to trade-offs (Sheate et al. 2008; Baard et al. 2012). This approach can also be used to identify goal conflicts and synergies by linking assessed impacts under different aspects of sustainability to different types of policy goals, to determine if a measure for reaching a target will help or hinder the achievement of other targets (Fauré et al. 2017).

3.6. Network analysis

Objective-based sustainability assessments of scenarios are typically used to consider complex systems, where drivers of change rarely act in isolation, and a given driver will be associated with several different impacts and consequences. In order to better understand these interactions, the methodology can be adapted by incorporating network analysis to explore causal links between drivers, impacts, and sustainability performance (Tzanopoulos et al. 2011; Boron et al. 2016). Network analysis provides a means of illustrating and understanding the relationships between entities and their influence in a system, and can be used to identify which pathways or entities play a central role in the system (Bausch et al. 2014; Fauré et al. 2017; De Nooy et al. 2018). Network analysis is a particularly appropriate tool for investigating sustainability, because a core feature of sustainability is the interconnectivity of environmental, social, and economic systems, so pursuing sustainable development depends on exploring these interrelationships, and finding ways to show how impacts on different sustainability dimensions interact (Hacking & Guthrie 2008).

The causal relationships that are identified and assessed against the set of sustainability objectives can be explored using network analysis software to generate graphical representations of the networks and find the central nodes (those aspects of the system that are most responsible for overall performance of the scenario) in the networks (Tzanopoulos et al. 2011; Boron et al. 2016). Once the network graphs are validated, they can be used as the basis for the scenario comparison matrix, summarising the scenario effects on each objective and reporting the drivers directly responsible for those effects (Boron et al. 2016). Analysis of the network graphs together with the scenario comparison matrix can then be used to inform decision-making for sustainable development. Combining scenario analysis, network analysis, and sustainability assessment is useful for taking a holistic approach to understanding systems where drivers interact at different scales affecting different aspects of sustainability (Boron et al. 2016).

3.7. Implications for a territorial assessment of ecological farming adoption scenarios

A quantitative, indicator-based approach is unsuitable for assessing the territorial sustainability of ecological farming under alternative scenarios. Since this assessment has to be conducted rapidly across many different case study areas, it would not be possible to gather the required quantitative data in time. Different study areas in different countries may differ in the type of data that is accessible at the territorial level, making it challenging to apply a consistent quantitative methodology across case study areas. Moreover, quantitative indicator-based approaches for assessing agricultural sustainability at the territorial level are still poorly developed, and the increased methodological complexity associated with using quantitative data on landscape patterns and processes could make stakeholder involvement more challenging (Inwood et al. 2018). Finally, given that the assessments are built upon a scenario-based approach, quantitative assessment tools would require predicting future values of sustainability indicators, which would be heavily reliant on assumptions that are unlikely to be valid given the explorative nature of the scenarios.

Therefore, the issues concerning landscape-scale data, the timeframes of the scenarios, and the need to quickly apply the methodology to a variety of case study areas, all suggest that a qualitative assessment of sustainability impacts would be most appropriate for this assessment. A checklist or matrix-based approach to map driver impacts against different sustainability objectives (Sheate et al. 2008; Partidário et al. 2009) provides a convenient and effective basic format for a rapid assessment. The use of an objective-led approach means that sustainability objectives must be carefully defined so that they are comprehensive and meaningful, while still being appropriate to the territorial context of the assessment, and acknowledging stakeholder perspectives (Hacking & Guthrie 2006). Tiering, conceptual models, and stakeholder consultation have all been used in generating sustainability objectives, and given the costs and benefits associated with each of these methods, this assessment will apply a combined approach to defining objectives, in an attempt to balance the strengths and weaknesses of each option.

Given that a territorial sustainability assessment considers a complex system, where drivers of change are likely to interact, network analysis would be useful for understanding the patterns of influence and causal relationships involved, and help identify those entities that are especially important for scenario performance (Tzanopoulos et al. 2011; Boron et al. 2016). Network analysis could therefore form an optional extension to the basic assessment design. Previous studies have designed assessment methodologies with both basic and optional parts depending on resources, time and participant availability (Baard et al. 2012), and taking this approach would allow flexibility in applying the methodology to different case study areas.

Finally, a recurring theme across the sustainability assessment literature, whether considering the application of specific analytical tools, or the design of the assessment procedure itself, is the need for stakeholders to be closely involved in the assessment (Morris et al. 2011; Arushanyan et al. 2017; Fauré et al. 2017). Therefore, the assessment methodology should include a strong participatory element. Stakeholder input will be required for the choosing and weighting of the objectives, selection of drivers, assessment of sustainability impacts, and identifying interactions between drivers and impacts, through the use of surveys and workshop or focus group discussions.

4. Method

Based on the literature discussed above, a qualitative approach to the territorial sustainability assessment of ecological farming was adopted, which involved the following steps for each case study area:

a. Define the specific **sustainability objectives** for the case study area
b. Identify the farming **practices and approaches** that are relevant to the adoption scenarios
c. Identify the **drivers of change** and how they contribute to each scenario
d. Complete the **qualitative assessment matrices** by determining how each driver impacts on each objective under each scenario
e. Create the **network graphs** for each scenario to show the interacting cause-effect relationships between drivers and impacts, and apply network analysis to identify critical paths and nodes
f. Refine the assessment results using **stakeholder consultation**, asking stakeholders to give their feedback on the assessment matrices for each scenario.

The methodology is illustrated in Figure 1, and below, we explain each of these steps in more detail.

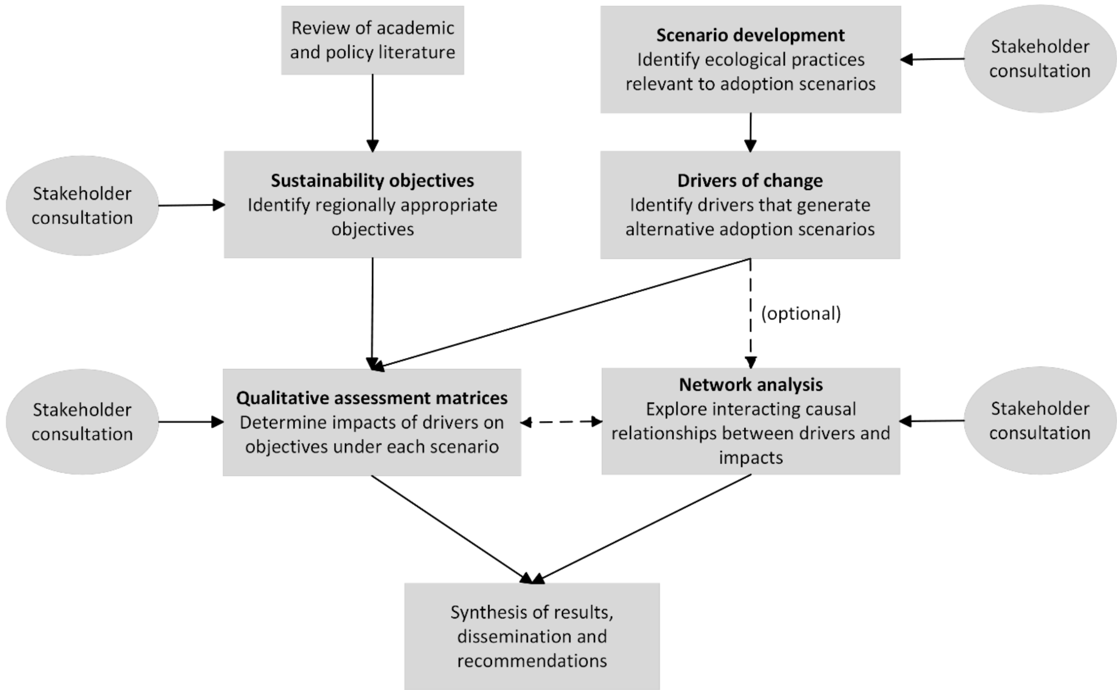

Figure 1. An overview of the sustainability assessment methodology, showing how the different steps of the process fit together, and the role of stakeholder input.

4.1. Defining the sustainability objectives

A 3-stage process was used to produce a set of location-specific sustainability objectives for each case study area. Each adoption scenario (as described in section 4.2) was assessed in terms of its performance against this set of sustainability objectives.

The first step was to produce a generic list of objectives associated with agricultural sustainability assessments. This involved screening the academic literature by using the search terms ("sustainability assessment" OR "sustainability appraisal") AND ("farming" OR "agriculture") to look for publications since 2000 in both Web of Science (screening all results) and Google Scholar (going through the first 3 pages of results), ignoring assessments for systems outside Europe. Assessments varied in the exact approach used, but they all divided the sustainability concept into a few sustainability dimensions, which were operationalised using lists of objectives (or 'attributes' or 'themes'). At this stage, we considered assessments at all spatial scales. We compared the different objectives lists, identifying areas of overlap, to consolidate them into a single generic list of objectives for a territorial-level agricultural sustainability assessment. This generic list of objectives was created once, and then shared with all participating LIFT partners. In the subsequent steps, this generic list was refined by each LIFT partner to produce a tailored list that was relevant to the specific case study area.

In the second step, the local context for the sustainability objectives in each case study area was established by reviewing national, regional, and local policy documents relevant to sustainability, that covered objectives and priorities for a range of environmental, economic, and social issues. These objectives were merged with the generic list of sustainability objectives from agricultural assessments to produce a draft list of around 50 objectives for each case study area, that reflected what sustainability meant for that case study area.

Finally, this long draft list of objectives was refined and prioritised using stakeholder input. A link to a shared access spreadsheet containing the draft list of objectives was sent to a number of stakeholders, who were asked to give their opinion on the significance of each objective for local sustainability. The guidance given to stakeholders emphasised that this was not an exercise in voting, but an opportunity to indicate which objectives resonated with them. Stakeholders rated each objective as either 'very significant', 'partly significant', 'not significant', or 'unknown', where they were unsure of the significance. Stakeholders were also invited to add their own objectives that they felt might be missing from the list, which could be specific to their area of expertise or the field they work in, or more general. A shared spreadsheet was used to collect stakeholder views on the objectives, in an effort to encourage stakeholders to reflect on their answers, allowing them to refine and revisit their preferences based on how others had scored the objectives (for example, if another stakeholder added another objective that they had not originally considered).

Based on the significance assigned by the stakeholders to each objective, the most important objectives from each of 4 sustainability themes (environmental, social, economic, and institutional capacity) were selected (and combined where appropriate) to obtain a final list of 15-25 objectives for use in the sustainability assessment. These lists of objectives for each case study area are provided in Appendix 1.

4.2. Identifying the ecological farming practices and approaches relevant to the adoption scenarios

The subjects of the sustainability assessment were a set of 4 scenarios representing alternative futures (in 10 years' time) for ecological farming adoption in each case study area.

These scenarios that were developed differ in terms of the rate and spatial distribution of adoption:

- **Scenario 1**: **High** adoption of ecological farming (50% of farms in the case study area have converted) in a **clustered** pattern (ecological farms are close together in the landscape)

- **Scenario 2**: **Low** adoption of ecological farming (10% of farms in the case study area have converted) in a **dispersed** pattern (ecological farms are widely spaced across the landscape)

- **Scenario 3**: **High** adoption of ecological farming (50% of farms in the case study area have converted) in a **dispersed** pattern (ecological farms are widely spaced across the landscape)

- **Scenario 4**: **Low** adoption of ecological farming (10% of farms in the case study area have converted) in a **clustered** pattern (ecological farms are clustered together in the landscape)

Ecological farming encompasses a range of approaches and practices, so before the assessments could be carried out, it was necessary to clarify the specific approaches and practices that were relevant to the adoption scenarios for each case study area. This information was provided by the results from the initial round of a Delphi exercise (see Bailey et al. (2021)). In this round of questions, a panel of experts were asked to rank 12 farming practices according to their importance in defining an ecological farm within the context of the case study area. For the purposes of the sustainability assessment, the practices with the highest average ranking were selected as the practices that characterised ecological farming in the case study area's adoption scenarios (the number of practices selected was left up to the discretion of each LIFT partner, depending on the spread of the ranking averages). Other practice suggestions and participant opinions on the feasibility of different farming practices expressed during these Delphi exercises were also used to help inform the final selection of practices.

The practices chosen to represent ecological farming under the adoption scenarios could also be expressed in terms of the adoption of certain farming approaches, because the LIFT typology associated different farming approaches with particular combinations of practices (Rega et al. 2021). This meant that it was possible to link the dominant practices identified in the Delphi exercise with a specific farming typology or mix of typologies, that reflected the approaches underpinning ecological farming in the scenarios for this case study area.

4.3. Identifying the drivers of change

In order to perform the sustainability assessment, the rate and distribution of adoption in a given scenario was described as the product of a set of drivers of change. A particular type or category of driver could affect ecological farming adoption in different ways, or have different settings, depending on the scenario. Moreover, some drivers were contributing factors for one scenario, but not another, and while some drivers influenced both the rate and distribution of adoption in the scenarios, others only affected one of these variables.

Establishing the drivers of change was a 2-step process:

a. Identify and define the overarching driver categories that could shape adoption patterns in the case study area
b. For each scenario, decide which driver categories could be contributing to the given pattern of ecological farming adoption, and determine how the 'setting' of these drivers contributes to this adoption pattern

This process was informed by the results of the Delphi exercises (Bailey et al. 2021), where stakeholders considered possible reasons for different rates and distributions of adoption, as well as information from local literature, expert opinion, and researcher knowledge of the area.

4.4. The qualitative assessment matrix

The drivers of change were tabulated against the sustainability objectives selected for the case study area to produce an assessment matrix that was completed for each scenario.

Completing the matrices involved deciding whether the state of each driver in each scenario impacts each sustainability objective, and if this impact is positive or negative, strong or weak, or uncertain. Assigning impacts was initially done by interdisciplinary panels of researchers for each LIFT partner, drawing upon expert knowledge of the case study area, local literature, and output from LIFT.

These impacts on each objective were then aggregated to show the scenario's overall performance against the objectives. Impact aggregation involved the application of consistent rules in combination with expert judgement. When accounting for differences in the impact strength of magnitude, it was agreed that strong impacts should not be diluted by the presence of weaker impacts, and drivers which individually have weak impacts may combine to have an overall strong impact. When drivers had both positive and negative impacts on the same objective, the direction of the overall impact was determined based on expert judgement and discussion.

4.5. Network analysis (High Weald case study area only)

For the High Weald case study area in England, the basic qualitative impact mapping for the assessment matrices was complemented by the creation of network graphs representing the cause-effect relationships between drivers and impacts for each scenario. In these graphs, the vertices, or nodes, represented the drivers of change, their impacts, and the sustainability objectives, while the lines represented the causal relationships between them.

The lines in network graphs can be either undirected (where the order between a pair of vertices does not matter) or directed (where the order of the vertices is important) (De Nooy et al. 2018). In the networks developed for this sustainability assessment, the order of the vertices does matter, because for a given pair of vertices, one represents the cause and the other represents the effect. Therefore, these graphs were treated as directed graphs, with arrows used to signify the direction of cause and effect for each line.

These basic network graphs were then modified based on interdisciplinary researcher discussion, expert knowledge, local literature, and stakeholder consultation (as described below) to illustrate potential interactions amongst the different drivers and their impacts. The resulting pattern of interactions was then explored using the network analysis software Pajek version 5.14 (De Nooy et al. 2018).

Exploratory network analysis techniques can be used to assess a variety of vertex properties that characterise the structural position of vertices in a network, and therefore identify those vertices that are particularly well-connected and play a disproportionately important role in the network (De Nooy et al. 2018). In the context of the sustainability assessment, this means that it is possible to identify those elements of the system that are primarily responsible for a scenario's performance against the sustainability objectives.

The appropriate analysis techniques and properties to investigate vertex position depend on whether the network is directed or undirected. As described above, the lines in these network graphs represent cause-effect relationships, and therefore the network was treated as a directed network for the purpose of the analysis. In directed networks, the relative importance of a vertex can be expressed using the concept of structural prestige, where more prestigious vertices send or receive more directed connections to or from other parts of the network (Zhao et al. 2015; De Nooy et al. 2018). This idea can be expressed in terms of a vertex's influence domain: the proportion of all other vertices that are connected by a path to this vertex. Dividing this value by the mean distance from the chosen vertex to all other vertices in its influence domain gives the proximity prestige of the vertex: an index of structural prestige that gives more weight to connections from closer neighbours (Zhao et al. 2015; De Nooy et al. 2018).

Therefore, proximity prestige values were calculated for each node in the network graphs (excluding the sustainability objectives), to explore their relative importance in the network. Those nodes with the highest proximity prestige could be expected to play a pivotal role in the sustainability performance of the adoption scenario.

4.6. Stakeholder consultation

Once the initial drafts of the assessment matrices had been completed, the assessments were refined based on stakeholder input. Stakeholder involvement came at the end of the impact assessment process, rather than during, because a workshop of a few hours would have been insufficient for creating the assessment from scratch. Moreover, because the scenarios being considered were fairly nuanced (the differences between scenarios being differences in the rate and distribution of adoption rather than necessarily radical or transformative changes in society) it was harder for stakeholders to grasp the implications of the different scenarios without the framework of an existing draft assessment to refer to.

Participants for consultation were identified by targeting stakeholders known to have good knowledge or an overview of at least one of the sustainability dimensions in the case study area. These included researchers, extension officers, government representatives, and farmers (a full list of the different types of participants is provided in Appendix 2). Willing participants were briefed on the consultation process and gave their consent before taking part.

The assessment matrices (and, where applicable, the network graphs), along with a brief description of each scenario, were presented to each of the stakeholders individually via email or phone/video call. Stakeholders were asked to provide their feedback on the assessment, highlighting any impacts that they disagreed with, or giving their opinion on areas of uncertainty. The feedback from all participants was then collated and reviewed to identify any possible areas of disagreement between stakeholders, or between stakeholders and researchers. Where possible, the stakeholders were contacted again to try and resolve these disagreements.

If major disagreements persisted, participants were brought together at a workshop. These workshops sought to facilitate a discussion to try and resolve outstanding areas of disagreement and ask stakeholders to justify and explain any feedback that may have been unclear. Based on the feedback and workshop discussion, the assessment matrices and network graphs were updated to reflect the stakeholder views, and the final assessment output was then disseminated to all participants.

5. Results

This section presents the results from the assessment methodology across the case study areas. The qualitative assessments of performance for all case study areas are explored using the results from the assessment matrices. For ease of visualisation and comparison, these results are presented using radar charts, by converting the assessment scores into a simple ordinal scale (where strong positive impact = 1, positive impact = 0.5, no overall impact = 0, negative impact = -0.5, strong negative impact = -1). The results from the network analysis for the High Weald case study area in England are then presented to illustrate some of the possible pathways and interactions that could underpin the performance of the different scenarios.

5.1. Qualitative assessment matrices

5.1.1. Overview

The qualitative mapping of impacts on sustainability objectives illustrated how the rate and distribution of adoption could shape sustainability performance of rural landscapes, and how impact of adoption rate and distribution varies depending on the local context.

Rate of adoption

With regards to the rate of adoption, higher rates of adoption for ecological farming approaches were generally associated with more positive impacts on sustainability objectives compared to lower rates of adoption. For those case study areas that assessed both high and low adoption scenarios, the percentage of objectives that were positively impacted was greater under high adoption (Table 1). Only a small minority of case study areas confidently identified negative impacts on any sustainability objectives under high adoption scenarios. Conversely, low adoption scenarios were associated with a greater frequency of negative impacts (Table 1). Therefore, the assessments suggest that an increase in the proportion of farms adopting ecological farming approaches has the potential to make a largely positive contribution to territorial sustainability in range of different local contexts across Europe.

Table 1. Percentage of sustainability objectives for each case study area that were assessed to be subject to each type of impact (positive impact, no / neutral impact, negative impact, or uncertain) under the 4 different scenarios for the adoption of ecological farming practices.

Impact on objectives	High & clustered	High & dispersed	Low & clustered	Low & dispersed
Salzburg, Austria				
Positive impact	88%	81%	6%	6%
No impact / neutral	13%	19%	25%	25%
Negative impact	0%	0%	63%	63%
Uncertain	0%	0%	6%	6%
Hageland-Haspengouw, Belgium				
Positive impact	100%	95%	0%	0%
No impact / neutral	0%	5%	10%	5%
Negative impact	0%	0%	90%	95%
Uncertain	0%	0%	0%	0%
Emilia Romagna, Italy				
Positive impact	100%	95%	70%	40%
No impact / neutral	0%	5%	20%	40%
Negative impact	0%	0%	10%	10%
Uncertain	0%	0%	0%	10%
Highlands and Islands, Scotland				
Positive impact	69%	56%	0%	0%
No impact / neutral	19%	19%	13%	13%
Negative impact	0%	0%	56%	63%
Uncertain	13%	25%	31%	25%
High Weald, England				
Positive impact	88%	69%	13%	0%
No impact / neutral	6%	19%	0%	0%
Negative impact	6%	6%	69%	94%
Uncertain	0%	6%	19%	6%
North Kent, England				
Positive impact	72%	67%	6%	6%
No impact / neutral	11%	17%	28%	17%
Negative impact	11%	11%	67%	78%
Uncertain	6%	6%	0%	0%
East Crete, Greece				
Positive impact		89%	0%	
No impact / neutral		0%	11%	
Negative impact		0%	83%	
Uncertain		11%	6%	
Upper Bavaria, Germany				
Positive impact	52%			
No impact / neutral	4%			
Negative impact	20%			
Uncertain	24%			

Impact on objectives	High & clustered	High & dispersed	Low & clustered	Low & dispersed
Ille-et-Vilaine, France				
Positive impact	67%			67%
No impact / neutral	28%			28%
Negative impact	6%			6%
Uncertain	0%			0%
Sarthe, France				
Positive impact	73%			60%
No impact / neutral	20%			33%
Negative impact	7%			7%
Uncertain	0%			0%
Puy-de-Dôme, France				
Positive impact	78%			67%
No impact / neutral	11%			22%
Negative impact	0%			0%
Uncertain	11%			11%
Lubelskie, Poland				
Positive impact			95%	90%
No impact / neutral			5%	0%
Negative impact			0%	5%
Uncertain			0%	5%
Podlaskie Voivodeship, Poland				
Positive impact			85%	80%
No impact / neutral			15%	20%
Negative impact			0%	0%
Uncertain			0%	0%
Suceava, Romania				
Positive impact		85%		
No impact / neutral		15%		
Negative impact		0%		
Uncertain		0%		
South Sweden				
Positive impact		96%		0%
No impact / neutral		0%		39%
Negative impact		4%		61%
Uncertain		0%		0%
Veszprém, Hungary				
Positive impact			53%	21%
No impact / neutral			42%	58%
Negative impact			5%	21%
Uncertain			0%	0%

Distribution of adoption

Differences in sustainability performance were also identified in relation to the spatial distribution of adoption. Clustered adoption of ecological farming tended to make a more positive contribution to territorial sustainability than dispersed adoption. For case study areas that assessed both clustered and dispersed scenarios, the percentage of objectives that were positively impacted was higher under clustered adoption, and dispersed scenarios had greater frequencies of negative impacts (Table 1).

However, for 5 out of the 6 case study areas where both rate and distribution of adoption were considered, the difference in sustainability performance due to the distribution of adoption was smaller than the difference in performance due to the rate of adoption (Figure 2). This suggests that the rate of adoption of ecological approaches is a more important consideration for territorial sustainability than the distribution of adoption.

Performance in different sustainability dimensions

By categorising the different objectives for each case study area as either environmental, social, or economic, it is possible to compare the territorial performance of ecological approaches for different dimensions of sustainability.

High adoption of farming approaches characterised as ecological was associated with stronger performance (more positive impacts and fewer negative impacts) against environmental, social, and economic sustainability objectives (Figure 2).

When accounting for the spatial distribution of adoption, the impacts on environmental and social sustainability largely followed the same pattern as overall sustainability. Clustered adoption scenarios were associated with more positive environmental and social impacts compared to dispersed adoption scenarios, and the effect of spatial distribution on sustainability performance was less pronounced than the effect of adoption rate (Figure 2). However, the impact on of adoption distribution on economic performance was less clear: across most case study areas, there was minimal or no difference in economic sustainability performance between clustered and dispersed scenarios.

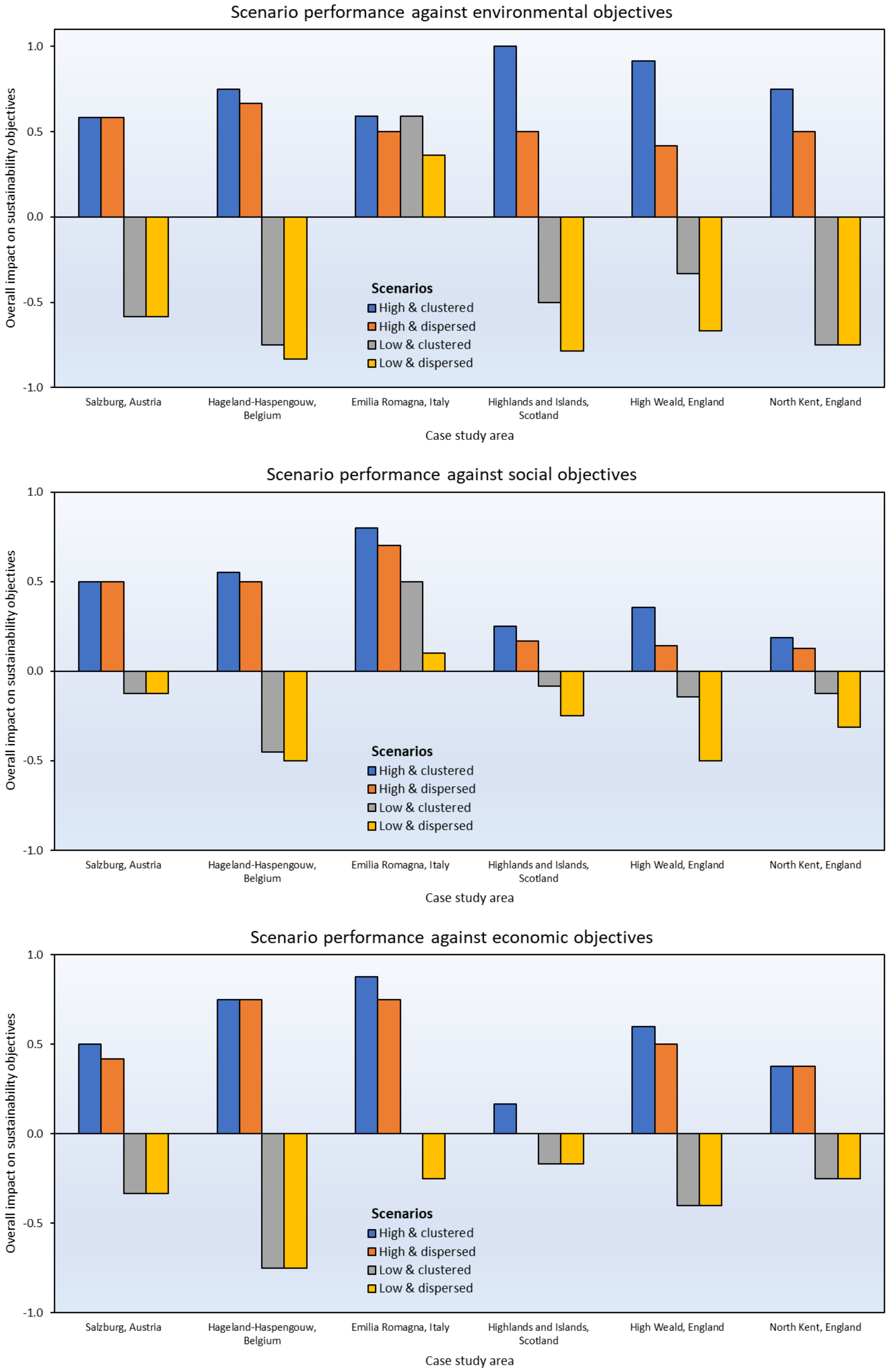

Figure 2. Scenario performance against environmental, social, and economic sustainability objectives for the case study areas where all 4 adoption scenarios were assessed. A simple, unweighted measure to display overall performance was generated by multiplying impact 'scores' (i.e., 1 = strong positive, 0.5 = positive, -0.5 = negative, -1 = strong negative) by the percentage of objectives with that impact and summing the results.

Performance against different sustainability objectives

Although overall, high clustered adoption scenarios tended to show the strongest sustainability performance, across all case study areas, there was no one scenario that performed best for every single sustainability objective. Even if the high clustered adoption scenario was associated with the most positive impacts on objectives, there were at least some objectives for which an alternative scenario performed better, or at least matched the high clustered scenario.

The proportion of objectives that were better served by a scenario other than the overall 'best' scenario differed between case study areas. In some case study areas, such as Hageland-Haspengouw in Belgium, there was a pronounced difference in sustainability performance between high and low adoption scenarios across almost all objectives. A high, clustered adoption pattern of ecological farming positively contributed to a wide variety of objectives, encompassing different dimensions of sustainability. In this location, therefore, there is the potential to achieve many different objectives simultaneously if adoption of ecological farming occurs at a high rate and in a clustered distribution. By contrast, in Emilia Romagna in Italy, although the high clustered adoption scenario was still associated with the greatest frequency of positive impacts on objectives, there were also many objectives where the low adoption or dispersed scenarios were associated with a stronger positive impact. Here, therefore, it is especially important that the benefits of a high, clustered adoption pattern are weighed against its shortcomings relative to other adoption patterns.

5.1.2. Austria – Salzburg und Umgebung

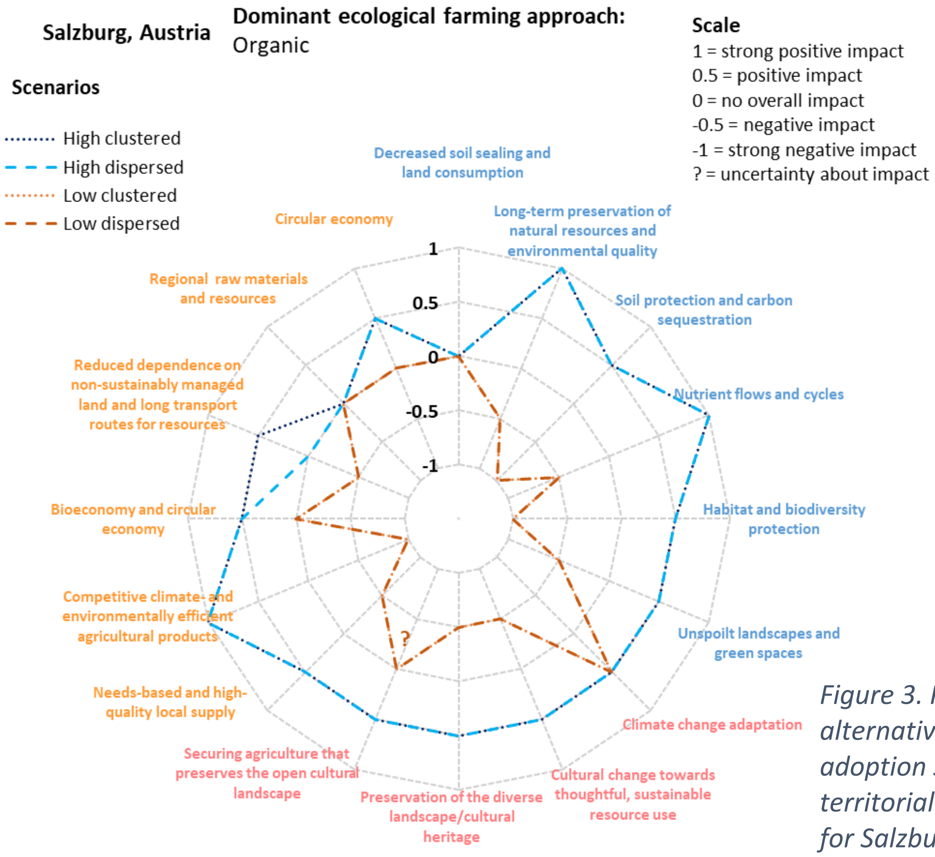

Figure 3. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for Salzburg und Umgebung, Austria

In Salzburg und Umgebung (Figure 3), the spatial distribution of adoption had little overall impact on sustainability performance: clustered and dispersed adoption scenarios had similar impacts on sustainability objectives. Instead, differences in sustainability performance were mainly associated with the rate of adoption, with the high adoption scenarios tending to be associated with better performance across most environmental, social, and economic objectives.

The most pronounced difference in performance was identified when considering the competitiveness of climate- and environmentally-efficient agricultural products. Under a high adoption scenario, social pressure, high demand, technological progress, and high payments for measures under agri-environment schemes all operate to increase the competitiveness of produce from organic dairy farms that are characteristic of the region.

However, there were some cases in which the high adoption scenario was not the obvious optimal option for achieving a given sustainability objective. None of the assessed scenarios were judged to have any meaningful impact on minimising the amount of soil sealing and land consumption or securing regional raw materials and resources. Policy measures to address these needs will therefore need to consider factors other than the rate and distribution of organic farming adoption. Climate change adaptation, on the other hand, was positively impacted under all adoption scenarios, which suggests that regardless of how the drivers of change influencing adoption play out, an improvement in the area’s capacity to adapt to climate change appears likely. Therefore, an increase in the rate and clustering of organic farming adoption has little value in terms of contributing to landscape-scale climate change adaptation relative to other agricultural change scenarios.

5.1.3. Belgium – Hageland-Haspengouw

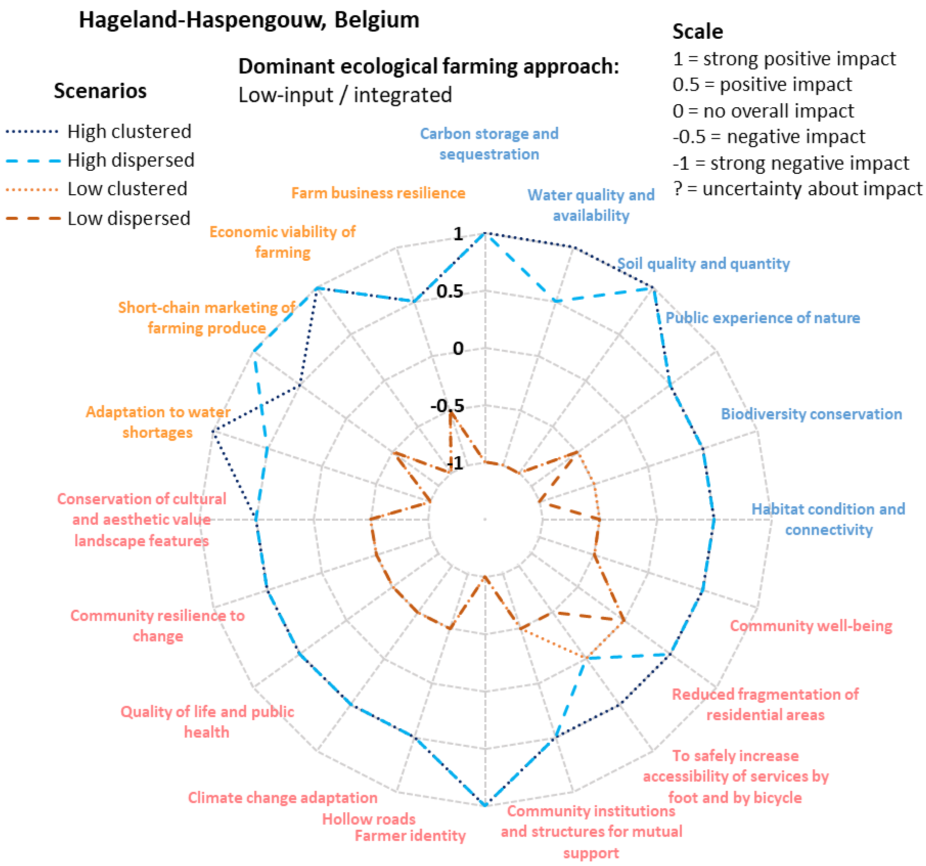

Figure 4. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for Hageland-Haspengouw, Belgium

In Hageland-Haspengouw (Figure 4), there was a pronounced difference between the performance of high and low adoption scenarios, with objectives across almost all dimensions of sustainability being better served by high adoption of an ecological approach, involving a mix of low-input and integrated practices.

However, in some cases, the strength of these positive impacts on objectives under high adoption varied depending on the spatial distribution of adoption. A clustered pattern of adoption was assessed to better contribute to positive impacts on water quality and availability, and the ability of the agricultural sector to adapt to water shortages, through the concentration of appropriate management practices around water sources to strengthen benefits. Clustering was also judged to improve regional social sustainability performance, with regards to accessibility of local services by foot and bicycle, through enabling farmers to work with each other and with extension workers to implement 'slow roads' that span multiple farm boundaries.

There was one sustainability objective, developing short-chain marketing for agricultural produce, where it is possible, however, that dispersed adoption may be more beneficial. Assessors had more confidence in a strong positive impact on this objective under the dispersed scenario. However, this difference was primarily due to uncertainty over the impact of agricultural policy on this objective under the dispersed scenario. This could point to a need to improve understanding of how agricultural policy measures can be designed to facilitate short-chain marketing, especially if adoption of ecological practices does occur in a clustered manner.

5.1.4. England, UK – High Weald and North Kent

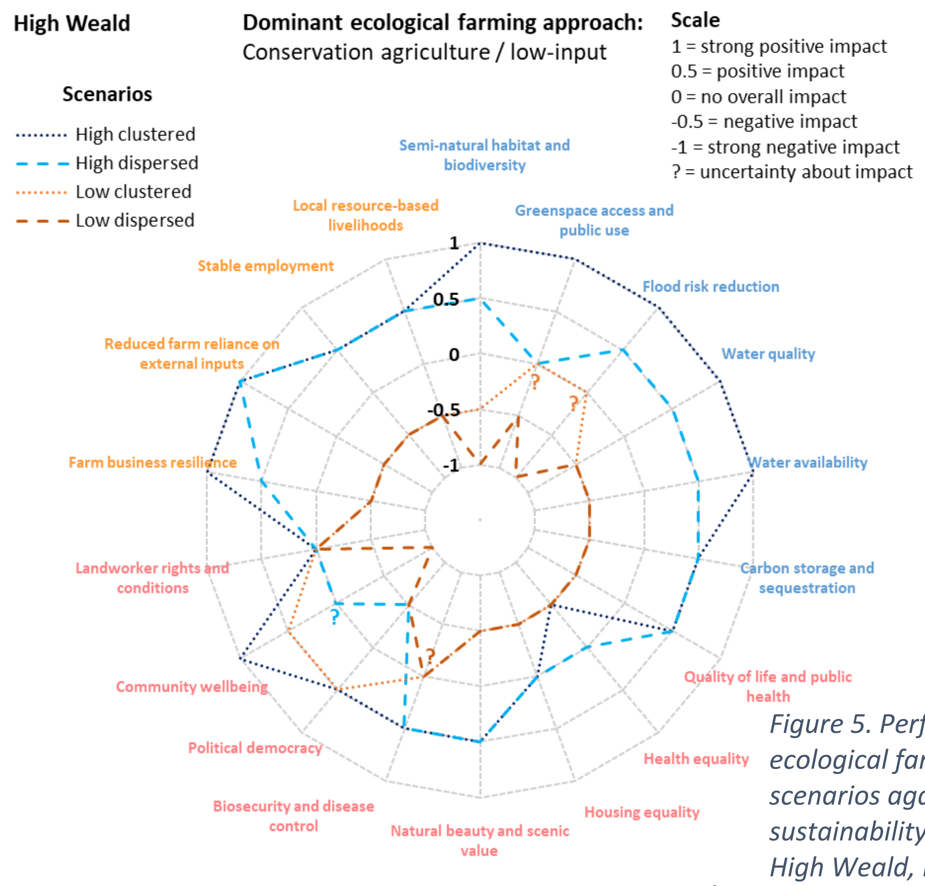

Figure 5. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for the High Weald, England

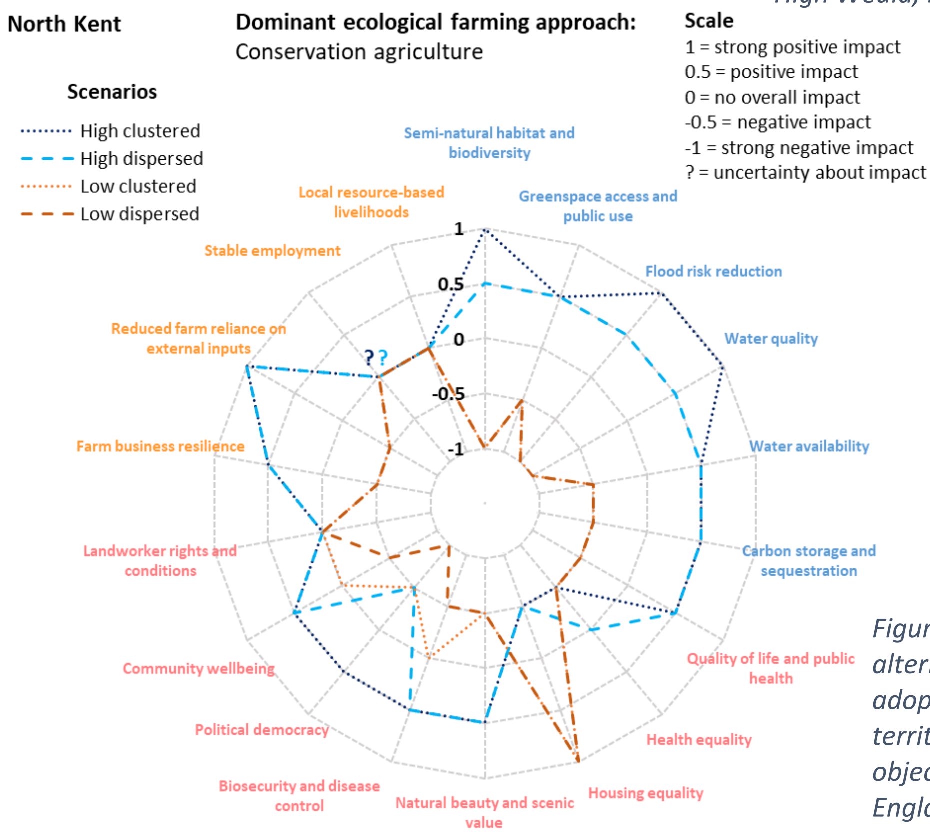

Figure 6. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for North Kent, England

In the High Weald (Figure 5), high adoption of ecological farming, characterised by a blend of conservation agriculture and low-input farming practices, was assessed to be the best option for achieving environmental objectives for the region. In addition, performance against environmental objectives under high adoption scenarios was stronger when adoption occurred in a clustered pattern, typically linked to the coordination or aggregation of management effects across farm boundaries to enhance delivery of public goods and ecosystem services.

A similar pattern was identified for sustainability performance against social and economic objectives. However, although higher rates of adoption tended to be associated with more positive impacts for the majority of social and economic objectives, for political democracy and community well-being, the distribution of adoption was a more important determinant of performance than the rate of adoption. Performance against both of these objectives was stronger under the clustered adoption scenarios, regardless of the rate of adoption. Achieving these objectives was linked to the ability of farmers and other rural stakeholders to form connections with each other, providing opportunities for mutual support, collective decision-making, and discussion between different perspectives. The clustered adoption of ecological farming approaches created an environment that favoured the development and strengthening of these connections, even if the overall rate of adoption was low. For most other social and economic objectives, however, the distribution of adoption made no difference to regional sustainability performance.

The scenarios in North Kent and the High Weald were assessed against the same set of sustainability objectives, and sustainability performance of the adoption scenarios North Kent (Figure 6) follows a broadly similar pattern to the High Weald. Again, high adoption scenarios were assessed to better contribute towards achieving the environmental and economic objectives for the region. However, these benefits may need to be balanced against the detrimental impact on housing equality, especially compared to the potential gains for the low adoption scenario, which was associated with a strong positive impact on housing equality. The development of affordable housing developments in this region may increase levels of home ownership and ensure that locals are not priced out of the housing market. However, demand for land for urban development encourages short-term land management perspectives and favours an increase in the size of remaining farms, as farmers are able to use profits from the sale of land to buy larger parcels of land elsewhere. Both of these factors are negatively associated with adoption of conservation agriculture in the area.

Reconciling environmental and economic performance in the rural landscape with housing equality therefore appears to be a particular challenge for North Kent. The spread of ecological farming in North Kent may be associated with conditions that contribute to social inequality in relation to access to housing, and regional policy will need to consider how to balance this with environmental and economic objectives for the area. It is possible, for example, that authorities may decide that it is preferable to sacrifice some of the environmental and economic benefits of increased ecological farming adoption for greater social equality in the region.

5.1.5. France – Ille-et-Vilaine, Sarthe, and Puy-de-Dôme

Ille-et-Vilaine, France **Dominant ecological farming approach:** Conservation AND Integrated / circular

Scenarios

High clustered
Low dispersed

Scale
1 = strong positive impact
0.5 = positive impact
0 = no overall impact
-0.5 = negative impact
-1 = strong negative impact
? = uncertainty about impact

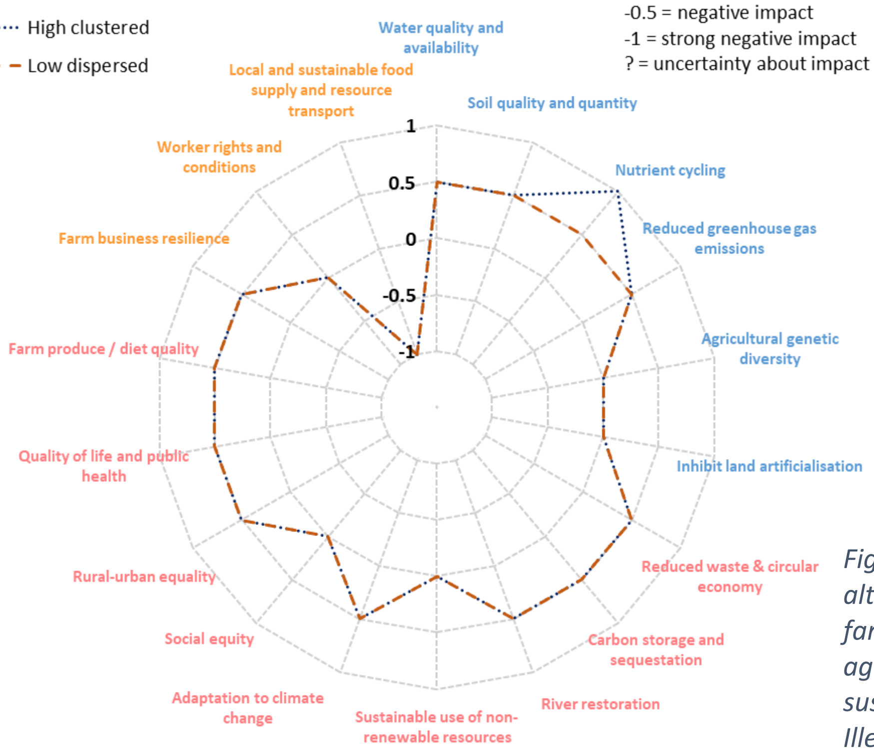

Figure 7. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for Ille-et-Vilaine, France

Puy-de-Dôme, France **Dominant ecological farming approach:** Conservation agriculture

Scenarios

High clustered
Low dispersed

Scale
1 = strong positive impact
0.5 = positive impact
0 = no overall impact
-0.5 = negative impact
-1 = strong negative impact
? = uncertainty about impact

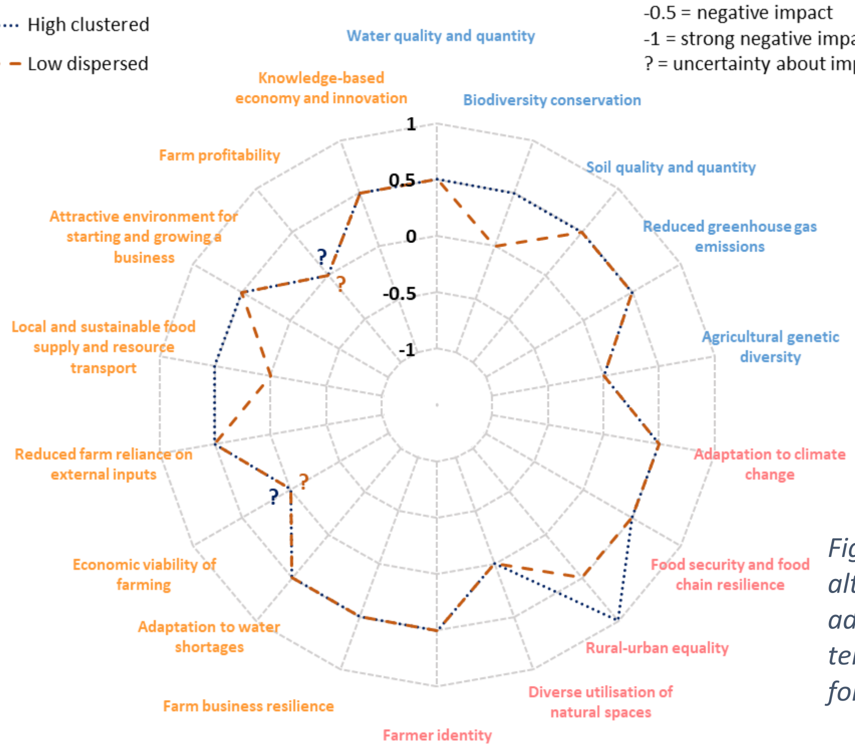

Figure 8. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for Puy-de-Dôme, France

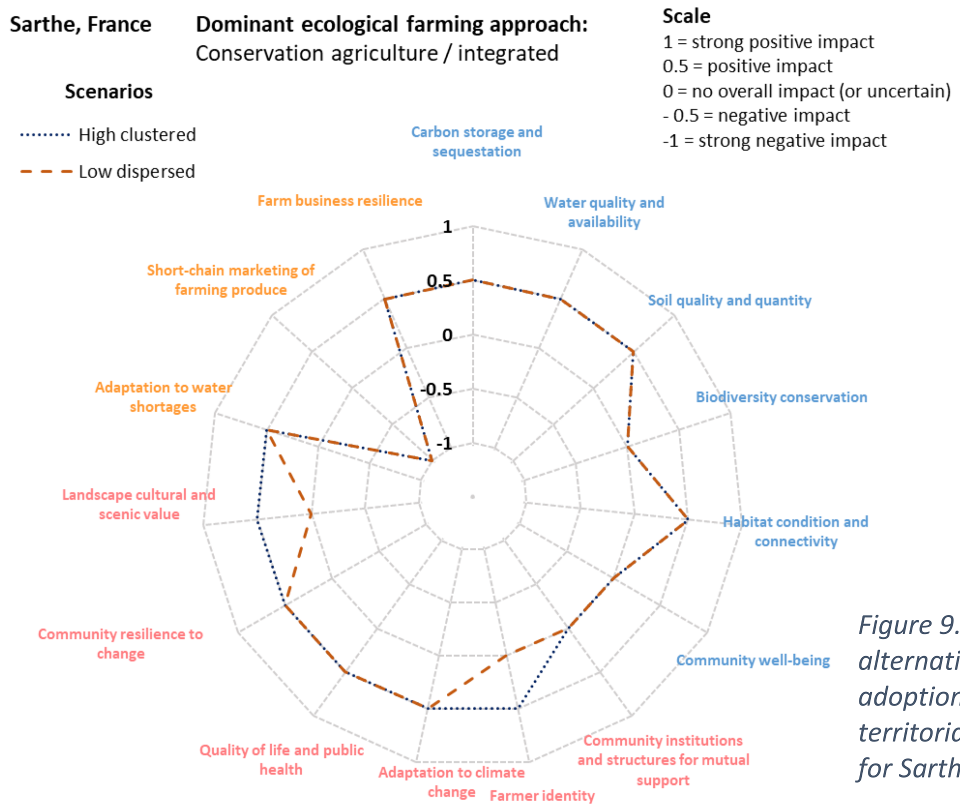

Figure 9. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for Sarthe, France

The high and low adoption scenarios in the French case study areas had similar performance across most sustainability objectives. This was in contrast to other regions, where differences in adoption rate were typically associated with marked differences in performance. However, those differences in performance that were identified highlight key opportunities for enhancing sustainability through the spread of ecological farming in these regions.

In Ille-et-Vilaine (Figure 7), overall scenario performance was the same across the different sustainability objectives, with one exception. High clustered adoption of ecological farming was associated with a stronger positive impact on sustainable fertiliser use to preserve and restore natural nutrient flows and cycles, enhancing environmental sustainability under this scenario. Nutrient pollution from large, intensive livestock farms is a major issue in Ille-et-Vilaine (sub-region of Brittany), and so increasing the adoption rate of alternative ecological approaches that use nutrient inputs and outputs more efficiently may be important for improving environmental sustainability here.

By contrast, in Sarthe (Figure 8), the regional benefits of increasing ecological farming adoption were linked to social rather than environmental sustainability objectives. The high clustered adoption scenario outperformed the alternative due to its positive impacts on farmer identities and the conservation of landscape features of cultural and aesthetic value. Hence, ecological farming adoption may present different opportunities for environmental or social sustainability in different regions.

While in Ille-et-Vilaine and Sarthe, differences in the rate and distribution of ecological adoption presented opportunities for one specific aspect of sustainability, in Puy-de-Dôme (Figure 9), differences in rate and distribution translated into differences in environmental, social, and economic sustainability performance. High clustered adoption was identified as better contributing to the achievement of biodiversity conservation, rural-urban equality, and local food supply and transport: here, increasing the rate and clustering of adoption could deliver environmental, social, and economic benefits simultaneously.

5.1.6. Germany – Upper Bavaria

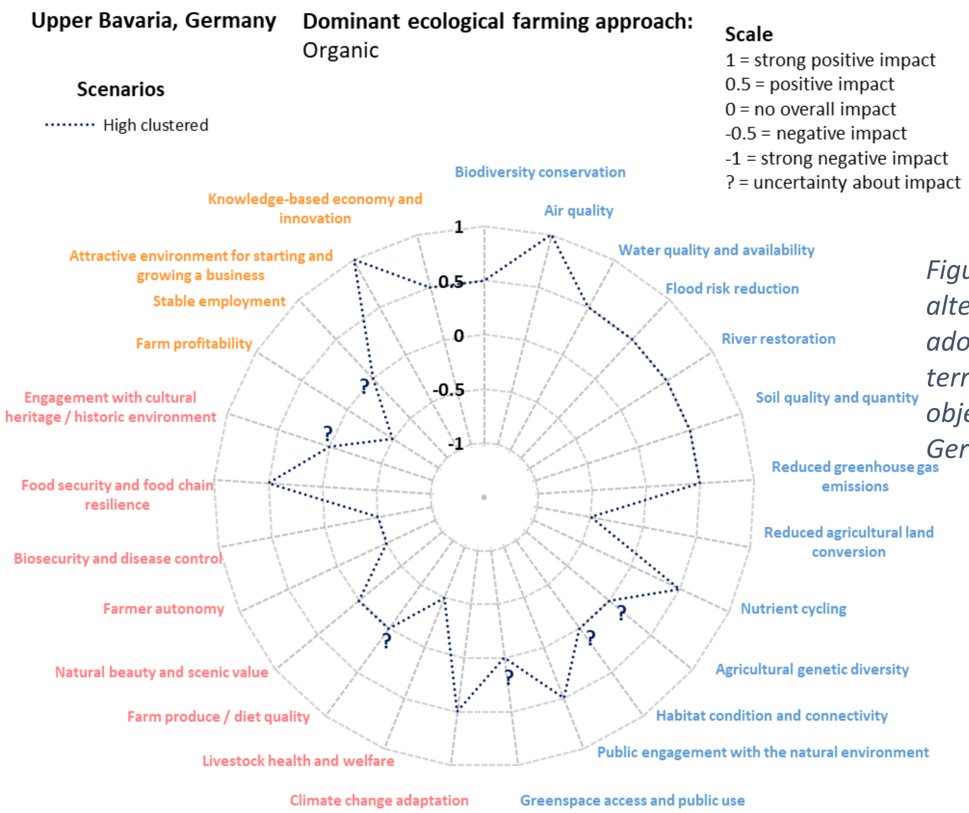

Figure 10. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for Upper Bavaria, Germany

Only one scenario (high, clustered adoption) was assessed for the Upper Bavaria case study area (Figure 10). Therefore, while it was not possible to explore how differences in the rate or distribution of adoption of ecological farming could impact sustainability performance for this area, the assessment output does give some illustration of how the adoption of ecological farming contributes to different aspects of territorial sustainability for Upper Bavaria.

A high rate of adoption was clearly linked to positive impacts on sustainability performance for most environmental objectives: there is potential for appropriate ecological practices to make an overall positive contribution to territorial environmental sustainability. However, this high clustered adoption scenario was also associated with the loss of agricultural land. Under this scenario, the technological drivers of increased ecological practice adoption are also associated with the continued expansion of solar farms and biogas generation in the area, reducing the available land area for agriculture. Therefore, while this scenario may have widespread positive impacts on environmental sustainability, it also brings with it increasing potential for land use conflicts that will need to be navigated.

Moreover, the assessment suggests that environmental sustainability benefits of high clustered adoption of ecological farming will also have to be weighed against the risks of negative impacts on social and economic sustainability. Although this scenario was linked to overall positive impacts for climate change adaptation, food chain resilience, attractive conditions for business creation and growth, and developing a knowledge-based economy, impacts against other social and economic objectives were negative, absent, or uncertain. Therefore, the extent to which the environmental sustainability of ecological farming at the territorial scale can be reconciled with the area's social and economic needs is unclear. A better understanding of the potential synergies or trade-offs could be achieved by focusing research attention, and stakeholder engagement efforts, on those areas of uncertainty that were identified in the assessment.

5.1.7. Greece – East Crete

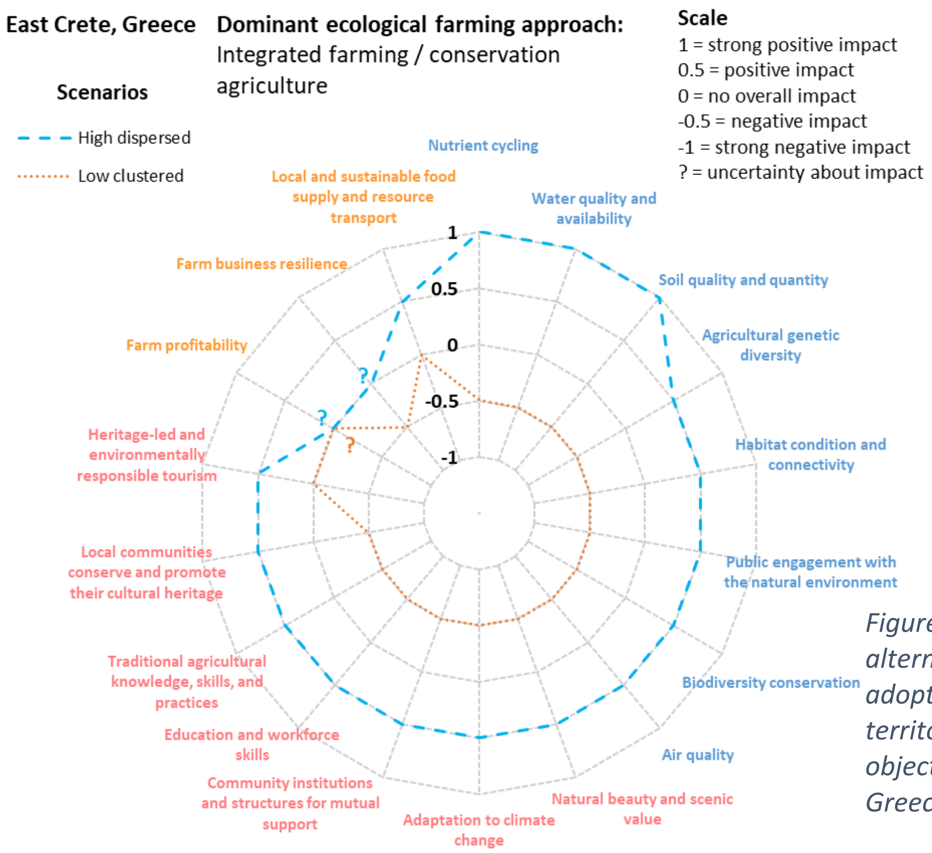

Figure 11. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for East Crete, Greece

In East Crete (Figure 11), high dispersed adoption of an ecological farming approach was assessed to contribute positively to the achievement of all identified environmental and social objectives, while the low clustered scenario was linked to a negative or absent impact for these objectives. This suggests that for this region, the territorial-level social and environmental performance of ecological farming approaches likely to be important in the future is closely aligned and appropriate for the local context.

However, economic performance of ecological farming at the territorial level is more ambiguous. In particular, the stakeholder assessment revealed a lack of certainty over impact of the rate and distribution of ecological farming adoption on the profitability and resilience of farming businesses. Agriculture (along with tourism) is one of the primary bases of the Cretan economy, and it is crucial to understand how farming's ability to contribute to the regional economy would be impacted if the rate of ecological practice adoption increases. How ecological approaches may impact regional economic sustainability may therefore be a priority area for research to establish whether economic performance aligns with the social and environmental dimensions at territorial level, or if economic sustainability considerations will need to be balanced against opposing social and environmental impacts.

5.1.8. Hungary – Veszprém

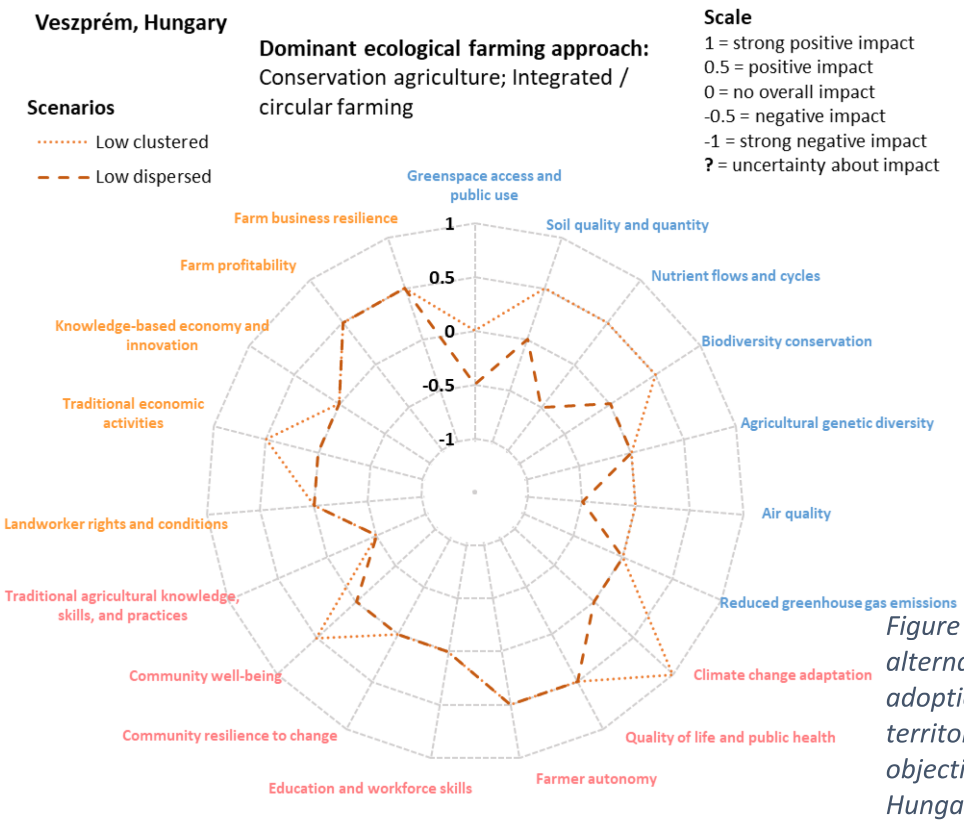

Figure 12. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for Veszprém, Hungary

The sustainability assessment for Veszprém county focused on the performance of the low adoption scenarios, as stakeholders did not consider the high adoption scenarios feasible for this case study area (Figure 12). This means that this assessment can be used to focus specifically on how spatial distribution of adoption contributes to sustainability performance.

For 11 out of the 19 sustainability objectives for Veszprém, there was no overall difference in performance between the clustered and dispersed adoption scenarios. However, where there was a difference in performance, clustered adoption was associated with more positive impacts on objectives. These differences in performance highlight opportunities to enhance territorial sustainability through increasing the level of clustering of ecological farms.

Opportunities for enhancing territorial sustainability through clustered adoption were identified across environmental, social, and economic objectives. The fact that clustering could meet the region's needs for a wide variety of types of objectives suggest that the relevant ecological approaches likely to be adopted in Veszprém have the potential to reconcile performance across sustainability dimensions, rather than having to trade off performance in one dimension against another.

5.1.9. Italy – Emilia Romagna

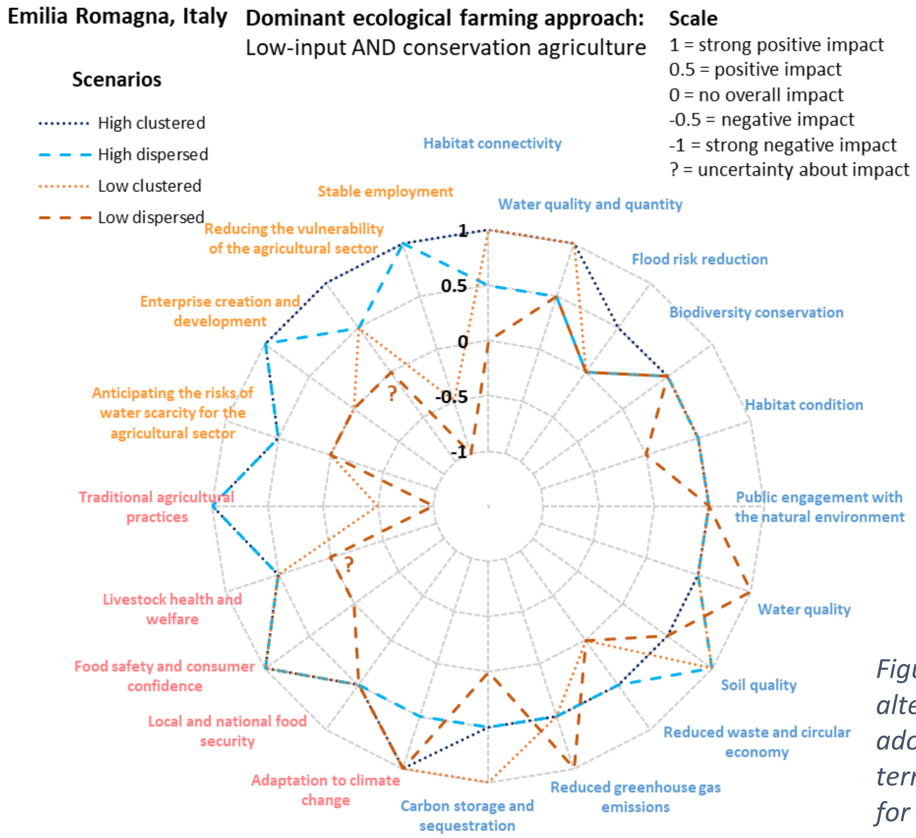

Figure 13. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for Emilia Romagna, Italy

As with other case study areas, in Emilia Romagna (Figure 13), high adoption scenarios were associated with the highest frequency of positive impacts on sustainability objectives. However, unlike the assessments presented here, the environmental objectives were not necessarily best served by high adoption of the chosen ecological farming approach.

High adoption outperformed low adoption for achieving social and economic objectives, but the difference between the performance of high and low adoption scenarios was less clear-cut for environmental objectives. For water quality, greenhouse gas emissions, and carbon storage and sequestration, low clustered or low dispersed adoption scenarios were more beneficial. For waste reduction and flood risk management, some form of high adoption scenario was best suited to achieving objectives. Part of this difference was attributed to the types of measures supported by agricultural policies that could help drive increases in ecological practice adoption. For example, agri-environment schemes were judged to be an effective means for improving soil drainage, minimising soil erosion and associated flood risk, but have low potential for climate change mitigation.

The mixed scenario performance against environmental objectives was also linked to the nuanced effects of consumer preferences. Consumer preferences may translate into voluntary certification schemes, but the farmers who would engage in these schemes were thought to be those who were already farming in an environmentally-sensitive manner. The effect of consumer preference may therefore enhance performance in farms that are already implementing ecological practices but have little effect on the spread of ecological practices. This also means that farmers may stand to gain more from being part of voluntary certification schemes when adoption rates are low, so they face less competition with other certified producers.

Therefore, while increasing adoption of ecological practices in Emilia Romagna may be the most beneficial option for most social and economic objectives, which scenario is best for environmental objectives is more ambiguous. Regional policy may need to carefully consider the relative importance and desirability of the different environmental objectives in Emilia Romagna when charting the preferred direction for agriculture.

5.1.10. Poland – Lubelskie and Podlaskie

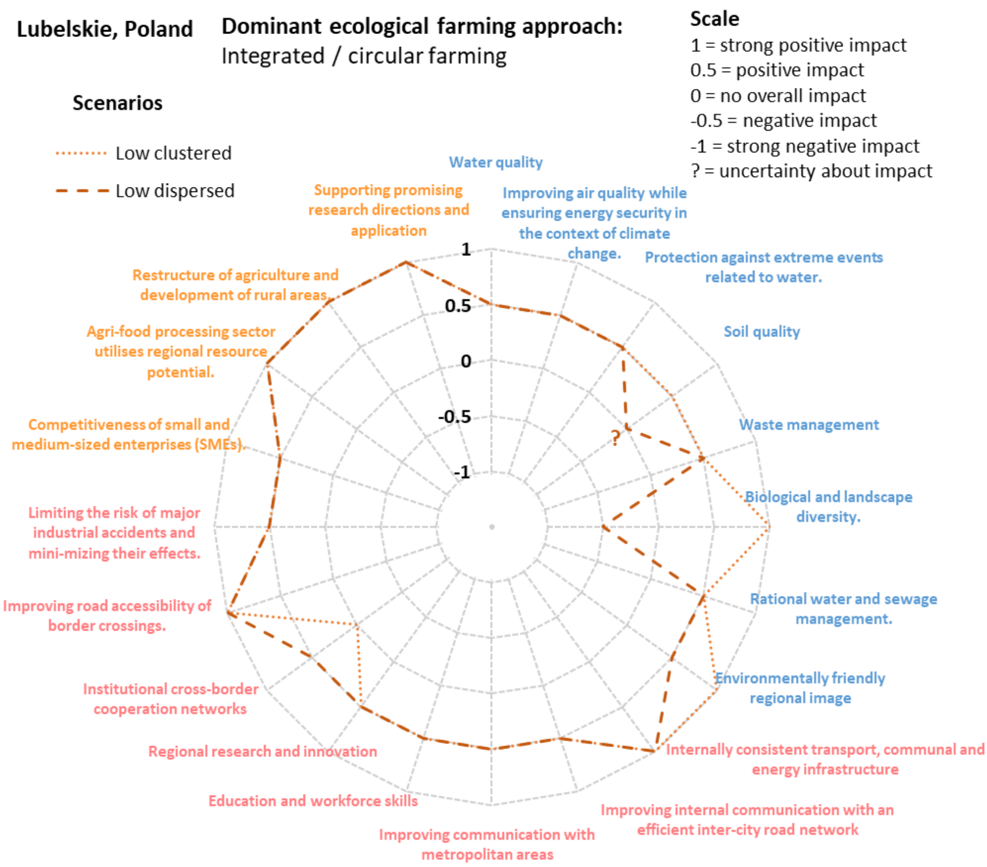

Figure 14. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for Lubelskie, Poland

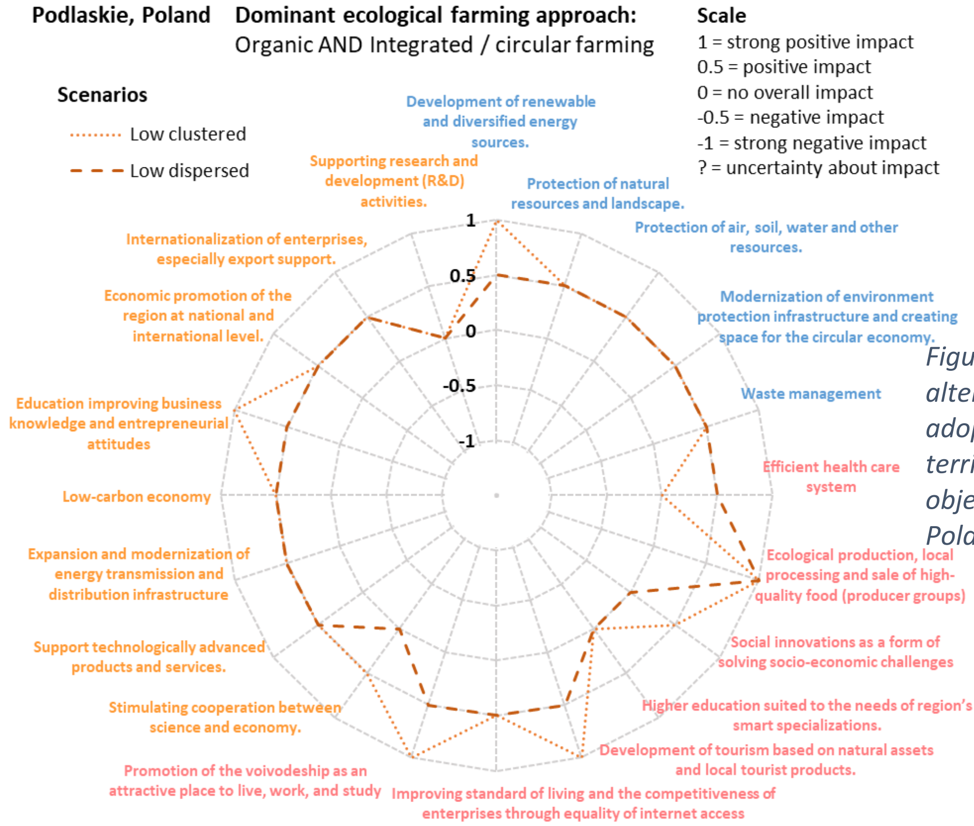

Figure 15. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for Podlaskie, Poland

The assessments for the Polish case study areas only considered the performance of the low adoption scenarios, as stakeholders did not consider the high adoption scenarios feasible for these areas. This means that these assessments focus specifically on how the spatial distribution of adoption contributes to sustainability performance.

For most objectives, the distribution of ecological farms had little impact, with no meaningful difference between the clustered and dispersed adoption scenarios. However, in Lubelskie (Figure 14), performance against some environmental objectives, including soil quality, biological and landscape diversity, and generating an environmentally-friendly regional image, was stronger under the clustered adoption scenario. Lubelskie's landscape is characterised by large areas of contiguous farmland, with the largest proportion of agricultural land by area of any of Poland's main administrative regions. There is therefore considerable potential for clustered adoption of ecological practices to make large differences to environmental performance at the landscape scale. For Podlaskie (Figure 15), which has a more varied landscape, clustered adoption did not outperform dispersed adoption for environmental objectives to the same extent. However, clustered adoption in Podlaskie was associated with more positive impacts on social objectives, particularly for the development of tourism based on natural assets and local products, and the promotion of the region as an attractive place to live, work, and study.

5.1.11. Romania – Suceava

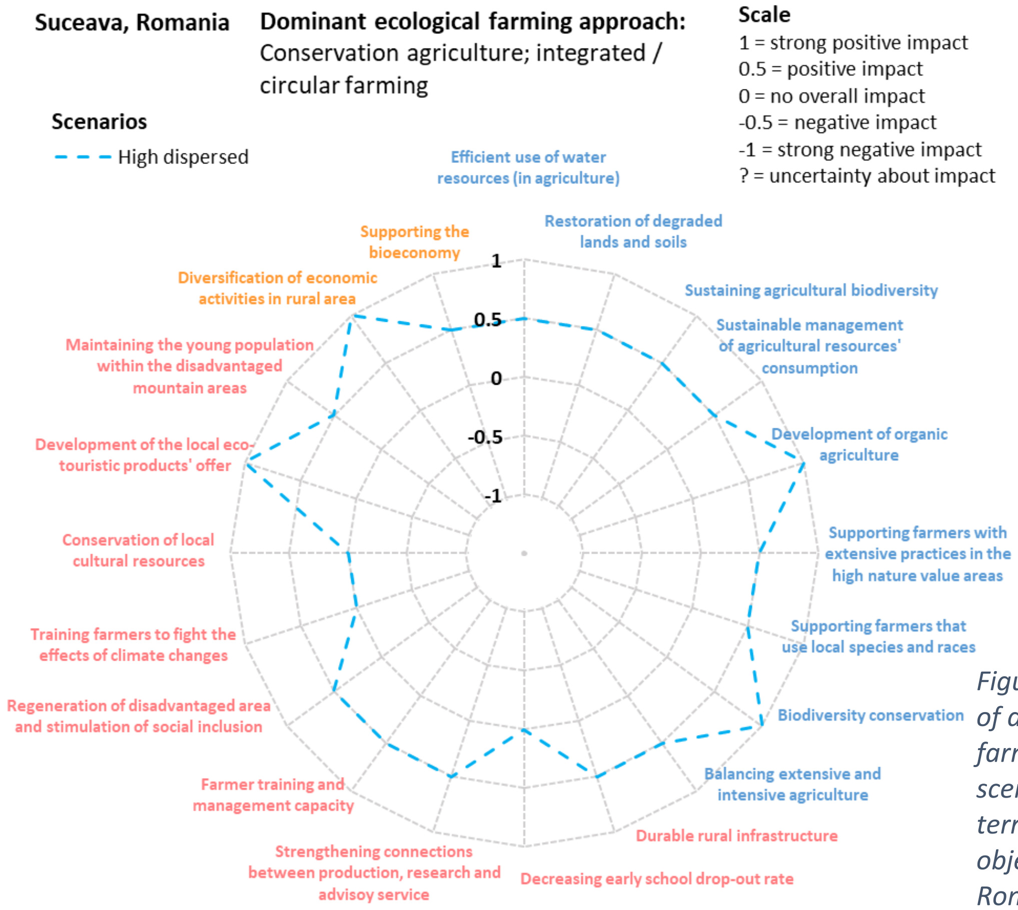

Figure 16. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for Suceava, Romania

Only one scenario (high, dispersed adoption) was assessed for the Suceava case study area (Figure 16). Therefore, although the assessment output cannot be used to compare the sustainability performance associated with the differences in the rate or distribution of adoption, the results can be used to explore how an ecological farming approach contributes to different aspects of territorial sustainability for Suceava. In particular, the fact that no overall negative impacts were identified for any of the regional objectives suggests that the adoption of appropriate ecological farming approaches has the potential to not only meet Suceava's environmental sustainability needs, but also reconcile performance across different dimensions of sustainability at the territorial level.

However, some sustainability objectives were unaffected under this scenario. The drivers of change that contributed to this high dispersed pattern of ecological farming adoption had no overall impact on school drop-out rates, farmer ability to adapt to climate change, and the conservation of local cultural resources. It is possible that these objectives would have been better served under an alternative adoption scenario, or that the drivers affecting the rate and distribution of ecological farming are not strongly linked to these objectives. In either case, this assessment suggests that while creating favourable conditions for ecological farming adoption will help in achieving most of Suceava's sustainability objectives, this is not a panacea, and if this scenario plays out in practice, further intervention will be needed to ensure the delivery of certain social objectives.

5.1.12. Scotland, UK – Highlands and Islands

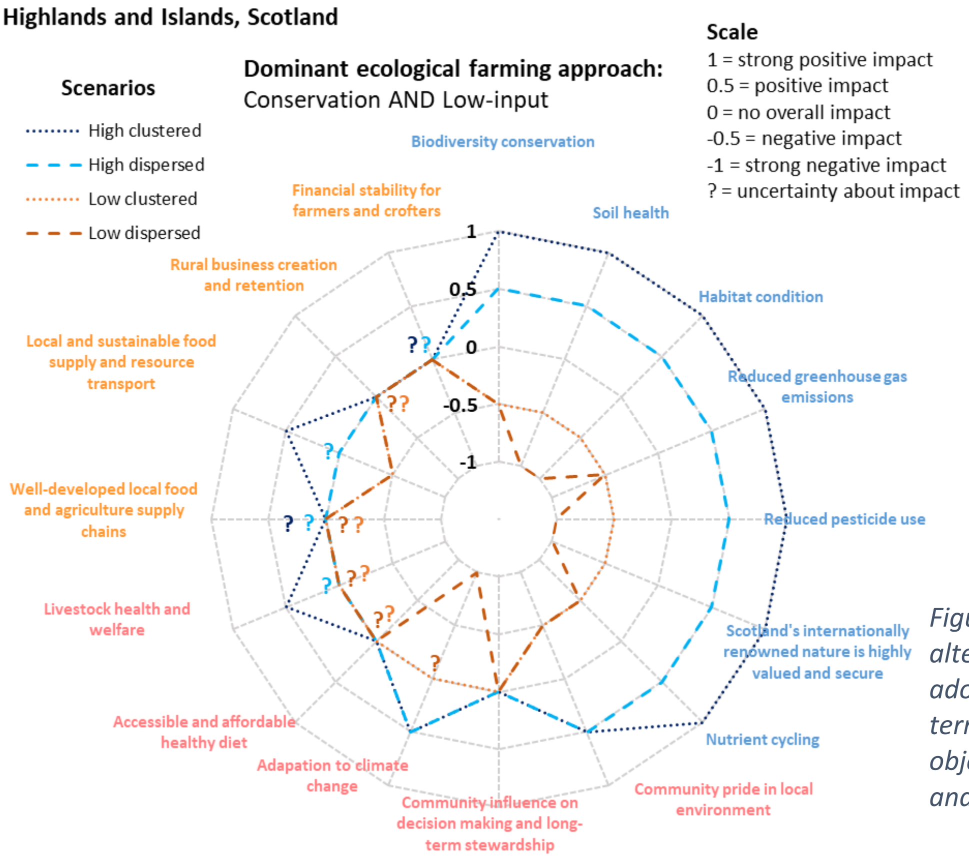

Figure 17. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for the Highlands and Islands, Scotland

In the Highlands and Islands (Figure 17), increased adoption of ecological farming practices was clearly judged to be associated with the achievement of environmental sustainability objectives, and positive impacts would be stronger under a clustered pattern of adoption. Under dispersed patterns of adoption, a lack of cooperation was identified repeatedly as a factor that would reduce the strength of positive environmental impacts associated with different drivers of change.

However, the picture was more complex for social and economic objectives. The experts and stakeholders participating in the assessment tended to be uncertain about how the different scenarios would impact on these objectives, and so it is difficult to discriminate between the scenarios in terms of their social and economic sustainability performance. Therefore, if an ecological approach is to be pursued to achieve environmental objectives in this area, prioritisation should be given to understanding how the various drivers that favour ecological farming adoption may also influence key economic and social sustainability objectives.

5.1.13. South Sweden

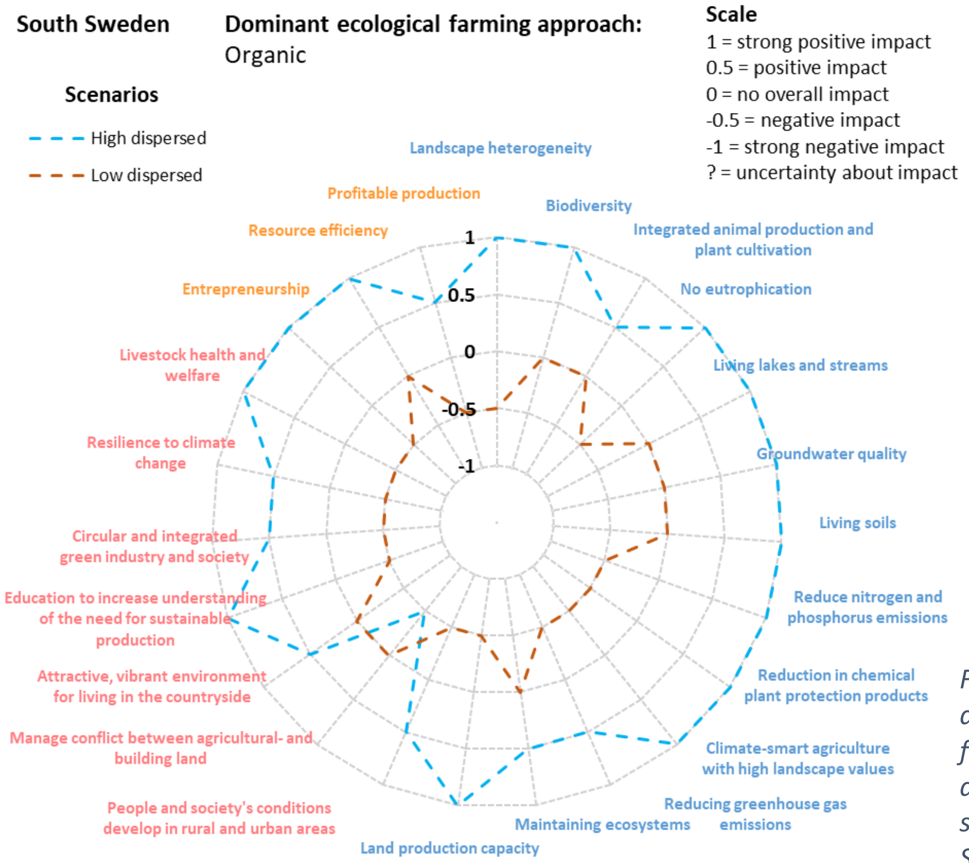

Figure 18. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for South Sweden

In South Sweden (Figure 18), high adoption of organic farming was assessed to contribute positively to sustainability objectives across the environmental, social, and economic dimensions, particularly when compared to the low adoption scenario, which was associated with negative or absent impacts on these objectives. This indicates strong alignment between the social, economic, and environmental performance of organic farming at the territorial scale: in South Sweden, organic farming provides a means of achieving diverse aspects of sustainability simultaneously.

However, the assessment results also highlight an objective where the impacts were at odds with the overall performance of each scenario. When it comes to managing conflict between land for agriculture and building, performance is reduced under the high adoption scenario. High adoption was associated with a negative impact on this objective, whereas the low adoption scenario had no overall impact. Under the high adoption scenario, the public goods generated from organic farming systems, public interest and consumer demand for organic approaches, and the availability of technology, all contributed to make living in rural areas more desirable and accessible, increasing demand for and conflict over rural spaces. Therefore, in this region, efforts to promote ecological farming as a means to achieve a range of sustainability objectives should also consider how this can be done while minimising the potential for conflict with other land uses and impacts on housing accessibility.

5.2. Network analysis – High Weald (England, UK)

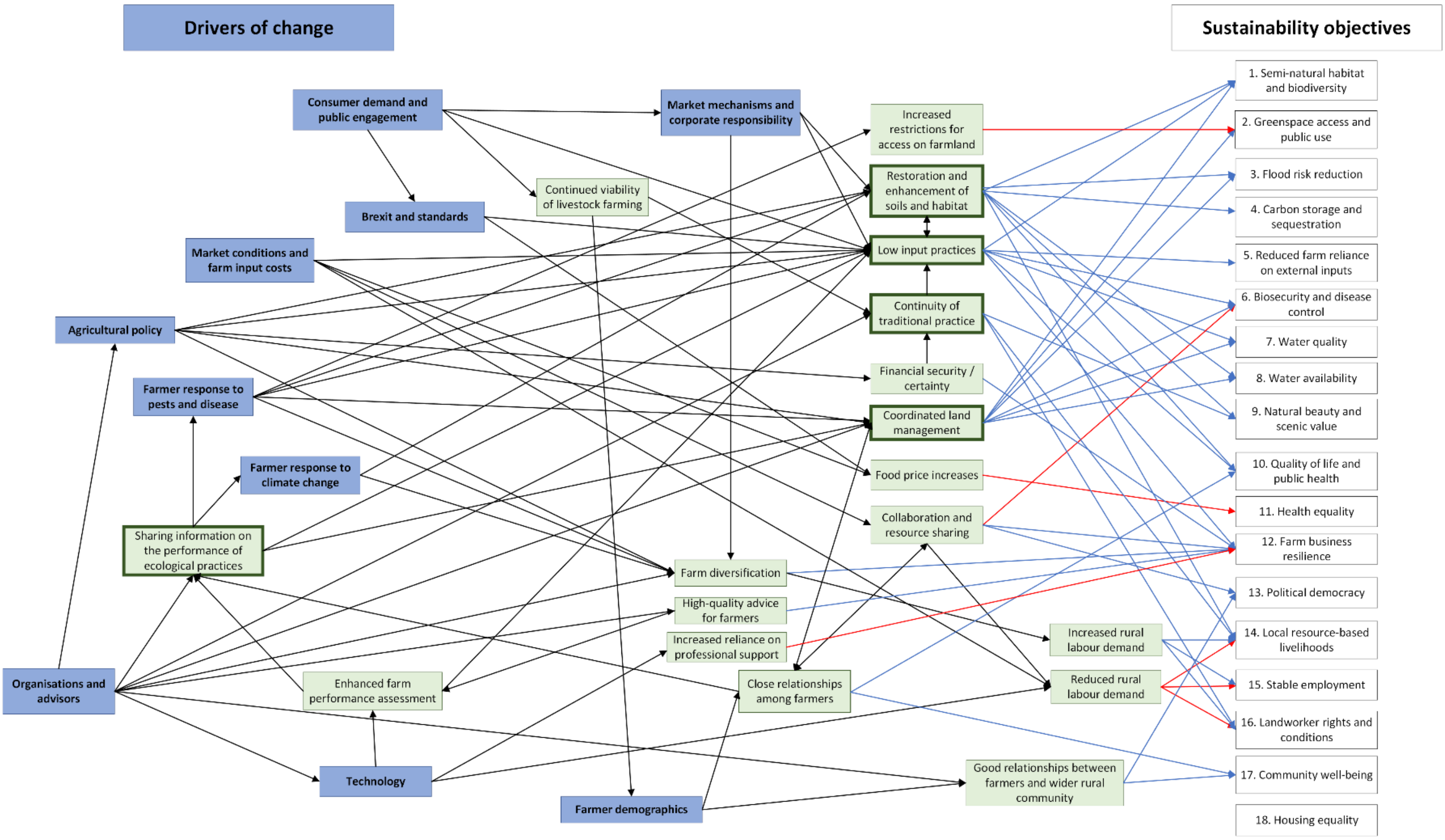

Figure 19. Network graph showing the key cause-effect relationships between the drivers of change, their consequences, and subsequent positive (blue lines) and negative (red lines) impacts on the sustainability objectives for the High Weald under Scenario 1 (high, clustered adoption of a mix of conservation agriculture and low-input farming, referred to locally as 'regenerative agriculture'). Boxes with thick outlines represent structurally key nodes in the graph (the top 5 nodes with the highest proximity prestige values).

The causal relationships that underpin the strong sustainability performance of the high, clustered adoption scenario for the High Weald are presented in Figure 19. While the graph shows that the relationships between drivers, impacts, and objectives in this scenario are complex and interdependent, some key processes can be identified by identifying the most influential nodes in the network (those with the highest proximity prestige). The five nodes occupying the most influential positions in this network of cause-effect relationships have been highlighted in Figure 19.

The importance of soil and habitat restoration and low-input practices in the network is to be expected, as these are features of the farming approach being adopted in this scenario. Drivers of change were chosen in part for their potential to affect these aspects of agricultural land management, and so every driver, except for farmer demographics, is directly or indirectly linked to these two nodes. At the same time, these aspects of land management were linked to positive performance for a range of sustainability objectives: 11 out of 18 of the territorial sustainability objectives were positively impacted by soil / habitat restoration or low-input practices, including objectives representing environmental, social, and economic dimensions of sustainability. Therefore, the features of an ecological approach at the farm level are central to the potential for this high adoption scenario to reconcile positive performance across different aspects of sustainability at the territorial scale.

The next most influential node in this network concerns the continuity of traditional farming practices within the High Weald. The importance of maintaining traditional practice in this context is largely due to the fact that achieving many of the sustainability objectives for the High Weald depends on the persistence of traditional, low-input livestock farming practices, which have helped to shape the area's distinctive landscape, underpinning its designation as an Area of Outstanding Natural Beauty. Moreover, these traditional practices were largely compatible with those identified by stakeholders as the focus of an appropriate ecological farming approach for the area. Among other things, these low-input livestock farms are important for the conservation of semi-natural habitats that depend on grazing, improving soil and water quality, preserving the scenic value and landscape character of the area, and supporting land-based livelihoods that make use of the High Weald's natural and cultural heritage.

While soil and habitat restoration, and maintenance of low-input and traditional farming practices, are farm-level features of this adoption scenario that can have sustainability implications at the landscape level, the next two structurally key nodes in the network are associated with ways in which farmers across the landscape may interact with each other to influence territorial sustainability performance.

The first of these nodes represents the sharing of information among farmers on the performance of ecological practices. The ability of farmers to see for themselves how an ecological approach (and management coordination) could be beneficial for the performance of their farm and the rural landscape, was highlighted in discussions with stakeholders as a key step ensuring a high level of adoption that would deliver the positive impacts across a range of sustainability objectives in this scenario. This sharing of information was not only directly linked to the application of low-input practices on agricultural land, but also impacted the role of other drivers of change. In particular, farmers may adopt ecological approaches as a strategy to increase farm resilience to climate change or the spread of pest and disease resistance, but they would be unlikely to do so without some prior awareness of the performance of ecological approaches. Assessment participants argued that this prior awareness could come from the dissemination of knowledge and experience from other land managers already implementing these approaches.

Two drivers were identified as key contributors to increased information exchange on ecological practice performance: use of technology on the farm, and the role of organisations and advisors in supporting farmers. In the high adoption scenarios, technological developments and improvements in accessibility provided a means to better assess and quantify farm performance, so that the benefits of ecological approaches could be more clearly communicated to others. External organisations and advisors, meanwhile, were seen to provide a framework to mediate between farmers and facilitate the exchange of information on ecological farming performance (as well as supporting farmers with accessing and using novel technologies).

The role of organisations and advisors was also thought to contribute to the high rate of ecological practice adoption and its associated sustainability impacts through interaction with agricultural policy, another driver of change. Given that agricultural policy in England is currently in a transitional phase, with the shape of future agri-environment schemes being determined through policy trials, there are opportunities for regional organisations to work with policy makers to influence the direction of policy and help ensure that new schemes promote ecological approaches that are sympathetic to local sustainability objectives.

Alongside the sharing of information on ecological practice performance, the other highly influential node related to interactions between farmers concerns the coordination of land management at the landscape scale. This node was closely associated with the clustering of ecological farming adoption in this scenario. Clustered adoption of ecological practices makes it easier to coordinate management practices across neighbouring farms, and this coordination was in turn linked to further positive impacts on most of the environmental sustainability objectives, including biodiversity and habitat condition, water quality and availability, flood risk reduction, and greenspace access and public use.

However, the importance of coordinating land management in this scenario was not just due to its direct contribution to environmental sustainability, but also its indirect links with social and economic aspects of sustainability at the territorial level. Management coordination was associated with closer relationships between participating farmers. Close relationships among well-connected farmers were in turn directly linked to improvements in quality of life for farmers and other rural land workers, and more generally, the well-being of rural communities, creating favourable conditions for the development of structures that help community members support each other and strengthen community cohesion. Moreover, strong farmer relationships also promoted collaboration among farms, involving the exchange and pooling of resources, providing a means to support farm businesses in times of difficulty, and increasing opportunities for farmers to get involved in collective action to represent their interests in local and democratic decision-making processes.

In the high clustered scenario, close relationships between farmers are not only linked to coordinated land management, but also to the sharing of information on ecological performance. The 'farmer relationships' node therefore links two structurally key nodes in the network. Farmer relationships contribute towards this scenario's strong sustainability performance, due to their effects on collaboration and coordinated management, but also their role in information exchange, because the sharing of information on practice performance is promoted by close communication between farmers with good working relationships. Therefore, the connections between farmers appear to be important when considering how both the clustering and the rate of ecological farming adoption impact on sustainability at the territorial scale.

Identifying the most influential nodes in the network in Figure 19 helps highlight key pathways contributing to the strong territorial sustainability performance of the high, clustered adoption scenario in the High Weald. Comparing these network analysis results with those for the low, dispersed adoption scenario could give further indication of potential barriers or risks that would restrict the rate or clustering of ecological farming adoption and depress sustainability performance at the landscape scale.

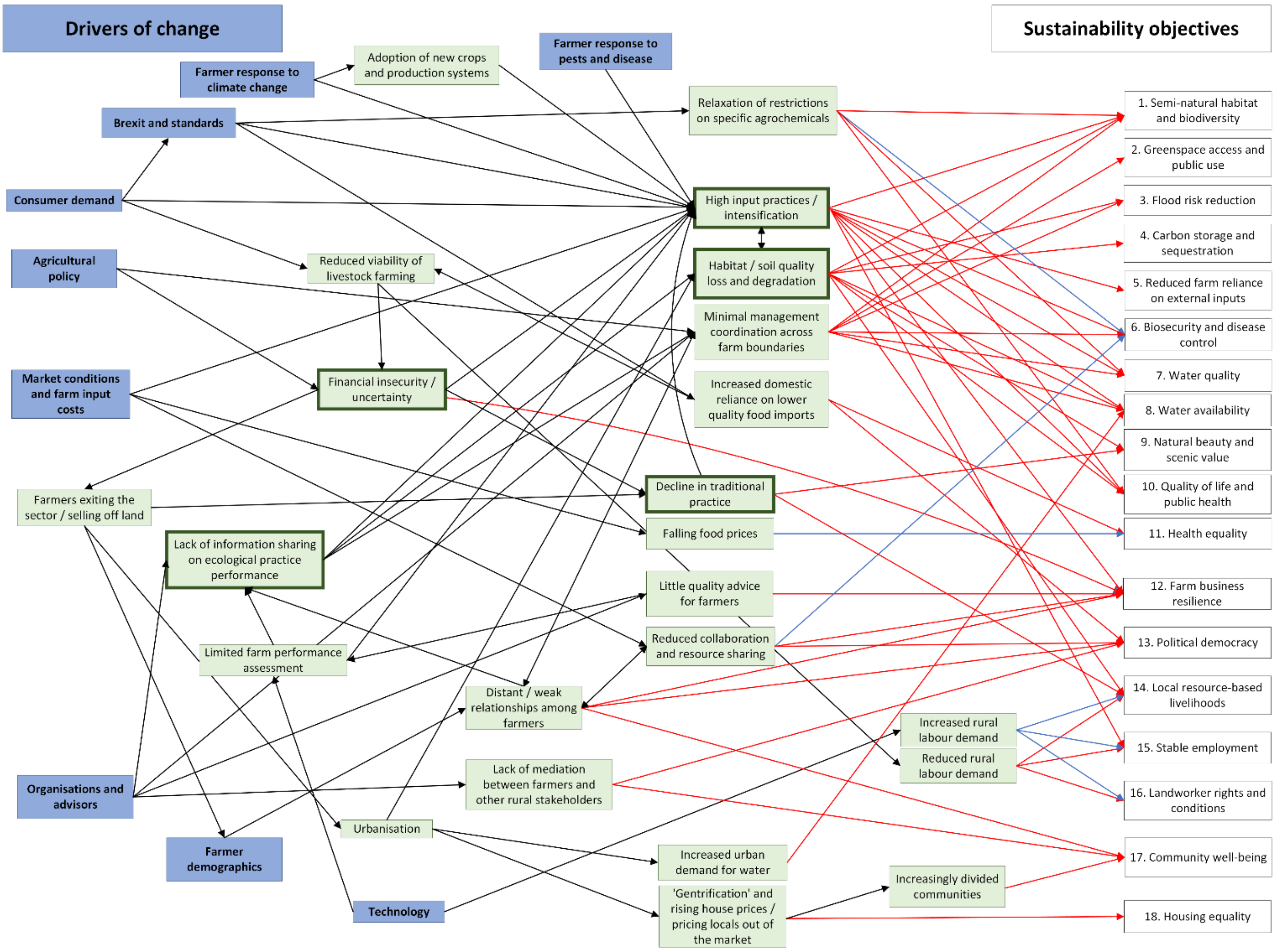

Figure 20. Network graph showing the key cause-effect relationships between the drivers of change, their consequences, and subsequent positive (blue lines) and negative (red lines) impacts on the sustainability objectives for the High Weald under Scenario 4 (low, dispersed adoption of a mix of conservation agriculture and low-input farming, referred to locally as 'regenerative agriculture'). Boxes with thick outlines represent structurally key nodes in the graph (the top 5 nodes with the highest proximity prestige values).

Figure 20 shows the network of causal relationships underpinning the poor sustainability performance of the low and dispersed adoption scenario in the High Weald. Among the 5 most influential nodes in this network, 4 represent the reverse of the equivalent nodes in the high clustered scenario network.

In the high clustered scenario, low-input practices and soil / habitat restoration occupied the most structurally key positions, reflecting features of the ecological farming approach that were widespread in that scenario. In the low dispersed scenario, agricultural intensification / high input practices, and the loss or degradation of soils and habitats, were the most important nodes. Again, this is unsurprising, because these nodes characterise the absence of ecological farm management approaches, and the dominance of more conventional, intensive agricultural practices in the landscape. These aspects of intensive practice were linked to negative effects on a range of environmental, social, and economic sustainability objectives. Therefore, the features of agricultural intensification at the farm level play a large role in contributing to the overall negative sustainability performance of this low adoption scenario.

Again, the ability of farmers to access information on the performance of an ecological approach is crucial in determining overall sustainability performance. In the high clustered scenario, the information dissemination on the benefits of ecological practices and management coordination is highly influential in achieving the scenario's strong territorial sustainability performance. Conversely, in the low dispersed scenario, limited sharing of this information reinforces the use of farming practices associated with high intensity and input use, continued degradation of soils and habitats, and a focus on land management within, rather than across, individual farms, compromising territorial sustainability performance. Under this scenario, failure to share information is the outcome of insufficient support and expertise from external organisations and advisors, a lack of technologies to accurately measure the impact of ecological practices, and demographic change disrupting established networks of farmers, weakening relationships and reducing communication. Therefore, this analysis identifies limited production and diffusion of information on ecological farming performance as a key barrier to achieving landscape scale sustainability objectives in the High Weald.

The remaining highly influential nodes in the network for the low dispersed scenario concern financial insecurity or uncertainty for farmers, and the decline in traditional farming practices within the High Weald. As described above, the High Weald landscape is the product of a tradition of low-input extensive livestock farming, and performance against many of the area's sustainability objectives is strongly dependent on the persistence of these traditional land management practices. However, farmer financial insecurity or uncertainty threatens their ability to continue applying these practices, and in a low dispersed adoption scenario, agricultural policy, consumer demand, and post-Brexit trading conditions all act to increase the financial precarity of farmers in the High Weald.

Under the low dispersed adoption scenario, poorly designed agri-environment measures following policy reform, coupled with the phasing out of area-based subsidies, mean farmers no longer have the financial security or certainty they had under the old policy regime. Stakeholders argued that this loss of security has three major implications for the sustainability of the High Weald landscape. Firstly, farmers may respond to greater uncertainty by prioritising short-term profitability over long-term performance, encouraging the use of more intensive practices that are at odds with the traditional low-input practices that have contributed to the High Weald's distinctive character. Secondly, without financial support that has 'no strings attached', farmers may no longer have the luxury of conducting practices that contribute to the High Weald's cultural heritage (due to its status as an ancient pastoral landscape), which have been overlooked by previous agri-environment measures. Thirdly, a lack of financial security may drive farmers to leave the area or exit the sector entirely, cashing in on their assets by selling up their land, much of which may then be used for building, given a growing interest in large-scale urban developments in the area. In this scenario, the increased pressures on High Weald farmers resulting from policy changes are compounded by changes in consumer demand and effects of Brexit. A continued reduction in red meat consumption, and trade agreements with countries with lower standards of food production, reduce the financial viability of domestic livestock production in England, and so drive further declines in low-input livestock farming in the High Weald.

Therefore, under this low dispersed scenario, much of the low-input farmland key to the High Weald's character and designation as an Area of Outstanding Natural Beauty, may be lost to land uses less sympathetic to the local landscape character, whether these are urban developments or more intensive forms of agriculture. Drivers of change that reduce the rate of ecological farming adoption therefore also act to threaten the wider environmental, social, and economic value of the High Weald landscape.

6. Conclusions

This study used a qualitative, objective-led approach to assess the sustainability of ecological farming approaches at a territorial level, specifically focusing on how the rate and distribution of adoption of ecological approaches impact on regional sustainability objectives. Across case study areas, territorial sustainability performance was enhanced under scenarios with a higher rate of adoption and when adoption occurred in a clustered distribution (although the distribution of adoption tended to have a smaller, less pronounced impact on objectives than the rate of adoption). Therefore, the 'high, clustered' adoption scenario typically made the strongest contribution to achieving regional sustainability objectives.

The same overall theme was seen when considering the environmental and social dimensions of sustainability separately, with the high and clustered scenarios performing best overall for environmental and social objectives. The importance of the spatial distribution of land management practices for environmental and social goals is now well established in the literature, and the results of this assessment reinforce this perspective. Since the drivers of public good and ecosystem service provision operate across farm boundaries, joined-up management approaches that span neighbouring farms have the potential to enhance environmental performance, with implications for human health and well-being (Abler 2004; Renting et al. 2009; Lawton et al. 2010; Mckenzie et al. 2013). Moreover, cooperative initiatives that may be associated with clustering of management practices have also been linked to social benefits for rural communities, including enhancements to community cohesion, education, and engagement with local issues (Jarrett et al. 2015). Economic sustainability, however, according to the assessments conducted here, tended to be impacted by the rate of adoption, but only rarely by adoption distribution. This suggests that if the social and environmental benefits of clustered adoption of ecological approaches are to be realised, interventions may be required to address the economic performance of the resulting agricultural landscapes.

The fact that higher rates of adoption of ecological practices positively impacted a wide range of sustainability objectives indicates two key points. Firstly, the practices expected to be applied as part of an ecological approach in each case study area are appropriate for achieving sustainability objectives specific to that area. It might seem self-evident that high adoption of ecological approaches would positively contribute to a region's environmental sustainability objectives, but this does demonstrate that the practices identified by stakeholders as relevant to future ecological adoption scenarios do tend to be appropriate for regional objectives. There is an alignment between a region's requirements for environmental sustainability, and what the chosen ecological farming approaches for the region deliver. Secondly, in at least some areas, the adoption and spread of these appropriate ecological farming approaches appear to be able to deliver 'win-win-win' outcomes for the region that reconcile performance in environmental, social, and economic dimensions of sustainability.

However, the results of these assessments also show how, even if high clustered adoption of ecological approaches maximises positive impacts on regional sustainability objectives, there are likely to be some sustainability objectives where this scenario will not be the preferred option. For nearly all case study areas, there was at least one objective that performed as well or better under a lower rate of adoption, or a dispersed distribution, of ecological approaches.

Therefore, even if high clustered adoption of an ecological farming approach makes a more positive overall contribution to sustainability at a territorial level, if this scenario plays out in practice, policy makers still have to manage trade-offs when considering sustainability objectives that would be better served under alternative adoption patterns. Navigating such trade-offs may require an understanding of the relative importance or desirability of the different sustainability objectives, which could be achieved through assigning weights to objectives. The stakeholder-based approach used in this exercise to generate the shortlist of objectives for each case study area could be modified to generate these weights. This would require a more survey-based, quantitative design for collecting data from a representative sample with sufficient replication on stakeholder preferences for different objectives. However, there is a risk that applying weights to objectives could compromise some of the strengths of this qualitative approach, encouraging non-technical audiences to overlook the need for compromise between different objectives, neglecting interdependencies among objectives, and possibly distorting assessment outcomes.

The example of the High Weald case study area shows how this process of combining scenario analysis and qualitative impact mapping can be extended with network analysis to identify key pathways underpinning the assessed sustainability performance of ecological farming approaches at the territorial level, highlighting barriers or opportunities for realising the benefits associated with a particular scenario.

In particular, the network analysis output stressed the importance of the ability of farmers to generate, share, and access information on the performance of ecological practices (at both farm and landscape level), for achieving the positive impacts across environmental, social, and economic sustainability objectives under a high clustered adoption scenario. Moreover, the network graphs indicated how strong organisational and advisory support, the use of technology to quantify the effects of ecological practices, and the quality of relationships between farmers, all contribute to the level of information exchange and therefore could present targets for cost-effective interventions focused on improving territorial sustainability performance.

Access to easily observable and communicable information on the benefits of practice performance has long been recognised as a key condition for the adoption of ecological approaches (Feder & Slade 1984; Wandel & Smithers 2000; Kallas et al. 2010; Wossen et al. 2013; Dessart et al. 2019). The assessment approach used here shows how information dissemination can not only play a key role for adoption and therefore performance at the farm level, but also has the potential to shape wider territorial sustainability.

The networks also illustrate how the territorial sustainability performance of the ecological farming adoption scenarios is the product of processes at the farm level (the use of low-input and traditional practices, soil, and habitat restoration), accumulated across the landscape, and processes operating between farms, across the landscape (farmer relationships, information sharing, coordinating management). Moreover, the networks also suggest possible areas of interaction between these farm- and landscape-level processes, identifying factors which influence territorial sustainability performance through their association with both the rate and distribution of adoption.

This can be illustrated in relation to the role of farmer interpersonal relationships in the High Weald scenarios. The relationships and networks among farmers provide means for the dissemination of information on farm performance, which promotes increased adoption of ecological approaches on individual farms, which contributes to positive impacts on territorial sustainability objectives. These same relationships, however, can also encourage the coordination of management across farm boundaries, along with farmer collaboration and resource sharing, with associated social and economic benefits. Again, there is a well-established body of evidence from spatial analyses and farmer surveys showing how farmer interpersonal relationships can influence the distribution of agricultural approaches across a region (Lastra-Bravo et al. 2015; Dessart et al. 2019). The assessment methodology used here builds on this theme by showing how these interpersonal relationships contribute to territorial performance across different aspects of sustainability.

This combination of qualitative impact mapping and network analysis has been applied to objective-led sustainability assessment before. However, in previous cases, assessments focused on scenarios that explicitly reflected alternative policy directions (Tzanopoulos et al. 2011; Boron et al. 2016). In this case, the scenario development process instead focused on the spread of a set of practices for agricultural land management, rather than starting with any particular policy philosophy. This methodology could provide the starting point for assessing and comparing the territorial sustainability performance of alternative farming approaches or systems. A key challenge here is to reconcile this approach with farm-level sustainability assessments. At the farm level, assessments can easily focus on a set of practices or an approach that characterises a specific type of farms. However, a region or territory is likely to contain a variety of farms applying a range of practices in different combinations, making it difficult for a territorial-scale assessment to consider the performance of a certain farming approach. If this challenge can be overcome, combining farm- and territorial-level assessments while using the methodological framework described here could help identify elements or pathways where farm-level sustainability performance may align with territorial performance, and where there may be disconnects between farm- and territorial-level performance.

The results presented here illustrate several potential applications of this sustainability assessment methodology for studying landscape scale performance of ecological farming, or other rural land uses and management approaches. This assessment framework can be used to determine whether a given ecological approach is appropriate for the local context. If the high adoption scenario is not clearly associated with the strongest sustainability performance, it could prompt policy makers and stakeholders to re-think what kinds of approaches are best suited for the local conditions. However, it is also possible that this result could reflect a lack of stakeholder awareness of potential benefits of an ecological approach, and therefore highlight a need to raise awareness about the performance of alternative ecological agriculture approaches. In order to discriminate between these possibilities, it is important that the results from stakeholder input are interpreted in the context of the academic literature and expert knowledge. Determining which specific objectives may be positively impacted under high adoption scenarios helps identify opportunities for ecological approaches to deliver landscape scale benefits. Conversely, the negative impacts associated with these scenarios highlight costs or threats to sustainability performance that arise if ecological farming spreads in a particular way, which could focus the attention of policy makers on developing solutions to mitigate these costs. If the adoption of ecological farming starts to proceed in a direction that resembles one of the assessed scenarios, authorities will then be well-equipped to identify the risks or trade-offs for territorial sustainability that will need to be addressed in this situation.

The assessment output can also be useful for pinpointing areas of uncertainty that prevent stakeholders and experts from coming to a consensus about the territorial performance of different farming approaches. The iterative nature of the assessment process and stakeholder participation, however, means that this methodology could also provide opportunities to foster productive discussion and convergence among stakeholders representing contrasting viewpoints. If areas of uncertainty persist, this could highlight where further research and stakeholder engagement efforts should be prioritised. More generally, although the use of a qualitative approach means these results are influenced by subjective judgements and may be vague about the relative magnitude of different impacts, this approach can be valuable for identifying key topics that merit further study using quantitative methods.

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Appendices

Appendix 1: Sustainability objectives per case study area

Table A.1.1. Sustainability objectives for Salzburg und Umgebung, Austria. Number of stakeholders: 15

1	Achieve resilience towards environmental and natural hazards and the consequences of climate change
2	Promote the selling of regional food (awareness raising among consumers, regional labels, etc.)
3	Raising public awareness of the natural resources in the region and their sustainable use
4	Promotion of the sustainable use of agricultural land to supply local markets, reduction of Austria's dependence on non-sustainably managed land and the necessity of long transport routes for resources with the associated global, social and ecological effects
5	Maintaining and securing agricultural production (among other things by securing agricultural priority areas, yields, jobs)
6	Securing the forest stand and multifunctionality of forests (productive, protective, welfare and ecological function)/improving forest ecosystems
7	Promoting the diversification and competitiveness of farms in the region
8	Achieving a cultural change towards more sustainable behaviour
9	Pursuing collaborations that enable more efficient use of resources
10	Promoting the production and consumption of renewable energy and resources (in the private and public sector)
11	Securing regional and demand-oriented local supply and public services and increasing the population's awareness of their importance
12	Primarily inward-oriented development to reduce urban sprawl and soil consumption, awareness raising among decision makers
13	To preserve and promote biodiversity in the region
14	Adaptation to the expected risks of water shortage
15	Adaptation to the effects of already unavoidable climate change
16	Protecting and restoring natural carbon stocks and increasing carbon sequestration

Table A.1.2. Sustainability objectives for Hageland-Haspengouw, Belgium. Number of stakeholders: 8

1	To maintain and develop diverse, vibrant, creative, and locally distinctive communities, encouraging pride in the rural community and cohesion within it, recognising the needs and contributions of all individuals]
2	To protect and restore natural carbon stores and increase carbon sequestration
3	To minimise the fragmentation of residential areas by promoting the renovation of existing infrastructure as well as planning new infrastructure as compactly as possible
4	To promote the sustainable / rational management of water resources for agriculture, protecting and improving water quality, and the availability and continuity of the water supply
5	To adapt to anticipated risks of shortages in the water supply for agriculture
6	To ensure the sustainable / rational management of soils for agriculture, preserving and restoring soil quality and quantity
7	To stimulate short-chain marketing of farming and food products
8	To safely increase accessibility of services by foot and by bicycle
9	To promote the development of (formal and / or informal) institutions or structures that allow members of the community to support each other, according to their own values and norms e.g. local associations and cooperatives
10	To enable farmers to feel professional pride in their work, and reconcile the daily reality of being a farmer with their expectations / perceptions of their role / identity
11	To increase the potential for farming to be an economically viable option for making a living / managing land
12	To sustainably maintain and restore hollow roads in consultation with farmers
13	Targeted biodiversity initiatives which contribute to the experiencing of nature by those in the surrounding area
14	To enable the agricultural sector, and wider society, to adapt to the effects of that climate change which is already unavoidable
15	To maintain / increase the quality of life, health, and well-being associated with the farming lifestyle and for the rural community, and minimise threats to public health
16	To protect / improve the resilience of rural communities to change
17	To ensure that landscape features of cultural heritage or aesthetic value are recognised, conserved, and enhanced
18	To conserve and enhance natural biodiversity / protect endangered species
19	To conserve, restore, and create semi-natural habitats and their connectivity (within and outside of protected sites), to establish and improve functional and resilient ecological networks
20	To reduce farm vulnerability to external events / increase the resilience of farm businesses

Table A.1.3. Sustainability objectives for High Weald, England, UK. Number of stakeholders: 14

1	To conserve and restore characteristic semi-natural habitats and the biodiversity they support, enhancing habitat connectivity to support functional and resilient networks
2	To maximise accessibility to high quality, natural spaces that the public can use for the benefit of their health and well-being, and increase public understanding of, and engagement with the natural environment
3	To reduce the risk posed by flooding to people, the environment, and the economy
4	To protect and improve water quality
5	To protect and improve the availability and continuity of the local water supply, and adapt to anticipated risks of shortages in the water supply
6	To protect and restore natural carbon stores and increase carbon sequestration
7	To increase the quality of life, health, and well-being of those living and working in the region, including minimising threats to public health
8	To reduce inequalities in health and life expectancy
9	To ensure an adequate supply of affordable, well-constructed housing, with an appropriate mix of types and tenures to reflect the demands and means of all sections of society
10	To ensure that the natural beauty and scenic value of the region is recognised, conserved, and enhanced
11	To enhance biosecurity to protect wildlife, crops, and livestock by managing the impact of existing diseases, reducing the risk of new ones, and tackling invasive non-native species
12	To increase the resilience of farm businesses to crisis / external events
13	To increase farm self-sufficiency in terms of resource use, minimising reliance on external inputs on the farm
14	To increase the level and stability of local employment and income / increasing access to rewarding and well-located employment opportunities, so everyone has the chance to benefit from economic growth in the region
15	To promote new livelihood opportunities based on local resources
16	To protect labour rights and good working conditions for farmers and agricultural workers
17	To encourage the active participation of local communities in local policy and decision-making processes, giving communities more power to influence the decisions that affect them
18	To develop structures that help community members support each other, according to their own values / norms, encouraging cohesion within diverse, vibrant, and locally distinctive communities, recognising the needs and contributions of all individuals

Table A.1.4. Sustainability objectives for North Kent, England, UK. Number of stakeholders: 15

1	To conserve and restore characteristic semi-natural habitats and the biodiversity they support, enhancing habitat connectivity to support functional and resilient networks
2	To maximise accessibility to high quality, natural spaces that the public can use for the benefit of their health and well-being, and increase public understanding of, and engagement with the natural environment
3	To reduce the risk posed by flooding to people, the environment, and the economy
4	To protect and improve water quality
5	To protect and improve the availability and continuity of the local water supply, and adapt to anticipated risks of shortages in the water supply
6	To protect and restore natural carbon stores and increase carbon sequestration
7	To increase the quality of life, health, and well-being of those living and working in the region, including minimising threats to public health
8	To reduce inequalities in health and life expectancy
9	To ensure an adequate supply of affordable, well-constructed housing, with an appropriate mix of types and tenures to reflect the demands and means of all sections of society
10	To ensure that the natural beauty and scenic value of the region is recognised, conserved, and enhanced
11	To enhance biosecurity to protect wildlife, crops, and livestock by managing the impact of existing diseases, reducing the risk of new ones, and tackling invasive non-native species
12	To increase the resilience of farm businesses to crisis / external events
13	To increase farm self-sufficiency in terms of resource use, minimising reliance on external inputs on the farm
14	To increase the level and stability of local employment and income / increasing access to rewarding and well-located employment opportunities, so everyone has the chance to benefit from economic growth in the region
15	To promote new livelihood opportunities based on local resources
16	To protect labour rights and good working conditions for farmers and agricultural workers
17	To encourage the active participation of local communities in local policy and decision-making processes, giving communities more power to influence the decisions that affect them
18	To develop structures that help community members support each other, according to their own values / norms, encouraging cohesion within diverse, vibrant, and locally distinctive communities, recognising the needs and contributions of all individuals

Table A.1.5. Sustainability objectives for Ille-et-Vilaine, France. Number of stakeholders: 15

1	To promote the sustainable / rational management of water resources for agriculture, protecting and improving water quality, and the availability and continuity of the water supply
2	To ensure the sustainable / rational management of soils for agriculture, preserving and restoring soil quality and quantity
3	To promote the sustainable use of synthetic fertilisers in a way that preserves and restores natural nutrient flows and cycles
4	To reduce greenhouse gas emissions through more efficient energy use and increasing the proportion of energy generated from renewable sources
5	To reduce farm vulnerability to external events / increase the resilience of farm businesses
6	To conserve cultivated plants and animals and their associated genetic resources
7	Inhibit land artificialisation
8	To reduce waste generation by minimising waste disposal and increasing recycling and re-use of materials to support the development of a circular economy
9	To protect and restore natural carbon stores and increase carbon sequestration
10	To enable the agricultural sector, and wider society, to adapt to the effects of that climate change which is already unavoidable
11	To ensure equal human rights and security / sharing access to services and benefits of prosperity fairly
12	To respond positively to trends in the wider economy, ensuring that inhabitants of rural areas are not left behind / suffer an unreasonable disadvantage, relative to urban areas
13	To protect labour rights and good working conditions for farmers and agricultural workers
14	To promote the sustainable use of agricultural land for supplying local markets, reducing the region's (and France) dependency on non-sustainably managed land and the need for the long-distance transport of resources with its associated global, social, and environmental impacts
15	To maintain and restore natural functions / processes within river catchments, promoting benefits for water quality, storage, and flow regulation
16	To meet the needs of the present without compromising the ability of future generations to meet their own needs in terms of non-renewable resources (oil, natural gas, minerals, precious metals…) that must be used sparingly
17	To maintain / increase the quality of life, health, and well-being of those living and working in Ille-et-Vilaine, including minimising threats to public health
18	To enhance the safety and nutritional quality of agricultural produce, increasing diet quality and consumer confidence in food
19	To give farmers the freedom to make their own management decisions, according to personal insights, capabilities, and desires
20	To increase the capacity of farming to meet local demand and contribute to national food security, increasing the resilience of the food chain in the face of changing conditions
21	To increase the potential for farming to be an economically viable option for making a living / managing land
22	To enable farmers to increase self-sufficiency in terms of resource use, minimising use of external inputs on the farm
23	Insure consistency between European, national, regional and local public policies for a better articulation between local and global issues

Table A.1.6. Sustainability objectives for Sarthe, France. Number of stakeholders: 8

1	To maintain and develop diverse, vibrant, creative, and locally distinctive communities, encouraging pride in the rural community and cohesion within it, recognising the needs and contributions of all individuals]
2	To protect and restore natural carbon stores and increase carbon sequestration
3	To promote the sustainable / rational management of water resources for agriculture, protecting and improving water quality, and the availability and continuity of the water supply
4	To adapt to anticipated risks of shortages in the water supply for agriculture
5	To ensure the sustainable / rational management of soils for agriculture, preserving and restoring soil quality and quantity
6	To stimulate short-chain marketing of farming and food products
7	To promote the development of (formal and / or informal) institutions or structures that allow members of the community to support each other, according to their own values and norms e.g. local associations and cooperatives
8	To enable farmers to feel professional pride in their work, and reconcile the daily reality of being a farmer with their expectations / perceptions of their role / identity
9	To enable the agricultural sector, and wider society, to adapt to the effects of that climate change which is already unavoidable
10	To maintain / increase the quality of life, health, and well-being associated with the farming lifestyle and for the rural community, and minimise threats to public health
11	To protect / improve the resilience of rural communities to change
12	To ensure that landscape features of cultural heritage or aesthetic value are recognised, conserved, and enhanced
13	To conserve and enhance natural biodiversity / protect endangered species
14	To conserve, restore, and create semi-natural habitats and their connectivity (within and outside of protected sites), to establish and improve functional and resilient ecological networks
15	To reduce farm vulnerability to external events / increase the resilience of farm businesses

Table A.1.7. Sustainability objectives for Puy-de-Dôme & border areas, France. Number of stakeholders: 15

1	To enable the agricultural sector, and wider society, to adapt to the effects of that climate change which is already unavoidable
2	To reduce farm vulnerability to external events / increase the resilience of farm businesses
3	Manage usage conflicts between different users of natural spaces / reconcile diverse utilisation of natural spaces (agriculture, leisure, nature protection, urbanism…)
4	To promote the sustainable / rational management of water resources for agriculture, protecting and improving water quality, and the availability and continuity of the water supply
5	To adapt to anticipated risks of shortages in the water supply for agriculture, in particular in the plain of Limagne
6	To increase the potential for farming to be an economically viable option for making a living / managing land
7	To conserve cultivated plants and animals and their associated genetic resources
8	To promote the sustainable use of agricultural land for supplying local markets, reducing the region's (and France) dependency on non-sustainably managed land and the need for the long-distance transport of resources with its associated global, social, and environmental impacts
9	To ensure the sustainable / rational management of soils for agriculture, preserving and restoring soil quality and quantity
10	To increase the capacity of farming to meet local demand and contribute to national food security, increasing the resilience of the food chain in the face of changing conditions
11	To increase the total farm profit / income that the farmer (and their household) has at their disposal
12	To enable farmers to increase self-sufficiency in terms of resource use, minimising use of external inputs on the farm
13	To conserve and enhance the biodiversity of the Puy-de-Dôme
14	To reduce greenhouse gas emissions through more efficient energy use and increasing the proportion of energy generated from renewable sources
15	To enhance the safety and nutritional quality of agricultural produce, increasing diet quality and consumer confidence in food
16	To enable farmers to feel professional pride in their work, and reconcile the daily reality of being a farmer with their expectations / perceptions of their role / identity
17	To protect the welfare, health, and well-being of livestock
18	To enhance biosecurity to protect wildlife and livestock by managing the impact of existing diseases, reducing the risk of new ones, and tackling invasive native and non-native species (*Arvicola terrestris*, *Ambrosia artemisiifolia*...)
19	To respond positively to trends in the wider economy, ensuring that inhabitants of rural areas are not left behind / suffer an unreasonable disadvantage, relative to urban areas
20	To increase the level and stability of local employment and income / increasing access to rewarding and well-located employment opportunities and greater earning power for all, so everyone has the chance to benefit from economic growth in the region
21	To provide an environment that is attractive to starting and growing a business
22	To support development of a dynamic and knowledge-based economy that maximises opportunities for farm / business innovation

Table A.1.8. Sustainability objectives for Upper Bavaria, Germany. Number of stakeholders: 2

1	To conserve and enhance biodiversity in the catchment's regions
2	To protect and improve air quality, supporting farmers to invest in / adopt farm infrastructure, equipment and techniques that reduce emissions, and minimising pollution from fertiliser use
3	To promote the sustainable / rational management of water resources for agriculture, protecting and improving water quality, and the availability and continuity of the water supply
4	To reduce the risk posed by flooding to people, the environment, and the economy
5	To enable the agricultural sector, and wider society, to adapt to the effects of that climate change which is already unavoidable
6	To protect the welfare, health, and well-being of livestock
7	To maintain and restore natural functions / processes within river catchments, promoting benefits for water quality, storage, and flow regulation
8	To ensure the sustainable / rational management of soils for agriculture, preserving and restoring soil quality and quantity
9	To reduce greenhouse gas emissions through more efficient energy use and increasing the proportion of energy generated from renewable sources
10	To enhance the safety and nutritional quality of agricultural produce, increasing diet quality and consumer confidence in food
11	To ensure that the natural beauty / scenic value of the regions of the catchment are recognised, conserved, and enhanced
12	To increase the total farm profit / income that the farmer (and their household) has at their disposal
13	To increase the level and stability of local employment and income / increasing access to rewarding and well-located employment opportunities and greater earning power for all, so everyone has the chance to benefit from economic growth in the region
14	To reduce the amount of agricultural land converted to areas for settlement, industry or traffic.
15	To promote sustainable use of fertiliser / nutrients in a way that preserves and restores natural nutrient flows and cycles
16	To conserve cultivated plants and animals and their associated genetic resources
17	To conserve and restore semi-natural habitats characteristic of the catchment's regions, enhancing habitat condition and connectivity to establish and improve functional and resilient ecological networks
18	To increase the public's understanding of / engagement with the catchment regions' natural environment
19	To maximise accessibility to high quality, natural spaces that the public are encouraged to visit for the benefit of their health and well-being
20	To give farmers the freedom to make their own management decisions, according to personal insights, capabilities, and desires
21	To enhance biosecurity to protect wildlife and livestock by managing the impact of existing diseases, reducing the risk of new ones, and tackling invasive non-native species
22	To increase the capacity of farming to meet local demand and contribute to national food security, increasing the resilience of the food chain in the face of changing conditions
23	To provide an environment that is attractive to starting and growing a business / helps farmers establish and retains existing ones
24	To support development of a dynamic and knowledge-based economy that maximises opportunities for farm / business innovation
25	To improve access to the local historic environment, providing better opportunities for people to learn about, experience, and celebrate the heritage and history of the regions of the catchment, encouraging people to care for those regions and support their conservation, with their cultural heritage acting as a source of inspiration and enjoyment

Table A.1.9. Sustainability objectives for East Crete, Greece. Number of stakeholders: 9

1	To promote the sustainable use of fertiliser / nutrients in a way that preserves and restores natural nutrient flows and cycles
2	To promote the sustainable / rational management of water resources for agriculture, protecting and improving water quality, and the availability and continuity of the water supply
3	To ensure the sustainable / rational management of soils for agriculture, preserving and restoring soil quality and quantity
4	To ensure that the natural beauty / scenic value of the regions are recognised, conserved, and enhanced
5	To conserve genetic resources of cultivated plants and livestock
6	To conserve and restore semi-natural habitats, establishing functional and resilient ecological networks
7	To increase the public's understanding of / engagement with the natural environment (ecosystem services)
8	To adapt to anticipated risks of shortages in the water supply for agriculture
9	To maintain and restore natural functions / processes within river catchments.
10	To enable the agricultural sector, and wider society, to adapt to the effects of that climate change which is already unavoidable
11	To increase the total farm profit / income that the farmer (and their household) has at their disposal
12	To reduce farm vulnerability to external events / increase the resilience of farm businesses
13	To promote the development of (formal and / or informal) institutions or structures that allow members of the community to support each other, according to their own values and norms e.g. local associations and cooperatives
14	To conserve and enhance biodiversity
15	To promote the sustainable use of agricultural land for supplying local markets and reducing dependence on products derived from non-sustainably production systems and the need for the long-distance transport of resources resulting in a high carbon footprint
16	To protect and improve air quality, supporting farmers to invest in / adopt farm infrastructure, equipment and techniques that reduce emissions, and minimising pollution from fertiliser use
17	To improve education services and opportunities for training and lifelong learning in the area, ensuring a skilled workforce
18	To promote the continued application of traditional agricultural knowledge, skills, and practices
19	To retain and restore the distinctive medieval landscape features, pattern, and character of the regions
20	Encourage local communities to improve, preserve and promote their cultural heritage
21	To support a heritage-led and environmentally responsible tourism sector
22	To increase the potential for farming to be an economically viable option for making a living
23	To protect labour rights and good working conditions for farmers and agricultural workers
24	To connect agricultural biodiversity, human health and nutrition

Table A.1.10. Sustainability objectives for Veszprém, Hungary. Number of stakeholders: 6

1	To conserve and enhance biodiversity in the catchment's regions
2	To promote the sustainable / rational management of water resources for agriculture, protecting and improving water quality, and the availability and continuity of the water supply
3	To ensure the sustainable / rational management of soils for agriculture, preserving and restoring soil quality and quantity
4	To enable the agricultural sector, and wider society, to adapt to the effects of that climate change which is already unavoidable
5	To conserve cultivated plants and animals and their associated genetic resources
6	To conserve and restore semi-natural habitats characteristic of the catchment's regions, enhancing habitat condition and connectivity to establish and improve functional and resilient ecological networks
7	To promote the sustainable use of fertiliser / nutrients in a way that preserves and restores natural nutrient flows and cycles
8	To reduce waste generation by minimising waste disposal and increasing recycling and re-use of materials to support the development of a circular economy
9	To improve education services and opportunities for training and lifelong learning in the area, and improve levels of educational achievement, including focusing on equipping local people with the necessary skills for finding and remaining in work / ensuring a skilled workforce
10	To respond positively to trends in the wider economy, ensuring that inhabitants of rural areas are not left behind / suffer an unreasonable disadvantage, relative to urban areas
11	To provide an environment that is attractive to starting and growing a business / helps new farmers establish and retains existing ones
12	To support development of a dynamic and knowledge-based economy that maximises opportunities for farm / business innovation
13	To increase the level and stability of local employment and income / increasing access to rewarding and well-located employment opportunities and greater earning power for all, so everyone has the chance to benefit from economic growth in the region
14	To increase the public's understanding of / engagement with the catchment regions' natural environment
15	To protect and improve air quality, supporting farmers to invest in / adopt farm infrastructure, equipment and techniques that reduce emissions, and minimising pollution from fertiliser use
16	To adapt to anticipated risks of shortages in the water supply for agriculture
17	To maintain and restore natural functions / processes within river catchments, promoting benefits for water quality, storage, and flow regulation
18	To reduce greenhouse gas emissions through more efficient energy use and increasing the proportion of energy generated from renewable sources
19	To reduce inequality in health and life expectancy, both across society (e.g. between rich and poor), and between geographical areas, closing the gaps between the areas with the most deprivation and exclusion and the rest of the region
20	To support a heritage-led and environmentally responsible tourism sector

Table A.1.11. Sustainability objectives for Emilia Romagna, Italy. Number of stakeholders: 3

1	Improvement in the connectivity of natural and seminatural habitats
2	To support a rational management of water
3	Reducing the risk of floods
4	Helping the agricultural sector to adapt to climate change
5	To improve the capacity of the agricultural sector to meet the local demand of food and the national food security
6	Biodiversity conservation
7	Conservation and restoration of natural and seminatural habitats
8	Improvement in the engagement of the public toward the natural environment
9	Improving the quality of water
10	Anticipating the risks of water scarcity for the agricultural sector
11	Ensuring a sustainable use of the soil and soil quality
12	To reduce waste generation by minimising waste disposal and increasing recycling and re-use of materials to support the development of a circular economy
13	Improving the efficiency of energy use to reduce the emission of greenhouse gases
14	To protect and restore natural carbon stores and increase carbon sequestration
15	Improving food safety and improving the trust of consumers in food
16	To protect the welfare, health, and well-being of livestock
17	To protect and support traditional agricultural practices
18	To create an attractive environment that supports the creation and the development of enterprises
19	Reducing the vulnerability of the agricultural sector
20	Increasing the level and the stability of local employment

Table A.1.12. Sustainability objectives for Lubelskie, Poland. Number of stakeholders: 8

1	The good state of surface and groundwater bodies.
2	Development of agri-food processing sector that utilize the resource potential of the region.
3	Providing rural areas with transport, communal and energy infrastructure in an internally consistent manner, as well as, coordinated with other undertakings.
4	Improving the internal communication of the region based on the connection of its most important cities with an efficient road network, built in the first place where its imperfection is a barrier to development.
5	Improving the quality of air while ensuring energy security in the context of climate change.
6	Protection against extreme events related to water.
7	Protection of soils against negative anthropogenic impact, erosion and adverse climate changes.
8	Waste management in accordance with the hierarchy of waste management methods, taking into account the sustainable development of the Lubelskie Voivodeship.
9	Protection of biological and landscape diversity.
10	Improving communication between Lublin and the metropolitan areas of Poland and abroad.
11	Rational water and sewage management.
12	Strengthening the competitiveness of small and medium-sized enterprises (SMEs).
13	Supporting higher education courses, which are particularly important for the future labour market of the region and are of unique importance on a supra-regional scale.
14	Strengthening the regional research and innovation system.
15	Creating cross-border cooperation networks between institutions and organizations dealing with the natural environment, culture, tourism and sport.
16	Improving road accessibility of border crossings.
17	Limiting the risk of major industrial accidents and minimizing their effects.
18	Environmental protection and shaping the image of the region as environmentally friendly.
19	Restructure of agriculture and development of rural areas.
20	To support the most promising directions of research and commercialization of their results.

Table A.1.13. Sustainability objectives for Podlaskie, Poland. Number of stakeholders: 8

1	Supporting the development of renewable energy sources (RES) and diversified energy sources.
2	Improving the efficiency of the health care system in the Podlaskie Voivodeship.
3	Effective waste management system (reducing the amount of waste generated; increasing public awareness; waste segregation; elimination of illegal waste storage sites; municipal waste monitoring system).
4	Development of ecological forms of agricultural production and related development of local processing and sale of high-quality food, also through participation in producer groups.
5	Social innovations as a form of solving socio-economic challenges (aging of the society, digital revolution, climate change, the need to constantly adapt the competences of inhabitants, and others).
6	Higher education suited to the needs of region's smart specializations.
7	Stimulating cooperation between science and economy.
8	Support technologically advanced products and services.
9	Expansion and modernization of energy transmission and distribution infrastructure, including the development of intelligent energy transmission and distribution systems.
10	Protection of natural resources and landscape.
11	Protection of air, soil, water and other resources.
12	Low-carbon economy (including energy efficiency and reducing material consumption).
13	Providing knowledge about conduction of business, as well as, shaping entrepreneurial attitudes at all stages of formal education.
14	Development of tourism based on natural assets and local tourist products.
15	Improving the standard of living of inhabitants and the competitiveness of enterprises through equal access to the Internet (broadband network).
16	Economic promotion of the region at national and international level.
17	Internationalization of region's (Podlaskie) enterprises, in particular, export support.
18	Supporting research and development (R&D) activities.
19	Promotion of the voivodeship as an attractive place to live, invest, work, study and rest.
20	Development and modernization of environment protection infrastructure, as well as, creation a space for the circular economy.

Table A.1.14. Sustainability objectives for Suceava county, Romania. Number of stakeholders: 23

1	Providing the conditions for a durable development of the rural area, by investments in the local infrastructure (technical/urbanistic, rural, ICT)
2	Substantial increase of the water's use efficiency in industrial, commercial and agricultural activities
3	Tackling desertification, restoration of degraded lands and soils, inclusively of lands affected by desertification, drought and floods
4	Development of alternative economic activities in the rural area, including the capacity of young entrepreneurs
5	Restoration and replenishing of genetic data banks, especially for local or endemic species, as well as supporting the scientific research activities in this field.
6	Eco efficient management of the consumption of resources (agricultural, forestry and fishery) and their capitalization by promoting some production and consumption practices that allow a sustainable economic growth
7	Decreasing the early school drop-out rate, especially for young people from the rural areas and disadvantaged communities
8	Strengthening the connections between agriculture, food production and forestry, on one hand, and research and innovation, on the other hand, for a better environmental management
9	Improving the professional training and management capacity of farmers for a better capitalization of local natural resources
10	Development of ecological agriculture, with impact on environmental protection and obtaining value added products
11	Regeneration of disadvantaged area and stimulation of social inclusion of marginalized communities, by creating the premises for provisioning essential services and decent living conditions
12	Training, information and supporting farmers regarding the methods of adapting the agricultural production to the effects of climate changes
13	Encouraging the land owners to adopt or to maintain extensive practices, in the HNV areas, important areas for wild birds' species and butterflies
14	Supporting the production and diversification of local species, with high genetic value, inclusively by stimulating the research and development in the agro-food sector
15	Conservation of biodiversity, by consolidating the protected areas' network, elaboration/implementation of plans/management measures of protected natural areas
16	Capitalization of specific cultural resources on local level by protecting the cultural patrimony, cultural identity and traditional occupations (crafts, artistic, gastronomy); supporting the development of agro tourism.
17	Providing a balance between extensive agriculture, more environmentally friendly and intensive one
18	Supporting the intelligent specialization in the field of bio economy with real potential in the security and optimization of food products sub domains, development of horticultural, forestry, animal breeding and fishery sectors/ capitalization of biomass and bio fuels
19	Expansion of the eco touristic products' offer provided by rural communities with eco touristic potential
20	Maintaining the young population within the disadvantaged mountain areas, with focus on the rural area

Table A.1.15. Sustainability objectives for the Highlands and Islands, Scotland, UK. Number of stakeholders: 12

1	Protect and promote biodiversity at local and landscape scales
2	Promote the sustainable use of agricultural land for supplying local markets, reducing dependency on non-sustainably managed land and the need for the long-distance transport of resources
3	Communities take pride in their local environment
4	Communities have greater power in influencing the decisions that affect them, including in the planning, design, and long-term stewardship of their community
5	Improve soil health to reduce run off, improve quality and contribute to carbon savings
6	Increase capacity of agricultural sector, and wider society, to adapt to the effects of that climate change which is already unavoidable
7	Wildlife habitats are secure and protected
8	Provide an environment that is attractive to starting and growing a business / helps new farmers establish and retains existing ones
9	Financial stability for farmers and crofters
10	Reduce Scotland's emissions of all greenhouse gases to net-zero by 2045 at the latest, with interim targets for reductions of at least 56% by 2020, 75% by 2030, 90% by 2040.
11	A healthy diet is available and affordable to all
12	Reduce pesticide use
13	Scotland's internationally renowned nature is highly valued and secure
14	Ensure efficient use of fertilisers and better recycling of nutrients, reducing related emissions
15	Protect and promote welfare, health and well-being of livestock
16	Have well-developed local food and agriculture supply chains
17	Enable communities to function well, socially, economically and environmentally when faced with uncertainty, change and adversity caused by emergencies.
18	Increase employment opportunities in agriculture and wider food and drink sector
19	Working in the food and farming sector is rewarding: workers and producers enjoy good workplace environments, and are paid fair wages and prices.
20	Promote the sustainable management of water resources for agriculture, protecting and improving water quality, and the availability and continuity of the water supply

Table A.1.16. Sustainability objectives for Southern Sweden. Number of stakeholders: 7

1	People and society's conditions develop, both in rural areas and in urban areas
2	Manage conflict between agricultural- and building land
3	Attractive, vibrant countryside for living in the countryside
4	Attractive countryside for the development of entrepreneurship
5	Profitable production
6	Resource efficiency
7	Educational and information initiatives to increase acceptance and understanding of the need for sustainable production
8	Create variation in the landscape: mosaic-like landscape with different forms of natural grazing
9	Biodiversity: a rich flora and fauna
10	Cultivation in balance: Integrated animal production and plant cultivation
11	No eutrophication
12	Living lakes and streams
13	Groundwater of good quality
14	Living soils
15	Reduce nitrogen and phosphorus emissions, which can provide resource efficiency
16	Reduced dependence on chemical plant protection products
17	Climate-smart agriculture with high landscape values
18	Reducing greenhouse gas emissions, so that agriculture becomes climate neutral.
19	Maintaining ecosystems
20	Strengthened circular and integrated green industry, circular society
21	Increased resilience to climate change
22	High animal welfare, good animal health (good and healthy animals)
23	Arable land and land production capacity: increased carbon storage, long-term fertility, improved nutrient quality

Appendix 2: Qualitative assessment participants

Table A.2.1. Participants involved in qualitative impact mapping for each case study area

Country	Case study area	Participants	No. of participants
Austria	Salzburg und Umgebung	Researcher (agricultural economics) (6) Extension officer Farmer / regional development expert Civil servant	9
Belgium	Hageland-Haspengouw	Researcher (agricultural economics & bioscience) (7)	7
England	High Weald	Researcher (agricultural economics, rural geography, landscape ecology) (5) Farmer Extension officer (designated area representatives) (2) Civil servant	9
	North Kent	Researcher (agricultural economics, rural geography, landscape ecology) (5) Farmer (2) Agribusiness consultant	8
France	Ille-et-Vilaine	Researcher (3) Local government representative	4
	Sarthe	Researcher (2) Local government representative	3
	Puy-de-Dôme	Researcher (3) Agricultural college representative Farm environmental organisation	5
Germany	Upper Bavaria	Farmer (2) Researcher	3
Greece	East Crete	Researcher (3) Civil servant Extension officer Food chain (2)	7
Hungary	Veszprém	Researcher (agricultural economics) (2) Integrators / wholesalers (2) Farmer (2)	6
Italy	Emila Romagna	Researcher (agricultural economics / statistics) (5) Researchers (external academic and research institute) (2) Civil servant	8
Poland	Lubelskie	Researcher (2) Civil servant Extension officer Farmer (3)	7
	Podlaskie	Researcher (2) Civil servant Extension officer (2) Farmer (2)	7
Romania	Suceava	Researcher (agricultural economics) (2) NGO representative Regional development officer Local agro food products / agricultural activities expert	5
Scotland	Highlands and Islands	Researcher (2) Extension officer (2) NGO representative (2)	6
Sweden	South Sweden	Agricultural administration / advisor (2) State consultant / researcher (rural development) Researcher (rural development / climate, agricultural economics) (2) Researcher (agricultural economist)	5
		Total	99