Opportunities and challenges for the adoption and sustainability performance of alternative agricultural practices at the regional level:

Agri-environment schemes and ecological farming approaches in England

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December 2022

Thesis submitted for the degree of Doctor of Philosophy in Biodiversity Management

76,337 words (excluding abstract and bibliographies)

Acknowledgements

I would like to sincerely thank my supervisors, Dr Joseph Tzanopoulos and Professor Robert Fish, for all their support. Rob's input was invaluable for guiding my initial approach to reading the literature, and for planning and conducting the data collection for chapters 2 and 3. Joseph's feedback and advice kept me on the right course throughout the PhD, and his encouragement pushed me to apply for a PhD position in the first place. Also at Kent, I was able to collaborate with Dr Khalil Betz-Heinemann and Stuart Henderson for some of the data collection in chapter 5: I have a lot of gratitude for their contributions.

I am hugely grateful to all the farmers, and other stakeholders and experts, who freely gave up their time to participate in this research, delivering a wealth of information and useful insights. The Covid-19 pandemic presented me with some unforeseen challenges for data collection, but the patience and understanding of research participants helped me navigate this successfully.

This research was made possible by an Economic and Social Research Council (ESRC) -funded studentship award provided by the South East Network for Social Sciences (SeNSS) Doctoral Training Partnership. I feel extremely privileged to have had this support, and thankful for the opportunities and experiences that came with being part of the SeNSS community.

Author's Declaration

This research was designed and conducted by Peter Matthews. All chapters of the thesis were written by Peter Matthews. Dr Joseph Tzanopoulos (primary supervisor) provided feedback and suggested edits for all chapters, while Professor Robert Fish (secondary supervisor) gave comments on chapters 2 and 3.

In chapter 5, Dr Khalil Betz-Heinemann and Stuart Henderson helped with data collection (consulting with stakeholders for the objective prioritisation exercise, ranking of farming practices, and development of the impact mapping and network graphs for scenarios). All other data collection and analysis in chapter 5, and in the other thesis chapters, was done by Peter Matthews.

Abstract

The ability of alternative 'ecological' farming approaches and agri-environment schemes (AES) to deliver on sustainability goals will depend on their adoption rate and distribution at the regional level, which is a neglected topic in the agricultural literature, which focuses primarily on farm-level factors. Filling this gap is especially relevant to agriculture in England following Brexit, which prompted a reform of agri-environment policy with greater emphasis on 'public money for public goods', and landscape-scale actions. The aim of this thesis was to use an interdisciplinary approach to assess challenges and opportunities for the adoption of alternative farming approaches and AES to impact regional sustainability, focusing on English agriculture post Brexit. Semi-structured interviews were used to examine farmer drivers of adoption at the farm level and beyond by asking farmers about their willingness to identify as public good providers, and their relationship with cooperative management for public good delivery. Spatial analysis was used to assess the regional distribution of AES engagement and test the role of possible factors in explaining this distribution. Finally, a mix of scenario analysis, qualitative impact mapping, and network analysis was used for a sustainability assessment of ecological farming approaches, exploring how their adoption rate and distribution relates to their regional sustainability.

The interviews illustrated how farmers chose their own interpretations of 'public goods' to fit with their views about what being a farmer meant. By defining public goods as being 'good for the public', farmers could connect their willingness to be seen as providers of public goods to a desire for the public to properly recognise the value of outputs from farming. Farmer attitudes towards public good provision also reflected how they reconciled private and public good provision with their chosen identities, whether these were separate aspects of their identity that had to weighed against each other, or interdependent features of their role. Respondents often preferred to focus on public good delivery at the farm level due to the perceived costly and onerous nature of cooperative management, and the lack of any obvious reward for their efforts, highlighting the importance of quantifying and communicating the benefits of cooperative management for its widespread adoption. A tendency of farmers to be mistrustful of institutional control means successful cooperative initiatives must have a strong farmer-driven component, but the distribution of participating farms will likely depend on the occurrence of farmers who are able to make new connections with others (who may not necessarily share views or ideals around good farming) and thus facilitate the creation of loose farmer clusters.

The application of spatial analysis and modelling showed that AES distribution in England was clustered at the district level, and these cluster locations differed for different scheme types. Protected area coverage was consistently positively associated with regional adoption rates, but the impact of other explanatory variables varied according to the scheme type. Modelling also indicated that a mix of other, unidentified spatially correlated variables were likely driving a large part of the observed clustering, and that this clustering was unlikely to be due to any form of spillover or neighbourhood effect, as might be expected at a more local level.

Finally, the sustainability assessment demonstrated how the adoption of locally appropriate ecological farming approaches (in this case conservation agriculture and low-input farming) could enhance regional sustainability in southeast England. Sustainability performance was maximised in scenarios where the adoption of these approaches occurred at a high rate and in a clustered distribution. The high clustered adoption scenario could reconcile positive performance across many different aspects of sustainability, although even in this scenario it was not possible to completely avoid trade-offs or resolve all ambiguities between different sustainability objectives. Applying network analysis to the scenarios highlighted the importance of information access for the regional sustainability of ecological approaches, which in turn depended on strong advisory support, use of technology, and quality of farmer social relationships.

Taken together, these methods show how the processes underpinning the adoption and sustainability of ecological farming and AES may vary across different scales, and that the regional sustainability of an ecological approach depends on the geographic context in which it is applied. Utilising the full diversity of ecological approaches and ensuring that farmers can be supported to adopt locally relevant approaches, will be important for optimising regional sustainability, as will an increased emphasis on mechanisms for information sharing and building relationships with and within farming communities. Given that the sustainability of ecological farming appears to be the product of processes operating at different scales, multi-scale assessments should be a priority for future agricultural sustainability research, and the versatile methodological framework used for this regional assessment could readily be applied to such a multi-scale assessment with a few modifications.

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1.1. Introduction

The production of food through farming is the basis of settled human civilisation, and ensuring that agriculture produces enough quality food, now and in the future, distributed equitably, is one of the major current challenges for humanity (Godfray et al. 2010; Foley et al. 2011). Moreover, given the dominance of agriculture in land use, appropriate management of the farmed landscape is essential to ensure the provision of ecosystem services and goods besides food production that benefit human well-being, such as clean air, water, landscape quality, recreation, and cultural heritage (Abler 2004; Renting et al. 2009).

In order to keep pace with growing demand (due to a combination of population increase and rising per capita consumption), and in response to food security concerns, agricultural production has accelerated dramatically in recent history. This has been effective in improving access to food: despite the global population doubling in the twentieth century, the rate of food production also increased drastically, so that the average daily supply of calories per person has increased, and fewer people are going hungry (Pingali 2012). However, this increase in productivity has typically been achieved through increasing the intensity of land use, supported by greater reliance on external inputs, such as nutrients, pesticides, water, and fuel, and the simplification and destruction of farmland habitats (Donald et al. 2006; Campbell et al. 2017). These changes have resulted in a range of negative impacts on the natural environment, such as biodiversity loss, increased greenhouse gas emissions, soil erosion, and reduced water quality (Campbell et al. 2017). This is a cause for concern, not just in terms of the preservation of the natural environment itself, but because this degradation undermines the continued viability of farming, threatening our ability to adequately feed future generations (Godfray et al. 2010; Foley et al. 2011).

In response to this challenge, farming approaches have been proposed as alternatives to conventional intensive agriculture, that aim to produce food in a manner that minimises the negative externalities generated by farming, through increasing efficiencies, making use of natural processes, and prohibiting or substituting for certain inputs (Pretty & Bharucha 2014). Different practices and philosophies characterise different approaches, such as conservation

agriculture, integrated farming, organic farming, and agroecology, and their performance depends on farmers making the transition from conventional farming and adopting the practices that characterise these approaches. While adoption of these alternative approaches may be initiated by the farmers themselves (McKenzie 2013), policy makers have also acted to try and mitigate the negative impacts of intensive agriculture, primarily through the introduction of agri-environment schemes (AES). AES do not necessarily require farmers to change their whole approach, but provide payments designed to incentivise farmers to adopt environmentally friendly management practices that can fit in alongside their existing farming operations, such as taking strips of land out of cultivation, retaining crop residues, or restoring semi-natural habitats, to enhance biodiversity and ecosystem service provision on their land (Dobbs & Pretty 2008; DEFRA 2013a, 2013b).

There has been a lot of variation in the uptake and effectiveness of AES and alternative farming approaches for addressing the negative impacts of industrialised agriculture (Craheix et al., 2016a; Govaerts et al., 2009; Mckenzie et al., 2013). Therefore, a body of research, spanning many disciplines, has developed that explores what drives farmers to adopt innovative and alternative farming approaches and practices, and engage with AES, and what factors shape the performance of these different approaches (Fraser et al. 2016; Dessart et al. 2019). Initially, most of this research focused on the drivers and impacts at the farm level, but the performance of these approaches and practices cannot be understood without also considering how they are distributed across the wider landscape, so there is a need to look at how these approaches perform at the regional level too (Batáry et al., 2011a; Winqvist et al., 2012).

The regional performance of alternative approaches to farming in delivering environmental, social, and economic benefits has become a particularly pertinent issue in the UK following its withdrawal from the European Union. Brexit was perceived as an opportunity to reform agricultural policy and prompted widespread discussion and reflection on the role of farming in the rural landscape (Helm 2017; Howe & Ross 2019). One of the key initial messages of post-Brexit agricultural policy proposals in England was that public support would be linked to the provision of public goods, incentivising more efficient use of natural capital and the adoption of environmentally beneficial practices, with an emphasis on landscape scale actions (Gove 2018; DEFRA 2022). There is therefore an opportunity for research to assess how farming with an emphasis on public good delivery could perform at the regional level in England, and in order to inform the aims and objectives of this research, it is useful to first review the literature on the following themes:

- What is the historical background and context for the argument that agricultural policy should target public good provision?

- What do we know about the drivers of farmer adoption at the farm-level, and what frameworks can be used to interpret and explain farmer adoption decisions?

- How may agricultural management be designed to enhance performance at the regional level, and what do we know about farmer relationships with regional or landscape-level action?

- How can we assess adoption distribution at the regional level, and what do we know about the processes and factors that could contribute to different spatial patterns of adoption?

- How can the concept of sustainability be applied to the assessment of alternative farming approaches with different rates and distributions of adoption at a regional level?

1.2. Agricultural policy and public goods

1.2.1. The evolution and impacts of the Common Agricultural Policy

In agricultural markets, fluctuations in productivity can threaten food insecurity and mean that farmers face uncertainty over their income, encouraging farmers to be conservative in investment decisions, while long term declines in farm incomes can make farming unattractive to new entrants or unsustainable for existing farmers, with knock on effects for the health of the rural economy (Ackrill 2000). These factors meant that after the Second World War, the risks of food insecurity and poverty among food producers prompted European governments to intervene in the agricultural sector (Donald et al. 2002). To this end, in 1957, the six initial members of the European Economic Community (EEC) agreed to the Common Agricultural Policy (CAP), with the aim of raising agricultural productivity, securing food supplies, and minimising price fluctuations for member states, and supporting farmer incomes to ensure a fair standard of living (Ackrill 2000; Dobbs & Pretty 2008). Although these objectives have remained more or less the same since the CAP's inception, the means of achieving these

objectives have changed radically (Ackrill et al. 2008). The CAP initially protected farmers by guaranteeing fixed prices for produce, establishing a price threshold below which the EU became the buyer, and ensuring that any surpluses could be traded competitively on global markets by adding levies to cheaper imports and allowing refunds on exports (Ackrill 2000; Donald et al. 2002).

While the CAP did indirectly succeed in raising farmer wealth by increasing land prices, subsidies linked to production meant that the biggest economic advantages went to those farmers in the most productive areas, using the most intensive methods: for most farmers, production-related subsidies had little impact on their economic security (Donald et al. 2002). Through the creation of a protected market with price guarantees, the CAP directly promoted agricultural intensification, rewarding the most intensive farms and making extensification more costly (Bignal 1998). At the same time, many farmers became more specialised in order to further boost productivity, with mixed farms giving way to large areas devoted to a single type of production (Donald et al. 2002).

There is strong evidence linking agricultural intensification and specialisation to biodiversity declines and negative impacts on ecosystem services in Europe (Stoate et al. 2009; Bateman & Balmford 2018). The CAP is likely to have at least accelerated intensification and farm structural change, especially prior to the major reforms to the CAP (Hodge et al. 2015). These shifts in the way agriculture operated were also associated with major social and economic changes in European agriculture. The number of individual farms has fallen as smaller, less productive farms disappeared, while average farm size has increased, and the proportion of the population employed in agriculture has dropped sharply (Robson 1997; Ackrill 2000).

Researchers have therefore linked the CAP to many environmental, social and economic changes in Europe's agricultural sector. However, discussions of the eventual reforms to the CAP tend to identify economic, rather than social or environmental concerns, as the primary trigger of these reforms (Bignal 1998). The high public expenditure needed to maintain price support for farmers, along with the pressures imposed on the EU in trade negotiations led to the partial decoupling of subsidies from productivity levels, helping to avoid surpluses, while also allowing the EU to meet its commitment to trading partners to remove most production subsides (Bignal 1998). These reforms therefore required a means of controlling production while continuing to support farmers, which created an opportunity for the widespread implementation of AES (Hodge et al. 2015).

Reforms to the CAP in the early 1990s involved a shift away from market support to alternative means of securing financial flows to farmers, introducing direct payments to farmers to compensate for the cuts to intervention prices (Ackrill 2000; Donald et al. 2002; Dobbs & Pretty 2008). Then, at the turn of the century, further reforms defined two 'pillars' of CAP support: while farmers could continue to receive price and income support, such as direct payments, through Pillar 1, there was now also support for rural development and agri-environment initiatives via Pillar 2 (Ackrill et al. 2008; Hodge et al. 2015). Rural development and environmental protection were now major policy objectives under the CAP, and with this change, came explicit acknowledgement of the 'multifunctionality' of agriculture (Dobbs & Pretty 2008; Ackrill et al. 2008). Increasingly policy measures were introduced to encourage farming to play a range of roles in rural environments and economies, challenging the traditional view within the sector of farming as an enterprise devoted exclusively to increasing food production (Lowe et al. 2002).

1.2.2. Brexit and agriculture: 'public money for public goods'

Agricultural policy in the UK has been shaped by the evolution of the CAP as described above. However, the UK's withdrawal from the EU has meant that it has also left the CAP, and there was a consensus among the UK government and agricultural stakeholders that this presented an opportunity to radically change policy, addressing the flaws and inefficiencies of the CAP, and providing the means to establish and commit to stronger sustainability targets for the sector (Gravey et al. 2017; Whitfield & Marshall 2017; Downing & Coe 2018). Although payments to farmers for environmental protection has been a central feature of UK agri-environment policy in the 21st century, there is widespread recognition that this has not delivered many of the intended environmental benefits (Klaar et al. 2020). The intentions for post-Brexit agricultural policy were outlined in a new Agriculture Bill that signalled the government's intention to move away from an inefficient subsidy structure and model of general support for agricultural activities, towards the objective of targeting public money specifically towards activities that support the provision of public goods and ecosystem services (DEFRA, 2018a; Downing & Coe, 2018; Gove, 2018). Under this principle of 'public money for public goods', financial assistance should be provided to those managing the land to deliver benefits to the public that are otherwise unaccounted for in agricultural markets (Coe & Downing 2018; Gove 2018). This was to be achieved through a new AES, the Environmental Land Management (ELM) scheme, designed to pay land managers for improvements in soil health, air and water quality,

biodiversity, public access, and carbon storage, while the remaining area-based payments to farmers are phased out (DEFRA, 2020b; EFRA, 2022).

The basic concept of public goods is well established in economic theory, which defines public goods as delivering benefits to society that are both non-rivalrous (use by one individual does not affect the availability of the good to others) and non-exclusive (it is too costly to prevent others from enjoying the benefits of access to the good) (Anderson 2000; OECD 2001; Cooper et al. 2009). According to this definition, agricultural produce are clearly private goods, but agricultural activities can also be associated with the generation of public goods (Brunstad et al. 1995). The notion that agriculture can provide (or challenge) public goods, such as landscape character, clean drinking water, hydrological flows across watersheds, domestic food security, and the socio-economic viability of rural areas, alongside marketable goods, is recognised in both academic research and policy circles (OECD 2001; Abler 2004; Renting et al. 2009).

However, applying this definition in practice can be challenging. Truly public goods are rare, because the potential often exists to exclude people who make no contribution to covering the costs of the provision of the public good, and excessive use of certain purported public goods, such as a cultural landscape, can reduce people's enjoyment of them (Cooper et al. 2009). Therefore, most goods associated with agriculture are likely to fall somewhere along a continuum from purely private to purely public good (Cooper et al. 2009). Moreover, the concept of public goods also overlaps with other terms used to describe agricultural impacts. Ecosystem services, which represent the ways in which ecosystem structure and function contribute to human well-being, encompass public goods, which can be described as cultural or regulating ecosystem services that cannot be exclusively controlled or monopolized by one party (Burkhard et al. 2013; Westhoek et al. 2013). The positive externalities of agriculture are the net benefits that farmers deliver to society, that are not captured by markets, and public goods can be thought of as those positive externalities that are appreciated by society (Anderson 2000; Westhoek et al. 2013).

Regardless of the potential for ambiguity around defining public goods, researchers have repeatedly found that these goods are unaccounted for within market economies (Brunstad et al. 1995; Angus et al. 2009). For example, modelling Norway's agricultural sector reveals that the actual size of this sector is far larger than necessary in order to meet the needs of society in terms of public goods provision, so there is deficit in the supply of public goods (Brunstad et al. 1995). Some public goods from agriculture may be produced incidentally, as a by-product of economically viable activities, or deliberately due to farmer altruism or self-interest (Cooper et

al. 2009). However, for many public goods, the non-excludability and non-rivalry in consumption means that users have little incentive to pay for them, and without payment, farmers are typically not motivated to provide these goods (Cooper et al. 2009). Government policy interventions have therefore been suggested to correct these potential market failures and bring the supply of public goods in lines with society's requirements (Angus et al. 2009; Westhoek et al. 2013). Such interventions are typically proposed in the form of economic incentives that encourage farmers to shift resources from the efficient generation of farm commodities towards public good provision and compensate for the extra costs incurred in doing so (Cooper et al. 2009).

An agricultural policy based on the principle of public money for public goods will therefore need to ascertain demand and assign prices to these goods, which is not always straightforward, given that the nature of public preferences for public goods is not always recognised by markets (Hall et al. 2004). As well as understanding demand, policy makers should also have access to a quantitative and spatially explicit picture of the current levels of different public goods supplied by agriculture, to support informed decisions, but this has been hindered by a lack of consensus over what constitutes public goods delivered by agriculture, and difficulty in measuring some of the more abstract public goods (such as landscape quality) (Westhoek et al. 2013). Moreover, policy makers will need information on the possible future, as well as current, supply of public goods, to ensure policies are designed to safeguard their provision in the face of future changes in agricultural character (Westhoek et al. 2013).

Among both environmental organisations and farmers' groups, there was broad agreement with the stated aim of 'public money for public goods' in the new Agriculture Bill, but stakeholders often disagreed in the interpretation of this aim (Coe & Downing 2018; NFU 2018). There was disagreement over the extent to which the bill struck the appropriate balance between encouraging protection of the environment and promoting food production (Coe & Downing 2018; EFRA 2018). The lack of specific details in the Agriculture Bill also fed into wider debate on what public money for public goods will mean in practice. Formal scrutiny of the bill raised concerns over the absence of any information on how public money would be allocated to each public good and how different public goods would be prioritised, other than an indication that further details will emerge from pilot schemes in cooperation with the agriculture sector (EFRA 2018). This has already been identified as one of the key challenges for an effective agricultural policy focused on rewarding public goods delivery, and continued ambiguity is problematic for farmers who need to plan how best to focus their resources to qualify for the finite amount of financial support available under a new policy regime (Bateman & Balmford 2018; EFRA 2018).

Uncertainty over allocation and prioritisation of funds for different public goods may also reflect confusion over what constitutes a 'public good' in the first place, and differing perspectives on the role of farming in society. After the Brexit referendum, DEFRA ran a consultation on the future of farming, allowing representatives of different interest groups and competing visions of agriculture to promote their views and seek to influence the outcome of the debate on a new policy direction (DEFRA, 2018a; Hill, 2017). Respondents identified a wide range of services and commodities that they viewed as important public goods, and frequently disagreed with the list of public goods proposed by the government as targets for financial support: for example, many felt that food and public health should have been recognised as public goods (DEFRA, 2018a). These responses reflect different interpretations of the term 'public good' which may be at odds with the principles of non-rivalry or non-exclusivity in consumption which underpin the usage of this term in economics (Anderson 2000; Cooper et al. 2009; H.M. Treasury 2018).

Although the principle of 'public money for public goods' was intended to underpin the UK's future agricultural policy, the Agriculture Bill does not explicitly refer to, or define, the term 'public good' (EFRA 2018). There are some outputs of agriculture that are widely agreed to be public goods requiring financial support, which are clearly recognised in the Agriculture Bill, such as environmental protection and enhancement of the rural landscape (Gravey et al. 2017; Coe & Downing 2018). However, continued vagueness in defining public goods meant that many of the stakeholders who made submissions to the scrutiny of the bill were able to express conflicting opinions on what commodities or services are classed as public goods. Representatives of food producers, for example, have criticised the bill for not recognising food security as a public good and expressed a need for greater emphasis on maintaining domestic food security, something that has long been at the forefront of both UK and EU agricultural policy (EFRA 2018). This debate over public goods has led some commentators to express concern that political desires to satisfy farming lobbies could lead to the new agri-environment policy being steered away from its originally intended purpose by producer interest groups (Helm 2022). Given these concerns, some environmental organisations have interpreted the recent announcement of a review into the ELM proposals as threatening to undo progress towards more environmentally friendly agriculture in England, although the government has stressed that this will not be the case (Benwell 2022; EFRA 2022; Helm 2022).

Meanwhile, some researchers claimed that there were more fundamental issues with the government's approach, arguing that the new emphasis on public money for public goods, and primarily financial perspective adopted by the bill is inadequate to shift agriculture post-Brexit onto a more sustainable trajectory (Howe & Ross 2019). In order to address the underlying

forces shaping the social and ecological system associated with farming, there may be a need for greater recognition of the legitimacy of farmer perspectives on what practices are most ecologically appropriate for their land, and openness to locally supported solutions (Howe & Ross 2019). Previous experiences of the effects of agricultural policy reform in England have highlighted the importance of adapting policy to support the priorities of a given agricultural system and establishing these priorities may depend on the outcome of complex debates between stakeholders with contrasting visions for the purpose and definition of agriculture and farmers (Whitfield & Marshall 2017).

1.3. Drivers of adoption

1.3.1. Researching farmer adoption

The reform of agricultural policy following Brexit provided an opportunity to develop new agri-environmental measures informed by evidence on their ability to deliver environmental benefits. Previously, voluntary AES have often been met with only limited, or short-term, success, with plenty of room for improvement (Burton 2004; D'Alberto et al. 2018). Much research effort has been devoted to identifying the factors affecting the performance of alternative farming practices and approaches, including those supported by AES. A complete understanding of agricultural sustainability, whether at the farm or regional level, must consider impacts and drivers of adoption, and so this research has looked at how performance relates to both the impacts of alternative practices, and the extent to which farmers are willing to adopt these practices. Impact assessment at the farm level has typically involved the quantitative assessment of metrics for the delivery of different goods and services from agriculture (Gerrard et al. 2012; Coteur et al. 2016), while adoption research has tended to assess the values, attitudes and behaviours of farmers themselves (Pannell et al. 2006; D'Emden et al. 2008; Prokopy et al. 2008).

Farmers vary in their tendency to adopt a given novel farming approach or practice. Some farmers may readily adopt new agricultural techniques, while others reject or delay adoption (Lobley & Potter, 1998; C. Morris & Potter, 1995). Different farmers will adopt a new technology at different times: some are innovators or early adopters, pioneering the use of new approaches long before their neighbours, while late adopters may persist in using conventional techniques even when new ecological practices are widespread (Lobley & Potter 1998; Läpple & Rensburg 2011). There may also be varying degrees of resistance among late or non-adopters: some may still be encouraged to adopt following changes to the design and delivery of agricultural policy,

but others may even increase their resistance following efforts to increase participation (Lobley & Potter 1998; Andrews et al. 2013). Much of the focus of adoption research has been centred around identifying factors that explain this variation.

Studies have addressed both farmer uptake of individual practices or agri-environmental measures, and conversion to entirely new farming approaches (Knowler & Bradshaw, 2007; Meijer et al., 2015; C. Morris & Potter, 1995). This research has contributed to an acknowledgement that farmer uptake of ecological approaches is a complex process, affected by an array of interacting internal and external factors, neither of which can be neglected in explanations of farmer adoption (Meijer et al. 2015). At the same time, these alternative farming approaches can also be viewed as innovations to support a transition to a more sustainable society, and innovation theory and research has therefore also been used to highlight key processes that underpin the spread of ecological farming (Padel 2001; Brunori et al. 2013).

1.3.2. Economic and structural factors

The features of a novel farming approach help determine its acceptability to farmers and therefore its likelihood of uptake. The relative economic costs and benefits of an ecological approach are a key factor determining farmer willingness to adopt. Where agri-environment measures are used to promote ecological practices, the level of payment offered or compensation for costs incurred, are among the most important drivers of adoption (Defrancesco et al. 2008; Lastra-Bravo et al. 2015). The anticipated increase in farm income is also important for those practices where farmers do not receive direct payment. A survey of Dutch hog farmers found that the primary factor motivating farmers to invest in the construction of certified sustainable stables was the expectation of economic gain, due to increased efficiency and performance driving greater profitability, as well as anticipated tax benefits (Trujillo-Barrera et al. 2016). Conversely, poor returns from conventional farming can also make ecological approaches more attractive. For example, the higher costs of insecticides under continued conventional farming, along with the potential for further losses due to increased risk of pest resistance, were the main reasons cited by vegetable farmers in Thailand for switching to using integrated pest management (Timprasert et al. 2014). Equivalent results, emphasising either profitability gains, or cost and labour savings, are found when considering farmer decisions to convert to a new system, such as conservation agriculture or organic farming (Tranter et al. 2007; Lahmar 2010). British farmers converting to organic farming in the early 21st century tended to do so because they viewed organic farming as a financially desirable

means of production, especially for those experiencing falling incomes from conventional farming approaches (Tranter et al. 2007).

In addition to the regional environmental and economic conditions, the importance of the various costs and benefits in farmer adoption decisions can be influenced by the characteristics of the farm itself. Farm size, turnover and profitability have all been shown to influence AES participation (Lastra-Bravo et al. 2015; Gailhard & Bojnec 2015). Farm incomes, or the scale of farming operations, are often among the most important factors affecting uptake (Wandel & Smithers 2000; Frondel et al. 2012; Rodríguez-Entrena & Arriaza 2013; Trujillo-Barrera et al. 2016), and farm households that are more dependent on farm income compared to other income sources are usually less likely to engage with alternative ecological approaches (Defrancesco et al. 2008; Lastra-Bravo et al. 2015). Farms that are larger or generate high turnover may have less difficulty in employing measures that require reductions in agricultural intensity and have greater capacity and willingness to invest in sustainable practices (Lastra-Bravo et al. 2015; Trujillo-Barrera et al. 2016). The fixed costs of participating in an AES or adopting a new ecological practice, such as specific equipment or technology, may be a proportionately greater burden for smaller, less profitable farms, making them less willing and able to engage with the new practice (Ducos et al. 2009).

1.3.3. Farmer attitudes and values

In early studies into drivers of adoption, the explanations sought by researchers tended to focus on economic factors such as expectations of reduced profitability or high costs, or structural factors such as distance to key markets (Burton 2004). However, economic or structural factors alone are often insufficient to fully explain variation in adoption behaviours, and how exactly farmers evaluate the costs and benefits of an approach can depend on their individual characteristics and personalities (Greiner & Gregg 2011). A more comprehensive explanation of farmer adoption must also consider how differences in the personal characteristics of farmers affect adoption decisions (Flett et al. 2004; Mzoughi 2011; Läpple & Kelley 2013). Farmer decision-making can often be a very different process to that associated with the more widely studied decisions behind pro-environmental behaviours of citizens and consumers, and so cannot necessarily be understood by generalising results from research into the adoption of other environmentally friendly behaviours (Dessart et al. 2019).

Farmers differ in their innate tendency to adopt innovative ecological approaches. These differences relate to dispositional behavioural factors, which concern the natural propensity of individuals to act in a certain way (Dessart et al. 2019). These factors encompass the attitudes

(judgements based on pre-existing evaluations of a particular object) and values (guiding principles or goals that shape an individual's attitudes) held by farmers towards ecological approaches (Eagly & Chaiken 1993; Schultz et al. 2004; Dutcher et al. 2007). Empirical research has identified key values and attitudes that influence farm management decisions and behaviours, either directly, or indirectly, through their effect on farmer objectives (Willock et al. 1999).

Farmers using alternative ecological farming approaches have often been found to have contrasting value systems to more conventional farmers, with adopters more likely to be motivated in their decisions by an intrinsic sense of duty to nature or stewardship for their land than any economic or social consideration (Beharrell & Crockett 1992; Greiner & Gregg 2011). Positive attitudes towards the environment and higher levels of environmental concern, are frequently found to significantly predict farmers' intention to engage with, and actual adoption of environmentally friendly management practices (Defrancesco et al. 2008; Lokhorst et al. 2011; Lastra-Bravo et al. 2015; Menozzi et al. 2015). The differences in the values held by farmers may influence what they view as the primary goals or objectives of farming, such as producing high quality food or providing public goods, which have also been linked to farmer tendency to use ecological approaches (Kallas et al. 2010; Kvakkestad et al. 2015). Besides farmer perceptions of environmental protection and food production, adoption behaviour has also been linked to farmer attitudes to risk and uncertainty. Alternative farming approaches can be high risk: if not implemented properly, they may fail to deliver desirable outcomes and profitability may decrease (Padel 2001), so farmers who are more risk averse may be less likely to adopt new environmentally friendly practices (Marra et al. 2003; Parra-Lopez et al. 2007; Kallas et al. 2010).

Initially, this attitude-based perspective dominated research into farmer uptake of AES and other alternative management practices (Burton, 2004; C. Morris & Evans, 1999). Although a focus on farmer attitudes, often assessed through survey-based tools, was useful for generating quantifiable answers to research questions that appealed to funding bodies, some authors argued that by breaking farmer behaviour down into its cognitive components, these studies were unable to address the true meaning behind farmer decisions (Burton 2004). Moreover, measuring attitudes to objects will be unlikely to deliver any deep insights unless researchers first understand what these objects mean or represent to farmers (Burton 2004).

1.3.4. Farmer cultural identity and social capital

Consequently, as adoption research has progressed, some authors started to reconsider approaches to studying farmer behaviour and shifted their attention to the role of farmer cultural identity in influencing agricultural change. A resistance to changing farming practices may be associated with concerns over the loss of identity or social standing that could come with abandoning traditional commercial practices (Burton 2004). Early studies in this area indicated that farmers' lack of participation or hostility towards AES could be attributed to the fact that these schemes did not align with their perceptions of themselves and conflicted with their identities as productive farmers (Watkins 1996; Burgess et al. 2000). The research community was initially slow to recognise the importance of farmer cultural identity in adoption behaviours, but this research gap has been addressed in recent years, particularly following a growth in research interest in the cultural construction of the ideals of 'good farming', and what this means for the way farmers practice agriculture (Sutherland & Darnhofer 2012).

As a result, farmer self-identity is now widely recognised as one of the most fundamental areas to address in order to understand farmer willingness to innovate and adopt alternative agricultural systems or practices. Although agri-environment policy is now well-established in the UK and EU member states, studies have repeatedly found that a large core of conventional farmers remain embedded in a mindset that places maximising productivity at the centre of their identity, and that exposure to AES has little lasting effect on farmer perceptions of themselves or their relationship with agriculture (Walford 2003; Saunders 2016). A survey of Belgian farmers' intentions to implement conservation measures found that the effect of attitudes, social norms and perceived behavioural control on willingness to act is almost completely mediated through the way they interact with individual's beliefs about their identity as good farmers (Wauters et al. 2017). While regulation and financial incentives can generate short-term changes to farm management behaviour, they may be insufficient to drive long-term change by themselves (Mills et al. 2017). Given that the application of environmentally friendly practices is generally lacking from established perceptions of the good farming identity and personal norms of the farming community, effective long-term improvements to the environmental performance of agriculture will depend strongly on internalising such behaviours and making them an established part of farmers' cultural identity (Wauters et al. 2017).

Much of the literature on the 'good farmer' identity has drawn upon earlier ideas about how the exchange and development of capital underpins an individual's status in their community, as outlined by Bourdieu (1977, 1986), using these theories as a conceptual framework to guide

research (Burton et al. 2008; Sutherland & Darnhofer 2012; Sutherland 2013). In this perspective, individuals acquire economic, social, and cultural capital, and when a community views these forms of capital as being legitimate under the existing 'rules of the game' then possessing them confers prestige on individuals, which comprises 'symbolic capital' (Bourdieu 1986). Within this framework, three forms of cultural capital have been identified, which each have their associations with good farming: institutionalised cultural capital (acknowledgement of competence via certification from formal organisations), objectified cultural capital (possession of indicators of prestige, such as high crop yields, a tidy field, or items of machinery) and embodied cultural capital (learned skills and knowledge) (Bourdieu 1986; Burton & Paragahawewa 2011). These concepts have been adopted by the 'good farming' literature, where farmers are viewed as working to accrue good farmer capital, be it economic, social or cultural, which influences the strategies used to manage their farm (Burton 2004). Much of the research in this field has focused on investigating how status as a 'good farmer' is conveyed by the capital they exhibit, which in turn depends on a skilled performance that discriminates between good and bad practice, and clear signals or symbols of performance quality that are accessible to others (Burton et al. 2008).

With the emergence of alternatives to conventional or traditional modes of farming, the standards by which a good farmer is defined, and therefore what values and practices are viewed as the most legitimate in farmer communities, can become contested (Saunders 2016). This can be especially relevant when policy makers are attempting to reform agricultural priorities or practices, as is the case in the UK, where the new direction for agricultural policy following Brexit means that farmer cultural identity is likely to be a key area of struggle in determining the shape of the future farming system (Howe & Ross 2019). The ideals of good farming can and have changed as different approaches to agriculture come in and out of favour. Agricultural industrialisation and intensification shifted the emphasis towards business profitability, but there are also signs that in some circles, pro-environmental management is permeating good farmer identities (Kizos & Kristensen 2011). Whereas earlier research has tended to frame farming practices as arising from responses to policy change, this more farmer-centred approach describes how an accumulation of changes to the 'rules of the game' are bringing symbols of good farming (and therefore good farmer identities) into alignment with more environmentally favourable management practices (Riley 2016).

1.4. Management beyond the farm level and farmer cooperation

1.4.1. Farmer cooperation for landscape scale management may enhance regional sustainability performance

A complete understanding of the performance of alternative farming approaches and AES requires an assessment of how drivers and impacts operate beyond the level of the individual farm. One of the factors proposed for poor performance of some of the initial AES, in terms of their lack of success in reversing biodiversity declines or enhancing ecosystem service provision, was their tendency to focus on management actions at the scale of individual farms, rather than across landscapes (Mckenzie et al. 2013; Jarrett et al. 2015). Researchers have expressed increasing concern over whether individual farm-based AES agreements can contribute to the protection and enhancement of the environment at a landscape scale. In England, while some more recent AES options have been designed to incentivise collective action in, so far uptake of these options has been limited, and most measures have been applied to relatively small areas, having little impact on ecosystem service delivery at the landscape or catchment scale (Mckenzie et al. 2013; Riley et al. 2018; Klaar et al. 2020).

The policy focus on farm-level management is reflected in the academic literature. To date, the dominant theories underpinning studies of agricultural change and environmental impacts have often focused on the individual farm as the primary unit of production, with academic research giving little attention to the causes and consequences of different spatial configurations of adopting farmers at the landscape or territorial level (Lucas et al. 2019). Farm-level AES may be failing to achieve their desired goals because species habitat requirements and ecosystem services provision often transcend ownership boundaries, making a territorial approach necessary (Lawton et al. 2010; Mckenzie et al. 2013). For example, around a third of the farmland species of conservation importance in England operate at a scale larger than the average farm during the breeding season (Mckenzie et al. 2013). Moreover, systems and landscape-level research studies frequently illustrate how the management of one farm may have consequences for the performance of others in the surrounding area or in the same catchment (Lawton et al. 2010; Mckenzie et al. 2013).

As a result, researchers have argued that achieving meaningful enhancements to public good delivery, in accordance with the stated aims of the post-Brexit Agriculture Bill, will depend strongly on the spatially coordinated management of agricultural landscapes across multiple farms, and optimising the distribution of environmentally friendly practices at the territorial

level (Westerink et al. 2017; Klaar et al. 2020). One way in which this can be achieved is through cooperation between rural stakeholders, especially through the joint efforts of groups of farmers (Sutherland et al. 2012; Westerink et al. 2017). Landscape scale management arising out of cooperation between multiple partners is now established as a central element of enhancing ecological networks, which has been promoted as a key conservation strategy for the UK and beyond (Lawton et al. 2010; Jarrett et al. 2015). Many of the species that use farmland, depend on a patchwork of habitats spread across a scale larger than that of individual fields or farms, and as a result, ecologists have been arguing for landscape scale conservation through cooperation between land managers (Dallimer et al. 2012). Multidisciplinary research looking at hotspots of conventional and organic farming in England suggest that additional environmental and biodiversity benefits can be delivered when organic farms are clustered in the landscape (Sutherland et al. 2012). Collective action is also important for ecosystem service delivery: the optimum management scale for many ecosystem services, such as water quality or flow regulation, is at the territorial level (Jarrett et al. 2015).

Cooperation among farms not only enhances the impacts of environmental measures but can also influence the drivers of adoption. Local cooperation can provide support for farmers seeking to make the transition to alternative, more environmentally friendly practices. In the absence of support from state or commercial operators, local cooperatives can assist farmers in adopting and implementing novel and sustainable approaches by coordinating resource sharing, building synergies between specialised farms, and the combined management of landscape scale features such as wildlife corridors that span multiple farms (Lucas et al. 2019).

There are also social and economic arguments for the importance of cooperation among farmers. Collective action has been highlighted as a key means of helping to ensure the sustainable management of shared or pooled resources, to avoid 'the tragedy of the commons' where shared resources are depleted due to competition among selfish individuals (Hardin 1968; Ostrom 1990). The literature on cooperative initiatives also suggest that they can enhance social cohesion, promote the exchange of ideas and knowledge among participants, increase community engagement in conservation, and support farmers through times of hardship or upheaval (Jarrett et al. 2015; Wynne-Jones 2017).

1.4.2. Drivers of farmer engagement in cooperative action

The successful implementation of policy initiatives designed to maximise sustainability performance at the territorial level will therefore benefit from an understanding of how, why, and when farmers will work together to deliver environmental management in an area.

Researchers have identified a need for analyses at the level of groups of farms, but still tend to have only a poor grasp of the factors underlying the willingness and ability of farmers to cooperate with regards to environmental management (Lucas et al. 2019). Previous cooperation studies focused on joint initiatives for buying and selling produce, assuming that the findings could be generalised to cooperation for other purposes, but recent research suggests that cooperation over land management is a distinct phenomenon, with its own set of drivers, so there remains a need for focused investigations into farmer cooperation for environmental objectives at the territorial level (Riley et al. 2018).

The dominance of economic perspectives in farmer cooperation research means that the most common drivers of cooperation identified in the literature have typically been associated with the potential for economic benefits (P. Wilson et al., 2014). Cost-savings, efficiency, reducing risk, timeliness of operations, and economies of scale have been highlighted as economic drivers for commercial cooperative initiatives (Valentinov & Iliopoulos, 2013; P. Wilson et al., 2014). Economic factors have also been identified as important for driving landscape-scale environmental initiatives: for example, where crop yields are dependent on ecosystem services delivered by mobile organisms, the potential for increased yields and profitability can motivate the development of cooperative environmental management (Cong et al. 2014).

Increasingly, however, social science research has started to shed light on some of the social factors motivating farmers to get involved in cooperative projects, including opportunities for enhancing social capital through the strengthening of interpersonal relationships, and supporting social learning (Mailfert 2007; Mills et al. 2011; Nelson et al. 2014; saint Ville et al. 2016). Participating farmers may also be motivated by the benefits of the social interaction that comes with group working, increasing their sense of belonging to a community, and therefore improving personal well-being and quality of life (Fandiño et al. 2006; Mills et al. 2011). As well as encouraging farmer cooperation, the quality of social relationships can also be associated with collaboration outcomes: where participants have better relationships with their neighbours, the performance of cooperative projects is enhanced (Macfarlane 1998; Mckenzie et al. 2013). Indeed, farmer relationships have been identified as a key constraint on the potential for collaborative environmental management: surveys with English farmers found that while most respondents recognised the potential of cooperative AES to deliver environmental benefits over and above AES focused on individual farms, willingness to participate was tempered by issues around the relationships with other farmers (Franks & Emery 2013; Franks et al. 2016). These included concerns that other farmers might go back on their word in cooperative agreements, and disagreements or differing opinions over best practice in

conservation and agriculture (Franks & Emery 2013; Franks et al. 2016). These issues may be symptomatic of a lack of trust among farmers, inhibiting the development of social capital consistent with a farmer's sense of identity, which is increasingly recognised as being central to farmer cooperation for public good delivery (Riley et al. 2018), just as it is for the adoption of alternative farming approaches and AES by individual farmers (Cusworth & Dodsworth 2021).

The value of performing practices that are desirable and valued by the farming community in helping to maintain social bonds relates to the importance of farmer self-identity according to the ideals of 'good farming'. Independence and individualism are values that have been linked to cultural constructions of the 'good farmer' and can influence farmer willingness to cooperate for environmental management. Individualism describes a preference for working in isolation, while independence reflects perceptions about a farmer's ability to manage their land in a direction that they choose, having autonomy in the running of their farm (Emery 2015). There is a longstanding recognition in the agricultural social science literature that independence is a prized quality among farmers (Gasson 1973; Ilbery 1978; Emery & Franks 2012; Franks & Emery 2013). However, the relationship between the value placed on independence and willingness to engage in cooperative action may be complex: farmer ideals of independence have provided the rationale for both cooperative and non-cooperative practices (Emery 2015). Farmers can assign different definitions to independence based on alternative ideologies, can make it difficult to ascertain whether cooperation enhances or reduces a farmer's sense of independence, with farmers reconciling even seemingly altruistic practices with an individualistic ideology (Emery 2015). The value placed by farmers on individualism and independence can be related to farmer perceptions of the ideals of the 'good farmer': farmer willingness to engage in cooperative environmental management may depend in part on the cultural constructions of what a good farmer does (Riley et al. 2018). Farmers have been observed to resist joining in with group efforts to achieve environmental objectives that would demand they perform cooperative activities that are at odds with local ideals of good farming (Sutherland et al. 2012). Similarly, research investigating how farmers relate to the aims and methods of collective AES indicate that they perceive participation in such collective schemes to characterise their associations with other farmers, which can have a bearing on their status and identity as good farmers (Riley et al. 2018).

1.5. Spatial distribution and dependency of farmer adoption

1.5.1. Spatial analysis to assess drivers of adoption distribution

Cooperative management among farmers can affect the distribution of adoption of alternative ecological farming approaches and AES, and therefore the territorial impacts of these agricultural practices. However, the development of formal or informal cooperative projects is just one of many possible factors that have been linked to spatial patterns of farmer adoption. Moreover, while qualitative research is can provide deep insights into how and why farmers adopt, either in isolation, or in collaboration, it is not option for studying what might be driving the distribution of adoption, and therefore the territorial performance, of alternative farming approaches. Another technique that researchers have employed to identify factors affecting the distribution and diffusion of different farming approaches and practices is the spatial modelling of adoption (Miller 2008; Wollni & Andersson 2014). While a qualitative approach has an advantage in that it can point towards factors and processes not predefined by the researcher and provides more in-depth understanding of what these drivers may mean to farmers, and how they operate, quantitative spatial data analysis makes it possible to explicitly test for and measure the role of specific processes and variables in explaining the distribution of adoption. Therefore, this could be an informative and powerful tool, especially when applied in combination with qualitative interview-based methods.

Spatial analyses of farmer adoption have been conducted at a variety of scales: many have focused on the local level, looking at the factors influencing the locations of individual farms using certain approaches or practices, while others have assessed the frequency or density of adoption across whole regions (Bartolini & Vergamini 2019; Kazakova-Mateva 2020; Yu et al. 2021). Where spatial studies are conducted at the local level, it is possible to make use of data on adoption behaviours and possible explanatory variables collected directly via surveys (Yu et al. 2021). However, at the regional level, it is usually impractical to collect primary data for these variables, and so regional or territorial studies of adoption typically rely on secondary data (Yang et al. 2014). This means that studies of adoption distribution at the regional level are typically constrained by the availability of secondary data and have tended to focus on farming approaches and practices for which datasets exist already, such as certified organic farming (Ilbery & Maye 2011), and measures applied under AES (Yang et al. 2014).

1.5.2. Spatial dependence in adoption

Spatial analyses provide an extra dimension to adoption research. They help to factor in the possible influence of farm location on adoption, by providing means to test for spatial dependence: the degree to which adoption rates are associated with the rates in the surrounding areas, and therefore whether adoption occurs in a random, clustered, or dispersed pattern (Ilbery & Maye 2011). Identifying the presence or type of spatial dependency in adoption is important for evaluating the potential environmental performance of a given farming approach, because the spatial configuration of adoption affects the delivery of ecosystem services (Winqvist et al. 2012; Tuck et al. 2014). Several explanations have been proposed to account for observations of clustered and dispersed patterns of adoption at local and regional levels, and spatial models can help indicate which of these explanations may be most appropriate. The environmental or socio-economic characteristics in an area that create favourable or unfavourable conditions for certain practices or approaches at that location are typically important for explaining spatial patterns in adoption, but researchers have also reported instances where adoption rates are linked to the characteristics of neighbouring areas (Schmidtner et al. 2012; Läpple & Kelley 2015). Farmer adoption does not necessarily occur in isolation: adoption by one farmer may be influenced by the adoption behaviour (or other characteristics) of nearby farmers (Läpple & Kelley 2015), an observation consistent with the growing literature pointing to the importance of a farmer's social environment in adoption decisions (Risgaard et al. 2007; Dessart et al. 2019). This suggests that some form of interaction between neighbouring locations, such as farmer communication, imitation, cooperation, or competition, could be influencing the diffusion or dispersal of adoption across an area (Lewis et al. 2011; Ilbery & Maye 2011; Wollni & Andersson 2014).

Whether any form of spatial dependence in adoption is observed, and the types of processes generating any observed dependence, appears to be highly variable, with different results reported from research carried out in different study areas, at different spatial scales, and on different types of farming practices (Schmit & Rounsevell 2006; Ilbery & Maye 2011; Schmidtner et al. 2012). To date, studies of spatial dependence in farmer adoption have focused on the distribution of adoption at the local level across individual farms, with relatively few studies assessing distribution at the regional level, despite the importance of adoption distribution at this scale for overall performance in the delivery of public goods and ecosystem services (Yang et al. 2014; Kazakova-Mateva 2020).

1.6. Sustainability assessment

1.6.1. Applying the sustainability concept to agricultural assessments

In order to effectively address the challenges facing humanity, agriculture must deliver on a multitude of different goals and objectives. The concept of sustainability provides a framework that can be used to achieve the necessary holistic understanding of how different farming approaches perform against these different objectives (Smith & McDonald 1998; Pretty 2008; Gerrard et al. 2012). However, given that the performance of different approaches can depend on the regional context and spatial configuration of adoption, the overall sustainability performance of a farming approach or AES must account for their impacts at the regional as well as the farm level (Smith & Mcdonald 1997; Graymore et al. 2008; Arnott et al. 2019). In order to understand how the sustainability concept can be best applied to evaluate the performance of alternative farming approaches at the regional level, it is necessary to review the literature on the application of the sustainability concept in sustainability assessments.

Sustainability has now become well-established as a dominant paradigm of environmental discussion. However, sustainability has also been subject to a range of definitions and interpretations that have made it challenging to define in a sufficiently meaningful or practical way that allows it to be operationalised and measured (Pope et al. 2004), which is necessary if the concept is going to be used to help understand the overall performance of agriculture. Despite this ambiguity, 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).

Assessing the current overall sustainability of a system typically makes use of sustainability indicators: quantifiable and measurable attributes of a system that are related to specific aspects of its sustainability (Pannell & Schilizzi 1999; Ness et al. 2007; Dillon et al. 2016). 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).

While indicator-based assessment frameworks are widely used in the agricultural sector, they tend not to be applicable for evaluating performance at the regional level (Inwood et al. 2018).

There is little published literature concerning applying sustainability metrics at the regional or 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 farms, such that data collection methods focus on farmer records that are unlikely to include landscape-level parameters (Inwood et al. 2018). However, there is potential to develop landscape-scale performance indicators for use in sustainability assessments. Environmental performance of agriculture at the landscape level has already been extensively studied using 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, 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).

1.6.2. Sustainability assessment and scenarios

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 using expert knowledge to suggest plausible changes under different scenarios, which can be used to 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; 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). While there is opportunity to develop quantitative indicator-based sustainability assessment tools for use with scenario research (Fauré et al. 2017), 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 scenarios,

given that the resulting quantitative output 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 idea of the space for manoeuvring within (Aligica, 2005; G. D. Peterson et al., 2003). 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).

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), which 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). Such an approach may therefore be appropriate for a regional level assessment where little quantitative data is available, or where complex spatial modelling methods would make the assessment process less transparent to participating stakeholders.

1.6.3. Objective-led sustainability assessment

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 which 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). Objective-led assessments are 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 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 objectives, against which the assessment can be performed (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, lacking a universal definition and being subject to individual value judgements, 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, according to the assessment context (Gibson 2001; Payraudeau & van der Werf 2005; 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 more 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 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, 2001a, 2001b). 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).

1.6.4. Qualitative impact mapping and network analysis

A 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-led 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 that compares the scenarios, showing whether objectives are met under different scenarios, based on aggregating impacts of multiple objectives on each objective (Sheate et al. 2008; Baard et al. 2012). 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).

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 (Boron et al., 2016; Tzanopoulos et al., 2011). Network analysis provides a means of illustrating and explaining 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; De Nooy et al., 2018; Fauré et al., 2017). 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 (Boron et al., 2016; Tzanopoulos et al., 2011). 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).

1.7. Conclusion: studying adoption and sustainability performance at the regional level

Ensuring that agriculture can continue to support human health and well-being, without undermining the natural resources and processes that underpin ecosystem function, requires an understanding of how different agricultural approaches perform in terms of their potential to deliver on these goals, and why farmers may engage with or reject these approaches. There is a large body of literature devoted to evaluating the sustainability performance of alternative farming approaches and assessing the factors that may influence their adoption. However, this has been dominated by research focused on adoption and performance at the farm level, despite the importance of accounting for the spatial dimension of adoption and impacts at the landscape or regional level in assessing agricultural sustainability. Therefore, there is still a need

to improve our knowledge of what drives the rate and distribution of adoption of at the regional level, and how this impacts sustainability performance. This is particularly relevant for England, where Brexit created an opening to reform agricultural policy to include an increased emphasis on supporting public good provision, especially through landscape scale actions. Despite the initial rhetoric around agricultural policy reform, there are concerns that in practice, any new AES will simply end up being 'business as usual' and that this will come to represent a missed opportunity to improve the sustainability performance of farming (Howe & Ross 2019; Helm 2022). If the new measures are going to improve on previous AES and deliver more for the environment and society, it would be useful for these to be informed by evidence from a detailed examination of potential drivers and barriers for adoption and how they relate to regional sustainability performance.

However, the research focus on drivers and performance at the farm level is at least partly due to the methodological challenges associated with regional level studies. Compared to the farm level, quantitative data on how drivers of adoption operate at the regional level can be costly or impractical to collect. Moreover, quantitative approaches for assessing agricultural sustainability across regions or territories are still poorly developed, and the increased complexity associated with using quantitative data on landscape patterns and processes could make stakeholder involvement (an integral part of any meaningful sustainability assessment) more challenging (Inwood et al. 2018). As a result, qualitative methods could be useful to improve our knowledge of regional adoption and sustainability performance patterns, alongside the greater objectivity provided by quantitative methods where data is available.

A regional level study may therefore benefit from applying a mix of complementary methods to get insights into the challenges and opportunities for employing alternative agricultural practices and approaches to achieve sustainability goals. A variety of approaches to researching adoption drivers have been explored in the literature, but one field that is gaining ground for investigating the fundamentals behind farmer adoption behaviours concerns farmer self-identity and cultural models of good farming. Research is increasingly using ideas from social science around cultural identity and social capital to explain the effects of different drivers or barriers to adoption, an approach which is typically best explored using qualitative methods such as semi-structured interviews (Burton et al., 2008; C. Morris & Evans, 2004). The growth in interest in this area is also influencing calls for policy makers to broaden their consideration of factors driving adoption, to go beyond the economic aspects and invest in means of promoting social and cultural capital, supporting connections among peers and social learning (Westerink et al. 2017). Therefore, a shift in policy direction signalled by the idea of 'public money for public

goods' and increasing emphasis on landscape-scale action should be guided by an understanding from qualitative interviews of how this change relates to farmer identities.

While these methods could suggest factors that contribute to regional adoption rates and distribution patterns under novel agri-environmental initiatives, where quantitative secondary data on adoption is available, we can use this to look back and see how adoption has been distributed in the past. This can be done using spatial analysis to test the significance of different geographic factors in influencing adoption at the regional level and suggest emergent processes that could shape adoption distribution, that would be otherwise overlooked by farm-level studies. The findings from qualitative interviews and quantitative spatial analysis can therefore be combined to provide a richer understanding of drivers of adoption rate and distribution. However, establishing how these different drivers come together to impact sustainability at the regional level can be challenging given the diversity and interdependency of territorial drivers of change. A combination of qualitative impact mapping and network analysis may therefore be useful to link drivers to impacts. This combined approach can help tell us something about the potential of alternative farming approaches, and different rates and configurations of adoption, to contribute to regional sustainability performance. This is a mix of methods that has been used for assessing drivers and impacts of land-use change associated with agricultural expansion and decline (Boron et al., 2016; Tzanopoulos et al., 2011), but not for comparing adoption patterns for different farming approaches, so it has the potential to make a novel contribution to our knowledge of how farmer adoption can impact regional sustainability performance.

1.8. Research objectives and chapter overviews

This mixed-methods, interdisciplinary approach is well-suited for tackling the challenge of researching adoption and sustainability performance at the regional level. Moreover, since this involves combinations of methods that have not been applied to adoption research before, it provides the potential for new perspectives and insights into key drivers, barriers, and pathways for regional sustainability. Given the need to improve understanding of adoption drivers and sustainability performance at the regional level, especially under the changing policy regime in England, this thesis aims to use this mix of methods to assess challenges and opportunities for adoption of alternative farming approaches to impact regional sustainability, focusing on English agriculture post Brexit. This aim will be achieved by addressing the following objectives:

1. To examine drivers of farmer adoption of approaches and practices for public good provision by using qualitative interviews to assess farmer perceptions of public goods and how this relates to their willingness to identify as public good providers

2. To examine drivers of adoption of cooperative or collective practices for enhancing regional public good delivery by using qualitative interviews to assess farmer understanding of cooperative management for public goods and how this relates to farmer self-perception and social relationships

3. To use spatial analysis and modelling to assess the distribution and spatial dependency of AES engagement at the regional level in England, and identify factors associated with this distribution

4. To integrate scenario analysis, qualitative impact mapping, and network analysis, to conduct a regional sustainability assessment of ecological farming approaches that explores how the regional rate and distribution of adoption of an approach may affect overall performance

The remainder of the thesis is structured around these objectives as follows:

- **Chapter 2** presents the results of a thematic analysis of semi-structured interviews conducted with a diverse sample of farmers in south-east England to understand how farmer perceptions of identity were associated with their reaction to the idea of being a provider of public goods.

- These farmers were also asked about their relationship with public good provision beyond the level of the individual farm, through cooperation with land managers. **Chapter 3** describes the key themes from these questions and considers their implications for the distribution of farms engaging in environmental management practices across rural landscapes.

- **Chapter 4** takes a quantitative spatial approach to examine the distribution of regional rates of AES adoption across England and seeks to identify variables that could help to explain this distribution. This is done by using secondary data on the uptake of Environmental Stewardship Scheme (ESS) agreements and management options within each English Local Authority District (LAD), national agricultural survey results, and other publicly accessible data on the socio-economic and physical features of each LAD. Exploratory spatial analysis is used identify any spatial dependence in adoption, and

spatial econometric modelling is used to test the role of candidate explanatory variables in driving the observed distribution, and possible reasons for spatial dependence.

- **Chapter 5** evaluates the potential of ecological farming approaches to contribute to sustainability at the regional level, for two case study areas in south-east England, using a framework that combines scenario analysis, qualitative impact mapping, and network analysis. This involves creating alternative scenarios (differing in terms of adoption rate and distribution) for the adoption of locally relevant ecological farming approaches. The performance of these scenarios is mapped against a set of sustainability objectives, and the relationships between drivers of change and impacts on objectives are explored using network analysis. The scenario generation, impact mapping, and network construction are performed through a mix of stakeholder discussion, expert consultation, and literature review. In this way, it is possible to qualitatively assess how adoption rate and distribution could affect the regional sustainability of ecological farming approaches and identify key causal pathways for explaining differences in sustainability performance between scenarios.

- In each of Chapters 2, 3, 4, and 5, the results of the methods described above are discussed in the context of the relevant literature. **Chapter 6** concludes the thesis by reviewing these key findings and discusses what they can tell us about the challenges and opportunities for the adoption of ecological farming and AES to contribute to regional level sustainability performance. This chapter builds on the preceding chapter-specific discussions by identifying common themes that link the different chapters and takes an integrated view of all the results together to generate further insights for research and policy in this field.

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Chapter 2: Farmer perceptions of public goods and reactions to being identified as a 'provider of public goods'

2.1. Introduction

UK agricultural policy in the late twentieth and early twenty-first centuries was shaped by the European Union's Common Agricultural Policy (CAP), but this is changing now the UK has left the EU (Finlay et al., 2020). In England, post-Brexit agricultural policy is moving away from general support for agricultural activities, towards greater emphasis on the provision of public goods (DEFRA, 2018a; Finlay et al., 2020; Gove, 2018). While many of the management practices incentivised under previous agri-environment schemes (AES) could already be described as contributing to public good delivery (G. A. Wilson, 2001), under this new direction, public good provision is intended to be the primary basis for financial support for farmers, through the implementation of the Environmental Land Management (ELM) scheme, rather than an additional option for income support (DEFRA, 2018a).

Economic theory defines 'public goods' as delivering benefits to society that are both non-rivalrous (use by one individual does not affect the availability of the good to others) and non-exclusive (it is too costly to prevent others from enjoying the benefits of access to the good) (Anderson, 2000; Cooper et al., 2009; OECD, 2001). While this definition would classify agricultural produce as private goods, it also means that many outputs of farming can be described as public goods, such as landscape character, clean drinking water, and regulation of water flows, and different farming approaches may differ in their impact on the delivery of different public goods (Abler, 2004; Brunstad et al., 1995; Jespersen et al., 2017; OECD, 2001; Renting et al., 2009). These goods are often unaccounted for within market economies (Angus et al., 2009; Brunstad et al., 1995), and agricultural policy interventions could be used to correct these market failures and bring the supply of public goods in line with society's requirements, by incentivising farmers to redirect resources towards public good provision (Angus et al., 2009; Cooper et al., 2009; Westhoek et al., 2013).

Reforming England's agricultural policy to focus financial support towards public good provision was met with broad support among both environmental organisations and farmer's groups (Finlay et al., 2020; NFU, 2018). However, a lack of specific details in the new Agriculture Bill outlining the change in policy fed into a wider debate over what public money for public goods means in practice. Formal scrutiny of the bill raised concerns over inadequate information on

the basis for allocating funds to each public good and how different public goods would be prioritised, and the lack of an explicit definition of 'public good' (EFRA, 2018).

Achieving consensus on the form of public goods in the agricultural sector, and how to prioritise and allocate funds to each public good, are challenges that must be addressed by the implementation of England's new agricultural policy (Bateman & Balmford, 2018; Gravey et al., 2017). While some outputs of agriculture are widely agreed to be public goods requiring financial support, and have been recognised as such in the Agriculture Bill, continued vagueness in defining public goods created the space for a debate over what qualifies as a public good amongst different stakeholders trying to make the most of this ambiguity (DEFRA, 2018a; EFRA, 2018; Gravey et al., 2017; NFU, 2018).

These policy reforms therefore prompt a fundamental discussion about what farming can, or should be expected to, provide (Howe & Ross, 2019). Researching farmer understanding of and attitudes towards public goods provision, could make a pertinent contribution to discussion around the role of farming after Brexit. There is a large body of research concerning farmer attitudes towards and willingness to engage in AES, to assess factors contributing to the adoption of ecological practices (Dessart et al., 2019). Farmer perceptions of agricultural policy instruments are known to influence how they engage with such schemes (Gorton et al., 2008; Kvakkestad et al., 2015). Therefore, it could be useful to investigate how farmers are responding to a change in policy approach that is portrayed as targeting public good delivery.

A key question that has been addressed by this research into farmer attitudes is what accounts for the limited effectiveness of AES to date, despite extensive government investment. Evidence has been accumulated that illustrates how lack of engagement may be the result of cultural resistance among farmers: farmer hostility to AES has been linked to conflicts with their identities as productive farmers (Burgess et al., 2000; Burton, 2004; Burton et al., 2008; Watkins, 1996; G. A. Wilson, 2004), prompting researchers to explore cultural models of the 'good farmer' and what this means for farmers' practices and responses to agri-environment policy (Burton, 2004; Burton et al., 2008; Sutherland & Darnhofer, 2012). Most cultural analyses of farmer behaviours have focused on schemes targeted towards specific species, habitats, or practices, with less consideration given to the provision of ecosystem services and public goods more generally. This topic has become especially relevant with the increased emphasis on public good provision in England's new ELM scheme, bringing new challenges for understanding the issues of identity underlying farm management decisions (Howe & Ross, 2019).

Commentators have argued that re-orienting policy around 'public money for public goods' will be insufficient to ensure a sustained shift in agricultural practice, unless accompanied by a reframing of farmer cultural identities, including addressing the deeply ingrained concept of the 'good farmer' and its current association with maximising productivity in conventional agriculture (Howe & Ross, 2019). This reflects a growing awareness that internalising changes to good farmer ideals will be more important in generating lasting change in farming than external factors such as financial incentives (Mills et al., 2017; Wauters et al., 2017). Financial incentives may encourage farmers to move away from a focus on private good provision to some extent, but they will likely be unwilling to make radical changes to their role as a farmer if they are not also compensated for social losses. Otherwise, farmers are being asked to revise their self-perceptions and the meanings attributed to their actions and experience a loss of status accrued through their farm's performance (Burton, 2004). The ideals associated with farmer cultural identities, and how they shape the legitimacy of different practices, are a key area of struggle for any process seeking to reshape agricultural goals or priorities (Howe & Ross, 2019; Saunders, 2016).

There is a need, therefore, to talk to farmers to gain an insight into their ways of thinking about public goods, their support for public goods provision, and the extent to which they can reconcile being a provider of public goods as part of their identity. Research into these topics has been primarily conducted through quantitative, survey-based approaches (Howley et al., 2014; Kvakkestad et al., 2015). Recent work has begun to apply qualitative methodologies to complement these quantitative studies (Cusworth & Dodsworth, 2021), and although this research explores attitudes to public good provision in terms of the 'good farmer' concept, it largely takes farmer understanding of the public good concept for granted: the research presented here aims to take a closer look at how farmers think about public goods, and how this relates to their willingness to identify as public good providers.

Using qualitative methods to study farmer perspectives has a long history in rural social science and has become increasingly influential in research into the behaviours and attitudes of farmers, following a broadening of perspectives in this field (Morris & Evans, 2004, 1999; Prokopy, 2011; Riley, 2010). Semi-structured interviews are especially well-suited for obtaining data on the values and perceptions of respondents while placing minimal restrictions on how the respondent wishes to interpret the subject (Fish et al., 2003; Kauneckis & York, 2009). The research described below employs a semi-structured interview approach to investigate farmer perceptions of public goods and the extent to which they can incorporate the provision of public

goods into their identities, during this key transition period as the sector prepares for the arrival of ELM.

2.2. Methods

The research presented here is based on interviews conducted with 18 different participants in south-east England. Interviewees were involved in the management of farms in either north-east Kent (14 participants) or the High Weald (4 participants). Together, these two study areas encompassed a variety of landscapes and farming systems largely representative of the those found elsewhere in lowland England. These two areas have distinct topographies, geologies, and histories, which help drive differences in the local agricultural context described below. In north-east Kent, the chalk hills of the North Downs, with their poorer, flinty soils, give way to the more fertile soils of the North Kent plain (Natural England, 2013b, 2015). The High Weald is an area of sandstone hills, with a more complex topography and generally less productive land and is covered by a mosaic of small farms and woodland (High Weald Joint Advisory Committee, 2019; Tubbs, 1997). The High Weald is also notable for the persistence of a historic landscape that has seen relatively little change since the medieval period, whereas the landscape of north-east Kent has seen much more pronounced change, with extensive urbanisation and industrialisation, and the loss of traditional low-input horticultural and pastoral farmland at the expense of more intensive arable farmland (Cobb, 2010; Natural England, 2015).

The first 4 interviews were conducted within a two-week period during March 2020, to pilot the interview design. Following these pilot interviews, a revised interview schedule was implemented for the rest of the interviews, which were conducted between November 2020 and February 2021. The High Weald interviews were conducted after the north-east Kent interviews. The number of High Weald respondents was smaller than the number of north-east Kent respondents because the overall sample was already approaching saturation at this point (as described below), with the High Weald interviewees tending to provide responses that were already familiar from speaking to farmers in north-east Kent.

The sample used for the interviews was obtained using a combination of chain referral and purposive sampling. Initial contacts were reached through approaching local farming businesses in the study areas. In a chain referral process, when the first individuals were interviewed, they were asked to provide suggestions for other farmers to approach. Out of the lists of farmers provided, participants were deliberately selected to maximise the diversity in farm type and farmer characteristics within the sample.

The purposive sampling strategy was adopted to maximise the potential variation in farmer approaches and experiences across participants, to provide a set of responses that would best address the research question (Marshall, 1996). Purposive sampling is useful for maximising efficiency in qualitative research, by ensuring that the research question can be addressed with the minimum possible sample size (Newing et al., 2011).

As with other non-probabilistic sampling methods, the findings will not necessarily be representative of the wider farming community, but a carefully chosen sample should illustrate the potential variety of viewpoints held by farmers in the study areas. There is a risk that purposive sampling could overlook key groups of respondents, due to lack of researcher knowledge or awareness, so the chain referral process was important for allowing access to new types of participants missing from the initial sample, especially given that interviewees were explicitly asked to suggest further participants who they might expect to hold contrasting views.

Sampling continued until saturation was reached, when each new interview no longer contributed any substantially different perspectives on the topics of interest. Interviews were analysed continuously, throughout the data collection phase (as described below), enabling me to monitor the occurrence of new themes in responses. The saturation point was therefore judged to be reached when the analysis of further interviews was no longer generating any major new thematic codes, even when targeting different types of respondent (Lewis-Beck et al., 2004).

The sampled farmers represented a large range in farm sizes, from around 10 to 2,000 hectares. Participants from north-east Kent represented a variety of different production systems, including arable, horticultural, and livestock farming, reflecting the diverse, mixed character of agriculture in the area (Natural England, 2013b, 2015). Participants from the High Weald tended to operate beef and dairy farms, reflecting the predominantly pastoral character of this region, which has traditionally been associated with extensive livestock systems on poor soils (High Weald Joint Advisory Committee, 2019; Tubbs, 1997). Interviewees also represented a range of different approaches to farming: although some managed conventional agricultural systems, there were also individuals who described themselves as operating conservation, regenerative, organic, or agroecological farming systems. Within the sample, there were farmers who were currently part of AES (12), farmers who had been involved in AES in the past (2), and those that had never been part of such schemes (4). The demographics of the sample were also varied. Although many interviewees came from well-established farming families going back several generations, there were also more recent entrants to the agricultural sector, including some

first-generation farmers. There was a nearly forty-year age gap between the youngest and oldest respondent, and the sample consisted of 13 men and 5 women. The selected interviewees therefore represented a broad spectrum of backgrounds and approaches to farming in north-east Kent and the High Weald.

Prior to participant recruitment, an ethics review was completed for the research project, which was submitted to and approved by the University of Kent's Ethics Committee. A copy of the participant information sheet (that was provided to all interviewees in advance of the interview) is included in Appendix 2.2. Each participant was first briefed on the nature of the research, including their anonymity, and the use of their responses, before agreeing to an interview. A semi-structured interview approach was used, with interviews lasting between 40 and 90 minutes, taking the form of in-depth conversations (either face-to-face or virtually, via video call) that were loosely organised around an interview schedule covering a set of topics of interest, focused on public good provision by agriculture.

The interviews coincided with the initial year of the Covid pandemic, which meant that not all interviews could be conducted in person: hence the combination of in-person (8) and video-call based (10) interviews used. It is possible that conducting interviews via video-call could have hindered communication slightly and made for less effective interviews. Moreover, researchers in geography are increasingly recognising the importance of the place and context of the research encounter, especially when working with farmers, who may hold highly distinctive relationships with the land they manage (Thomas et al. 2019a). Experiences from agricultural research indicates that there are practical and theoretical advantages to conducting research interviews on the farm itself, gaining new insights by accessing spaces and practices that would otherwise be overlooked, and creating opportunities for new and unforeseen narratives and trajectories to develop while exploring the farm (Riley 2010). Being able to interview farmers in situ was often useful for talking about the farm: on several occasions it was possible for the farmers to explain a point by physically showing it on their farm, so it was beneficial to conduct at least some of the interviews in-person, to complement the responses from virtual interviews. However, given that there was substantial overlap between the responses and themes picked up across interviews, regardless of method used, not being able to visit every farm due to pandemic constraints seems to have had a minor effect on the results.

Participants were asked about their relationship with their identity, their reaction to being labelled as a provider of public goods, the types of public good that were delivered by their farm, and the relative importance of these public goods for farm performance and wider society. In

addition, since the interviews were conducted at a time when both Brexit and the implications of the Covid-19 pandemic were dominant topics in the agricultural sector, participants were also questioned on the role of these factors in their attitudes and actions as farmers, to help understand how these might be influencing their wider outlook on farming and public good provision. The full final version of the interview schedule can be found in Appendix 2.1.

The questioning was not explicitly introduced as exploring farmer responses to post-Brexit policy – instead, the idea of farmers as 'providers of public goods' was raised by the questioning, and farmers were free to make the connection with Brexit and policy reform in response. Even if respondents did not make a direct link between public goods and Brexit, I provided the opportunity for farmers to explicitly reflect on the relevance of Brexit by including a question on this topic at the end of the interview.

The semi-structured design meant that the interview could pursue specific lines of enquiry while also having the flexibility to be adjusted according to the circumstances. The respondent had the freedom to explore each topic in a way that reflected their own perspective, without being constrained by a predetermined framework or structure, and the direction of the interview could be sensitive to other issues identified by the respondent (Fish et al., 2003; Newing et al., 2011).

All participants gave informed consent for their interviews to be recorded, and these recordings were transcribed verbatim. Each transcript was then read through multiple times and coded manually to identify overarching patterns or themes in the data. For the pilot interviews, this thematic analysis was based on a data-driven, inductive approach, which meant that coding was not guided by a predetermined coding framework, nor, as far as possible, researcher preconceptions about the subjects covered (Braun & Clarke, 2006). The codes developed through the pilot interviews provided a basic coding framework that then was applied and refined during the analysis of the remaining interviews. For the purposes of reporting key quotes that capture the essence of particular themes, each respondent has been assigned a number between 1 and 18 (i.e., R1, R2, R3 etc.).

2.3. Results

2.3.1. Awareness of 'public goods'

Although the idea of 'public goods' was familiar to many interviewees, it was not universally recognised. Respondents displayed differing levels of familiarity, understanding and engagement, reflecting the extent to which they saw this as an important or relevant issue in agriculture. Attitudes appeared to vary according to the respondent's relationship with the wider agricultural sector and community, and ranged from fully aware and engaged, to completely disinterested:

"*Never heard of it* [public goods] […] *you got all these buzzwords supposing… Yeah, there's a lot of them. Not that they've, to me make much difference. I don't get involved in it too much, to be frank.*" (R1)

For the respondent quoted above, the fact that they had "*never heard of*" public goods appeared to be a matter of personal choice, reflecting a desire not to get involved with wider issues in the agricultural sector. This wilful ignorance was in keeping with their fiercely independent mindset: this farmer saw themselves as staying apart from modern farming, not paying attention to the issues that dominated the agricultural sector, and instead focusing exclusively on their own farm. However, a lack of awareness of the 'public goods' phrase did not always mean a lack of understanding. There were other respondents who also had not heard of the phrase 'public goods', yet still demonstrated knowledge and understanding of the new public-goods oriented direction for agricultural policy. Equally, however, among those who did recognise the public goods terminology, respondents differed in the extent to which they felt they had a clear understanding of the concept, and gave different interpretations, as described in the following section.

Regardless of the interpretation of 'public goods', for interviewees that were familiar with the term, provision of public goods was widely recognised as a prevalent topic of discussion in the agricultural sector. Respondents identified public goods as having relevance to current policy developments and highlighted it as underpinning the future direction of AES. They could point to where they had come across the phrase, referring to its usage in the media, government communications and outreach events, and identify when they saw the term enter public consciousness and dominate agricultural discussion: "*Michael Gove mentioned it… eighteen months ago, and it's just been there ever since*" (R2). Awareness of the 'public goods' term could be found in both those participating in current AES, and those who had chosen not to

participate, and across farmers representing different systems, including representatives of conventional agriculture, and alternative production systems, such as conservation agriculture or organic farming. Where respondents were aware of the term, they also made efforts to engage with the concept: it was something they could give thought and consideration to, exploring questions raised by a public goods-oriented direction for agricultural policy.

2.3.2. Uncertainty and ambiguity in understanding of the 'public goods' concept

However, being aware of the idea of public goods as an output from farming did not necessarily translate into a solid understanding of what was actually meant by a 'public good'. There were some respondents who could clearly explain what they understood from the concept and confidently provide a justification for what farm outputs should be classified as public goods. Others, however, expressed uncertainty over the definition of public goods, questioned what kinds of output would qualify as public goods, and suggested different possible interpretations. The perception of 'public goods' as an ambiguous concept was a recurring theme, and greater engagement with AES or policy discussion, through participation in trial schemes or reading government material, for instance, did not automatically bring more certainty.

Some respondents linked their uncertainty over the nature of public goods to the idea that what could be classed as a public good was a matter of subjective interpretation. Although they identified certain farm outputs as public goods, they also acknowledged that this classification reflected their personal opinion, and that someone with a different perspective could disagree: "*So, it depends what angle you're coming at as far as public good*" (R6). This idea that 'public good' could be approached from different angles meant that some respondents saw this as a flexible concept, with a meaning that shifted depending on your perspective. This flexibility also affected how respondents perceived the usage of the public good concept in agricultural policy. If 'public good' was open to different interpretations, then a particular interested party could adapt its meaning so that it suited their agenda. Moreover, the choice to use the phrase 'public goods' itself could be seen as a strategic decision:

"*Errm, and that's the way the government is selling its proposed changes, in that we provide public goods* […] *Errm, in the formal words you use, you can tweak around that control* […] *You can certainly tweak it around to produce environmental goods if that's what your current thought in life is. Errm, you could certainly tweak it towards increased public access if that's what your ambition is.*" (R7)

For the respondent quoted above, using 'public goods' to describe farm output is effectively a branding exercise: they describe the government as using the term to 'sell' the new direction for agricultural policy. Calling certain farm outputs public goods is seen to be a conscious choice by the government to put a positive spin on a new policy direction. The need to sell these "*proposed changes*" arises because, in this respondent's view, agri-environmental measures are a way of the government exerting 'control' on farmers. The choice of wording to describe farm outputs, and how the phrase 'public goods' is used, are therefore seen as tools to control the output of agricultural landscapes. Manipulating "*the formal words you use*", or their meaning, enables the government to "*tweak*" these tools to get the desired output, whether this is food, environmental goods, or public access.

Out of the 18 farmers interviewed, only 3 were not already reliant on some form of government subsidy, and these 3 farmers were characterised by either very small-scale operations or having access to alternative sources of income besides farming. This situation reflects the national picture where the Basic Payment Scheme has been necessary for most farms to be financially viable given the prices consumers pay for food. For those farmers dependent on these subsidies, the introduction of ELMS will be something that they must sign up to if they are to continue farming, rather than being a voluntary choice. This meant that respondents often made associations between ELMS and feelings of being controlled or coerced into applying certain management actions, rather than having the freedom to manage their land in a way that reflects their acquired knowledge and respects their personal autonomy. As a result, it is not surprising that some respondents made a connection between 'public money for public goods' and a need for the government to promote a tool for controlling outputs from farming.

This idea of the 'public goods' phrase as means to sell a change in policy, coupled with the perceived malleability of the public goods concept, meant that some respondents felt the government was applying this label to whatever they wanted, to ensure that agriculture delivered outputs that aligned with political objectives. The idea of 'public money for public goods' was framed as just another way to justify imposing control of, or interference in, farming businesses, with the government choosing an interpretation of 'public goods' that fitted their interests. However, based on the interviews analysed here, many farmers could be described as doing the same thing: choosing an interpretation of public goods that included the outputs that they wished to prioritise or protect on their farm. Respondents typically identified food production as the defining characteristic of farming practice, central to their identity as farmers, and at the same time, many argued that food should be a public good, and therefore food

production needed support, and greater respect from the public, as reported in more detail below.

2.3.3. Defining public goods: 'public goods' and 'public good'

Although uncertainty and subjectivity were recurring themes associated with the idea of public goods, many respondents did give definitions for the public goods concept, either explicitly or implicitly, and could explain the reasoning behind their definitions. Respondents' discussions of their role in relation to the provision of public goods, and the public goods delivered from their farm, provided insights into the way in which they understood the public goods concept.

In considering what was meant by 'public goods', many respondents broke the phrase into its constituent parts, and explored the meaning of both the 'public', and 'goods', or 'good', aspect of the phrase, to reach a particular interpretation.

The 'goods' aspect of public goods meant that some respondent interpretations focused on farm outputs that can be bought and sold, leading to the conclusion that *"I do provide public goods, yeah, 'cos I grow produce to sell*" (R3). In this case, the reference to selling produce as a justification for seeing oneself as a provider of public goods reflects a view of public goods as items traded, subject to financial transactions, a view elaborated on elsewhere:

"*Public goods. Goods are generally things that are paid for, right. They're tangible, quantifiable, measurable, box of x number of kilos, that's a, that's a good. I'm buying five kilos of sugar, there are my goods. Goods in transit. Generally, paid for commodities traded. Tangible assets.*" (R2)

Here, the 'goods' in public goods not only implies that something must be paid for and traded, but also that these must be "*tangible assets*": they are things that physically exist and can therefore be quantified or measured in some way. This respondent also associates this potential for a quantity to be assigned to a public good with its capacity to be bought and sold. As a result, discussions of the public goods on their farm focused on how these public goods could be measured, how they would be paid for, or who would pay for them. 'Public money for public goods' was therefore understood to mean paying farmers for tangible, quantifiable outcomes on their farm. Consequently, where respondents took this view, labelling more abstract, subjective outcomes of farming, such as cultural heritage, as a public good, was met with scepticism, as farmers struggled to see how a meaningful numerical value could be assigned to these features.

However, if talking about a 'public *good*' rather than 'public *goods*', then the 'good' in 'public good' can have a different meaning, leading to a different interpretation. One farmer explicitly identified this distinction and the resulting two different interpretations:

"*So, to me, that's what public, public good, public goods or public good, it depends* […] *it's, it's a kind of play on words in a way, isn't it? So, public goods are things, that people see as things, as products, as outputs, I suppose. And public good, is something for the public good, for the benefit of. And I would say, you know, that the public goods come from that, that same root, so, it should be all of those things.*" (R9)

This respondent associates the two different perspectives on the meaning of this concept with whether it is described as 'public goods' or 'public good': a dual meaning arising from a "*play on words*". As described above, public 'goods' are things, quantifiable outputs from the farm. However, 'good' is also used to mean something that has a beneficial effect, and this links to the 'public' aspect of public goods, by focusing on the potential benefit to the public. These two perspectives are not mutually exclusive. The respondent argues that 'public goods' "*should be all of those things*": therefore, public goods are quantifiable outputs generated by the farm that also enhance public well-being, a view that was shared by respondents representing a range of backgrounds and farming systems.

The idea of public goods being for the benefit of the public meant that public well-being was central to respondents' personal interpretations of public goods, typically described as "*all to do* […] *with somebody having a good sense of well-being*" (R4). This point enabled respondents to draw a contrast between public goods and private interests, where private interests do not "*put food on the table*" (R2) and do not mean "*that we can keep ourselves healthy*" (R2), and therefore, the public's well-being is not being actively protected. This focus on farm outputs that were simply 'good for the public' provided respondents with a means to justify classifying food as a public good, because food was seen as contributing to people's well-being: "*If you eat well, you, you're a lot happier person*" (R4).

Related to this idea of public goods as being those goods that supported public well-being was the perception that public good provision was responding to public demand. The question of "*what does the public want?*" (R2) was used by some respondents when attempting to identify candidate public goods. However, this question was complicated by the suggestion made by some respondents that the public do not always want what is best for them. The idea of the public holding misguided desires was a recurring theme when farmers considered the nature of the relationship between farmers and consumers.

One of the topics that farmers immediately gravitated towards when asked about the public goods provided by their farm was public access, where the link between the farmer as a provider and the public as a beneficiary was direct and obvious. Respondents recognised that the accessibility of their land was valued by the public for its benefits to well-being, especially in the context of the coronavirus pandemic, which was associated with both increased use of local green space and greater awareness of the importance of outdoor exercise for personal health. Discussions of public access on the farm was also associated with a different interpretation of the 'public' aspect of 'public goods', where public goods are those farm outputs that are accessible to all, and outside of private market mechanisms.

Issues raised by the Covid-19 pandemic bought certain interpretations and attitudes towards public goods to the fore, and given many respondents reported large increases in people using their farms for exercise and recreation during lockdowns, it was perhaps unsurprising that public access was at the forefront of farmers' minds when discussing public goods. At the same time, however, many of the supply chain issues, and resulting empty supermarket shelves, that had been experienced during the pandemic, were also highlighted as drawing public attention to the value of farmers as food producers and were cited by multiple respondents seeking to justify food production as a public good. Hence, the influence of the pandemic on attitudes towards public good provision was complex and multidirectional, not obviously biasing responses in one direction or the other.

Given the different ways in which respondents could think about public goods, the interviews showed variation in how the public goods concept was interpreted. Respondents differed in the emphasis placed on the 'public' and 'goods' aspects of public goods, and in what they understood by each of these terms. These different interpretations of 'public goods' influenced how each farmer reacted to the idea of being identified as a provider of public goods.

2.3.4. Being a 'provider of public goods' as part of farmer identities

The idea that the labels assigned to respondents, or what they chose to identify as, had repercussions for how others perceived them, appeared in a range of contexts across interviews. Interviewees recognised the power that certain labels could have, and therefore reported preferences for particular labels or identities in an attempt to present a particular image of themselves, to influence how others saw them, or to distance themselves from other groups that they did not want to be associated with. This was evident when respondents discussed their relationship with the 'farmer' label:

"*… when there's bad press for, beef farmers, or sheep farmers, or cereal farmers, I quite happily call myself a fruit grower. But when it suits me, I'm quite happy to call myself a farmer.* […] *but there are times when people, the press, and the media, want to beat up farmers for, the EU subsidies and everything like that, and then then I'm happy to point out that, that I actually live or die by the price, I don't get massive, errm, area payments.*" (R8)

For the respondent quoted here, the fact that 'a farmer' was something that they called themselves "*when it suits me*" shows how their description of their identity reflects a personal, strategic choice. Rather than always being a farmer, they choose the appropriate label to ensure they present the best possible image to others. 'Farmer', being a general term, is seen to attract all the negative press associated with different types of farming. Across interviews, there was a shared view that society had a negative perception of 'farmers' as a group, seeing them as contributing to environmental degradation, or becoming lazy due to a reliance on subsidies. Several interviewees reacted to this by trying to avoid being labelled as a farmer, as illustrated above. Here, the interviewee's choice to call themselves "*a fruit grower*" represents an effort to distance themselves from the bad press associated with other farmers and present themselves as something different. 'Fruit grower' allows them to differentiate themselves from other types of 'farmers', who are associated with a dependence on subsidies, and instead paint a more favourable picture of themselves as financially independent. Therefore, reputation, not just amongst other farmers, but the wider public, was a concern that influenced respondents' relationships with their chosen identities.

These concerns over reputation were evident in attitudes towards being seen as a 'provider of public goods':

"*Do I like to be known as* [a provider of public goods]*? No, I don't think so.* […] *provider of public goods, I just don't, don't like the sound of that. Err, for the responsibility of maintaining and looking after the countryside, I'm more than, more than happy to err, do that, that. Yeah, I agree almost in a way, that that's got to be our role.*" (R10)

For the respondent quoted above, there was a wariness around being identified as a provider of public goods. In stating that they "*don't like the sound of*" provider of public goods, they indicate that they are giving thought to how this label will be received, something that is reinforced by their position that they do not "*like to be known as*" a provider of public goods. However, although this respondent may be uncomfortable with being seen as a provider of public goods, throughout the interview they also expressed motivation to deliver outputs that they identified as public goods, such as public access, habitat quality, and biodiversity, through

the management of their farm. Being responsible for "*maintaining and looking after the countryside*" was something that they believed in strongly, arguing "*that that's got to be our role*". Therefore, for this respondent, there is a distinction between working to provide public goods, which is something that they believe in, and actually being called a provider of public goods, which is a label that they prefer to distance themselves from for the sake of their self-image. Discomfort over being called a provider of public goods may be due, in part, to farmers' perception of the balance between their role in providing public goods and other aspects of their identity. They may feel that the label of 'provider of public goods' places expectations on them that go beyond what they are comfortable with.

Throughout the interviews, respondents described having multiple identities, often existing alongside each other. Some identities were seen as more important than others, as illustrated by respondent attitudes towards the relative importance of their role as food producers and their role as providers of public goods. Where farmers were happy to describe themselves as providing public goods, they also tended to stress that "*I'm not solely a provider of public goods*" (R15): this should not be the focus of their identity and providing public goods was not "*what I'm farming for*" (R7), or, in other words, "*I'm happy with the terminology, not just that it's the only thing that we're here for*" (R15). The possibility that being a 'provider of public goods' might come at the detriment of other, more important aspects of their farming role was a source of concern. Throughout interviews, respondents tended to emphasise that their identity needed to remain centred on the production of food to sell. Across respondents representing a range of farming systems, and irrespective of whether they classed food as a public good, respondents stressed that food was the primary output of the farm. The production of food for profit was the central, defining characteristic of their role: "*I'd like to think that we are primarily producers of food*" (R13). Being called a provider of public goods therefore appeared to raise concerns among some respondents that there was a risk of their primary role as food producers being overlooked. However, not everyone saw public good provision as something that needed to be weighed against the more important aim of food production. Despite widespread acknowledgement of the importance of producing food for personal profit, there were different perspectives on the relationship between public and private good provision, which influenced how farmers viewed their identity as providers of public goods or otherwise.

2.3.5. The relationship between private and public good provision

Maintaining a profitable business, whether this was achieved through maximising productivity of crops and livestock, minimising costs, or a combination of both, was the foremost

consideration for farm management for many respondents representing both conventional and alternative farming systems. Farmers employing conventional high-input farming approaches often spoke about the necessity of maintaining high levels of productivity to support a profitable business, while farmers involved in alternative approaches, including those identifying as practitioners of conservation or regenerative agriculture, placed greater emphasis on maximising profitability by minimising costs through reduced use of external inputs on the farm.

The attitude towards other aspects of farm performance, that do not contribute directly to these aims, was essentially: "*it will sound a bit brutal, but the rest of it's secondary to that*" (R7). According to this viewpoint, the delivery of public goods is an optional bonus or add-on to the main business of the farm: the production of food for profit. For farmers holding such a mindset, being a provider of public goods is just a minor part of their identity. Conversely, some interviewees, including those with additional income sources not tied to food production, prioritised developing a farming system with a positive environmental and social impact. Rather than trying to make an already profitable system more environmentally and socially sustainable, the aim was to take their sustainable system and make it profitable.

Whether respondents prioritised profit or environmental and social impacts, the idea of prioritising one over the other reflected the idea that the delivery of private and public goods from their farm were two separate objectives, and that one could be traded off against the other. This meant that maintaining a dual identity as both a provider of public goods, and a producer of food for profit, requires some compromise. For most respondents, this involved foregoing public good provision for the sake of maximising private good provision.

"*… we're a business and we, we have to survive, I mean if I farmed to my absolute beliefs and fundamentals, we might not make much money. You know, I have to temper what I think is right with what the market's going to return, so, yeah.*" (R15)

The respondent quoted above describes this trade off in terms of having to "*temper*" their personal beliefs with the need to make money from the farm. Management for public good provision was something that they did, in part, because of personal beliefs that this was the right thing to do. However, here, they imply that to prioritise these beliefs would mean unacceptable financial losses, threatening the viability and survival of their business, so providing public and private goods are not fully compatible with each other. In order to run a productive and profitable farm, the respondent has to go against some of their beliefs about what land management should deliver. Although they may desire to do more to provide public goods, this desire has to be set aside in order to be a productive and profitable food producer.

However, framing public and private good delivery as two separate, conflicting aims for land management was not the only way that respondents approached this issue. The public goods generated by farm management were also described as underpinning or coinciding with the provision of private goods.

"*I've got no problem, err, with doing it* [providing public goods]*, because I can also, I'm not only helping the public,* […] *by reducing, errm, soil erosion, wind erosion, topsoil* […] *I'm also helping myself by doing that, too. So, although I might be helping the public, I'm also, I'm also giving myself a bit of a leg up, in terms of cost saving, saving my soils.*" (R12)

In the example quoted above, the interests of the public, supported by the public goods provided by reduced tillage practices, and the farmer's private interest, in terms of the return from their business, are seen as fundamentally compatible. The resulting improvements to soil quality and erosion control mean their management is "*helping the public*", while also "*helping myself*", and so serving public and private interests simultaneously. The fact that they can reconcile public and private good provision also contributes to their willingness to embrace the idea of being a provider of public goods: they have "*no problem*" with providing public goods, because they see this as making business sense for themselves anyway: these outputs that are characterised as public goods also have a private value. Across interviews, a range of other features identified by respondents as public goods, such as biodiversity, water provision, and carbon sequestration, were recognised to also have a private value and contribute to farm productivity. Therefore, when considering the relative value of these different public goods, a repeated argument among farmers was that these could not be considered in isolation from private good delivery, because strong performance in delivering these goods provided the foundation for a productive and profitable farm, and running a profitable farm meant more money available for management to further enhance public good provision.

Although some respondents identified public goods that they saw as making no obvious contribution to farm business performance, such as opportunities for public access and recreation, others could assign a private value to these outputs too. One argument was that management to provide public access could support the farm business performance, because maintaining good quality public access infrastructure improved relations with the local community, and these good relations meant greater community support for the farm, which might increase opportunities for collaboration and assistance in times of difficulty. Where respondents argued that all aspects of farm performance, encompassing both private and public good provision, are interdependent, being a 'provider of public goods' was necessarily a

fundamental part of their identity, and so they readily accepted the label, as in the above example: being a provider of public goods was inseparable from being a provider of private goods.

The interviews therefore presented two contrasting perspectives on the relationship between the production of private and public goods, and how farmers perceived these different aspects of their role. One perspective treated private and public good provision as separate strands of farm performance, where one could be prioritised or traded off against the other, while the other viewed them as interdependent, such that one cannot be considered in isolation from the other. Respondents were capable of expressing a combination of both views, their position depending on the extent to which different public goods were seen to contribute to, rather than compromise, private good production.

2.3.6. Being called a 'provider of public goods' is associated with a lack of respect or appreciation for farmers

Given that public well-being was often central to interpretations of 'public goods', when respondents discussed the idea of farmers as providers of public goods, they tended to focus on their relationship with the public. Reactions to being a provider of public goods were associated with respondent perceptions of the public's attitudes towards farmers and farming.

In particular, the use of the term 'public goods' raised concerns among some participants, because this was interpreted to imply that farm outputs classified as public goods should be seen as a public right. This was expected to have undesirable effects on public attitudes:

"*… I think this, the language that they've used in the current bill, almost, almost sets out that everybody has a right to what, the land, and what we do with it. I don't think that's, I don't think that's a very helpful way for people to a, to understand where their food comes from, and the process that is involved in producing it.*" (R16)

Here, the choice to build agricultural policy around the language of public goods is described as implying that the public "*has a right to*" influence what farmers do with the land. This view of farm outputs as public rights means that the respondent anticipates the public thinking that they can dictate what they should get from agriculture: if farming is providing public goods, then its purpose is to deliver the benefits that the public wants. Therefore, classifying farm outputs as public goods is seen to encourage a feeling of entitlement among the public, where people think that they are owed these public goods from farmers. This sense of entitlement worried this respondent, and others, because it was seen as promoting the wrong kind of relationship

with food production. These fears fitted into a well-established narrative, repeated elsewhere, where the public do not properly appreciate what farmers do for them, or the true cost of providing food or public goods. Interviewees argued that given this lack of appreciation, the public do not understand the implications of what they demand from farmers. The public may think they are owed particular outputs from farming, but given their perceived lack of understanding, their demands are misguided and counterproductive.

The idea that public goods are seen as farm outputs that the public have a right to was particularly relevant when respondents were discussing whether food was a public good. Respondents gave different answers to this question: some saw it as a public good, some did not, and others suggested that there was no clear answer. Often, a key factor affecting whether food was seen as a public good concerned whether the public had an automatic right to food, especially cheap food. Since respondents argued that the public did not recognise the true cost of producing good food, and that this ignorance was associated with a sense of entitlement that came with good food being viewed as a right, respondents who argued against food being a public good typically justified this by claiming that the 'public good' label reinforced unhelpful public attitudes towards food and farming.

Moreover, as well as the public goods concept itself carrying unhelpful implications, respondents also linked the act of labelling farmers as providers of public goods to the idea that farmers are undervalued by society.

"*I don't know any farmer that doesn't appreciate conservation* […] *And that's the bit that always puzzles me of the, the way some of these things are termed, as though, you know, farmers are, are abusing the land, errm, so it's all gonna run out. I mean it's so short-sighted in the sense that, agriculture has been going on for several hundreds of years, based round a sustainable principle that what you put in, you get out.*" (R16)

The respondent quoted here argues that "*the way some of these things are termed*", namely, the labelling of farmers as providers of public goods, paints a misleading and unjustified image of farmers. If the new agricultural policy focuses on the role of farmers in providing public goods, then the implication, as this respondent sees it, is that if farmers are not being 'providers of public goods' then they must have been "*abusing the land*". Given that the respondent sees good farming practice as building upon a long tradition of sustainable land management, the idea that farming is abusing the land is "*short-sighted*": not seeing farmers for what they already contribute to the environment and society. Therefore, a shift in policy to focus on farmers as providers of public goods makes this respondent feel that they are being unfairly portrayed as

damaging the environment. The argument made by this respondent, and others, is that many of the outputs being classed as public goods are crucial for supporting farm productivity, and so public good provision is part and parcel of good farming practice, and something that any sensible farmer will have been doing already.

By contrast, asking farmers to be not just farmers, but also providers of public goods, is taken to mean that if farmers are focused on farming, they are not providing public goods. As in the above quote, this created a feeling among respondents that the 'provider of public goods' label means that food production is otherwise inherently damaging to the environment and society. This idea runs contrary to the argument, repeated across different farming systems, that good practice in public good provision can be reconciled with a profitable farming business. Therefore, the farmer's hard work to look after the environment to date is seen as having gone unrecognised, because it was a natural part of being a farmer and producing food, and not as 'a provider of public goods'.

While the interview questions were framed to ask farmers about their reaction to being providers of public goods in hypothetical terms, farmers tended to respond by assuming this was something that they would have to do soon, given their (often reluctant) dependence on external financial support. The provision of public goods may be a condition of receiving support, rather than a general expectation of all farmers, but because most farmers acknowledged that this support was a necessity under the current circumstances, this distinction tended to be glossed over in farmer responses. This meant that interviewees viewed the 'providers of public goods' role as something that would inevitably be expected of them under the post-Brexit policy regime.

As well as overlooking the existing positive contributions of farmers, being identified as a provider of public goods was also associated with a threat to the respondent's autonomy.

"*I find it a little bit worrying. Errm, because I think that, errm, that concept, lends itself for, errm, the government, or higher bodies, dictating how you should provide those goods.* […] *like I was saying before, no-one else really but me, will understand the farm in the way I understand it* […] *And I would be really annoyed, if, errm, someone, suddenly, there were a whole set of rules that dictated what I should do and how I should do things, because I'm providing, errm, a public service, and a public good.*" (R17)

The idea that the farmer quoted here should be providing something defined by an external label imposed upon them by a 'higher body', rather than something that they chose

independently, was seen to neglect their personal knowledge of their farm. Throughout the interviews, respondents described farm management as a continual learning process, constantly refining performance based on experience of what does and does not work. The resulting accrued wisdom meant that respondents felt they knew best how to manage their own farm, hence the statement that "*no-one else really but me*" understands their farm like they do. Therefore, what the respondent chooses to deliver from their farm is what they know works. The public goods concept, however, disregards this understanding, because it "*lends itself*" to use by other parties to demand certain outputs from farming. As described previously, calling farmers providers of public goods was seen as a way of justifying the imposition of control, and potentially misguided interference, in farmers' private businesses. The implicit lack of respect for the farmer's own knowledge was a source of resentment: this respondent, for example, expected to be "*really annoyed*" if being a provider of public goods meant that management practices would be dictated to them by others. Therefore, the perceived threat of control associated with classifying farm outputs as public goods contributed to the hostile or wary reactions of some respondents to the idea of being providers of public goods.

2.3.7. Farmer perceptions and experiences of public appreciation

Whether expressing concern over a lack of understanding, positive contributions going unrecognised, or a lack of respect for personal knowledge, reactions to being labelled as providers of public goods kept returning to a desire for greater appreciation. The ways in which this appreciation could be experienced varied across respondents. For some, the public were only described in general terms, and conclusions about society's relationship with farming were based inferences from other observations, such as the portrayal of farmers in the media, or as a reflection of the price of food. Others, however, also drew upon personal experience. Depending on the farming system being managed, respondents differed in their relationship with the public, and the extent to which they could recognise direct appreciation of their role, as opposed to describing public attitudes in a more general sense.

Some of the interviewed farmers ran businesses in which at least some of their produce was sold straight to the public. This direct connection with their customers gave them an opportunity to experience public appreciation of their produce first-hand.

"*Errm, when I grow something and you see the customer's face light up* […] *Errm, all of a sudden, you're like a, not god amongst ants, but you, their opinions change, and then they're not so much kind of errm, 'Oh that's cute, he's a farmer', but it's like 'Oh my god, he's growing amazing stuff'*." (R3)

In the above example, through selling to the public, the respondent is able to "*see the customer's face light up*", showing that not only is the respondent able to personally observe customer reactions to their produce, but also that they recognise appreciation in these reactions. Moreover, selling produce was seen as an opportunity to influence public attitudes, specifically to promote respect. The respondent distinguishes between two different mindsets, associated with before and after customers experience the produce. On the one hand, viewing the farmer as 'cute' implies that what they do is seen as trivial or quaint, rather than respected or admired, whereas customers who have purchased the produce see the true value of what the respondent is trying to achieve. Therefore, selling direct to the public gives the respondent an opportunity to both recognise and experience public appreciation, and get the respect for their work that they desire.

A sense of satisfaction from being able to see public enjoyment was also described in the context of other farm outputs:

"*… we've got, err, owl, err, barn owl hunts on the, and the, in the spring, there'll be sometimes a dozen people standing there with their binoculars watching, and that's, that's a real reward.* […] *they're fascinated by this sort of lovely, sort of, the cows just walking and doing what they do, and you've got the barn owls over there, and that's a good thing. It's a good thing for them to actually see what's, for, for the public to see what's, what we're doing.*" (R10)

Here, the good feeling that the respondent derives from their farm's wildlife and natural environment, is not just due the environment itself, but the fact that they can see members of the public enjoying it. Knowing that people are visiting their farm specifically to see wildlife resulting from their management is highlighted as a "*real reward*", indicating that this respondent values the public's enjoyment of their farm. Moreover, the respondent links this appreciation to increased understanding of their work: people being able to experience the farm environment is a "*good thing*", because it provides a means for them to "*actually see* […] *what we're doing*". Therefore, once again, by providing outputs directly to the public, the respondent seeks to promote more favourable public perceptions of farmers and farming.

On the other hand, even those who personally experienced public appreciation, whether for food production or environmental management, still also referred to the public in general as undervaluing farmers and failing to recognise their contribution to society. Therefore, there was a difference between what these respondents thought of public attitudes based on direct experience, and their perception of wider public attitudes towards farmers, based on more general knowledge.

The idea of public respect was something that respondents focused on when considering their willingness to be seen as providers of public goods. The below responses were typical in this respect:

"*Public goods for public money: yeah, fine. Errm, but does the public understand what, you know, farmers and land managers actually already put back into the economy? You know, you know, do they understand that, you know, that there is always a willingness to engage in environmental schemes, not just for the monetary aspect, but for the, you know, on the side of, errm, providing benefit to nature and ecology?*" (R11)

"*You know, the easiest one that I always come back to with, with the public good idea is: no problem if, if people are gonna come and use the area, the space and the countryside, that's great, but the principle applies, if I go back and I want to walk round their garden, and I want to park my car on their drive, it's no difference really, is it?*" (R16)

In the first quote, acceptance of the idea of being a provider of public goods is immediately followed by questions over whether this aspect of farming gets enough public recognition. The use of questions rather than statements implies that they doubt the public really do understand what farmers "*put back into the economy*", and what motivates farmers to engage in environmental management. Although this respondent is happy to be a provider of public goods, this comes with a desire for the recipients of these public goods to understand the role of farmers in delivering public goods, both in terms of what farmers do and how they think, acknowledging that farmers are not solely motivated by financial gain. Therefore, this respondent's relationship with their identity as a provider of public goods, can be linked back to concerns over reputation and public image.

Linking the provision of specific public goods with a desire for public recognition was also emphasised by the second respondent quoted. Again, this respondent has "*no problem*" with idea of being a provider of public goods, in this case, in the form of public access. However, this willingness to provide public access comes with a desire for people to understand what this means for farmers. In describing the public accessing their farmland as equivalent to the respondent walking "*round their garden*" and parking on their drive, they seek to frame the public access issue in a way that the public can understand, indicating a need for the public to empathise with their perspective. Moreover, using the analogy of invading a person's private property implies that allowing access on their farm is something the public should be grateful for, since the farmer is opening up their own property. This points towards a desire for the public

to recognise the value of access and view it as a privilege rather than taking it for granted, given that it involves a sacrifice on the part of the farmer.

Therefore, rather than delivering something that is an automatic right for the public, if the public expect public goods from farmers, in return, farmers expect the public not just to pay for these goods, but also to respect and understand them. If public goods were interpreted as farm outputs that are good for the public, farmers also thought about what the public should be doing in return for receiving these benefits. According to this perspective, both being a provider and a user of public goods comes with responsibilities: the provision of public goods requires that both farmers and the public fulfil obligations to each other.

2.3.8. Farmers and the public have responsibilities to each other as providers and users of public goods

Respondents acknowledged that being a provider of public goods meant responsibility to the public. To some extent, this responsibility was simply a consequence of being a recipient of public money:

"*I realise that the money is coming from the public, and we've got to be seen, 'we' – farming, whatever farming, has got to be seen, err, to be using it responsibly, if we're entitled to it.*" (R10)

As this respondent explains, being publicly funded carries an obligation to use the public's money in a responsible manner, and "*to be seen*" doing so. Specifying the need to be seen to be acting responsibly again emphasises the importance of maintaining a favourable public image. Moreover, in acknowledging that "*the money is coming from the public*" and that there are conditions to be met "*if we're entitled to it*", the respondent also implies that they see themselves as being entrusted with the public's money. To repay this trust, they have a duty to the public to use this money appropriately, so that the public know their money is being used in a way that delivers benefits for society.

Responsible provision of public goods was also viewed as a natural consequence of managing land. One of the justifications for public good provision was the fact that the privilege of having land to manage demanded a responsibility to manage the land in a way that would benefit society and leave a positive legacy. Farming, in this context, is "*all about leaving the land in better condition than when you found it*" (R1).

However, while respondents described public good provision in terms of responsibility to the public, they also argued that if the public were going to have a right to enjoy certain farm

outputs, then using public goods should come with responsibilities too. This was particularly apparent when discussing the provision of public access: if the public are going to access the agricultural landscape for recreation, they should act as responsible users of the countryside, respecting farmers by sticking to designated rights of way, not trampling crops or disturbing livestock.

Moreover, some interviewees suggested that public good delivery should not be the exclusive responsibility of farmers but should also be a consideration for consumers:

"*… all the things that make it* [food] *cheap, errm, are negatively affecting the, errm, environment, and all the repercussions that, errm, we're seeing, that are coming of that. So, I think, you know, the cost to the National Health Service, because we don't know how to feed ourselves very well, and people prefer to buy cheap junk food than feed themselves properly, errm, and I don't think that should be put back on the farmers.*" (R17)

The above response gives some indication as to where this interviewee thinks that the responsibility for the impact of food production lies. Here, cheap food is associated with both a "*largely unhealthy, public*" and negative repercussions for the environment. In stating that "*people prefer to buy junk food*" rather than food that is better for their health and the environment, they imply that consumer choice contributes to these negative impacts. Therefore, consumers are portrayed as having responsibility for the environmental impacts of food production. This statement was part of the respondent's justification for opposing the idea of farmers as providers of public goods, because, as they see it, this label puts the responsibility for the negative impact of food production "*back on the farmers*". Therefore, this respondent suggests that it is unfair to make farmers take all responsibility for food production's negative social and environmental impacts when these are influenced by poor consumer habits. Here, being a 'provider of public goods' is seen to come with unfair expectations of responsibility for public health and the environment.

2.4. Discussion

2.4.1. Variation in farmer awareness and understanding of public goods

Given the variable levels of awareness of the public goods concept among interviewees, if a wider cross-section of farmers is to be engaged with the public goods concept when ELM comes into effect, awareness of farmers as public goods providers may need to increase further. Previous case studies looking at the establishment of new policy instruments for public goods support have found that a key factor for success is simply allowing enough time for new ideas

to become embedded in farming communities and for commitment to grow (Blom-Zandstra et al., 2016). If the idea of farmers as providers of public goods has not yet fully permeated farming communities, it is possible that farmers are still in the early stages of responding to this concept. Therefore, the current transition phase to ELM represents a key period in determining whether farmers will commit to the change in policy, and whether 'public money for public goods' will deliver the desired results in the longer term.

Finding ways to increase the reach of information may be important to involve farmers with little understanding of the public goods issue. Lack of awareness or inadequate information provision have previously been identified as barriers to participation in AES (Page & Bellotti, 2015). At the same time, given that among respondents, there were some who expressed a deliberate intention to stay apart from the rest of the agricultural sector, or professed wilful ignorance of the public goods concept, there may be some farmers who will remain unreachable. A core group of farmers who are highly resistant to the ideas associated with AES and unwilling to participate have been repeatedly identified by researchers under different circumstances (Andrews et al., 2013; Lobley & Potter, 1998), and a shift to an emphasis on public money for public goods may do little to change this by itself. Even if the financial viability of farming businesses requires AES participation, policy changes that impose a new culture of farming could cause such farmers to simply leave the sector (Burton, 2004).

Moreover, the responses suggest that even if farmers show at least some level of recognition of the concept of public goods as an output from farming, this does not automatically translate into an understanding of or sympathy with the government's aims. Respondents gave their own interpretations and definitions of public goods, which informed their views of what farmers should be supported to provide, and some aspects of these interpretations differed between participants, or with the government's position. Since one of the identified themes relating to public goods concerned its subjectivity, and the idea that the definition is dictated by the government's interests, farmers may be less willing to participate in public goods support measures if the government's position conflicts with their personal interpretation of public goods. Responses sometimes expressed scepticism of the value of the public goods concept, and it is possible that this scepticism could increase as farmers become more familiar with the way the public goods concept is used.

2.4.2. 'Public goods' perceived as a means of justifying control of farming

Commentators have already described how the use of public goods in European policy has moved away from the technical definition grounded in economic theory, to a looser, more

inclusive definition (European Network for Rural Development, 2011; Gerrard et al., 2012), and this appears to be the case for England's post-Brexit agricultural policy as well (EFRA, 2018; Howe & Ross, 2019). Descriptions of the public goods definition as ambiguous or subjective suggest that farmers engaged in the public goods debate may be sensitive to this shift in usage of the 'public goods' terminology. Moreover, the view held by some respondents of public goods as something dictated by government interest could cast doubt on the meaningfulness of the public goods concept. There is a school of thought that states that the theory of public goods fails to explain public expenditure in practice, and that the public goods term only persists for political reasons, because it is a convenient tool that allows governments to justify the legitimacy of their activities (Holcombe, 1997; Maśniak, 2019). Given that some of the interviewees alluded to the idea that the targeted public goods reflect political priorities, and that the phrase 'public goods' is a tool to sell the need to exert control on farmers and dictate what outputs the agricultural landscape should provide, this way of thinking about public goods may already be present among farmers. If this is the case, then promoting the idea of public money for public goods may simply reinforce scepticism of any new agri-environmental initiatives associated with the change in policy.

This view of 'public goods' as just another means to exert control, has the potential, therefore, to contribute to farmer hostility to the idea of being a provider of public goods, and an unwillingness to accept this as part of their identity. Having to apply management practices that are imposed upon them to deliver the public goods that the authorities want to see, was associated with a lack of respect for the role of farmers, neglecting the value of their personal knowledge, and could therefore present an obstacle to AES targeting public good delivery. Resistance to AES due their prescriptive nature is well-documented, and the imposition of rigidly prescribed actions has been linked to the inability of farmers to express cultural identities through their practices (Burton et al., 2008). Here, interviewees reported how their personal experience of their farm has allowed them to build an in-depth understanding of how best to manage their farm. Therefore, their farm's performance provides them with an opportunity to demonstrate that acquired knowledge and experience, and this opportunity is threatened by the idea that they must provide certain outputs specified by an externally imposed definition of 'public goods'.

2.4.3. Choosing a productivist interpretation of the public goods concept

On the other hand, just as the government are seen to use the public goods concept as a tool to justify intervention and control in the agricultural sector, farmers may also take advantage of

the concept to suit their own objectives. While there was some acknowledgement of the non-rivalrous and non-exclusive characteristics of public goods, aligning with the conventional economic definition, many respondents focused on the idea of public goods as farm outputs that were 'good for the public', and used this interpretation to justify the importance of their role as producers of high-quality food. Although some respondents saw being a provider of public goods as something they were being asked to become, or adapt to, others instead adapted the concept of provider of public goods to suit their current view of their identity. In this case, the idea of being a provider of public goods does not really change anything: because the concept can be used by different parties to suit their own perspective, it has essentially been used to reinforce the respondent's existing views. If farmers are simply interpreting the idea of providing public goods in a way that fits their existing self-perception, there is no reframing of cultural identities, or internalising changes to good farmer ideals, that are required to produce lasting change in agricultural practice (Howe & Ross, 2019; Mills et al., 2017; Wauters et al., 2017). For these individuals, engagement with ELM under this new policy regime could be expected to be limited or superficial at best.

The occurrence of an effectively productivist interpretation of 'provider of public goods' among interviewees, that prioritises the maximisation of food production, suggests there is a strong possibility that rather than promote a transition to a post-productivist mindset, aiming for a more multifunctional agricultural landscape, 'public money for public goods' will simply reinforce a productivist culture among farmers (G. A. Wilson, 2001). Such a productivist culture has already been shown to be well-established among farmers in south-east England (Walford, 2003). The features of a productivist identity have already been found to influence farm management approaches to public good delivery, with farmer focus on maximising efficiency of food production meaning that they express a preference for achieving public good delivery through a land 'sparing' rather than 'sharing' approaches (Cusworth & Dodsworth, 2021).

2.4.4. Farmer identities and relationships between public and private good delivery

This productivist culture can be seen clearly in the interviews, with respondents repeatedly emphasising that their identities were centred on the production of food for profit. At the same time, respondents also indicated that their identities could be complex, recognising that they could have multiple roles, and that they could assume and discard different identities depending on the context. Previous surveys have found that the same farmers can identify both as producers of high-quality food, or private goods, and as providers of public goods (Kvakkestad

et al., 2015). However, while the production of some public goods, such as certain cultural landscapes and environmental benefits, may be recognised as an important component of their role, the production of private goods remains the primary characteristic of the farming identity among most conventional farmers (Davies & Hodge, 2007; Kvakkestad et al., 2015; G. A. Wilson, 2001). This view was reiterated by the farmers interviewed here: although many were willing to accept that they were providers of public goods, they were keen to stress that this remained of secondary importance compared to provision of private goods. The recognition that providing public goods does form a secondary aspect of their identity could align with a more nuanced interpretation of post-productivism described by researchers: a reduction in the emphasis placed on production in relation to other aspects of performance (Mather et al., 2006).

However, it should also be noted that some farmers would see the idea that they are providers of private goods first, and providers of public goods second, as an overly simplistic or reductive way of looking at their identity. While respondents often discussed the provision of private and public goods as separate aspects of their identity, with one having to take precedence over the other, another theme in the interview responses was the interdependence between the provision of private and public goods, such that public good delivery was an integral part of being a productive and profitable farmer. These two different positions represent two extremes, and respondents varied in the extent to which they could see public good provision as being traded off against, or reconciled with, private good provision, which has parallels with the wider debate in research and policy circles over the extent to which maximising agricultural productivity and profitability is compatible with environmental protection or rural development goals (Gove, 2018; Whitfield & Marshall, 2017).

2.4.5. Public goods and public recognition

Although respondents differed in how they saw the relationship between their roles as providers of private and public goods, the view of public goods as farm outputs that are 'good for the public', was widespread, expressed by a diverse cross-section of farmers. This meant that farmer reactions to the idea of being a provider of public goods were closely connected to their perception of their relationship with the public, and their reputation among wider society. The willingness of respondents to be seen as providers of public goods, was often linked to a desire for this role to be properly appreciated and respected by the users of these public goods. Previous quantitative research has found that the public hold a generally positive view of farmer behaviour and their role in managing the rural environment (Howley et al., 2014), while the respondents interviewed here felt that there was a lack of respect for their roles as providers of

both private and public goods. It is possible, therefore, that there is a difference between how people actually view farmers, and how farmers think they are perceived by the general public.

Concerns over perceived recognition of their role are known to be important in shaping farmer cultural identities: research considering how the 'good farmer' ideal is developed and expressed has focused on the accumulation and presentation of 'symbolic capital' that contributes to reputation and social status among farmers (Burton, 2004; Burton et al., 2008). The interviews analysed here suggest that the image farmers see themselves presenting to the wider public could also influence their relationship with their identity. While there is a body of research exploring how a farmer's management of their land can generate signals of performance quality – symbolic capital – that help other farmers recognise them as a good farmer (Burton et al., 2008; Sutherland, 2013; Sutherland & Darnhofer, 2012), it is also possible that some farm outputs could be viewed as signals of quality that contribute to public recognition. In the interviews, the ability to sell good quality food direct to the consumer, and the provision of public access, enabling people to experience and enjoy the farm landscape and wildlife, were identified as means to demonstrate respondents' roles as good farmers to the wider public. This raises the possibility that a wider view of symbolic capital may be needed, considering not just that required for social status among other farmers, but also the general public.

However, a key reason for the importance of status as a 'good farmer' in influencing management decisions is that farmers in an area tend to know each other by reputation, so they can make the connection between different signals of performance quality on a farm and a known individual (Lundqvist, 2001). While the interviews provide some examples of direct public recognition of the work of an individual farm or farmer, these were highlighted as special cases, and the general feeling among respondents that their work goes unrecognised implies that the general public tend not to know individual farmers by reputation. It is possible, therefore, that giving the public more opportunities to recognise the performance of individual farmers in providing public goods could increase farmer willingness to embrace the idea of being a provider of public goods. A desire for greater public appreciation and understanding of what farmers do was expressed across interviewees representing a variety of approaches to farming. Therefore, if farmers can see a way for management for public good provision to directly contribute to their personal reputation with the public, this could be a key step towards internalising the 'provider of public goods' identity. However, this may be complicated by differences in attitudes: while previous survey work has found that farmers and the wider public exhibit similar levels of concern for the environment, key differences occur when considering

specific environmental issues, where public views may conflict with the productivist attitudes of farmers (Howley et al., 2014).

2.4.6. Conclusion

There is widespread recognition among both researchers and policy makers that interventions are needed to correct the market failures that have led to public goods produced by farming being unaccounted for within market economies (Angus et al., 2009; Brunstad et al., 1995; Cooper et al., 2009; DEFRA, 2018a; Gove, 2018). The reform of agricultural policy in England centred on 'public money for public goods' is designed to address this need and so bring the supply of public goods in line with society's requirements (DEFRA, 2018a; Gove, 2018). The idea of public goods, as originally defined in economic theory, remains useful in helping to understand where interventions are required to enhance the sustainability of agricultural landscapes (Cooper et al., 2009), but the research conducted here suggests its application as the foundation of post-Brexit agri-environment policy could be ineffective or counterproductive if the aim is to reform farming practices in England.

Although respondents identified certain farm outputs as public goods that were true public goods in the economic sense, and that matched the outputs to be targeted by ELM, their interpretation of public goods also encompassed outputs that would not be public goods under the conventional economic definition, and their justification for classifying certain outputs as public goods reflects alternative interpretations of the concept. Given that farmers can interpret the public goods concept in a way that fits with existing productivist identities and may also associate the 'provider of public goods' label with undervaluing their role, asking farmers to be providers of public goods may not encourage farmers to reframe their identities around public good provision in the way that was originally intended. Farmers may enter new ELM schemes for public good provision to remain financially viable, but chances for long-lasting and more radical behavioural change may be more likely if farmers agree with what they are being asked to do or understand why these actions are desirable (de Snoo et al., 2012).

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2.6. Appendices

2.6.1. Appendix 2.1: Interview Schedule

(A) Introduction / Identity

1. How would you describe your approach to farming? What have been the biggest changes in how you approach farming since you started? Why did you make these changes?

2. Would you describe yourself as a farmer? Why [not]? [OR What do you see yourself as? What does that mean?]

(B) Recognising public goods / farmers as 'providers of public goods'

3. What does your land provide besides food? Which of these are most important to deliver, and why?

4. How would you feel if I were to describe you as a 'provider of public goods'? To what extent do you agree with this description and why? What about other farmers?

(C) Financial support for public good provision / prioritisation of public goods

5. What public goods should farmers be supported [or not] to provide and why?

6. What does a system of payments for public good provision need to be effective / acceptable?

(D) Assessing public good provision

7. What do you think of the standard of environmental land management locally? What public goods are farmers doing well / poorly at providing? How can you tell?

(E) Drivers of change in public good / ecosystem service provision

8. [How] has the standard of environmental land management locally changed over the course of your career? How do you think it might change in the future? Why?

(F) Cooperation

9. What roles do other land managers play in how you manage your land? [How] has this changed and why?

10. How important is working with other land managers for public good delivery / environmental benefits?

11. Under what circumstances would you cooperate with other farmers? What makes a good partner for cooperation?

12. What is your relationship with neighbouring landowners like?

(G) Future / Brexit / coronavirus

13. What would be your ideal scenario for your farm in 10 years' time? What would need to happen to achieve this scenario? What are the barriers to achieving this scenario?

14. What impact could Brexit have on your role as a farmer? What is changing for you as a result of Brexit?

15. How has the pandemic affected how you farm / see yourself as a farmer / work with others?

2.6.2. Appendix 2.2: Participant Information Sheet

PARTICIPANT INFORMATION SHEET

Researcher: Peter Matthews
Email: pgm20@kent.ac.uk
Mobile: 07944 415 898
School of Anthropology and Conservation
Marlowe Building, University of Kent
Canterbury, Kent, CT2 7NR

I am a PhD student from the University of Kent, and I would like to invite you to contribute to my research project. If you decide to take part, it is important that you do so with a good understanding of the reason for the research and what it will involve. I have provided the information below to help you make an informed decision.

Research project title

Sustainability performance of alternative approaches to farming at a regional scale

Why am I being invited to participate?

My project will explore possible futures for farming in the High Weald / North Kent and investigate the landscape-scale effects of the spread of alternative farming approaches on society and the environment. I will have access to a body of environmental and economic data to support my research. However, it is crucial that my research is also guided by the perspectives of farmers themselves.

To help me achieve this, I will be interviewing farmers (and other people who make decisions affecting the management of agricultural land) representing a variety of farm sizes, types and systems in my study areas.

What will happen if I take part?

If you agree to take part, we will arrange an interview at a time convenient to you. The interview will be loosely structured around the following topics:

- Farmers' views of their roles and identities as farmers, and how these views affect land management decisions
- Cooperation and working relationships with other farmers and land managers
- The perceived role of farmers in providing benefits to society (i.e. 'public goods')
- How farmer identities, and relationships, may change in response to current and future developments in the UK agricultural sector

The interview is expected to last around forty-five minutes.

If you give your informed consent, I will make an audio recording of the interview. This recording will be used to help me with the write up and analysis of the interviews.

After the interview, if you are interested, you might be approached for a follow-up interview, or invited to join a workshop. This could take place up to 2 years after the initial interview.

PARTICIPANT INFORMATION SHEET

Do I have to take part?

Your participation in this project is entirely voluntary. You can withdraw at any time, without giving a reason. If you do exit the project, all data collected on yourself will be deleted at once.

Are there any benefits or costs to participating in the research?

There are no immediate benefits from taking part in the research. However, it is hoped that the research will provide an alternative means for farmers' voices to be heard and make a productive contribution to academic and policy discussions about the value and purpose of farming in England.

Other than the time commitment for interviews, there are no costs or disadvantages expected from participating.

What if I want to know more?

You can ask questions during the interview, but if you want to know more about the research, or your rights as a research subject, please get in touch using the contact details at the top of this document. Let me know if you want to be kept updated about the research, and I will give you a copy of the findings when they are ready.

What will happen to my responses?

The results of this research will be written up as part of a PhD thesis, to be submitted in September 2022, and may be used in published journal papers. Your interview responses will be anonymised before any analysis. With your consent, I may include anonymous quotes from your responses in publications. It will not be possible to identify you from these quotes.

Data collected during the research will be kept strictly confidential, secured under password-protected electronic storage. Processing and handling of personal data will be managed in accordance with the requirements of the General Data Protection Regulation.

Who has approved this research?

This project has gone through the School of Anthropology and Conservation's Ethics Review process and been formally approved by the University of Kent's Ethics Committee.

What if am unhappy with the research experience?

If you wish to make a complaint about the project, please contact Dr Joseph Tzanopoulos (j.tzanopoulos@kent.ac.uk; 01227 823 146) in the first instance.

If you are not satisfied with the way in which your complaint has been handled, please contact Dr Simon Kerridge (DirectorofResearchServices@kent.ac.uk; 01227 823 229).

Thank you for taking the time to read this document and to consider my project. Please feel free to keep this information sheet for your own reference.

Identities and cooperative farm management

The farmer interviews conducted here illustrate some of the variation that exists among farmers in terms of their engagement with the public goods concept. This variation among farmers could in turn influence the distribution of public good provision across the agricultural landscape. So far, this research has considered the provision of public goods from the perspective of individual farmers thinking about the management on their own land. While resistance among farmers to prescriptions that conflict with established good farmer ideals has been suggested as a contributor to poor engagement with AES, the mixed performance of AES when they are adopted has also been linked to their tendency to focus on actions at the farm level rather than landscape level (Jarrett et al., 2015). Therefore, as well as increasing the emphasis on public good provision, ELM is also being designed with greater focus on cooperative management and landscape-scale impacts (DEFRA, 2020).

This means encouraging farmers to not only provide public goods but do so in concert with others to achieve sustainability goals beyond the farm level. The cooperative management for public good provision provides further opportunities to address some of the issues around farmer identity and self-perception discussed in the previous chapter. Relationships among farmers for cooperative management are recognised as a means by which shifts in identities and ideals can develop and spread. There is evidence to suggest that farmers may be able to better modify their self-identity with the support of their peers (McGuire et al., 2013), and participatory projects that encourage the cooperation for landscape-scale outcomes have also been associated with an increased likelihood of shifts in farmer identities without disrupting established dynamics of farming communities (Kizos & Kristensen, 2011; Mills et al., 2017). Therefore, a complete understanding of farmer identities in relation to public good provision should also consider how they can shape attitudes towards cooperative or collective management, and what this could mean for public good delivery at scale.

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Chapter 3: Farmer relationships with cooperation for public good delivery beyond the farm level

3.1. Introduction

Reforms to the EU's Common Agricultural Policy (CAP) in the late twentieth century brought about a growth in agri-environment schemes (AES), which were viewed as an opportunity to counter the damaging environmental effects of decades of agricultural intensification, fuelled by subsidies focused on maximising production (Ackrill et al., 2008; Hodge et al., 2015). However, to date, assessments of AES performance in delivering on biodiversity and ecosystem services goals have produced mixed results (Kleijn & Sutherland, 2003; Sutherland et al., 2012; van Dijk et al., 2016). In considering which elements of AES design could be contributing to this mixed performance, research and policy attention has focused increasingly on the tendency of AES to focus on actions at the scale of individual farms, and neglect landscape or regional-level processes (Jarrett et al., 2015).

This policy focus on farm-level management has been reflected in the academic literature, where research into agricultural change and environmental impacts traditionally focused on the individual farm (Lucas et al., 2019). However, there is growing awareness that farm-level AES may fall short of achieving their desired goals because ecological processes that they target often transcend farm ownership boundaries (Lawton et al., 2010; Mckenzie et al., 2013), such that meaningful enhancements to public good delivery are likely to need joined-up management approaches spanning multiple farms, and this will depend on the ability of farmers to work together (Westerink et al., 2017). Researchers have therefore argued for agricultural environmental management at a landscape scale through the efforts of groups of farmers (Sutherland et al., 2012). Landscape scale management arising from cooperation or collective action is recognised as a central requirement for enhancing ecological networks, and the delivery of associated ecosystem services and public goods (Lawton et al. 2010; Dallimer et al. 2012; Sutherland et al. 2012; Jarrett et al. 2015). Local inter-farm cooperation can also support farmers to develop alternative, ecological farming approaches, through resource sharing, building synergies between specialised farms, and the shared management of landscape scale features such as wildlife corridors (Lucas et al., 2019).

Within England, the policy context for a move towards landscape scale management, driven by farmers working together, is arguably already present (Riley et al., 2018). Prior to Brexit, agri-environment policy had taken a step in this direction with the implementation of the

Countryside Stewardship programme, which went further than previous AES in offering incentives targeted towards encouraging cooperation, by providing support to facilitators who help manage groups of farmers to deliver benefits greater than could be achieved if the farms were working in isolation (Franks, 2019). This objective is being expanded upon under the new ELM schemes, where the 'Local Nature Recovery' and 'Landscape Recovery' programmes are expected to make additional funds available for farmers wishing to engage in collaborative environmental action to deliver transformational environmental outcomes at the landscape scale (DEFRA, 2020b; Gove, 2018).

These measures to promote farmer cooperation may be more important than ever after Brexit. The transfer of financial assistance from direct payments towards support based primarily on public good provision may encourage more farmers to participate in AES, but if agricultural policy falls wholly under the control of the UK government, funding may come into increased competition with other departments, with the possibility of a reduction in the overall amount budgeted for environmental conservation (Helm, 2017). With added pressure for limited funding for public good provision to be spent efficiently, and deliver value for money, carefully targeted and designed collaborative and coordinated landscape scale activities, that may outperform individual farm-scale initiatives, may therefore be especially valuable (Franks, 2019). Understanding the opportunities and barriers for more efficient landscape-scale agri-environmental management should therefore be a research priority.

Although AES options designed to incentivise collective action, and deliver environmental benefits at a landscape scale, have already been a feature of agri-environment policy in England, so far, uptake of these options has been limited (Riley et al., 2018). Addressing this depends on understanding of how, why, and when farmers work together to achieve common aims in this area. However, researchers still have only a poor grasp of the factors underlying the willingness and ability of farmers to cooperate with regards to environmental management, in part due to the tendency of previous studies to focus on cooperation to produce private goods and assume that the findings can be generalised to cooperation for public good provision (Jarrett et al., 2015). Recent research suggests that cooperation for these different objectives are distinct phenomena, so there remains a need for more focused investigations into farmer cooperation for landscape scale environmental objectives, including public good delivery (Riley et al., 2018).

Moreover, research that has investigated cooperation for environmental management has concentrated on prescribed options under AES (Franks, 2019; Runhaar & Polman, 2018). Little consideration has been given to cooperation from an explicitly public goods perspective, outside

the scheme prescriptions. The nature of cooperative relationships between farmers varies widely and may be specific to certain practices: a close relationship between farmers for one activity may not be reflected in other areas of practice (Riley et al., 2018). Therefore, research exploring how farmer relationships with cooperation to provide public goods differs from cooperation for private good provision, could deliver novel and useful insights.

The literature on farmer cooperation in general was initially dominated by economic perspectives, and institutional advocates for cooperation have typically framed cooperation in terms of economic concerns. However, social science researchers have argued that emphasising economic gains will promote more individualistic reasons for cooperation and make farmers less willing to work in groups long-term, for truly collective reasons (Kasabov, 2016; Wynne-Jones, 2017). With growing recognition of the limitations of purely economic approaches to understanding farmer cooperation, researchers studying rural change have called for more in-depth understandings of cooperation, drawing on insights from rural social science and human geography, with greater use of qualitative methods, especially given the dominance of structured surveys or questionnaires in previous studies on this topic (Kasabov, 2016; Wynne-Jones, 2017). Moreover, while early research into farmer cooperation focused on the economic gains possible through formal initiatives such as cooperative marketing or purchasing, cooperation research is now extending its reach to consider more informal forms of cooperation and go beyond purely economic considerations (Emery et al., 2017). The literature now encompasses studies looking at cooperation as a movement, and work considering how cooperation reconciles or conflicts with farmer self-identities and the values farmers place on autonomy (Emery et al., 2017). Issues of identity that provide the broad context to farmer decisions and shape a farmer's worldview, and how these worldviews influence the tendency to collaborate, are all seen as key areas of investigation for research into cooperation in agriculture (Jarrett et al., 2015). This reflects broader trends in the literature on farmer behaviour, which has expanded beyond traditional perspectives on decision-making centred around goals, attitudes, and values, to approaches that place more emphasis on social capital, cultural identity, and individual variation (Burton, 2004; Burton et al., 2008; Sutherland & Darnhofer, 2012).

Therefore, although ELM is being designed with joined-up management for public good delivery in mind, as part of a new direction for agri-environment policy in England, there is a need to better understand how farmers relate to the idea of cooperation for public good delivery as part of their role. Investigations in this area could help identify challenges and opportunities associated with implementing ELM schemes with their increased emphasis on landscape-scale

actions. This research draws on a qualitative approach to explore the potential for farmer cooperation for public goods delivery, particularly in terms of farmer self-perceptions and social relationships. Semi-structured interviews are used to investigate farmer understanding of and reactions to joint working for public good delivery, especially in comparison to both cooperation for private good delivery and individual management for public good provision. Building a richer understanding of farmer relationships with cooperation for public good provision could not only inform how best to design and implement AES to meet regional sustainability objectives, but also help predict the likely distribution of public good delivery at a landscape scale, based on the spatial patterns of cooperation that arise from the occurrence of engaged farmers.

3.2. Methods

The research presented here is based on interviews conducted with 18 different participants in south-east England. Interviewees were involved in the management of farms in either north-east Kent (14 participants) or the High Weald (4 participants). Together, these two study areas encompassed a variety of landscapes and farming systems that were largely representative of the those found elsewhere in lowland England. These two areas have distinct topographies, geologies, and histories, which help drive differences in the local agricultural context described below. In north-east Kent, the chalk hills of the North Downs, with their poorer, flinty soils, give way to the more fertile soils of the North Kent plain (Natural England, 2013b, 2015). The High Weald is an area of sandstone hills, with a more complex topography and generally less productive land and is covered by a mosaic of small farms and woodland (High Weald Joint Advisory Committee, 2019; Tubbs, 1997). The High Weald is also notable for the persistence of a historic landscape that has seen relatively little change since the medieval period, whereas the landscape of north-east Kent has seen much more pronounced change, with extensive urbanisation and industrialisation, and the loss of traditional low-input horticultural and pastoral farmland at the expense of more intensive arable farmland (Cobb, 2010; Natural England, 2015).

The first 4 interviews were conducted within a two-week period during March 2020, to pilot the interview design. Following these pilot interviews, a revised interview schedule was implemented for the rest of the interviews, which were conducted between November 2020 and February 2021. The High Weald interviews were conducted after the north-east Kent interviews. This number of High Weald respondents was smaller than the number of north-east Kent respondents because the overall sample was already approaching saturation at this point

(as described below), with the High Weald interviewees tending to provide responses that were already familiar from speaking to farmers in north-east Kent.

The sample used for the interviews was obtained using a combination of chain referral and purposive sampling. Initial contacts were reached through approaching local farming businesses in the study areas. In a chain referral process, when the first individuals were interviewed, they were asked to provide suggestions for other farmers to approach. Out of the lists of farmers provided, participants were deliberately selected to maximise the diversity in farm type and farmer characteristics within the sample.

The purposive sampling strategy was adopted to maximise the potential variation in farmer approaches and experiences across participants, to provide a set of responses that would best address the research question (Marshall, 1996). Purposive sampling is useful for maximising efficiency in qualitative research, by ensuring that the research question can be addressed with the minimum possible sample size (Newing et al., 2011).

As with other non-probabilistic sampling methods, the findings will not necessarily be representative of the wider farming community, but a carefully chosen sample should illustrate the potential variety of viewpoints held by farmers in the study areas. There is a risk that purposive sampling could overlook key groups of respondents, due to lack of researcher knowledge or awareness, so the chain referral process was important for allowing access to new types of participants missing from the initial sample, especially given that interviewees were explicitly asked to suggest further participants who they might expect to hold contrasting views.

Sampling continued until saturation was reached, when each new interview no longer contributed any substantially different perspectives on the topics of interest. Interviews were analysed continuously, throughout the data collection phase (as described below), enabling me to monitor the occurrence of new themes in responses. The saturation point was therefore judged to be reached when the analysis of further interviews was no longer generating any major new thematic codes, even when targeting different types of respondent (Lewis-Beck et al., 2004).

The sampled farmers represented a large range in farm sizes, from around 10 to 2,000 hectares. Participants from north-east Kent represented a variety of different production systems, including arable, horticultural, and livestock farming, reflecting the diverse, mixed character of agriculture in the area (Natural England, 2013b, 2015). Participants from the High Weald tended to operate beef and dairy farms, reflecting the predominantly pastoral character of this region,

which has traditionally been associated with extensive livestock systems on poor soils (High Weald Joint Advisory Committee, 2019; Tubbs, 1997). Interviewees also represented a range of different approaches to farming: although some managed conventional agricultural systems, there were also individuals who described themselves as operating conservation, regenerative, organic, or agroecological farming systems. Within the sample, there were farmers who were currently part of AES (12), farmers who had been involved in AES in the past (2), and those that had never been part of such schemes (4). The demographics of the sample were also varied. Although many interviewees came from well-established farming families going back several generations, there were also more recent entrants to the agricultural sector, including some first-generation farmers. There was a nearly forty-year age gap between the youngest and oldest respondent, and the sample consisted of 13 men and 5 women. The selected interviewees therefore represented a broad spectrum of backgrounds and approaches to farming in north-east Kent and the High Weald.

For the purposes of this study, the interviewees were treated as a single pool of respondents – thematic analysis was used to describe and understand the variation in attitudes among respondents, but this variation was not explicitly linked to differences in respondent characteristics (such as farm size, type, AES involvement). Therefore, this research does not attempt to explain any possible relationships between farmer characteristics and responses, but merely illustrate the variation in farmer perspectives and understand the reasoning behind these different perspectives.

Prior to participant recruitment, an ethics review was completed for the research project, which was submitted to and approved by the University of Kent's Ethics Committee. A copy of the participant information sheet (that was provided to all interviewees in advance of the interview) is included in Appendix 2.2. Each participant was first briefed on the nature of the research, including their anonymity, and the use of their responses, before agreeing to an interview. A semi-structured interview approach was used, with interviews lasting between 40 and 90 minutes, taking the form of in-depth conversations (either face-to-face or virtually, via video call), that were loosely organised around an interview schedule covering a set of topics of interest, focused on perceptions of cooperative working for public good provision from agriculture.

The interviews coincided with the initial year of the Covid pandemic, which meant that not all interviews could be conducted in person: hence the combination of in-person (8) and video-call based (10) interviews used. It is possible that conducting interviews via video-call could have

hindered communication slightly and made for less effective interviews. Moreover, researchers in geography are increasingly recognising the importance of the place and context of the research encounter, especially when working with farmers, who may hold highly distinctive relationships with the land they manage (Thomas et al. 2019a). Experiences from agricultural research indicates that there are practical and theoretical advantages to conducting research interviews on the farm itself, gaining new insights by accessing spaces and practices that would otherwise be overlooked, and creating opportunities for new and unforeseen narratives and trajectories to develop while exploring the farm (Riley 2010). Being able to interview farmers in situ was often useful for talking about the farm: on several occasions it was possible for the farmers to explain a point by physically showing it on their farm, so it was beneficial to conduct at least some of the interviews in-person, to complement the responses from virtual interviews. However, given that there was substantial overlap between the responses and themes picked up across interviews, regardless of method used, not being able to visit every farm due to pandemic constraints seems to have had a minor effect on the results.

Participants were asked about their relationship with other land managers, their reaction to the idea of working with other land managers to provide public (and private) goods, and the factors influencing the feasibility of, and their attitudes towards, cooperating to achieve these aims. Understanding of the public goods concept differed among respondents and did not always align with the interpretation used by the government or that based on economic theory. For the purposes of this study, analysis focused on responses which discussed farm outputs that are expected to be targeted by ELM. Therefore, although some interviewees argued that food should be classed as a public good, cooperation for the explicit purpose of increasing profitability from food production was classified as cooperation for private good production during analysis.

The semi-structured design meant that the interview could pursue specific lines of enquiry while also having the flexibility to be adjusted according to the circumstances. The respondent had the freedom to explore each topic in a way that reflected their own perspective, without being constrained by a predetermined framework or structure, and the direction of the interview could be sensitive to other issues identified by the respondent (Fish et al., 2003; Newing et al., 2011).

All participants gave informed consent for their interviews to be recorded, and these recordings were transcribed verbatim. Each transcript was then read through multiple times and coded manually to identify overarching patterns or themes in the data. For the pilot interviews, this

thematic analysis was based on a data-driven, inductive approach, which meant that coding was not guided by a predetermined coding framework, nor, as far as possible, researcher preconceptions about the subjects covered (Braun & Clarke, 2006). The codes developed through the pilot interviews provided a basic coding framework that then was applied and refined during the analysis of the remaining interviews. For the purposes of reporting key quotes that capture the essence of particular themes, each respondent has been assigned a number between 1 and 18 (i.e., R1, R2, R3 etc.).

3.3. Results

3.3.1. Farmer understanding of the value of cooperation for public good delivery at landscape-scale

Given that the smallest and largest areas of land managed by respondents varied by around two orders of magnitude, respondents' relationships with landscape-scale management for public good provision varied accordingly. For those managing the smallest areas of land, landscape-scale management necessarily meant looking beyond their farm boundaries. Several respondents, however, especially those responsible for larger farms, described the application of principles associated with landscape-scale management within the context of their own farm. For example, they referred to the importance of connecting up key semi-natural habitats across different parts of the farm, the importance of managing the farm 'infrastructure' such as watercourses and hedgerows, promoting spatial heterogeneity across the farm, and zoning management according to the distribution of key public goods across the farm. This 'joined-up' approach to managing the farm environment was identified by many as a core element of good farming practice.

For some farmers, this management within their own farm was sufficient when considering public good provision at a landscape scale. There was little need to think about what was happening outside the boundaries of their farm, either because their own farm was big enough to accommodate a landscape-scale approach, or because the location of their farm meant that there were no or few neighbouring farms around them, with their farm instead being bordered by urban areas, woodland, or the sea.

Others acknowledged that management of their individual farm could only achieve so much when it came to delivering public goods across the landscape, and the responses below were typical of those justifying the need for farmers to work together to this end:

"*… we've got a quite a large marsh area going through, errm, and we can definitely, we can do better as a group of farmers through the area, to improve, err, environmental impacts* […] *if you look at this, East Kent there on the map,* […] *there's that great bank of the, err, marshes… Now, if they're not all working together, all the way through, what's the point? If we, we've got a hundred and twenty hectares down there, and we can do what we want. But if it's not being, the wildlife, the birds migrating and err…*" (R10)

"*I can do stuff on my farm which will encourage them* [dung beetles]*, but if no-one else around me is doing it, then, we're, it's a drop in the ocean.* […] *obviously, insects and animals and birds and things, don't just stay on one farm, they, they migrate and travel around, so, they find food everywhere.*" (R15)

In these examples, the necessity of working together was attributed to the way in which the distribution of public good provision spans multiple farms. In the first case, the area of marsh, recognised as a high value area of semi-natural habitat, is described as 'going through' an area managed by different farmers. Both respondents also refer to how wildlife moves across the landscape, and the second farmer quoted explicitly acknowledges that this movement means that wildlife ignores farm boundaries. Throughout the interviews, there were a variety of other descriptions of how features such as semi-natural habitat, species populations, public access networks, and flows of water or nutrients, moved across farm boundaries in their area. Above, these respondents show that they recognise the implications of the cross-boundary nature of such public goods: management of the marshland habitat, or wildlife, on a single farm in isolation, has little value if their neighbours are not also managing for these public goods, and aligning their management with each other, by "*all working together, all the way through*".

Following this line of reasoning, several respondents made arguments for farmers working together to enhance public good provision across multiple farms in the landscape, explaining the benefits of this approach over each farm working independently. The underlying principles and actions suggested to achieve this goal were little different to those that farmers reported applying for landscape-scale management within their own farms. The same practices relating to connectivity, spatial heterogeneity, prioritisation, and zonation were discussed, the only difference being that now these had to be achieved by multiple farmers working together for a common goal.

Not only did participants show understanding of the value of and need for cooperation to achieve landscape-scale public good delivery in general, but some could also specifically identify the role their own farm could play in such landscape-scale approaches. This was particularly the

case when discussing connectivity in a landscape. The connectivity of ecological networks was repeatedly referred to as a core characteristic of landscape-scale public good delivery, with respondents explaining how the use of corridors and connections could be used to ensure the uninterrupted flow of public goods across the agricultural landscape. These connections could be specific features within a farm, such as areas of semi-natural habitat, but some farmers also described the farm itself as a link in an ecological network and their responses presented two complementary ways of thinking about the role of their farm in such a network. One perspective was to view their farm as forming a connection between different high value areas for public good provision. Alternatively, respondents identified their farm as forming a connection through an area of otherwise poor value for public good provision, with one respondent describing their farm as "*the bit that connects up in between all of these slightly more intensely managed areas*" (R7). Together, these demonstrate that respondents are aware of how a landscape-scale perspective on public good delivery relates to their farm, potentially informing their approach to management for these public goods.

3.3.2. Attitudes to cooperation: complex, time-consuming, and low priority

However, the interviews also indicated that farmer recognition and understanding of the value of cooperating for public good delivery does not always translate into action. A recurring theme in the interviews was that cooperating with others for this purpose was a low priority. Several interviewees expressed an attitude that can be summarised in the response below:

"*So, I'm trying to link bits of my land with bits of cover and things like that, that's my strategy. Whether my neighbours do it, that's out of my control* […] *I've got enough on worrying about my farm, making sure I'm doing the right thing* […] *Errm, so, yeah, I think, it's all very well cooperating in that sense, but I don't have enough time in my day to be going to meetings all day and discussing what would you do here and how would you link it in with this and that. It becomes very complicated.*" (R6)

As in the above extract, respondents typically stated that their own farm dominates their attention. Their farms were described as placing a huge number of competing demands on their time, requiring all of their time and energy to manage. Although the respondent quoted above clearly valued landscape-scale approaches, seeking to increase connectivity on their own farm, working with others to enhance public good delivery was at or near the bottom of their list of priorities, and not worth spending any of their time on. This is particularly the case because this interviewee, in common with several others, saw cooperation for public good provision as something with the potential to be especially onerous and time-consuming. In the passage

above, working with others to ensure connectivity between farms is described as requiring careful thought and planning: participating farmers would need to implement management in exactly the right places relative to each other to ensure that they could "*link it in with this and that*". Management for public good provision on their own farm requires enough thought and planning already, and trying to align this management with the neighbours is seen as something with the potential to become "*very complicated*" to organise. This complexity is equated with increased time spent discussing management with other partners: while the idea that they will be "*going to meetings all day*" appears to be hyperbole, it does indicate that cooperating with others for this purpose is expected to consume an excessive amount of the respondent's available time, that would be better spent on other tasks that are more directly relevant to their own farm's performance.

While cooperation for landscape-scale public good delivery was seen as a burden and low priority, several respondents identified cooperation for private good provision, involving working with other farmers to increase the profitability and viability of their operations, as a worthwhile use of their time. Several farmers justified cooperation to this end as sensible, cost-effective course of action that could benefit both partners, for example, by sharing machinery to save costs, or swapping land to enhance productivity.

Equally, management for public good provision on a farmer's own farm, was also seen as more straightforward, and a better use of their time, compared to working with others to enhance public good provision at a wider scale. Although the prioritisation of management for public good provision could be partly attributed to the role of financial incentives, respondents also justified management actions because many of the public goods provided by their farm were also seen to be underpinning private good production. Farmers could recognise that outputs conventionally classed as public goods also had a private value, and so draw connections between enhancing the delivery of public goods on their land and the profitability or long-term viability of their business.

Moreover, management to deliver public goods on the respondent's own land was described as generating clear, observable outcomes, so that they can readily identify the benefits of such actions. What they see on their farm is the result of their own actions to manage for that public good, and therefore also demonstrates the quality of their individual performance. Where farmers cooperate for public good delivery, identifying specific benefits may not be so straightforward:

"*But what we're trying to do is provide a bit of a helping hand, provide a contiguous link* […] *ways of, you know, wildlife* […] *flowing through the farm.* [..] *But we'd hope that we can create a system which means that we can then go out to others, and we can work more collaboratively. Errm, we don't know what benefit that might bring, but we feel that that's the direction of travel…*" (R11)

The respondent quoted above was able to articulate why they thought working together would help enhance public good delivery in a general sense, facilitating the movement of wildlife across the agricultural landscape. However, despite this, they also admitted that they did not know what the exact benefit would be for them in terms of farm performance. Their motivation for collaboration in this case was simply that they saw this as the "*direction of travel*" for agri-environment policy and wanted to be well positioned to take advantage of any opportunities for support in the future. Beyond this, they were unable to define specific ways in which collaborative working would impact on their farm performance. Given that this same respondent was able to explain in detail how management for public good provision within their own farm would contribute to a sustainable, viable operation, this could suggest that, although farmers understand why collaboration may enhance public good delivery at the landscape scale, if and how this translates into an effect that they can actually observe themselves is less clear.

The importance of being able to see and understand the impact of one's actions was acknowledged as a requirement for effective collaboration for public good delivery, as illustrated by the respondent quoted below:

"*… it's got to be something that means something to everyone within it, for sure.* […] *Errm, so, a bit like anything, you need to have clear communication and clear messaging as to what you're trying to achieve, how you're going to achieve it. You know, regular updates and, and, and metrics to show that things are happening and changing.*" (R15)

This farmer identified continuous measurement and performance evaluation and clearly communicating these measurements back to participating farmers, as underpinning meaningful cooperation. The aim, as described here, is to "*show that things are happening and changing*": this ensures that participants can actually see how their collaboration is making a difference. This in turn means that participants are more likely to be invested in this cooperative management: it "*means something*" to those involved. The respondent describes the need to communicate results as "*a bit like anything*", indicating that this is a fairly universal principle, and indeed, this was not an unusual idea in the interviews. Measurement, or operationalisation, of public good delivery was highlighted by most respondents as a key issue for management on

their own farm, and something that they were giving more and more serious thought to. This was in part because measurement was recognised as a requirement for payment for public good provision under future subsidy schemes, but also because quantifying public good delivery provided them with a way to demonstrate the quality of their own performance and to show others that they know what they are doing.

On a related note, several respondents also referred to measurement of public good delivery in reference to coupling payment levels to the results of management actions rather than the actions themselves. These respondents tended to express scepticism or wariness of such results-based payments being awarded for the efforts of individual farmers, however, due to concerns over possible unfairness – expressing fears that farmers already delivering high levels of public goods would lose out in comparison to others that were starting from a much poorer baseline. This contrasts with the stronger support voiced for results-based schemes for cooperative rather than individual management actions, where farmers starting from different baselines are no longer competing, but cooperating.

Therefore, finding appropriate methods for measuring public good delivery at the landscape scale, across multiple farms, and making connections between farm and landscape-scale performance, could influence farmer willingness cooperate for public good delivery. Although there are farmers who recognise the value of cooperating for public good provision, the perceived complex and time-consuming nature of cooperation for this purpose, along with issues around assessing cooperation performance, mean many currently do not view this as a worthwhile use of their time. This attitude can be seen in the farmer quoted below:

"*And if the neighbour happens to have an environmental thing going on the other side of the hedge, well, you know, happy days. Errm, but, you know, if, if it's at the other end of the field, and ours is at this end of the field, well, you know, that's tough, but there we are.*" (R14)

Here, aligning management with others to enhance public good delivery is a seen as a bonus: good to have, due to the resulting environmental benefit, but if it does not happen, it is not their concern. They may recognise that management on their farm and those surrounding them falls short of that ideally required for effective public good delivery at scale, but unless it makes business sense to do so, and they can identify that the benefits outweigh the costs associated with the complexities of such initiatives, they are unlikely to engage in cooperative management for public good delivery.

3.3.3. Attitudes to cooperation: to be approached with caution

However, even if farmers understand the value of cooperating for public good delivery, and have the means, time, or resources to do so, they may hesitate for other reasons. Respondents varied in the degree to which they were involved in cooperative projects with other farmers, and for what purpose. Some were actively reaching out to others to make new connections as part of landscape-scale environmental management initiatives or farmer cluster groups, and some reported getting involved in such projects after being approached by their peers. Others reported being involved in cooperation for public good delivery only on an occasional or ad hoc basis, for example, in the sharing of key equipment for alternative farming practices or sharing farm outputs or inputs. Others still were fiercely independent, with minimal cooperation or sharing of resources with their peers.

These differences in enthusiasm for cooperation were often attributed to differences in personal attitudes rather than availability or ability. There was some indication from respondents that the act of reaching out to other farmers and initiating cooperative management for public good delivery required a degree of courage and boldness. Many farmers acknowledged that while cooperating is often a desirable and sensible course of action, working alone could also be seen as an appealing option:

"*… we really wanted to kind of open it up, and have more people involved […] So, not in a kind of, little bubble of, which is sometimes attractive, isn't it, in life? You know, I think, just stay where we are and do what we do and what we agree with.*" (R9)

The respondent quoted above shows aspirations to work closely with others, widening their network, with the aim of getting "*more people involved*". Nevertheless, their admission that being alone is "*sometimes attractive*" shows that they still understand the appeal that working in isolation can have. The idea of isolation as appealing or comfortable was highlighted by several other interviewees, especially those with smaller farms, particularly with reference to the ease with which they embraced lone working during the COVID-19 pandemic. In the above passage, isolation is described as working in a 'bubble', meaning that they can continue to manage their farm in the way they have always done and focus on doing "*what we agree with*". This implies that reaching out to others and cooperating could involve being challenged by new ideas or approaches that they may not agree with. This complements another theme identified in the interviews, where collaboration was seen as being risky, because farmers had to reach out to those who may have a different outlook on farming, disagreeing with the way they do things. In line with this idea, one farmer described the idea of initiating cooperation for public

good provision as "*you've got to stick your head above the parapet and start these things*" (R18): the use of the metaphor implying an element of danger to the exercise, in that they expect to be opening themselves up to attack from others. Even those respondents who expressed willingness to build their own cooperative networks for public good provision indicated that they were approaching this tentatively. One such farmer described how they "*would hope, quietly and privately […] that we can create a system which means […] we can work more collaboratively*" (R11), as they started to approach their neighbours. At this early stage, the fact that they expressed their hope "*quietly and privately*" suggests some caution over announcing their intentions for collaborative working publicly, and they, like others thinking about similar initiatives, were taking a slow and careful approach to starting this project.

3.3.4. Connecting with farmers who possess conflicting attitudes

These concerns are particularly relevant where cooperation for landscape-scale public good delivery requires farmers to reach out to neighbours with contrasting perspectives on good farming practice. When discussing cooperation generally, or for private good provision, respondents often identified the importance of similar or compatible mindsets among partners as a requirement for success. Cooperative relationships between farmers with contrasting approaches or mindsets may be harder to maintain and more limited or superficial. However, interviewees had different reactions to the challenge of engaging with others who disagree with how they do things, as can be seen by comparing the responses of two farmers applying ecological practices, who were managing their land in a manner that was at odds with the more conventional farming going on around them.

"*We're an island up here. It's been like, it's been like it since I started* […]*, you have to be stubborn. I don't really care what they think or what they say, I couldn't give a toss. I really couldn't. I know what I'm doing is right, and I'm happy with it, and I know what I'm doing will leave my land in a better state than I found it. And I know what I'm doing, and I'll be, I'll be blunt enough to say I know what I'm doing is helping on a global scale. It just needs more of us to do it.*" (R12)

In the first case, quoted above, it is evident that the farmer had concluded that they would be unable to engage with those around them. The difference in approach, and consequently viewpoints, was too great. They could not see any point in spending time and effort to engage with others who could not understand why they were managing their farm in this way: they were resigned to the fact that they will not understand each other, and that there is little they can do to influence their neighbours, Instead, it was enough for them that they "*know what*

[they are] *doing is right*". Therefore, what happened beyond their farm boundaries was none of their concern: they are content to be an 'island' among a sea of more conventional farmers and claim not care what their neighbours think of them. Notably, however, this respondent did also point out that for their system to make a real difference to public good delivery at a global scale, uptake of the practices that they were employing needed to increase: "*it just needs more of us to do it*". Despite recognising this need, this farmer's position outlined in the preceding sentences means that it seems unlikely they will be able or willing to encourage others around them to adopt similar practices. Given that this is something that needs to happen, but is seen to be beyond this farmer's influence, the implication appears to be that this change will be dependent on external intervention to change farmer mindsets and approaches.

The attitude of the farmer quoted above can be contrasted with that of another respondent, who had also adopted non-conventional practices, but had a different outlook on their relationship with the farmers around them.

"*I know that* [a nearby farmer] *doesn't think much about what we do, but I think he, even he might have changed over the last few years, you know, 'cause again, we try to kind of build bridges rather than, say, 'Well, we don't agree with you, so we're not going to talk to you'* […] *'we're doing things differently* […] *and you don't want to talk to us' and… Yeah, I'd rather find common ground really, which I think we've managed to do.*" (R9)

Again, this farmer's description of how they are "*doing things differently*" and identifying a gap that needs to be bridged, reflects an acknowledgement that there is a divide between their approach and that of others. Throughout their interview they also called for increased uptake of the practices that they are applying on their own farm. However, unlike the previous farmer quoted, they see themselves as still able to effect change on the farms around them. Although there is a difference between them and others, their view is that this difference is not too wide for them not to try to "*build bridges*", and therefore, they are still aspiring to reach out to farmers around them, in the hope of finding "*common ground*". This suggests that they see a way forward for engaging and cooperating with farmers in spite of disagreements over management and what constitutes 'good farming': as long as potential partners can identify those areas where they do think alike, then they have something they can build upon as a first step towards a closer relationship that will support cooperative working and influence.

3.3.5. What do farmers think about how cooperation for public good provision should be organised?

If management to deliver public goods at the landscape-scale requires not just widespread uptake of agri-environmental measures, but also farmers to actively work together, then this will require organisation of management across farms. As described previously, some respondents identified this organisation and alignment between farmers as something with the potential to be especially complex, onerous, and time-consuming, reducing their willingness to get involved in such initiatives. This view was also related to a recognition of the value of external stakeholders as facilitators for collective management for public good delivery at the landscape scale. These external non-farming stakeholders were seen as having the time and resources to take up this logistical burden of working out how farm management should be organised across the landscape, to ensure a spatial configuration of management that is optimal for the delivery of public goods at scale. Therefore, the way in which cooperative management is governed and organised may be important in securing willing participants. Respondents identified different approaches to how this could occur and provided their perspectives on the relative value of these approaches.

One perspective shared by several respondents was that cooperative landscape-scale management should be driven by the farmers themselves. A recurring theme in interviews was farmer scepticism or mistrust of intervention from external parties, outside farming circles, attempting to influence the direction of agricultural land management. Farmers resented external parties seeking to control the output of their farms and dictate what their business should be doing. In extreme cases, respondents, particularly those managing smaller farms, expressed outright hostility towards the idea of 'public money for public goods', even if they did not know exactly what this would involve, because they expected the government to interfere with their farm management in a way that would ignore their independence and accrued wisdom on how best to run their farm. These respondents stressed that their intimate knowledge built up over years of experience running the farm meant that they knew what was best for private and public good provision on their land, and government intervention risked riding roughshod over this knowledge with insensitive or misjudged prescriptions for land management.

Therefore, respondents highlighted that effective cooperation required trust among participants, and farmers trust and respect most information when it comes from other farmers, or, as one interviewee put it: "*farmers tend to listen to farmers*" (R15). Specifically, interviewees

suggested that farmers listen to those farmers that they perceive to be most knowledgeable and successful, as demonstrated by their farm's performance, whether observed directly, or disseminated through reported measures of performance that are shared between farmers, as described above.

This recognition of the value of trust underpinned arguments for farmer-driven schemes for public good provision at the landscape-scale, but there was also acknowledgement that such a bottom-up approach may not be the full solution:

"*So, you know, there will be, there does need to be some landscape-led schemes. And I think the best way for those schemes to be harnessed in the future is for them to be farmer, landowner, driven, err, collectively, because there's an element of less suspicion, but collaboratively alongside Natural England, DEFRA, you know, local wildlife trusts… At the moment, err, there's sort of good and bad sides to both, in some respects?*" (R11)

The respondent quoted above justified the need for landscape-scale schemes to be farmer or landowner driven "*because there's an element of less suspicion*". This indicates that they perceive farmers to be more suspicious of those outside farming circles, such as representatives of government bodies or non-governmental organisations, and suspicion of others implies that farmers do not trust their motives. Therefore, this respondent anticipates a farmer-driven scheme to be more effective because farmers will have greater trust in the scheme, being less likely to see it as misguided or concealing a hidden agenda, for instance. However, in arguing that such schemes should be conducted in partnership with organisations such as DEFRA, they acknowledge that the ideal scheme design is more nuanced than something purely bottom-up and farmer driven.

The need for some level of external input or outside coordination of can be attributed, at least in part, for the complex nature of cooperation for public good delivery at a landscape scale. When one interviewee described the role of a land management advisor in coordinating farmer action for this purpose, it illustrated the value of a coordinated approach:

"*… kind of unofficially, errm, one of the advisors, errm, has, has got a grand scheme to sort of link up a lot of these environmental, errm, activities, on the various farms […] he's got, got this unofficial sort of masterplan, […] he can see, 'Oh, they've got some of that there, and some of that there. Now if we can just get a bit in there, and, and encourage somebody to do something in that particular area, err, then that will join up, make it, you know, there will be some environmental benefit'*." (R14)

In this example, the advisor plays a key role in synthesising the information on environmental activities through the creation of their 'masterplan', and then evaluating this information to identify needs and opportunities. Unlike the farmers, who see it as not worth their time to get into the time-consuming and convoluted business of aligning their management with others, as described previously, the advisor has the time and resources to get to grips with this complexity, and then highlight the key messages for each farmer to encourage them to fill in the gaps and "*join up*" key components in ecological networks. The perceived value of coordination led some to argue that this should be a requirement for efforts to achieve public good provision at landscape scale. Working together for landscape scale public good delivery was described as "*definitely the way forward if we can manage to coordinate it*" (R15). The "*if we can manage*" is a key point: although it simplifies matters for the individual farmer, a coordinated approach does mean that farmers are being told what to do, and if this is coming from an outside party, then there is the aforementioned "*element of suspicion*", that could make farmers unwilling to engage.

If some level of coordination by non-farmers is required to optimise public good delivery at the landscape scale, then the lack of trust from farmers is an issue that needs to be addressed. One respondent suggested that trust, and therefore willingness to engage with external input and coordination, can be improved by prioritising the use of local knowledge and experience:

"*And so, if you could put a local advisor in the right place, or someone they trust, like a local, errm, agent or a local whatever, err, that's massive. […] Doesn't always work, but the majority of times, having a person to speak to resolves issues, particularly if that person's local, or becomes local and stays at that site.*" (R5)

Here, the respondent suggests that farmers will be likely to trust a third party providing advice or feedback if they are local to the farmer. Their recognition of the importance of this trust and locally sourced input is emphasised by their description of it as 'massive', and something that helps resolve issues "*the majority of times*". The quote above also provides some indication as to why being local is valued by farmers: because the respondent suggests that trust can still be built if the person "*becomes local and stays at that site*", it suggests that the advantages of being local are something that can be accrued over time. As the advisor or agent spends more time in the area, their experience and knowledge of the area increases, meaning that farmers are more likely to trust their advice, as more likely to be relevant to their farm and the local conditions.

Although respondents understood the need for coordination, and recognised the value of advisors to achieve this, on balance, respondents chose to emphasise the need for landscape-scale management to be farmer led:

"*… ultimately, I think the farmer and landowner want to feel that they are in the driving seat, and they, they are the ones driving it, pushing it, seeing the results, having some assistance to deliver those results.*" (R11)

In the quote above, the role of non-farmers is viewed as being limited to providing "*some assistance*" to achieve public good delivery. The focus remains on farmers as being "*in the driving seat*", as being the most desirable arrangement for farmers. Therefore, if there is a spectrum between completely farmer-driven and completely advisor-led landscape-scale management, this respondent suggests that the optimal balance lies much closer to farmer-driven management, with external advisors taking a back seat, facilitating action rather than driving it.

When it came to defining what being "*in the driving seat*" means in practice, respondents framed this as involving both setting the objectives and desired outcomes of management and identifying the most appropriate forms of management to deliver these outcomes. Respondents talked about how they thought they could and should be the ones to provide the initial ideas for cooperative management, and that farmers should be allowed and enabled to set the objectives themselves: "*we can come up with these initiatives*" (R11); "*we're supposed to have a meeting where we meet everyone and we, we talk, sit round, and say, what does everyone want to get out of it*" (R16). At the same time, given farmer dissatisfaction with having prescribed actions imposed upon them, and the belief that land management schemes should respect farmer autonomy and accrued local knowledge, there was also an evident desire to be able to choose the types of management that would be best for achieving these outcomes.

3.3.6. What do farmer attitudes mean for geographies of cooperation for landscape-scale public good delivery?

The interviews, as discussed above, suggested that maximising public good provision at the landscape-scale will depend on some combination of external coordination and farmer-driven cooperation, but more heavily weighted towards farmer-driven initiatives. If this plays out as these interviewees hope, given the central role that farmers will therefore have to play in driving cooperation, the distribution of cooperation for public good provision will be influenced by the occurrence of farmers with the means and motivation to initiate cooperative schemes. Among

the interviewees, two farmers expressed a desire to be driving cooperation in their area and described their efforts and aspirations to achieve this. These two farmers, therefore, could play a pivotal role in establishing farmer-driven collaborative management for public good provision within their respective areas.

However, most of those farmers interviewed would not fall into this category. Whether they end up participating in farmer-driven collaborative schemes for environmental management would therefore depend firstly on whether they were approached by other farmers to join such a project, and secondly on whether they would be willing to participate if asked. For some farmers, the main barrier to participation may simply be whether they are accessible to, and have been approached by, those initiating cooperation:

"*Errm, there is cooperation going on, not particularly around here. Errm, I think, partly because we're right on the edge* […] *Well, I know there's, yeah, I know there's, err, errm, a cluster, over, errm, further west, really, I suppose. Errm, which we're, we're not part of because we're too far away to be involved with it.* […] *I didn't know any of them until a couple of years ago. So, we, you know, no one ever thought to ask us.*" (R18)

As an example, the respondent quoted above explains their lack of involvement in agri-environmental cooperative schemes as due to their remoteness from centres or clusters of cooperation in the landscape. Without the presence of a farmer cluster in their local area, there was little to stimulate cooperation. This farmer's participation in cooperation for public good provision depends on whether they are approached by others, and this was unlikely given their distance from those attempting to initiate cooperation. Their observation that "*no one ever thought to ask us*" suggests that they may have got involved if someone had invited them. Therefore, willingness may be present, but cooperative management for public good provision is not something that they can initiate on their own, and so they are left out of these cooperative initiatives.

Although respondents referred to increased use of digital and online channels and media to work with each other, geographical considerations were still of fundamental importance to cooperation. A farmer's potential 'reach' to engage with other farmers was described as being linked to the number and distribution of neighbouring farms around them. Moreover, the geographic permanence of farms, with farmers typically staying in the same place throughout their lives, was identified as contributing to the development of strong, well-established relationships between nearby farmers, making them well-suited to cooperating and supporting each other. On the other hand, several respondents described how proximity to their

neighbours did not always translate into collaboration and openness between them. In some cases, despite having managed their farm alongside their neighbour for many years, relationships with neighbours were limited. This was the case, for example, where the farmer managed their own farm in an unorthodox way, that differed from the more conventional practice around them, or where they had moved onto a farm surrounded by more well-established farmers.

However, even if there are farmers in the local area who have the motivation and capacity to initiate cooperation for public good delivery, who are able to reach out to the farmers around them, this does not mean that all farmers in the vicinity will engage with them. As described previously, due to reluctance resulting from the perceived complex and time-consuming nature of working with others for public good delivery, or unwillingness to reach out to those with different attitudes, the interviews identified farmers who may resist attempts to involve them in such a collaborative scheme. As a result, participation across an area, even with a proactive farmer driving cooperation, may still be patchy or uneven.

Therefore, the occurrence of cooperation for public good delivery depends on both proactive farmers who can engage others, and farmers who can be convinced to join such initiatives. Where there is a farmer with the interest, time, and resources to engage others, they could be at the centre of an area where farmers are working together for landscape-scale management. In other areas without a farmer or farmers to provide this driving force, this does not occur. As a result, the agricultural landscape could have patches of farms working together to deliver public goods, and patches where this does not occur. Equally, even if there is a farmer trying to initiate a landscape-scale project, if a limited or insufficient number of farmers around them are willing to participate, there may only be cooperation amongst a few dispersed farms, or not at all, meaning that landscape-scale management across a contiguous area does not materialise in this region.

3.4. Discussion

3.4.1. Farmers are reluctant to engage in cooperative management despite understanding of the benefits for public good provision

Amongst interviewees, there was widespread recognition of the value of working at a landscape scale for improving public good delivery, whether through management of the respondent's own farm, or by cooperating with others, due to the way in which public goods were distributed across the landscape. In-depth understanding of the value of cooperative management, both in

general terms, and specifically relating to the respondent's own neighbourhood, was evident across respondents representing a variety of farming scales and systems. However, recognising and understanding the value of cooperating for landscape-scale public good delivery did not necessarily translate into a desire to engage in such initiatives, especially in comparison to management of one's own farm for public good delivery. Other researchers have also noted that even if farmers recognise the environmental benefits of working together, they may still be reluctant to cooperate for this purpose (Franks et al., 2016; Franks & Emery, 2013), and a gap between understanding and engagement was also observed in these interviews. Although a couple of respondents were willing and able to spend the time and effort required to engage with the farmers around them for the purposes of environmental management, the interviews showed considerable individual variation in this respect, with many respondents being resistant or dismissive of the idea of cooperative management for public good delivery.

Resistance to the idea of cooperating for public good provision was especially notable in comparison to farmer willingness to manage one's own farm for the delivery of public goods. Even if both options were associated with financial incentives, several respondents reported considerably greater enthusiasm for independent management for public good delivery compared to cooperative management. How farmers balance competing individual and collective priorities, and what this means for cooperation outcomes, has been identified as a key area of uncertainty in the agricultural cooperation literature (Wynne-Jones, 2017). In terms of public good delivery, therefore, the onerous and time-consuming nature of cooperative management, along with issues associated with relationships with other farmers, meant that this was considered a low priority compared to independent management: the anticipated results were not worth the required time and effort.

3.4.2. The importance of quantifying and communicating the benefits of cooperative management

Persuading these reluctant farmers to engage in cooperative management for public good provision could be achieved by either reducing the perceived costs of this activity, whether economic or social, or by increasing the perceived benefits. A key part of raising farmer perceptions of cooperation benefits, as identified from the interview responses, is for farmers participating in cooperative management to be able to see for themselves that their involvement makes a difference.

Quantifying and communicating the effects of that cooperative management was therefore highlighted as a key requirement for the success of cooperative initiatives. Being able to recognise the results of their own management was widely acknowledged as helping farmers refine and improve their management practices based on what does and does not work. However, the ability to see and understand meaningful results from cooperation was also linked to encouraging participation and engagement among farmers. In the context of individual farm management, farming practices can generate symbolic capital, in the form of observable signals of performance quality, that demonstrate that farmer's status or standing as a 'good farmer' (Burton et al., 2008; Riley, 2016). The need for farmers involved in cooperative initiatives to be able to see the results of management efforts raises the possibility that the ability to acquire symbolic capital may also be a consideration affecting farmer willingness to engage in cooperative management.

However, whereas signals of performance quality associated with individual farm management can be attributed to the individuals managing that particular farm, if cooperative management does generate observable outcomes in the landscape, it may be harder to link them to a particular individual, as they are the result of the efforts of a bigger group of individuals. Therefore, it is possible that cooperative management for public good delivery at the landscape scale is less amenable to the generation of symbolic capital for individuals, and this could contribute to the low priority assigned by farmers to cooperative management for public goods compared to management on their own farm. Further research in this area could be useful to explore the extent to which cooperative management supports or prevents the generation of symbolic capital for farmers, as individuals or as a group, and the form this symbolic capital could take, to see if there are opportunities to integrate cooperation for public good provision as part of 'good farmer' ideals.

3.4.3. Farmer cooperation, identity, and social capital

The connection between farmer identity, social capital and cooperation for public good provision was also evident in respondents' reactions to the idea of engaging with their neighbours for landscape-scale management. Respondents approached cooperation for this purpose cautiously and tentatively, in a way that acknowledged concern about the possible reactions of other farmers, giving thought to how they might be perceived by others. Research has already begun to explore cooperative behaviours in the context of farmer cultural identities and social relationships. Whether farmers are open to working with others for environmental land management may depend on cultural ideals of good farming, as farmers may resist

cooperative projects requiring them to perform activities that are at odds with these ideals (Sutherland et al., 2012). Continuous reliance on others, and close working relationships, for example, have previously been reported as being detrimental to 'good farmer' identities (Riley et al., 2018). The wariness expressed by some respondents regarding working with others for public good delivery could therefore be viewed in terms of concerns over the impact of these activities on their reputation as a good farmer.

However, while respondents did tend to stress the value of independence in farming, attitudes to working with others were mixed, with some arguing passionately for building close working relationships, and others preferring to stay apart. The relationship between working cooperatively for public good delivery and the 'good farmer' identity may therefore be variable. Ideals associated with good farming have been found to vary across the agricultural sector, with different 'subcultures' existing with their own ideas of what good farming means, and therefore may differ in how they interpret characteristics of farms and farming as signals of performance quality (Barbieri & Valdivia, 2010; Hunt, 2010; Naylor et al., 2018). Given the variation in relationships with cooperative working reported from respondents representing a variety of different farming systems and approaches, there is some indication that different groups of farmers may differ in their view as to whether cooperative land management for public good provision can be reconciled with their particular good farming ideals. Quantitative research could be used to further explore this idea by investigating whether there is an association between farming approach and attitudes towards cooperative management for public good provision.

If different sections of the agricultural community possess their own, distinct ideas of what good farming means, associated with different signals of performance quality, then this could present a challenge for cooperative management. Reputation, or recognition as a good farmer, can facilitate cooperative management (Lundqvist, 2001). A good reputation means a farmer has better access to social capital, and therefore access to support from their peers, while a bad reputation may restrict access to resources shared among farmers (Burton & Paragahawewa, 2011). The presence of different cultural identities, associated with different good farming ideals, across the study area, often among respondents in close proximity to each other, means that a given farmer may have a good reputation with some of their neighbours, and a poor reputation with others, with whom they do not share a common identity.

However, while respondents did acknowledge that differences in identity, and therefore reputation, affected their ability to work with others for management purposes, they differed

in the extent to which this affected their willingness to cooperate. Whereas some saw the differences in farmer identities as making it not worth reaching out, as they would be unable to reconcile their differences, others saw their differences with other farmers as a challenge to overcome. A key idea associated with reaching out to others was the need to find common ground with potential collaborators. Although different types of farmers may have different cultural identities, there may also be aspects of the good farmer identity, or recognised symbols of quality that are more widely shared (Sutherland, 2013), and these areas of shared identity could be used to build reputation that is recognised across different types of farmers.

Moreover, if connections can be made between farmers who identify in different ways, this may also provide opportunities for changing cultural identities and assisting those making the transition to more sustainable modes of agriculture. Social support from peers has been suggested to play a key role in the development and spread of alternative good farmer identities with greater emphasis on public good provision (McGuire et al., 2013). This also suggests that part of the solution to encouraging farmers to engage with a new self-identity that revolves around a role as 'providers of public goods' may come from key individuals within farming communities, who are willing to reach out and find ways of connecting with otherwise resistant farmers around them. Therefore, while the presence of different, conflicting 'good farmer' ideals or different cultural identities within a given area may make it more difficult to get farms to work together, this does not have to be an insurmountable barrier to cooperation for achieving landscape-scale public good provision.

3.4.4. Balancing collaboration and coordination

The idea that key individuals within the farming community with the time, resources, and willingness to reach out and engage other farmers could initiate cooperative networks of farmers across the landscape highlights the potential for cooperation for public good provision to be farmer-driven. There is generally consistent agreement in the literature that such 'bottom-up' approaches to cooperation tend to deliver greater environmental benefits and be more suited to levels of farmer experience and commitment (Jarrett et al., 2015). Evidence from case studies of farmer cooperatives has been used to argue that the schemes most likely to generate effective working relationships among farmers are those that are organised in a bottom-up, locally-led manner (Franks & Mc Gloin, 2007; van Dijk et al., 2015). To an extent, the interviews conducted here corroborated that view. The reported tendency of farmers to be mistrustful or sceptical of top-down control or intervention for landscape-scale schemes do support the idea of bottom-up, locally-led approaches being required to ensure farmer engagement and deliver

meaningful results. Previous research has also highlighted issues around trust as a key factor associated with farmer willingness to get involved in cooperative environmental schemes (Franks et al., 2016; Franks & Emery, 2013).

However, although there was widespread support for a bottom-up approach, responses also highlighted the value of having one party take on the perceived laborious and time-consuming task of coordinating participating farmers. A recurring distinction in the agricultural cooperation literature can be found between 'collaboration', where parties work together, exchange information, and are involved in an active and constructive dialogue, and 'coordination', where parties work independently towards a common goal, but are organised in a top-down manner (Boulton et al., 2013). Reviews of the literature on agri-environmental cooperation in Europe indicate that in practice, examples of cooperative schemes amongst farmers typically fall on a continuum between total coordination and total collaboration, with most schemes having a mix of elements from both approaches (Prager, 2015). The evidence gathered from these interviews helps illustrate why such a blended approach, that mixes elements of collaboration and coordination, may be likely to characterise successful schemes for achieving the delivery of public goods that span multiple farms. A combination of these two approaches ensures that participants will be more trusting and less sceptical of the project's aim and will be able to minimise the logistical burden associated with organising management across the landscape. However, among the respondents interviewed, the preferred balance between these two approaches appeared to be weighted in favour of collaboration. Coordination may be useful in providing guidance or assistance for farmers to optimise public good delivery at the landscape-scale, but the emphasis on the importance of collaboration, trust and engagement implied that successful cooperative management must be initiated by farmers themselves.

3.4.5. Implications for public good delivery at the landscape scale

However, if cooperative management for public good delivery is going to rely primarily on farmer-driven initiatives, this could produce an uneven distribution of public good provision at the landscape scale. In part, this is because the distribution of cooperative management will depend upon the occurrence of those farmers with the ability and motivation to initiate landscape-scale approaches and reach out to others, resulting in clusters of farms working together centred upon a key individual. At the same time, as discussed previously, differences between neighbouring farmers in terms of cultural identities, will make it harder to cooperate with some farmers than others, so that even within a cluster, not all farms will participate in cooperative management, and farms working together may not be contiguous.

The spatial nature of cooperation, including the scales and spatial arrangements for which cooperative initiatives are most successful or meaningful, has been a neglected area within research into farmer cooperation (Asai et al., 2014; Jarrett et al., 2015). The nature and quality of farmer social relationships with their peers are crucial to their ability to cooperate for environmental management, and therefore affect cooperation outcomes (Macfarlane, 1998; Mckenzie et al., 2013). However, as was evident from the interviews analysed here, social relationships may not map neatly onto geographical ones: although proximity tended to play an important role in who respondents worked with, respondents often reported having closer working relationships with other farmers further afield, with similar attitudes or shared identities, rather than their immediate neighbours, who they did not necessarily see eye-to-eye with. Therefore, while most literature investigating cooperation for environmental management consider farmers managing adjacent parcels of land, other geographies of cooperation may also be widespread. Moreover, although cooperation between farms close together may be best for the provision of public goods, it is possible that the most effective and rewarding forms of cooperation for the farmers themselves will be between farms spaced further apart (Riley et al., 2018). Some distance between cooperating farmers could be useful, because this makes it more likely that there will be different conditions on each farm, generating differences in practices or timings, so that operations on one farm can complement operations on the other farm (Riley et al., 2018). The interviews conducted here complement other recent research in pointing towards a complex relationship between farm geographies and cooperation. Therefore, in designing and implementing schemes to support groups of farmers in delivering public goods at a landscape scale, consideration should be given as to whether the cooperation arrangements that are best for public good delivery can be reconciled with existing farmer preferences or relationships, or if alternative approaches are needed to support the development of new cooperative relationships for enhancing public good provision.

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Alternative approaches for understanding adoption distribution

It is evident from the farmer interviews that the factors affecting farmer relationships with cooperative management can facilitate the development of local clusters of farmers adopting environmentally friendly approaches or practices. However, while these interviews are useful for exploring the reasons why certain adoption distributions may or may not be likely, they do not tell us what the actual distribution of adoption is as a result of these factors. Therefore, it would be useful to combine these interviews with a quantitative assessment of adoption distribution. The influence of a farmer's wider natural, social, or economic environment on adoption patterns at the landscape or regional level means it may be necessary to broaden our focus beyond the factors operating at the farm level in order to predict higher level distribution patterns. We can improve our understanding of regional adoption and sustainability performance by using analysis methods that explicitly account for the spatial dimensions of adoption. Using quantitative spatial analysis to investigate how previous AES have been distributed at the regional scale, and the factors underpinning this distribution, could be useful for guiding implementation of ELM for achieving the desired 'transformational change' in landscapes (DEFRA, 2020b), and identifying areas to prioritise interventions to facilitate management for public good delivery at different scales.

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Chapter 4: A Spatial Analysis of Agri-environment Scheme Uptake at the Regional Level in England

4.1. Introduction

The reforms of the European Union's Common Agricultural Policy (CAP) in the late 20th century brought about the widespread implementation of agri-environment schemes (AES), in which farmers receive compensatory payments in return for voluntarily conducting environmentally beneficial management on their land (Ackrill et al., 2008; Hodge et al., 2015). AES are now widely used as a tool to achieve conservation objectives outside of protected areas, and enhance the provision of ecosystem services from farming, to address the negative externalities associated with the intensification of modern agriculture (Foley et al., 2011; Macfarlane, 1998; Margules & Pressey, 2000).

Although AES are firmly established as a policy instrument, researchers often find that AES fall short of delivering expected levels of environmental benefits (D'Alberto et al., 2018). In order to understand how best to enhance AES effectiveness, considerable research effort has been dedicated to identifying the factors that affect whether farmers take part in AES, and whether the adoption of AES delivers their intended outcomes (Dessart et al., 2019). One of the issues that has been highlighted as contributing to the poor performance of AES concerns the spatially uneven distribution of AES uptake, and a lack of targeting of AES to the locations where they have the potential to deliver the greatest benefits (Raggi et al., 2015). The overall effectiveness of management applied under AES has been shown to depend strongly on their distribution and extent across the landscape, so there is a need to develop a comprehensive understanding of the processes that drive this distribution (Kuhfuss et al., 2016).

A spatially explicit approach that addresses the distribution of AES uptake at larger spatial scales is therefore necessary in order to develop a complete understanding of AES performance in shaping ecosystem service delivery (N. J. Evans & Morris, 1997). Despite this need, studies on farmer adoption of practices for environmental management rarely consider the spatial dimension of adoption behaviour, and the literature has tended to focus on the drivers and impacts operating at the farm scale, even though the landscape scale is often more relevant for interventions to improve the overall environmental sustainability of agriculture (Dessart et al., 2019; Gabriel et al., 2010; Yu et al., 2021). Few studies specifically consider the processes driving the spatial distribution of AES participation at larger geographic scales, and research in different study areas and at different scales has come to different conclusions about the spatial dynamics

of AES, suggesting that it may be difficult to make generalisations about the role of the spatial dimension in AES uptake at the regional level (Boncinelli et al., 2016; Kazakova-Mateva, 2020; Yang et al., 2014).

In England, environmental management at the territorial level has become a prominent feature of agri-environmental policy, with the proposed new Environmental Land Management Schemes (ELMS) placing a strong emphasis on landscape-scale initiatives (DEFRA, 2020b). The design and implementation of these schemes would therefore benefit from an understanding of how AES uptake in England is distributed at the territorial level, and what factors may be driving this distribution. However, while England has been the subject of studies exploring the distribution of alternative farming systems at the regional level in the form of organic production (Gabriel et al., 2009; B. Ilbery & Maye, 2011), there is a lack of equivalent research into regional levels of engagement in AES.

England has already seen several different generations of AES since their introduction in the late 1980s (Dobbs & Pretty, 2008). In the early 21st century, following changes to the budgets and conditions for the different pillars of CAP support, the government introduced the Environmental Stewardship Scheme (ESS), in which farmers could qualify for support under three different types of agri-environmental agreement. Under Entry Level Stewardship (ELS), farmers were encouraged to perform basic environmental management, while those farmers certified as organic could take part in Organic Entry Level Stewardship (OELS), and farmers willing to enter their land into a more demanding scheme could apply for Higher Level Stewardship (HLS) (DEFRA, 2013a; Dobbs & Pretty, 2008). ESS was open to new applicants from 2005 to 2015, with the end dates of the final round of the longer-lasting HLS agreements coinciding with the initiation of agreements under the new ELMS (DEFRA, 2022). With ESS agreements coming to an end, and ELMS about to begin, this is an ideal time to add to a neglected topic in the literature by looking back to assess the determinants of the distribution of ESS engagement, and gain insights which could be relevant to ELMS implementation in the future.

England is also a useful study area for assessing the role of different determinants of AES uptake at the regional level, because within a relatively small area, it contains considerable diversity in physical, social, and economic conditions between regions. This complex geography also means that different regions support contrasting agricultural systems and practices, with different levels of intensity and productivity, and focusing on different types of output. Therefore, there are many socio-economic and territorial factors that vary across the country and could be

candidates for explaining any observed spatial heterogeneity in AES uptake between different regions. There is a rich literature to draw upon when considering the role of different types of factors in affecting AES uptake, that can help to suggest candidate variables to choose in assessing determinants of ESS engagement at the regional level in England. Previous studies have linked AES adoption to the characteristics of the farmer that may shape their attitudes towards AES (such as age, educational background, whether they are part- or full-time) or the amount and type of resources available to the farm (such as farm size, farm type, financial status, workforce size, and use of external inputs) (Bartolini & Vergamini, 2019; Defrancesco et al., 2008; Läpple & Rensburg, 2011; Yu et al., 2021). At the same time, however, there is also evidence linking AES adoption to variables characterising the wider territory or landscape that farms are situated in, such as habitat and landscape quality, the potential for productive agriculture, and the structure of the rural economy and demographics (Bartolini et al., 2014; Boncinelli et al., 2016; Yang et al., 2014). Our ability to use quantitative methods, including modelling, to explain patterns in AES uptake will inevitably depend on the choice of explanatory variables to include in any candidate model, which should be informed by the existing literature as far as possible. Omitting key variables otherwise known to influence uptake may limit model performance in terms of the proportion of a variation in AES uptake that can be explained by the model.

Predicting regional rates of uptake for AES is aided by spatial analysis: being able to account for the spatial dimension enhances our ability to understand the occurrence of social and economic phenomena such as AES uptake (Miller, 2008; Tobler, 1970). The level of AES uptake at a given location may be due to the values of individual explanatory variables at that location but could also be due to the wider geographic context: high uptake may be not just because of the values of variables at that location, but also because the surrounding area is characterised by high AES engagement. Spatial analysis makes it possible to discriminate between these factors, which adds value to insights for policy makers, who can use this information to determine the extent to which AES engagement could be increased by location-specific interventions, compared to interventions that target the wider area (Wollni & Andersson, 2014). Exploratory spatial statistics can be used to identify and describe any patterns in the distribution of AES uptake, and a range of statistical econometric models have been put forward to test for the factors explaining how regional participation rates are related to their location. Spatial econometric modelling provides a way of incorporating spatial dependence interactions (relationships between values due to proximity) and spatial structure (variation in values across space) into regression models (Anselin, 1988; Anselin et al., 1996). This has become an increasingly

accessible tool for researchers with the advent of GIS and the growing availability of spatial data at different scales (Brady & Irwin, 2011). Where spatial dependence is detected, different types of spatial models can be used to explain why this spatial dependence occurs, whether this is due to association with a spatially correlated variable not explicitly accounted for in the model (spatial error) or some form of neighbourhood or spillover effect (spatial lag), or a combination of both (Anselin et al., 2008). Comparing the performance of these models can tell us something about the processes that may be generating any patterns in the distribution of engagement with AES at the regional level.

A combination of exploratory spatial analysis and spatial econometric modelling is therefore useful for describing and understanding the distribution of AES uptake. Given the opportunity presented by these methods, and the scarcity of research into the factors driving the distribution of AES uptake at the regional level, the aim of this study was to use these tools to assess the distribution of ESS engagement at the regional level in England, and the factors that might be driving this distribution, while accounting for the possibility of spatial dependence. The specific objectives were a) to map the distribution of ESS agreements and management options in England at the regional level, b) to use exploratory spatial data analysis to test for spatial dependence in regional ESS engagement rates and describe any patterns in distribution, and c) to use spatial econometric modelling to determine the processes that could account for any observed spatial dependence, and identify the role of candidate independent variables (representing both farm structural features, and socio-economic and physical features of the wider territory) in explaining the distribution of ESS engagement across England.

4.2. Methods

The methodology presented here follows a 4-step process:

a. The secondary datasets for the dependent and independent variables were collated, and where necessary, processed so that they were in a format suitable for spatial analysis at the regional scale.
b. An appropriate spatial weighting matrix (SWM) was chosen and constructed to describe the spatial relationships among the regions being studied.
c. The dependent variables were mapped to visualise the spatial distribution of ESS engagement, and spatial patterns in these variables were investigated with the use of exploratory data analysis.
d. Spatial regression methods were used to examine the role of the independent variables, alongside different potential spatial effects, in explaining the distribution of ESS engagement at the regional level.

Data preparation and visualisation was conducted using ArcGIS Pro 3.0.1 (ESRI, 2022), while SWM selection and spatial regression was performed using R 4.2.1 (R Core Team, 2022).

4.2.1. Data collection and preparation: dependent variables

Spatial data on all ESS agreements live as of the end of 2020 is freely available online in the form of polygon-based features for holdings (i.e., farms) entered into ESS agreements, and point-based features for the locations of individual options within these agreements (Natural England, 2022). ELS-only agreements or OELS-only agreements had a duration of 5 years, and since ESS stopped receiving new applicants in 2015, there were no ELS-only or OELS-only agreements in these datasets (Natural England, 2022). All holdings and options therefore belonged to either HLS-only agreements, or combined ELS-HLS or OELS-HLS agreements.

Publicly accessible data on the structure of the agricultural sector is provided under a range of spatial frameworks, including National Character Areas, Local Nature Partnerships, and various levels of administrative divisions. The choice of spatial framework was influenced by the scale of that framework, its coverage of England, and whether data on key explanatory variables was available at that level. The distribution of ESS engagement was assessed at the level of Local Authority Districts (LADs), because this was the smallest spatial scale at which it was possible to get publicly accessible data across the whole country on the structure of the agricultural sector necessary for the independent variables (as described below). Although using higher-level administrative subdivisions, such as NUTS3 (Nomenclature of Territorial Units for Statistics 3)

regions, would increase the availability of territorial, socio-economic, and policy data relevant to AES engagement that could be used for independent variables, using LADs instead helped to maximise the size of the dataset used for analysis, and so increase the power of the spatial models. Aggregating data into a smaller number of higher-level administrative regions, would reduce regional diversity in ESS engagement, simplifying and potentially obscuring spatial patterns (Schmidtner et al., 2012). However, for some LADs, data on key agricultural independent variables was not available, as the number of holdings was too small to avoid disclosing personal data, so LADs with low numbers of holdings had to be grouped together for this analysis. Combining these LADs where appropriate resulted in a final set of 234 LADs and groups of LADs in England.

The spatial data layer for the LAD boundaries was sourced from the Office for National Statistics' Open Data Portal online (Office for National Statistics 2016). I used the LAD boundaries as of December 2015, to help ensure consistency with the round of DEFRA farm survey data most relevant to the timeframe in which the ESS agreements were being adopted (as described in section 4.2.2 below).

Investigating the distribution of holdings and options under ESS agreements in England depended on being able to aggregate the ESS data by LAD. The ESS data was used to generate 2 types of dependent variable for each LAD to address the study aims:

1. **Participation rate:** Percentage of agricultural holdings in each LAD that were part of an ESS agreement

To calculate the participation rate per LAD, first an intersection was performed between the commercial holdings under ESS agreements and LAD shapefiles. Differences or imprecision in digitisation where ESS agreement holding boundaries coincided with LAD borders, meant that the intersection operation created a number of small 'sliver' polygons. These were dealt with by reviewing and removing features with an area to perimeter ratio of less than 0.004, that also shared an edge with a LAD border. The output of the intersection was dissolved based on LAD name, scheme type, and agreement reference. A spatial join between the LAD shapefile and processed ESS holdings shapefile was used to get a count of all ESS holdings contained in each LAD.

Dividing this count by the number of commercial agricultural holdings (from the DEFRA survey, as described below) provided a measure of the participation rate. In this DEFRA farm survey, most holdings were assigned to an LAD based on the holding grid reference used in any previous subsidy claims (DEFRA, 2012). This means if a farm holding spans the border between different LADs, the LAD that it is allocated to will depend on the location of this grid reference. This approach therefore assumes that those farm holdings that are only partially within an LAD are equally likely to have been allocated to that LAD or a neighbouring LAD. If farm holdings partially within small LADs (which have higher edge to area ratios) are more likely to have been assigned to neighbouring LADs, participation rate may be overestimated in smaller LADs. This is because much of the land under ESS agreements near the edges of the district will belong to holdings that have been assigned to other districts in DEFRA's farm business survey, and so will be omitted from the total number of commercial holdings in the district. However, the lack of a significant relationship between LAD size and participation rate, suggests that smaller LADs did not automatically tend to have higher participation rates, so any such bias is negligible, and this issue can be disregarded for the purposes of this analysis.

2. **Option density:** Number of individual options (under certain agri-environmental management themes, see below) applied under ESS agreements per km^2 of agricultural land

The options available under ESS agreements were designed to help achieve a range of different environmental objectives (DEFRA, 2013a), and so one could expect that the adoption of options for different objectives would have different management requirements and be influenced by different independent variables (Yang et al., 2014). Therefore, model fit could be enhanced if options were divided into separate groupings according to the environmental objectives being targeted. This was done by classifying the ESS options according to 6 agri-environmental management themes: habitats and biodiversity, landscapes, public access and education, historic environment, soil quality, and water quality. Where possible, classification was guided by Natural England's ESS option directory, which identified certain options as priorities for each environmental objective (DEFRA, 2013a). Options could belong to more than one theme, and not all options were allocated to one of these themes. A spatial join operation was used to count the number of options under a given theme in each LAD, and this count was divided by the area of agricultural land in the LAD to give the option density.

Given this approach to measuring option density, it is possible that regional variation in option density could reflect variation in average field sizes across the country. Option data are referenced by the polygon in which an option is situated, so an area with smaller average field size will typically have a greater number of options than an equivalent area of farmland with fewer, larger fields. Due to the absence of adequate district-level data on average field sizes, for the purposes of this analysis, I assumed that average holding size (which has been included as one of the candidate explanatory variables) correlates with average field size, and so the performance of this variable in spatial models could also reflect the role of variation in average field size in spatial patterns in option density. Larger farms typically occur in highly productive landscapes, which tend to be dominated by larger fields for maximising efficiency of farming operations (Clough et al., 2020; Svobodová et al., 2022), so this is a reasonable assumption to make.

Estimating the participation rate and option density for each LAD required data on the number of agricultural holdings and the area of agricultural land per LAD. These data came from the DEFRA survey of agriculture and horticulture. Since 2010, this survey methodology has been designed to exclude smaller, less commercially active farms (DEFRA, 2012). The thresholds for including farms in the survey vary depending on farm type, but the minimum size for a commercially active farm was at most 5 hectares. Therefore, to improve the compatibility of the ESS data with the DEFRA survey data, all holdings under ESS agreements that were less than 5 hectares (and the options within these holdings) were removed from the ESS datasets.

4.2.2. Data collection and preparation: independent variables

13 candidate independent variables were identified to use in modelling the variation in these different measures of ESS engagement, reflecting the structure of individual farms and the agricultural sector, as well as socio-economic and physical features of the region (Table 4.1). Selection of independent variables was informed by the literature on factors affecting AES participation as mentioned in the introduction above but was also constrained by the availability of data at the LAD level: fewer variables relating to the agricultural sector are reported at the LAD level compared to larger administrative units.

An element of spatial differentiation was built into the process of awarding stewardship schemes with an HLS component. A set of target areas were designated across England, with local priorities chosen to reflect the conditions in each of these target areas (Staley et al., 2018).

While HLS is open to all landowners, HLS applications within target areas that align with the management priorities for that target area have a higher chance of being approved. HLS applications are still possible outside target areas, however, but here they are evaluated against their compatibility with wider regional themes (Staley et al., 2018). Rather than directly investigate how the distribution of these target areas and regional themes influenced ESS engagement, I chose independent variables that instead reflected features of the agricultural landscape and environmental quality (that in theory should have influenced the distribution of target areas) – allowing me to investigate whether this spatial targeting of HLS has resulted in an alignment with specific environmental variables at the regional level.

Independent variable	Description	Source
Average holding size	Total farmed area per LAD / Number of holdings per LAD	DEFRA (2016). *Structure of the agricultural industry in England and the UK at June. (*Local authority breakdown for key crops areas and livestock numbers)
% of agricultural land used for arable farming	Area of arable crops (including cereals) per LAD / Total farmed area per LAD	
% of agricultural land used for horticulture	Area of fruit and vegetable crops per LAD / Total farmed area per LAD	
Number of sheep per ha of grassland	Number of sheep per LAD / Area of grassland per LAD	
Number of cattle per ha of grassland	Number of cattle per LAD / Area of grassland per LAD	
Nitrogen fertiliser application	Mean of the average annual fertiliser application rate in each 1km x 1km square within the LAD	Osório et al. (2019). *CEH Land Cover plus: Fertilisers 2010-2015 (England).*
Phosphorus fertiliser application		
Glyphosate application	Mean of the average annual pesticide application rate in each 1km x 1km square within the LAD	Jarvis et al. (2020). *CEH Land Cover plus: Pesticides 2012-2017 (England, Scotland, and Wales).*
% of agricultural land in Grades 1 and 2	Area of agricultural land classified as Grade 1 or 2 per LAD / Total area of agricultural land under all grades per LAD	Natural England (2019). *Provisional Agricultural Land Classification (ALC) (England)*
Average number of workers per holding	Total labour (number of farmers and workers) per LAD / Number of holdings per LAD	DEFRA (2016). *Structure of the agricultural industry in England and the UK at June. (*Local authority breakdown for the agricultural labour force on commercial holdings)
Population density	LAD population / LAD area	Office for National Statistics (2020). *Estimates of the population for the UK, England and Wales, Scotland, and Northern Ireland*
% of region in designated landscape	Area covered by National Park or AONB per LAD / LAD area	Natural England (2022). *Areas of Outstanding Natural Beauty (England)*; *National Parks (England)*
% coverage by protected areas	Area covered by SSSI, SAC, SPA, or Ramsar site per LAD / LAD area	Natural England (2022). *Sites of Special Scientific Interest (England); Special Areas of Conservation (England); Special Protection Areas (England); Ramsar (England)*

Table 4.1. Independent variables used in the spatial regression modelling for the distribution of ESS engagement in England at the Local Authority District level

To maximise the validity of the models, it was important for the values of the independent variables to reflect, where possible, the conditions at the time farmers entered into ESS agreements. The last ESS agreements in the dataset started in 2014, and the next year in which agricultural data was collected by DEFRA at the LAD level was 2016 (DEFRA, 2016). Therefore, for variables relating to the structure of the agricultural sector, the 2016 DEFRA farm survey was used as the data source.

4.2.3. Spatial weighting matrix selection

Defining the spatial relationships between sites is a key prerequisite for both exploratory spatial data analysis and spatial regression, and this depends on the construction of a spatial weighting matrix (SWM) to represent these relationships. A SWM describes whether each pair of sites in a spatial dataset is connected or unconnected (connectivity matrix) and uses weights to reflect the strength of the association between connected sites (weights matrix) (Bauman et al., 2018). There are many types of SWM that differ according to how sites are related to each other, which may be shaped by a location's neighbourhood and/or distance from other sites (Corrado & Fingleton, 2012). I focused on SWM that constructed relationships based on proximity alone, because the impact of other spatial factors that could influence uptake distribution was addressed through the choice of independent variables for the spatial model as described above.

The choice of SWM strongly influences the results of spatial analyses, including the accuracy of model parameter estimates and the detection of spatial dependency (Corrado & Fingleton, 2012; Stakhovych & Bijmolt, 2009). It is therefore important to choose the most appropriate SWM for the dataset in question. In order to help address this issue, Bauman et al. (2018) developed a procedure for optimising the selection of a SWM from a shortlist of appropriate candidates, by comparing the fit of spatial predictors to a response variable under each SWM. This procedure was applied using the specially designed listw.candidates and listw.select functions in R, to choose the optimal SWM for modelling distribution of the dependent variable out of a combination of connectivity (distance-based, relative, and Gabriel's) and weighting (binary, linear, concave-down, and concave-up) matrices (Bauman et al., 2018).

4.2.4. Exploratory spatial analysis

With the optimal SWM identified and constructed, it was then possible to test for global spatial autocorrelation for each dependent variable using the Global Moran's I Index, and therefore determine whether the overall distribution of ESS engagement displayed a random, dispersed or clustered pattern (Moran, 1948). If the Global Moran's I indicated the presence of significant spatial dependency in ESS engagement, Local Moran's I could be used to assess the contribution of individual LADs on the overall Global Moran's I value and describe the level of engagement in a region relative to the surrounding regions. This makes it possible to map locations where high or low levels of ESS engagement are concentrated, and locate significant clusters of LADs with similar values of the dependent variables, as well as outlier LADs that differ from their

neighbourhood (Anselin, 1995). The Bonferroni correction was applied to the p-values from the Local Moran's I test, to address the issue of an increased likelihood of false positives due to the large number of tests being conducted: clusters were only recognised if the Bonferroni-corrected p-values were less than 0.05 (Anselin, 1995).

4.2.5. Spatial regression

Not all dependent and independent variables were normally distributed, so the R package bestNormalize was used to identify the most effective transformation for normalising the data (R. A. Peterson, 2021), so the data could be analysed using linear models. For each transformed dependent variable, an aspatial linear model including all the independent variables was used as a starting point, and the MuMIn R package was used to identify the model(s) with the minimal set of significant independent variables, organised in optimal order, by comparing the fit of each model as measured by Akaike Information Criterion (AIC) scores (Bartoń, 2022; Bozdogan, 1987). An Ordinary Least Squares (OLS) regression was run using the resulting minimal model, to assess the significance of the independent variables in accounting for variation in the dependent variables in an aspatial model.

In order to establish whether model fit could be improved by incorporating spatial dependency, Lagrange Multiplier diagnostic tests were run on the OLS model residuals. The Lagrange Multiplier diagnostics help assess the suitability of applying a spatial error model (that accounts for spatial autocorrelation in the disturbance term), a spatial lag model (that accounts for a missing spatially lagged dependent variable), or a combination of both, to the dataset (Anselin, 1988; Anselin et al., 1996). The relationship between the dependent and independent variables was then assessed using the appropriate model according to the results of the Lagrange Multiplier tests.

4.3. Results

4.3.1. Spatial weights matrix

For the dependent variables, the application of the listw.candidates and listw.select functions in R identified the optimal SWM as a Gabriel connectivity matrix with a linear weighting matrix. Gabriel's W matrix (Matula & Sokal, 1980) was therefore used to define the relationships between LADs for exploratory spatial analysis and spatial regression (Fig. 4.1).

While Gabriel's W matrix is not dependent on contiguity for connectivity (so it can accommodate LADs that are separate from mainland England, namely the Isles of Scilly and the Isle of Wight), it also addresses some of the limitations of purely distance-based matrices. Since LAD area varies widely, using a fixed distance to determine a LAD's neighbours would mean that the smallest LADs would be connected to a large number of neighbours far beyond their boundaries.

Figure 4.1. Connectivity among Local Authority Districts in England as defined by Gabriel's W spatial weighting matrix

4.3.2. Participation in Environmental Stewardship Agreements

The ESS agreements dataset included 10,052 holdings over 5 hectares, representing 9.41% of total commercial holdings in England. Of these, 8,623 holdings were in ELS-HLS schemes (8.07% of all holdings), 990 were in HLS-only schemes (0.93% of all holdings), and 439 were in OELS-HLS schemes (0.41% of all holdings). Owing to the small number holdings under OELS-HLS schemes, with many LADs having no OELS-HLS agreements at all, analysis of ESS participation rates focused on just the ELS-HLS and HLS-only schemes.

The rates of participation in ESS agreements were not evenly distributed across England's LADs, with the percentage of holdings in ESS agreements varying widely across the country (Fig. 4.2). Moreover, the positive and significant Global Moran's I statistics for both ELS-HLS participation (Moran's I = 0.356, z = 8.15, $p < 0.001$) and HLS-only participation (Moran's I = 0.331, z = 7.50, $p < 0.001$) were indicative of spatial dependency in the form of clustering: LADs with similar participation rates tend to occur close together. This can be seen in the maps of LAD participation rates: for ELS-HLS schemes, for example, most LADs in the far north of England exhibit similarly high levels of participation (>12.5% of holdings).

The contribution of individual LADs to this clustered spatial pattern is revealed by the Local Moran's I tests, which identified certain LADs as part of significant clusters of both high and low participation rates, and other LADs as outliers, where participation rates were markedly different from their neighbours (Fig. 4.3).

However, although both ELS-HLS and HLS-only participation rates exhibited strong spatial dependency in the form of clustering, the distribution of participation rates at the LAD level differed between the two schemes, giving rise to different locations of clusters and outliers (Fig. 4.2, Fig. 4.3). Indeed, there was no correlation between ELS-HLS and HLS-only participation rates at the LAD level (Spearman's rank $\rho = 0.056$, $p = 0.392$). Accordingly, Local Moran's I identified different LADs as outliers or part of clusters of high and low participation rates for each scheme (Fig. 4.3). For ELS-HLS, LADs in the far north-west of England are part of a significant cluster of high participation rates, but this area does not feature as a cluster of high participation rates for HLS-only schemes. Instead, LADs with the highest HLS-only participation rates are concentrated around London and southern England.

Therefore, while participation in both ELS-HLS and HLS-only schemes shows pronounced spatial heterogeneity and clustering at the regional level, the precise distribution of participation differs

between each type of scheme. This could suggest that different factors may be driving participation in each case, giving rise to different distribution patterns.

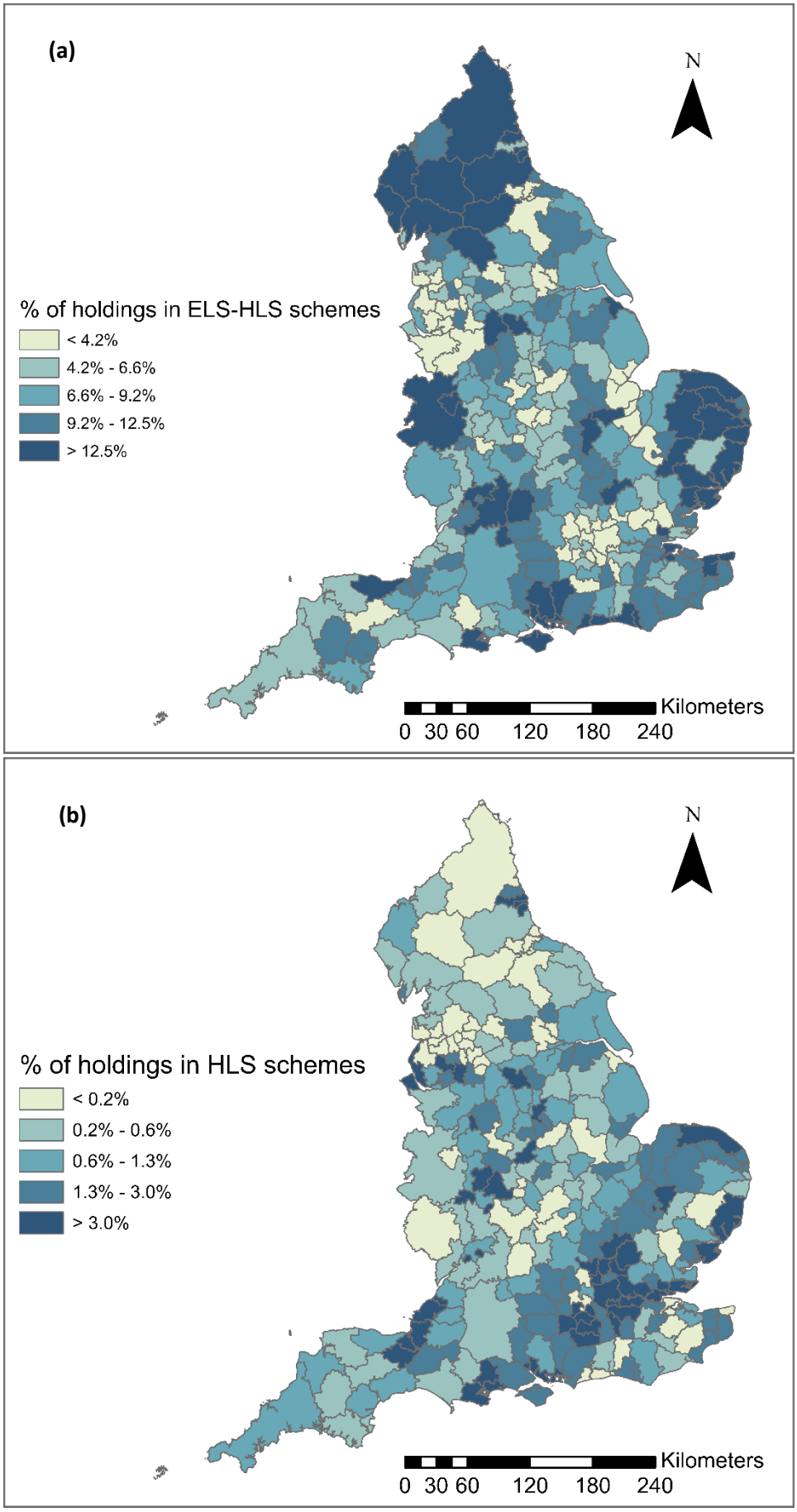

Figure 4.2. Percentage of holdings (over 5 hectares) in each English Local Authority District entered into Environmental Stewardship Agreements under either **(a)** ELS-HLS schemes, or **(b)** HLS-only schemes

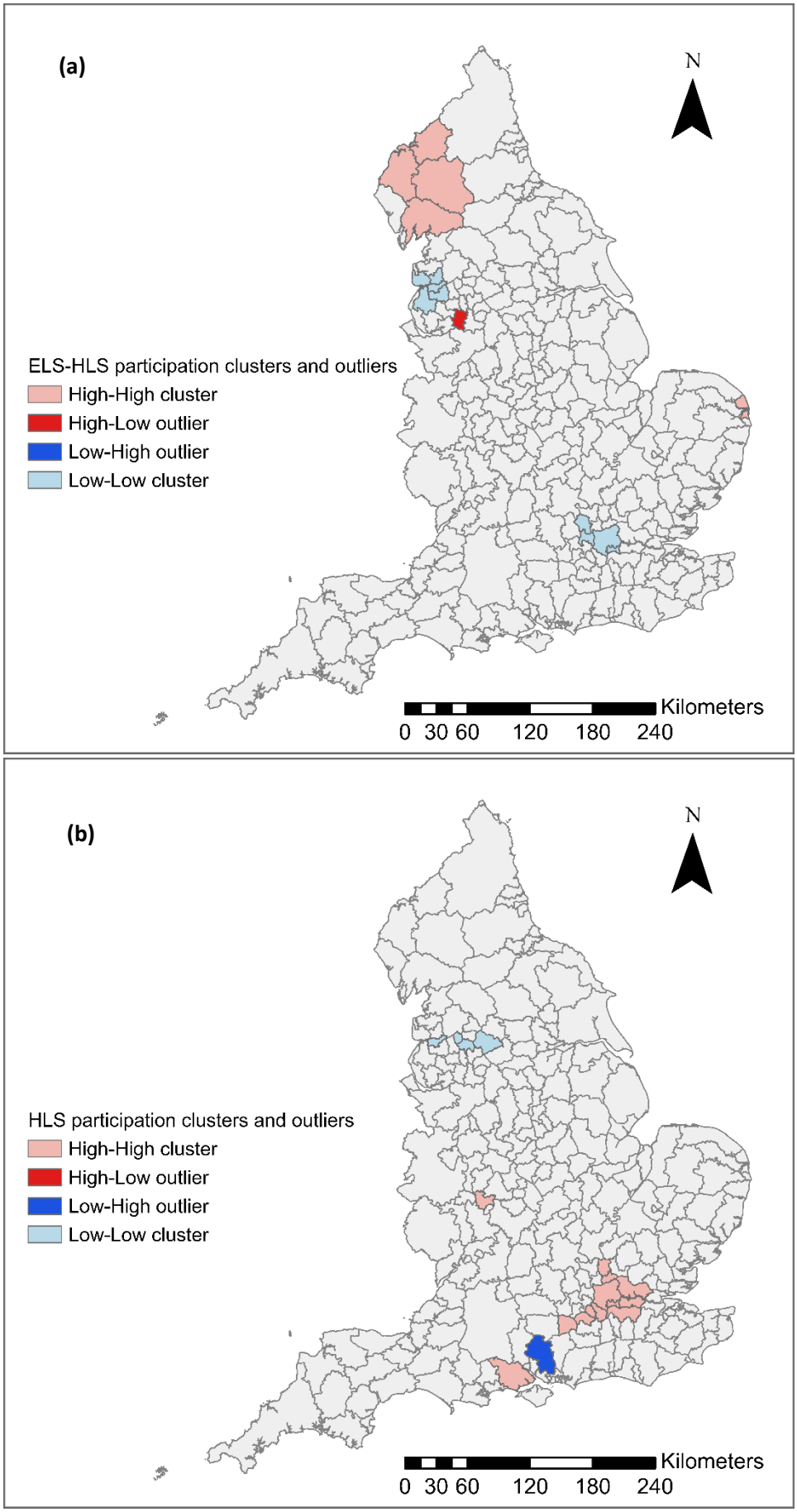

Figure 4.3. English Local Authority Districts that are part of significant clusters of high or low participation, or outliers, (as identified by Local Moran's I) for **(a)** ELS-HLS schemes, and **(b)** HLS-only schemes

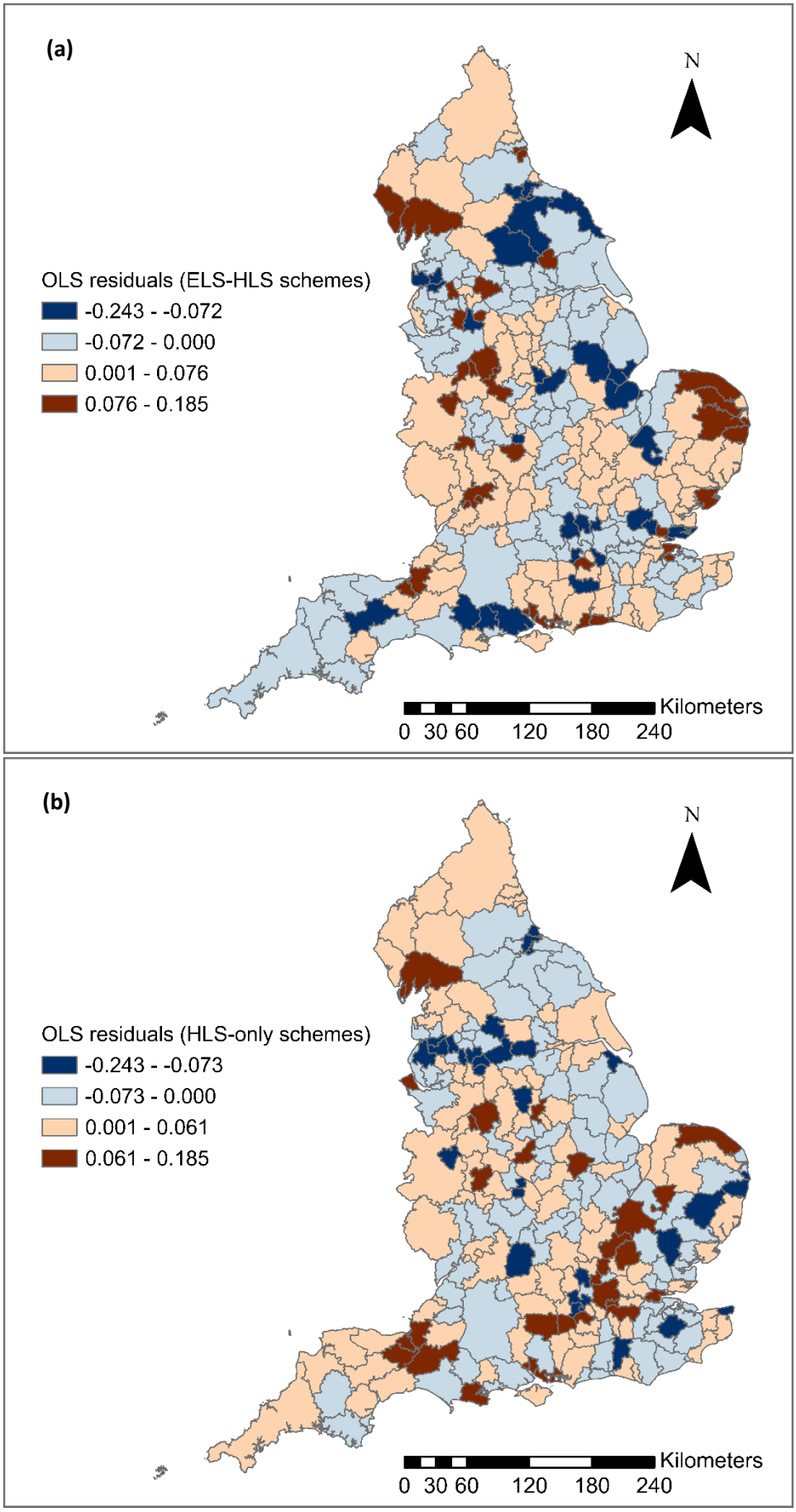

Figure 4.4. Residual values per English Local Authority Districts from OLS regression modelling participation in **(a)** ELS-HLS schemes, and **(b)** HLS-only schemes

The residuals from the best-fitting aspatial OLS models for ELS-HLS and HLS-only participation are mapped in Fig. 4.4. These maps highlight the LADs with the greatest (positive and negative) error values relative to the model's predictions. There are some pronounced differences between the models, which is to be expected, given that they employ different sets of independent variables to explain the variation in participation rate, but there are also some patterns in the distributions of residual values that appear to be common to the models for both schemes. The OLS models tended to underestimate participation rates in the far north-west England (as reflected in positive residual values) and overestimate participation rates across much of north-east England (negative residuals). Other areas showed little similarity between the models: in south-west England, the residuals for the ELS-HLS model were mainly negative, but the residuals for the HLS-only model were mainly positive. Moreover, in both cases, the maps suggest that there may be some form of spatial dependency in the residuals, with areas with similarly high or low residual values frequently occurring close together.

	ELS-HLS participation rate		**HLS-only participation rate**	
	Statistic	**p-value**	**Statistic**	**p-value**
OLS Moran's I	6.326	0.000***	6.152	0.000***
LM (spatial error)	31.828	0.000***	29.729	0.000***
Robust LM (spatial error)	5.128	0.024*	4.253	0.046*
LM (spatial lag)	27.729	0.000***	27.15	0.000***
Robust LM (spatial lag)	1.029	0.311	0.794	0.373

Table 4.2. Lagrange Multiplier diagnostic tests for spatial dependency in the form of spatial error and spatial lag in the residuals from the standard aspatial OLS regressions for ELS-HLS and HLS-only participation rates.

This observation is supported by the results of the Lagrange Multiplier tests, to check for different forms of spatial dependence in linear models, conducted on the residuals from the OLS regressions for participation rate, as shown in Table 4.2. The standard Lagrange Multiplier diagnostics for spatial dependency in the form of spatial error and spatial lag both return significant results. Selection of the appropriate spatial model is therefore determined by comparing the robust forms of the Lagrange Multiplier test statistic: the robust test for spatial error tests for error dependence while controlling for false positives due to the presence of a missing spatially lagged dependent variable, and vice versa for the robust test for spatial lag (Anselin et al., 1996; Okunlola et al., 2021). For both ELS-HLS, and HLS-only schemes, the robust Lagrange Multiplier test for spatial error generates a significant result, but the robust test for spatial lag does not. Therefore, the null hypothesis of no spatial dependency due to spatial

autocorrelation in the model error term can be rejected. This means that adopting a model that incorporates spatial error effects, instead of a traditional OLS model, will ensure more robust estimates of model coefficients and their significance.

The results of the optimal spatial error models, containing the minimal set of significant independent variables for explaining variation in ELS-HLS and HLS-only participation rates are shown in Table 4.3. The suitability of a spatial error model in each case is supported by comparing the goodness of fit in terms of AIC score for these models with those of alternative models: the AIC score for both spatial error models is lower than the equivalent aspatial OLS, spatial lag, or spatial Durbin / mixed model. For both models, the spatial error coefficient, λ, is positive and highly significant, indicating that the error term shows a strong positive association with its value at neighbouring sites. This could be indicative of other spatially correlated variables, not included in these models, that influence the regional distribution of participation.

Independent variable	**ELS-HLS participation rate**	**HLS only participation rate**
Average holding size	0.031***	
% of agricultural land used for arable farming		0.132**
% of agricultural land used for horticulture		0.242**
Number of sheep per ha of grassland		-0.024*
Number of cattle per ha of grassland		
Nitrogen fertiliser application		
Phosphorous fertiliser application		
Glyphosate application	-0.027*	
% of agricultural land in Grades 1 and 2		-0.062*
Average number of workers per holding		-0.052**
Population density		0.003***
% of region in designated landscape	0.077***	
% coverage by protected areas	0.145**	0.175***
Spatial error coefficient, λ	0.469***	0.527***
AIC - OLS	-574.89	-610.38
AIC - Spatial Error	**-603.00**	**-642.83**
AIC - Spatial Lag	-568.36	-613.91
AIC - Spatial Durbin / mixed	-594.70	-640.14

Table 4.3. Summary of spatial error model results for ELS-HLS and HLS-only participation rates, showing significant independent variables and coefficients, spatial error coefficients, and Akaike Information Criterion (AIC) scores for alternative models for each dependent variable (the lowest model AIC score is in **bold**). A square root transformation was applied to the data prior to running the models.

Although the spatial error coefficient may reflect the presence of important spatial factors missing from these models, several of the independent variables included in the spatial error models were associated with significant effects.

There was one variable that was a key determinant of participation rates for both ELS-HLS and HLS-only schemes. The percentage coverage of protected areas for conservation, was positively associated with participation rates in both schemes: farmer participation in ELS-HLS and HLS agreements is higher in local authorities with a greater extent of protected areas.

However, as would be expected, given that the distribution of participation rates differed between ELS-HLS and HLS-only schemes, the significance, magnitude, and direction of the effects associated with other independent variables varied between the 2 scheme levels. While the extent of protected areas for nature conservation was a significant independent variable for both scheme types, the extent of designated landscapes, in the form of AONBs and National Parks, was associated with higher participation rates for ELS-HLS, but not for HLS-only schemes.

Alongside quality of the natural environment, variation in participation rates was also linked to features of the agricultural sector in each region. ELS-HLS participation rates increased with average farm size, but farm size had no significant effect on participation in pure HLS schemes. Conversely, HLS-only participation decreased in areas with higher numbers of sheep per hectare of grassland, but sheep density showed no association with ELS-HLS participation.

The other structural features of the agricultural sector identified as significant determinants of HLS-only participation rates were the percentage of agricultural land used for arable farming or horticulture in each region. An increasing dominance of both arable farming and horticulture was associated with higher rates of participation in HLS-only schemes but showed no association with the rate of participation in ELS-HLS schemes.

The use of external inputs and labour on the farm was also significantly associated with ESS participation, but again, the key variables and their roles differed between the two scheme types. Areas with higher rates of glyphosate application were associated with lower ELS-HLS participation, but not HLS-only participation, while areas with a higher density of farm labour were associated with lower HLS-only participation, but not ELS-HLS participation.

Therefore, while there may be one or more spatially correlated variables not included in these models that help account for the clustered distribution of ESS participation at the LAD level, the differences in the roles of the assessed variables in contributing to farm participation rates for ELS-HLS and HLS-only schemes can help explain some of the differences in distributions and

regional clusters when comparing the two types of schemes. The far north of England contains large areas of protected landscapes (including two National Parks and the North Pennines AONB), high sheep densities, and less arable land. The model results show that these factors are associated with higher rates of participation for ELS-HLS schemes but a negligible or negative association with HLS-only scheme participation. Hence, this area is home to a regional cluster of high ELS-HLS participation rates, but no cluster of high HLS participation.

4.3.3. Density of Environmental Stewardship options

The total number of management options applied by participants in the ELS-HLS and HLS-only schemes on holdings over 5 hectares was 1,194,444. Overall, 13 management options were applied per km^2 of agricultural land as part of these ESS agreements (Table 4.4).

Theme	Number of individual options applied	% of all options applied	Number applied per km^2 of farmland
All options	1,194,444	--	13.10
Habitats and biodiversity	502,546	42.1%	5.51
Landscape	136,975	11.5%	1.50
Historic environment	27,023	2.3%	0.30
Public access and education	26,968	2.3%	0.30
Soil quality	149,283	12.5%	1.64
Water quality	87,518	7.3%	0.96

Table 4.4 Frequency and densities of ESS ELS-HLS and HLS-only management options in England under different agri-environmental themes

When categorising options by theme, habitats and biodiversity accounted for the largest number of individual options, with 502,546 options, or 42% of all options, falling under this category. This translated into an overall density of 5.51 options applied per km^2 of agricultural land (Table 4.4). The rarest management themes concerned the historic environment and public access and education: for each of these themes, the relevant options accounted for 2.3% of all options, and had an overall density of 0.30 options per km^2 of agricultural land (Table 4.4).

However, as with participation rates, the densities of options applied on farmland under these different themes varied widely across LADs (Fig. 4.5), and all 6 themes were associated with significant ($p < 0.001$) positive Global Moran's I values, reflecting a clustered distribution of option densities. For any given management theme, LADs with similar option densities tended to be located close together. Many of the broad patterns in the distribution of option density at the LAD level recurred across the different agri-environmental management themes. LADs in

the far north-west of England were typically characterised by high option densities for each theme, while a group of LADs with low option densities was present in central east England for each theme (Fig. 4.5). However, there are also slight differences between the details of the distribution of option density values when comparing themes. For example, while LADs with some of the lowest option densities tended to be concentrated in central east England, this pattern was less pronounced for the water quality theme, with fewer LADs in this region falling within the bottom 20% of LADs for option density when compared to the other management themes (Fig. 4.5).

Likewise, the locations of significant clusters and outliers of option density, as identified by the Local Moran's I statistic, showed some broad similarities and subtle differences between each management theme (Fig. 4.6). No one LAD was part of a cluster for every management theme, but several general cluster locations were shared across management themes.

Part of north-central England appeared as a cluster of high option densities for every management theme considered, although the precise LADs that were identified as part of this cluster varied slightly between themes (Fig. 4.6).

Other clusters of LADs with high option densities were present for some themes but not others. LADs in north west England, were part of a cluster of high option densities for the landscape, historic environment, and water quality themes, but there was no cluster in this area for the other management themes. A cluster of high option densities was present in central southern England for the habitat, landscape, and public access and education themes, but absent for the other management themes (Fig. 4.6).

Some LADs had significant Local Moran's I values for multiple themes, but the nature of their relationship with neighbouring regions differed depending on the theme. In south-west England, Cornwall was part of a cluster of high option densities for the habitats and public access themes but was identified as a low-high outlier for the soil quality theme, with a markedly lower density of options relating to soil quality management compared to neighbouring regions (Fig. 4.6).

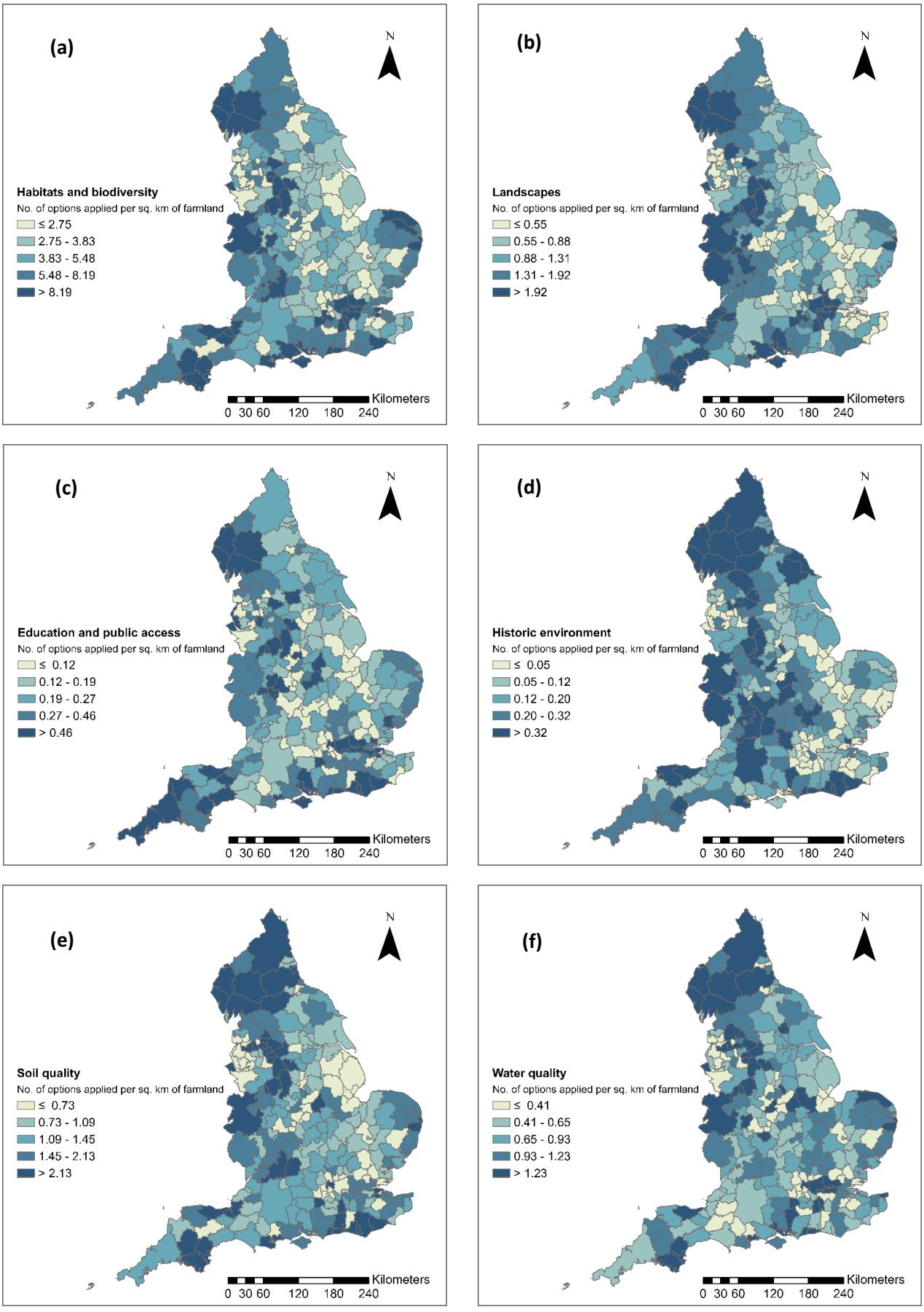

Figure 4.5. Number of ESS management options (under ELS-HLS, OELS-HLS, and HLS-only schemes) applied per km^2 of agricultural land (i.e., 'option density') for each English Local Authority District for **(a)** habitats and biodiversity, **(b)** landscapes, **(c)** public access and education, **(d)** historic environment, **(e)** soil quality, and **(f)** water quality

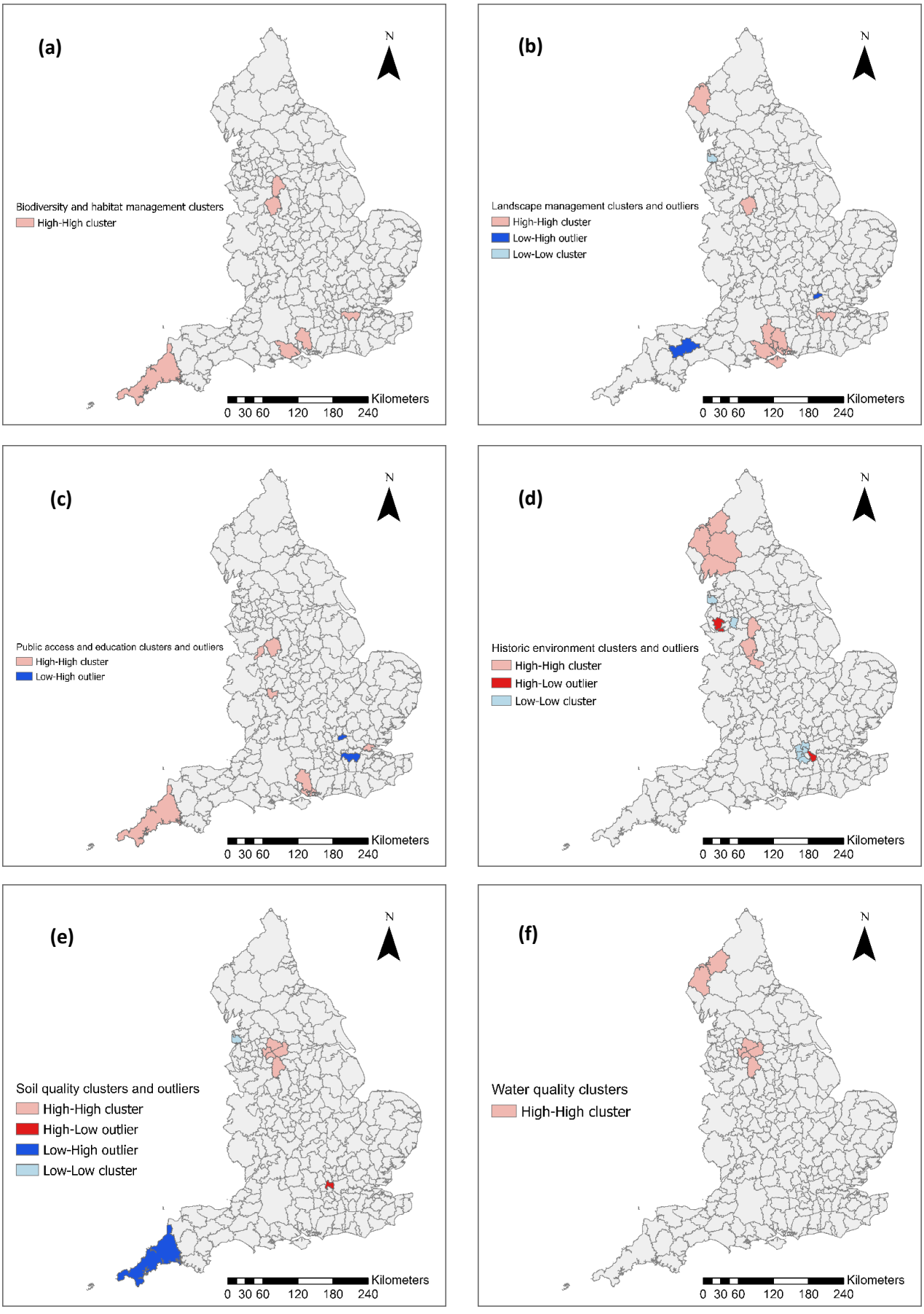

Figure 4.6. English Local Authority Districts that are part of significant clusters or outliers (as identified by Local Moran's I) for the density of ESS management options for **(a)** habitats and biodiversity, **(b)** landscapes, **(c)** public access and education, **(d)** historic environment, **(e)** soil quality, and **(f)** water quality

	Habitats and biodiversity		Landscapes		Public access and education		Historic environment		Soil quality		Water quality	
	Statistic	p-value	Statistic	p-value	Statistic	p-value	Statistic	p-value	Statistic	p-value	Statistic	p-value
OLS Moran's I	5.655	0.000***	8.547	0.000***	4.425	0.000***	3.104	0.001**	2.67	0.004**	2.472	0.007**
LM (spatial error)	27.741	0.000***	61.546	0.000***	16.531	0.000***	6.047	0.014*	4.312	0.038*	4.184	0.041*
Robust LM (spatial error)	6.32	0.012*	11.976	0.001**	9.505	0.002**	1.536	0.215	0.558	0.455	0.37	0.543
LM (spatial lag)	21.575	0.000***	50.952	0.000***	10.345	0.001**	4.511	0.034*	3.796	0.051	3.814	0.051
Robust LM (spatial lag)	0.154	0.695	1.382	0.24	3.32	0.078	0.000	0.994	0.042	0.838	0.000	0.984

Table 4.5. Lagrange Multiplier diagnostic tests for spatial dependency in the form of spatial error and spatial lag in the residuals from the standard aspatial OLS regressions for ESS option density for 6 types of broad agri-environmental management objectives

Comparison of either the standard or robust Lagrange Multiplier tests on the OLS model residuals for option density for each theme indicated that spatial dependency in model residuals for the habitats, landscape, public access, soil, and water quality themes could be accounted for by a spatial error model (Table 4.5). For the historic environment theme, although the test statistics were significant for both spatial error and spatial lag, a lower p value for the spatial error statistic suggested that a spatial error model would be appropriate here too. The choice of model for each management theme is further supported by comparing the fit of alternative models (OLS, spatial error, spatial lag, spatial Durbin / mixed) in terms of AIC scores: across all themes, the spatial error model had the lowest AIC score, and so the best fit (Table 4.6).

	Spatial error					
Independent variable	**Habitats & biodiversity**	**Landscapes**	**Public access & education**	**Historic environment**	**Soil quality**	**Water quality**
Average holding size	-0.007*		-0.003*	0.004***	0.004*	0.006**
% of agricultural land used for arable farming		0.099*		-0.025*		
% of agricultural land used for horticulture						
Number of sheep per ha of grassland				0.010***	0.010*	
Number of cattle per ha of grassland						
Nitrogen fertiliser application				-0.001**	-0.001**	
Phosphorous fertiliser application				0.001*	0.001*	
Glyphosate application		-0.026**			-0.010*	-0.010*
% of agricultural land in Grades 1 and 2						
Average number of workers per holding		-0.018*				-0.014*
Population density	0.002***		0.001***			
% of region in designated landscape	0.055*		0.015*	0.011*	0.020*	
% coverage by protected areas	0.238***	0.067*	0.057***		0.051*	0.059**
Spatial error coefficient, λ	0.436***	0.639***	0.368***	0.298**	0.215*	0.197*
AIC - OLS	-540.54	-734.22	-1048.34	-1203.97	-927.60	-963.45
AIC - Spatial Error	**-564.51**	**-794.81**	**-1062.91**	**-1209.55**	**-930.09**	**-965.54**
AIC - Spatial Lag	-537.95	-735.36	-1045.53	-1207.26	-921.92	-959.38
AIC - Spatial Durbin / mixed	-559.83	-787.51	-1058.07	-1208.68	-923.39	-960.91

Table 4.6. Summary of spatial error model results for the density of ESS management options per Local Authority District for 6 types of broad agri-environmental objectives, showing significant independent variables and coefficients, spatial error coefficients, and Akaike Information Criterion (AIC) scores for alternative models for each dependent variable (the lowest model AIC score is highlighted in bold). A square root transformation was applied to the data to create normally distributed variables before running the models.

The minimal set of significant independent variables in the final models for option density under each theme is given in Table 4.6. Some independent variables are common to models for different themes, but variables also differ in terms of the significance, magnitude, and direction of their effects depending on the theme.

Of the 13 independent variables assessed, protected area coverage was associated with the strongest and most consistent effects on management option density across the different themes. For all themes except the historic environment, an increase in the proportion of a region that falls within a protected area for nature conservation was associated with an increase in the density of management options applied on agricultural land. An increase in the coverage of designated landscapes was associated with an increase in option densities for the habitats, historic environment, public access, and soil quality themes, but not the landscape or water quality themes. The values of the coefficients for protected area coverage in each model tended to be larger than those for designated landscape coverage, indicating that the extent of protected areas in a LAD was associated with greater increases in option density than the extent of designated landscapes.

Alongside the quality of the natural environment, variables relating to characteristics of the agricultural sector were associated with significant model coefficients for one or more of the agri-environmental themes. Average farm size was associated with a significant impact for all themes except landscapes, however, the direction of the relationship between farm size and option density varied. For habitats and public access, option density decreased as average farm size increased, but this relationship was reversed for historic environment, soil, and water quality options, where option density increased with average farm size.

With regards to the type of farming being conducted in each LAD, the extent of arable farming was identified as having a positive relationship with the density of landscape management options, but a negative relationship with the density of historic environment options. For management of the historic environment, option density was also positively associated with the density of sheep (but not cattle) on grassland. Sheep density was also a significant positive predictor of option density for the soil quality management options.

Use of external inputs on the farm, in the form of nutrients, agrochemicals, or labour, was also identified as a significant contributor to option densities under some management themes. An increase in labour availability, as measured by the average number of workers per holding, was associated with a decrease in the density of landscape and water quality management options being applied on farmland. Landscape, soil quality, and water quality option densities were also

negatively associated with rates of glyphosate application in each LAD. Meanwhile, fertiliser application rates were also significant independent variables in the models for historic environment and soil quality option densities (which were negatively associated with nitrogen fertiliser levels and positively associated with phosphorus fertiliser levels), however, the values of these coefficients were very small, indicating only a slight effect in each case.

The relationships with the different independent variables identified through the different models can be used to help interpret the regional clusters found using the Local Moran's I tests. The cluster of high option densities in north central England that recurred across all agri-environmental management themes (Fig. 4.6) coincides with an area with moderate to high sheep densities, low numbers of farm workers per holding, and extensive protected areas and landscapes. These factors favour high option densities across different agri-environmental management themes, and so it is unsurprising that this cluster of regions with high option densities was identified repeatedly.

On the other hand, not all the regional clusters and outliers of option density can be easily related back to patterns in the independent variables. The models for option densities under the habitats and public access themes share the same significant independent variables, with coefficients of similar proportions and directions, and yet there are LADs that belong to significant clusters and outliers for one theme but not the other. Thurrock, on the Thames Estuary in south-east England, and Bromsgrove in the West Midlands, are both part of significant clusters of high option density for public access but are absent from any habitat management clusters (Fig. 4.6). Given that spatial error models were the best fit for explaining option density for 5 out of 6 of the agri-environmental management themes, and the spatial error coefficients for these models were significant and positive, it is possible that some of these differences in cluster distribution could reflect differences in other spatially clustered variables not included in this analysis.

4.4. Discussion

4.4.1. Environmental Stewardship Scheme uptake displays a clustered distribution at the Local Authority District level in England

This study used a combination of exploratory spatial data analysis and spatial econometrics to assess the distribution of Environmental Stewardship Scheme (ESS) agreements and management options in England at the Local Authority District (LAD) level. Exploratory spatial analysis indicated that at the LAD level, the rate of participation in ESS agreements, and the density of management options applied under these agreements, exhibited a clustered distribution, with LADs with similar levels of ESS engagement tending to occur close together. The locations of regional clusters of high and low participation differed markedly between ELS-HLS schemes and HLS-schemes, with no correlation between regional participation rates for each scheme type. However, there was overlap in the location of regional clusters of management option density under different agri-environmental themes. Model comparisons and diagnostic tests demonstrated that spatial error models were most appropriate for explaining the distribution of ESS participation rates and management option densities, suggesting that the clustering of ESS engagement at the LAD level is at least partly driven by spatially correlated variables that were not explicitly identified in the models. Out of the candidate independent variables that were assessed, the coverage of protected areas for nature conservation was the most consistent predictor of ESS participation and management option density clustering.

Although this is the first time that AES distribution has been assessed in this manner at the LAD level for England, this result is consistent with several other studies finding that at the regional level, farmer adoption of AES (and other alternative agricultural practices designed to enhance ecosystem service delivery) is not randomly distributed, but spatially clustered. This regional clustering has been reported in a variety of contexts. AES participation and expenditure at the parish level also shows a clustered distribution in Scotland (Yang et al., 2014), while adoption of organic farming in England and Wales has become increasingly concentrated in a few regional hotspots (Gabriel et al., 2009; B. Ilbery & Maye, 2011), and this clustering has been observed for organic farming (and organic AES) elsewhere in Europe (Bjørkhaug & Blekesaune, 2013; Boncinelli et al., 2016; Schmidtner et al., 2012). However, this is not a universal result for European agriculture: in Bulgaria, when NUTS3 regions are considered, AES uptake shows no spatial dependence (Kazakova-Mateva, 2020). NUTS3 regions lie above LADs in England in the hierarchical classification of administrative areas (so that one NUTS3 region contains multiple

LADs), and spatial dependency in farmer adoption or conversion behaviours may be observed at some spatial scales but not others (B. Ilbery & Maye, 2011; Schmidtner et al., 2012). Therefore, it is possible that repeating this study using NUTS3 regions rather than LADs may not deliver the same results in terms of significance of spatial dependence and clustering.

4.4.2. Determinants of the distribution of Environmental Stewardship Scheme engagement at the Local Authority District level

Researchers have identified a range of spatially correlated environmental, economic, and social variables that can create favourable or unfavourable conditions for certain farming practices or agri-environmental policy interventions, and so help explain why farmer adoption behaviours for sustainability may be clustered in space (Läpple & Kelley, 2015; Schmidtner et al., 2012). This existing literature informed the selection of candidate independent variables in the models for this study, but not all these variables proved to be determinants of ESS engagement at the regional level, and the significance, magnitude, and direction of the effects on ESS engagement frequently varied depending on scheme type and management theme. Some variables had pronounced impacts that could be corroborated from the findings of other spatial studies of AES uptake, while others had more mixed or ambiguous impacts, that could not be so clearly reconciled with the existing literature.

Of all the candidate independent variables assessed, the coverage of protected areas for nature conservation showed the strongest and most consistent association with regional levels of ESS engagement. Moreover, the role of protected area coverage was most pronounced in explaining the distribution of ESS management option density for habitats and biodiversity. HLS was designed to focus on areas of high priority for environmental management, with HLS applications being promoted within designated target areas that were defined based in part on the distribution of key habitats and species of conservation importance (Staley et al., 2018). As such, the process for awarding HLS schemes may favour areas in and around protected areas (DEFRA, 2013b; Dobbs & Pretty, 2008). The results presented here suggest that this approach has been successful in targeting relevant management options under ESS towards areas of high biodiversity conservation value. Given the emphasis on biodiversity conservation in HLS, it is unsurprising that the primary factor affecting its regional distribution relates to the quality of the natural environment. An equivalent study looking at AES uptake in Scotland found a positive association between regional participation rates and SSSI coverage, but a negative association when considering all types of designated natural sites, which was interpreted to suggest that further policy effort was required to improve AES uptake in protected areas outside of SSSIs

(Yang et al., 2014). This does not appear to be the case for England: the strong positive effect associated with overall protected area coverage suggests that the HLS scheme under ESS has been appropriately targeted for the country's full protected area network.

However, these protected areas typically represent the fragmented remnants of formerly more extensive semi-natural habitat, and interventions outside of protected areas to link up these fragments and create functioning ecological networks is a core tenet of modern nature conservation (Jackson et al., 2009; Lawton et al., 2010; Margules & Pressey, 2000). The data on the locations of ELS-only agreements under ESS was not publicly available during the research timeframe, but if this data could be accessed, it could be informative to assess the relationship between protected area coverage and the distribution of ELS-only agreements, to evaluate the role of these schemes in fulfilling conservation objectives in the wider countryside, outside protected areas. Given the different functions of ELS (which promoted basic environmental management and was designed to broaden AES coverage across agricultural land in general) and HLS, it could be expected that the effect of protected area coverage would be weaker or absent when modelling participation in ELS-only schemes.

Besides protected area coverage, the next variable most frequently associated with increased ESS engagement was the percentage of LAD area within a designated landscape (AONB or National Park). Where this variable had a significant effect, the magnitude of the model coefficient was usually smaller than that associated with protected area coverage. However, when considering the density of management options for the historic environment, designated landscape coverage had a significant effect, but protected area coverage did not. This provides further support for the conclusion that HLS management options are being targeted appropriately at the LAD level. The statutory sites included under the protected area coverage variable are not created for the protection of historic features, but historic and cultural character is a factor in determining the location of AONBs and National Parks (Natural England, 2018), and so it makes sense that the density of historic environment options should be linked to the extent of designated landscapes but not protected areas. Moreover, it is possible that the distribution of management options for the historic environment merely reflects the distribution of surviving archaeological features in the landscape. These may have been more likely to have been preserved within protected landscapes, and this relationship might also help account for why the extent of arable farmland was negatively associated with the density of management options for the historic environment if fewer archaeological features have been preserved in more heavily modified arable landscapes.

The extent of designated landscapes was also a significant component of the models for habitat, public access, and soil quality option density, and participation in HLS-only agreements. The importance of designated landscapes as a determinant of engagement could also reflect higher levels of rural tourism in designated landscapes. Previous research has suggested that AES participation may be correlated with the development of rural tourism in an area, as areas with higher levels of tourism provide more opportunities for income through diversifying rural land use (Bartolini et al., 2014; Bartolini & Vergamini, 2019). Therefore, in AONBs and National Parks, which typically have high scenic and recreational value, alternative land management practices supported under HLS may be more likely to help contribute to business viability for farms diversifying to take advantage of rural tourism, contributing to higher engagement with HLS. Tourism statistics, in terms of total number of visits and total spend from visitors, are published at the LAD level in England (Visit England, 2021), but the available data does not discriminate between urban and rural tourism, which makes it of limited value for further clarifying the role of rural tourism sector in regional levels of AES engagement in England.

The relationship between protected landscape coverage and greater participation in ELS-HLS schemes could also reflect the greater resources available to facilitate environmentally friendly farming within these areas. National Parks and AONBs frequently provide additional resources and advice to help farmers looking to adopt environmentally friendly practices, especially those that are in keeping with the character of the wider landscape (DEFRA, 2021), a source of support that may be lacking outside these protected landscapes. While protected landscape coverage was not a significant factor in explaining the distribution of participation in HLS-only schemes, it could be that HLS-only applicants are more likely to represent more specialist landowners and land managers (as described below), who are therefore less dependent on facilitation and resource availability to access these schemes. ELS-HLS applicants, by contrast, may be more likely to represent more conventional farmers who stand to benefit more from the extra support provided within these protected landscapes to successfully apply for stewardship agreements.

Alongside habitat and landscape quality, another feature of the natural environment that was linked to ESS engagement at the regional level was the land's potential for productive agriculture, as measured by the proportion of agricultural land classified as Grade 1 or Grade 2. Greater productivity was negatively associated with participation rates in HLS-only schemes. Reduced adoption of alternative farming and agri-environmental practices in more productive areas has been recognised by other studies (Ilbery & Maye, 2011; Schmidtner et al., 2012; Yang et al., 2014). This result has been attributed to the greater perceived opportunity cost of sacrificing yields by adopting alternative land management options under AES in areas with

more potential for productive agriculture, making farmers in these regions less willing to move away from conventional intensive farming (Espinosa-Goded et al., 2013). However, this effect was only found when assessing participation in HLS-only agreements: there was no association between the proportion of high-grade agricultural land and participation in ELS-HLS schemes in LADs. One possible explanation for this difference is that the combined ELS-HLS agreements tended to be dominated by the less demanding, more basic, management options under the ELS scheme, making it easier to reconcile them with more intensive agricultural practices that are favoured in high productivity areas.

The proportion of high-grade agricultural land was not the only independent variable which was a significant determinant of participation rate in one scheme type but not the other. In fact, protected area coverage was the only variable with a significant effect on participation rate for both ELS-HLS agreements and HLS-only agreements. All other variables with a significant effect on ELS-HLS participation were not significant for HLS-only participation, and vice versa. At the regional level, a different set of factors appears to be influencing participation rates for each type of agreement. There are several differences between these two agreement types that could contribute to this contrast. Application for HLS funding is competitive, but ELS funding is not, and is therefore more accessible, attracting a wider range of farmers, and HLS targets a more diverse set of outputs from land management protection (Dobbs & Pretty, 2008; Hodge & Reader, 2010). HLS has been designed to complement ELS, so most farmers and land managers entering into HLS agreements do so in combination with ELS (DEFRA, 2013b). Farmers and land managers entering into HLS-only agreements are therefore in the minority, and since HLS-only agreements do not include the more accessible ELS options that are more compatible with intensive farming, it is possible that they are attracting a different type of entrant and are applied on less conventionally farmed land.

ELS options are designed to be appropriate specifically for farmed land, and it may be difficult or impossible to apply these options on non-farmed land, whereas HLS options may be relevant on a wider range of habitat types, not just conventional farmland (DEFRA, 2013b). Therefore, the distribution of HLS-only agreements may also reflect uptake by other, non-farming landowners (including those with responsibility for nature reserves, country parks, and other rural landscapes not used for food production), for which meeting the requirements of ELS was not possible. This difference may help to explain why, for instance, average holding size was positively associated with participation rate for ELS-HLS agreements but not for HLS-only agreements. Previous research has suggested that the fixed costs associated with participating in AES may be a proportionately smaller burden for larger farms with higher turnovers, making

them more likely to engage with such schemes (Ducos et al., 2009). If landowners entering into HLS-only agreements are less likely to be conventional farming businesses relying on food production for income, these costs of participation may be less of an issue, hence the lack of a relationship between average farm size and regional participation rate.

While the effects of some independent variables on ESS engagement can be explained with reference to established themes in the literature on AES participation, others had more unexpected or counterintuitive effects. The rate of participation in HLS-only agreements, and the density of landscape and water quality management options, showed a negative association with the average number of farm workers per holding. The academic consensus on farm labour and AES participation indicates that the more demanding agri-environmental practices typical of HLS are more likely to be adopted by farmers with greater availability of labour and human capital (Boncinelli et al., 2016; Defrancesco et al., 2008). Previous research on the relationship between AES uptake and labour availability has highlighted the level of casual or seasonal labour, particularly during peak workload periods, as a key determinant of participation, rather than overall farm labour rates (Defrancesco et al., 2008; Yang et al., 2014). Therefore, it is possible that repeating this study focusing only on the amount of casual labour per holding would produce a different result. However, whereas the DEFRA farm survey provided figures for overall farm labour rates for every LAD, the availability of data on casual labour was restricted as causal labour, it was not possible to comprehensively assess casual labour rates at the LAD level using the publicly accessible data due to the occurrence of LADs with very low casual labour rates, for which data was redacted to comply with data privacy requirements.

Equally, however, it is unsurprising that not all the relationships between independent variables and ESS engagement are corroborated by research for other study areas. How a given farm structural or territorial factor influences AES adoption rates can often be strongly dependent on the geographic context: a given independent variable may affect AES engagement in different ways in different areas (Mozzato et al., 2018). Therefore, while the results of this research may show some similarities to spatial analyses of regional AES uptake rates in other countries, there may also be limits to how readily the findings presented here can be generalised to other areas, especially for countries further afield (Mozzato et al., 2018).

4.4.3. Missing spatially correlated variables contributed to the regional clustering of Environmental Stewardship Schemes

While spatial regression did identify variables that could help explain the regional clustering of ESS engagement, the strong performance of the spatial error models relative to other models, and the significance of the spatial error term in these models, indicates that this clustering is also due to the occurrence of spatially correlated variables that were omitted from this study. Some of these missing variables could have been included if this study had been conducted using higher level administrative regions. Many of the results of the DEFRA farm survey are aggregated and published for regional subdivisions higher up the administrative hierarchy, such as NUTS3, but not at the LAD level (Table 4.7). Therefore, performing this study at the NUTS3 level would have enabled assessment of a greater variety of independent variables.

If it had been possible to include these variables at the LAD level, it is possible that one or more of these variables, could help account for some of the observed spatial dependency in ESS engagement. The omission of these variables may have contributed to the significance of the spatial error term in the scheme participation and option density models. If we want to achieve a more complete understanding of the determinants of AES engagement at the regional level in England, it will be useful to fill in these gaps in data at the LAD level. Finding a way to responsibly access and use these datasets at the LAD level should therefore be a target for future studies replicating this methodology.

Independent variable	Smallest administrative region with accessible data	Source
Area of rented farmland	NUTS3	DEFRA (2016). *Structure of the agricultural industry in England and the UK at June.*
Area of owned farmland		
Area of grassland by type (temporary, permanent, or rough grazing)		
Area of farm woodland		
Area of arable land by crop type		
Area of horticultural land by crop type		
Average farm rent per hectare of farmed land	NUTS1	DEFRA (2022). *Farm rents*.
Total income from farming (TIFF) per hectare of farmed land	NUTS3	DEFRA (2019). *Total income from farming for the regions of England.*

Table 4.7. Candidate independent variables for which data is made publicly accessible at the NUTS3 level or above, but not at the Local Authority District level

However, even if it is possible to increase the variety of datasets available at the LAD level, it is likely that spatial error will continue to be an important component of the optimal model.

Previous research modelling AES or organic farming engagement at the regional level, employing a larger set of independent variables than was included in this study, also found that the overall predictive ability of the optimal spatial model using independent variables with available quantitative data tended to be low (Blaće et al., 2020), and spatial error models still provide the best fit for the data (Yang et al., 2014). Moreover, although OLS model residuals were spatially clustered, when mapping these residuals, it was not immediately apparent what geographic features could be underpinning this clustering. Therefore, it may be that the spatial error term reflects a complex combination of spatially correlated variables, driving subtle variations in levels of regional ESS engagement across England. The evidence from quantitative and qualitative research implies that AES participation and distribution is the result of many different factors that may show spatial dependency and interact in complex networks of cause and effect. Other key, potentially spatially correlated, variables that were not captured by the models in this study and may contribute to regional clustering of AES uptake include farmer attitudes and behaviour, the distribution of the quality and quantity of institutions and extension services promoting AES participation, farmer social norms and networks (Baumgart-Getz et al., 2012; Cullen et al., 2020; Dessart et al., 2019; Risgaard et al., 2007; G. A. Wilson & Hart, 2000).

4.4.4. There is little evidence for regional spatial spillovers in Environmental Stewardship Scheme engagement

Explanations for the spatial distribution of farmer adoption behaviours have referred to both the occurrence of spatially correlated explanatory variables (i.e., the inherent patchiness of spatial variables giving rise to clustering of related management activities), and the presence of neighbourhood or spillover effects across spatial units (Bartolini & Vergamini, 2019; Boncinelli et al., 2016). In this study, the better fit of the spatial error model indicated that the former option was more effective at accounting for the regional clustering of ESS engagement. Thus, while the diagnostic tests and model comparisons indicate that the regional clusters of ESS engagement in England can be attributed to the presence of spatially correlated variables (regardless of whether they were explicitly identified in the models), the poorer performance of spatial lag models suggests it is less likely that any neighbourhood or spillover effect is causing this clustering. This means that high ESS uptake in one region, in of itself, does not make high ESS uptake more likely in neighbouring regions. This is contrary to the processes that have often been observed at the local level, where the adoption of novel farming practices by one farmer can increase the likelihood that nearby farmers will adopt the same practices, due to shared

social norms, peer pressure, farm imitation, or information sharing, giving rise to clusters of adoption (Boncinelli et al., 2016; Läpple & Kelley, 2015; Lewis et al., 2011).

However, spatial spillovers of adoption are not always observed at the farm level (Schmit & Rounsevell, 2006), and such a spillover effect can be found at some spatial scales but not at others within the same area (Ilbery et al., 2016; Ilbery & Maye, 2011), suggesting that the spatial clustering of farming practices and systems may be driven by different processes at different spatial scales. Moreover, the regional level, spatial dependency in AES participation may be due to spatial spillovers for some agricultural practices and systems but not others (Bartolini & Vergamini, 2019; Boncinelli et al., 2016). Therefore, while the lack of any spatial lag effect at the LAD level indicates that spillover of ESS engagement did not occur between neighbouring regions, this does not rule out the possibility that at the farm level, farmer uptake of ESS was influenced by the level of ESS engagement among neighbouring farms, or that spillover effects could be observed at the regional level for different AES schemes within England.

4.4.5. Spatial analysis provides valuable information to support policy design and implementation

Being able to describe the distribution of AES engagement across different regions and understanding the factors and processes that contribute to this distribution, could provide insights to help deliver AES in a way that optimises the delivery of public goods and ecosystem services at the territorial level. Although this spatial analysis only provided a partial picture of the factors that underpinned ESS distribution, it is still useful as a tool for monitoring AES uptake in combination with other research methods and can help point to priorities for further study. This methodology could be especially valuable for monitoring the progress of ELMS against the objectives of England's post-Brexit agri-environmental policy. Understanding how different spatial variables relate to the distribution of management options for different types of agri-environmental objective helps indicate if schemes are being targeted appropriately, identifying whether options relating to specific management themes are concentrated in areas where they are most needed. Repeating this methodology to monitor the distribution of uptake at regular intervals could be used as part of an adaptive approach to policy design, ensuring that areas where uptake falls short of targets, or regional barriers to engagement, are identified early, and interventions can be designed to address these issues as they arise.

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The limits of spatial analysis for researching adoption distribution

The spatial analysis of ESS engagement across England provided an effective means of describing the regional-level distribution of AES adoption, showing that adoption rates were spatially clustered. However, it was perhaps less effective at explaining why this clustering had occurred. Using spatial modelling, it was possible to identify some explanatory variables that affected ESS distribution, but these effects were relatively small, and the model diagnostics and comparisons showed that much of the regional variation in adoption rates was being driven by other spatially correlated variables that had not been included in the model.

Other studies applying this methodology to AES adoption at this scale have also found model predictive ability to be low, and that spatial dependencies are influenced by the occurrence of unknown spatially correlated variables (Yang et al. 2014; Bartolini & Vergamini 2019; Blaće et al. 2020). Moreover, given that mapping the model residuals in this study did not suggest any clear geographic pattern, it is not immediately apparent what these missing variables could be. When considered in the context of the adoption literature and the farmer interviews in chapters 2 and 3, this spatial error likely arises because adoption distribution is the product of a complex combination of environmental, economic, social, cultural, and institutional drivers, which may be hard to capture in a simple spatial econometric model. At the same time, if we are going to able to evaluate the potential for alternative farming approaches and practices in addressing the negative impacts of intensive agriculture at the regional level, then we need to be able to make connections between this mix of drivers and sustainability performance. Complementing quantitative data analysis with qualitative methods, to articulate relationships between drivers of adoption distribution and their consequences for regional sustainability, may help address this challenge. Network analysis may be particularly appropriate, being designed to describe and summarise key features of complex systems with many interactions between components. Therefore, the next chapter connects drivers of adoption to sustainability performance at the regional level by using a qualitative assessment framework that employs network analysis together with scenario analysis and impact mapping.

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Chapter 5: A Territorial Sustainability Assessment of Ecological Farming Approaches in south-east England

5.1. Introduction

Different approaches to farming are associated with different types of positive and negative impacts on society and the environment (Abler, 2004; Jespersen et al., 2017; Renting et al., 2009). Much of modern, intensive agriculture has disrupted ecosystem functions in a way that undermines future food production and compromises delivery of other ecosystem services necessary for human health and well-being (Campbell et al., 2017). There is a need, therefore, to ensure that agriculture can meet current food security and nutritional needs in a way that does not compromise the environmental, social, and economic foundations for the well-being of future generations (Timmermans et al., 2014).

A variety of alternative farming approaches have been proposed to contribute to this aim, attempting to mitigate the negative environmental impacts of conventional agriculture. The focus of these approaches ranges from simply increasing the efficiency of conventional practice, to fully redesigning agroecosystems so their operation is based on naturally occurring ecological processes (Gliessman, 2016). Despite this diversity, there are some common features, linking agricultural land management to ecological performance, that can be used to describe these approaches. These include soil conservation (preserving soil structure and biochemistry to support long-term productivity) (Gomiero, 2016; Schreefel et al., 2020), reducing input intensity (in terms of total input quantity) (Parr et al., 1990), increasing internal integration (reliance on inputs produced within rather than outside the farm) (Biala et al., 2007), and promoting ecological infrastructure (habitats that can support biodiversity within the farmed environment) (Hass et al., 2018). Based on these management features, it is possible to classify farms based on their management from an 'ecological' perspective. Rega et al., (2021) took this route to identify six different farming approaches, each characterised by the adoption of a particular set of practices at the field or farm level: standard (or conventional) farming, conservation agriculture, low-input farming, integrated / circular farming, organic farming, and agroecological farming.

If these alternative farming approaches are to be used in a way that maximises their contribution to solving the challenges facing agriculture, it is important to have a full understanding of their costs and benefits, and the factors affecting their performance. Classifying farms according to the uptake of ecological practices provides a useful framework

for research, because in order to be able to assess the potential of a given type of farming to address the negative impacts of intensive agriculture, it is necessary to define what is being assessed. While the labels used by Rega et al., (2021) have not always been used consistently by researchers or practitioners (Findlater et al., 2019; Stavi et al., 2016),there have been some studies of the impacts of these different farming approaches. A number of analyses and meta-analyses have attempted to assess and compare their performance from environmental, social, and economic perspectives, and these studies often conclude that more ecological alternatives to conventional agriculture can indeed deliver many of the desired environmental benefits (Bernués et al., 2011; Craheix et al., 2016; Pittelkow et al., 2015; Reganold & Wachter, 2016; Seufert et al., 2012). However, the different approaches may not be beneficial for every ecosystem service, there is sometimes ambiguity concerning their performance for certain ecosystem services, and the extent to which these approaches can reconcile environmental benefits with social and economic performance continues to be debated (Craheix et al., 2016; Govaerts et al., 2009; Powlson et al., 2014).

The concept of sustainability provides a framework that can be used to evaluate and compare the overall performance of different farming approaches accounting for the various social, economic, and environmental criteria (Dobbs & Pretty, 2008; Gerrard et al., 2012). Applying sustainability concepts to impact assessment has spawned many sustainability assessment techniques and frameworks, which evaluate the sustainability implications of an initiative, to integrate sustainability into decision-making (Pope, 2006). Some assessment frameworks are designed for evaluating the sustainability of an existing system, using indicators to compare sustainability performance with other systems, against reference points, or baseline values (Bausch et al., 2014; Bockstaller et al., 2015; Dillon et al., 2016). Other assessments are used to compare future scenarios, and in this context, can be used to inform planning or policy development, or simply as an exploratory approach to guide decision-makers (Fauré et al., 2017).

Sustainability assessments of agriculture at the farm level are widespread in the literature, and a recurring theme across many of these agricultural assessments is the idea that the sustainability performance of different farming approaches depends on the circumstances in which they are applied (Coteur et al., 2016). Given that each farming approach performs differently, and may be more or less effective under different conditions, no single approach may be a universal solution, with different options being more appropriate for different contexts (Fraser et al., 2016). Understanding how the sustainability of different farming approaches varies with context helps ensure that each approach can be implemented where it is most

effective (Fraser et al., 2016). The performance of ecological approaches relative to conventional agriculture, in terms of ecosystem service delivery, yields, and other socio-economic impacts, has been linked to features of the natural environment such as soils, climate, and erosion hazard, as well as socio-political and technical conditions, such as national or local policy regimes, and farmer expertise and education (Baccar et al., 2019; Coteur et al., 2016; Seufert et al., 2012). This means that we could expect the sustainability of a farming approach to be closely linked to the characteristics of the territory where it is implemented.

Moreover, when considering the sustainability performance of ecological farming in a territorial context, it becomes necessary to account for interactions between farms alongside farm-level impacts (Payraudeau & van der Werf, 2005). Ecological farming impacts can be influenced by the spatial configuration as well as rate of adoption of farming approaches across the landscape (Batáry et al., 2011; Gabriel et al., 2010; Winqvist et al., 2011). Therefore, a holistic understanding of the performance of a farming approach should not isolate that approach from the context in which it is applied, and must account for its territorial impacts (Graymore et al., 2008; C. S. Smith & Mcdonald, 1997). There is a well-established body of research assessing the environmental impacts of different farm management practices at the territorial scale, using a variety of methods (Payraudeau & van der Werf, 2005). Some of these studies have also incorporated social and economic criteria to provide a more comprehensive assessment of agricultural performance, but territorial sustainability assessment of agriculture has remained a neglected and underdeveloped research area, especially with regards to the relationship between spatial configuration of farming approaches and territorial sustainability (Inwood et al., 2018; Payraudeau & van der Werf, 2005).

Given the links between agricultural sustainability performance, farm spatial distribution, and other territorial characteristics, there is a need for further research into the territorial sustainability of ecological farming approaches. While quantitative indicator-based assessments are widely used in farm level studies, indicators for territorial agricultural sustainability are still in their infancy (Inwood et al., 2018; Nogués et al., 2019). Quantitative data can also be used in scenario-based assessments by generating indicator values through model simulations using different assumptions about processes of change (Oudshoorn et al., 2011), but the nature of scenario research makes it well suited for integration with qualitative methods. Rather than precisely quantify the future performance of a given option, scenario analysis aims to illustrate the range of possibilities for a system, and provide decision makers with an idea of the space for manoeuvring within (Aligica, 2005; G. D. Peterson et al., 2003). Qualitative approaches can

accommodate the inherent uncertainties associated with discussing futures, and so align with the basic premise of scenario-based research (Arushanyan et al., 2017).

Therefore, a scenario-based assessment provides opportunities for an in-depth study of territorial agricultural sustainability using qualitative methods, avoiding some of the current challenges associated with using quantitative indicators at the territorial level (Inwood et al., 2018; Ness et al., 2007). In particular, the qualitative mapping of impacts on different aspects of sustainability can be used to assess scenarios in terms of their contribution towards aspirational sustainability objectives, using expert and stakeholder consultation to generate matrices showing how drivers of change under each scenario impact objectives (Baard et al., 2012; Sheate et al., 2008). However, a purely matrix-based approach assumes each driver acts in isolation, but a territorial assessment considers a complex system, where drivers may interact, and impacts on objectives will be the product of interdependent cause-effect relationships. Consequently, it may also be useful to employ network analysis, which describes the relationships between entities and their influence in a system, to explore causal links between drivers, impacts, and objectives, and identify pathways crucial for determining sustainability performance (de Nooy et al., 2018; Tzanopoulos et al., 2011).

A combination of scenario analysis, qualitative impact mapping, and network analysis is therefore well-suited for studying the territorial performance of alternative ecological farming approaches, to help determine how these approaches can be best used to address the negative impacts of modern agriculture and contribute towards a sustainable food system. Thus, the aim of this study was to use this suite of tools to conduct a territorial sustainability assessment of ecological farming approaches, for two differing, but comparable, study areas in south-east England. The specific objectives were a) to investigate how the frequency and distribution of ecological farming approaches may affect their environmental, social, and economic performance; b) to explore how ecological farming approaches perform against regionally tailored sustainability objectives; and c) using drivers-to-impact network analysis to identify key causal relationships contributing to the overall sustainability performance of different ecological farming adoption scenarios.

5.2. Methods

5.2.1. Study areas

In order to investigate how the sustainability of ecological farming may vary according to the territorial context, it was important to choose study areas that are different enough to potentially affect the relative performance of ecological approaches (Graymore et al., 2008; C. S. Smith & Mcdonald, 1997), but also similar enough to let us make meaningful comparisons between them. The selection of the High Weald Area of Outstanding Natural Beauty (AONB) and North Kent, two regions in south-east England (Fig. 5.1), satisfied these criteria. Agriculture is a dominant land use in both areas, which experience a similar mild temperate climate, and farmers are subject to many of the same policy and market drivers. However, there are also marked differences in the characteristics of the agricultural sector in each area: the High Weald is dominated by small livestock farms, while North Kent is a more diverse agricultural landscape with a greater frequency of medium and large farms (Natural England, 2013a, 2015). The two areas differ in terms of physical geography, such as soils and terrain, and the role of human factors, such as urbanisation, population demographics, socio-economic status, and cultural heritage. Therefore, while the two study areas have much in common, their differences let us explore different ways in which ecological farming approaches may fit into wider land use systems.

North Kent

This area includes the part of south-east England between the high ground of the North Downs in the south and the Thames Estuary in the north (Fig. 5.1). The chalk hills of the North Downs, with poorer, flinty soils, give way to the North Kent plain, a large area of fertile loam soils (Natural England, 2015). The coexistence of arable, livestock and horticultural systems has generated a complex pattern of agricultural land uses in the area (Natural England, 2015). However, recent agricultural intensification has favoured the spread of arable land, particularly at the expense of traditional orchards and coastal grazing marsh: habitats that are also under pressure from the region's rapid industrial and urban development (Cobb, 2010; Natural England, 2015). At the same time, there are examples of close engagement with agri-environment schemes in the region. The North Kent Marshes Environmentally Sensitive Area (ESA) was created in 1995, making it a priority region for implementation of stewardship schemes (Cobb, 2010). The Kent Downs AONB covers the southern part of the study area, and

close relationships between AONB management, advisors, and farmers, have built large-scale conservation networks across neighbouring farms (Kent Downs AONB, 2021; Tuson, 2021).

High Weald AONB

The High Weald is an area of sandstone hills lying between the North and South Downs in south-east England (Fig. 5.1), covered by a mosaic of small farms and woodland (High Weald Joint Advisory Committee, 2019). The region is nationally significant as a rare example of a relatively intact medieval landscape, the product of grazing practices associated with the persistence of traditional extensive livestock systems on poor soils (Tubbs, 1997). Declines in High Weald livestock numbers during the late 20th and early 21st century have been highlighted as cause for concern, because this threatens the ecology, rural economy, and landscape character of the area (Vorley, 2013). While the High Weald falls within a regional hotspot of organic farming (Gabriel et al., 2009; B. Ilbery & Maye, 2011), rates of engagement with agri-environment schemes have been notably lower than the national average (Vorley, 2013). With some support from facilitators and extension officers, including AONB management representatives, the area has begun to see the development of landscape-level networks of farmers for the implementation of ecological practices (High Weald AONB, 2019).

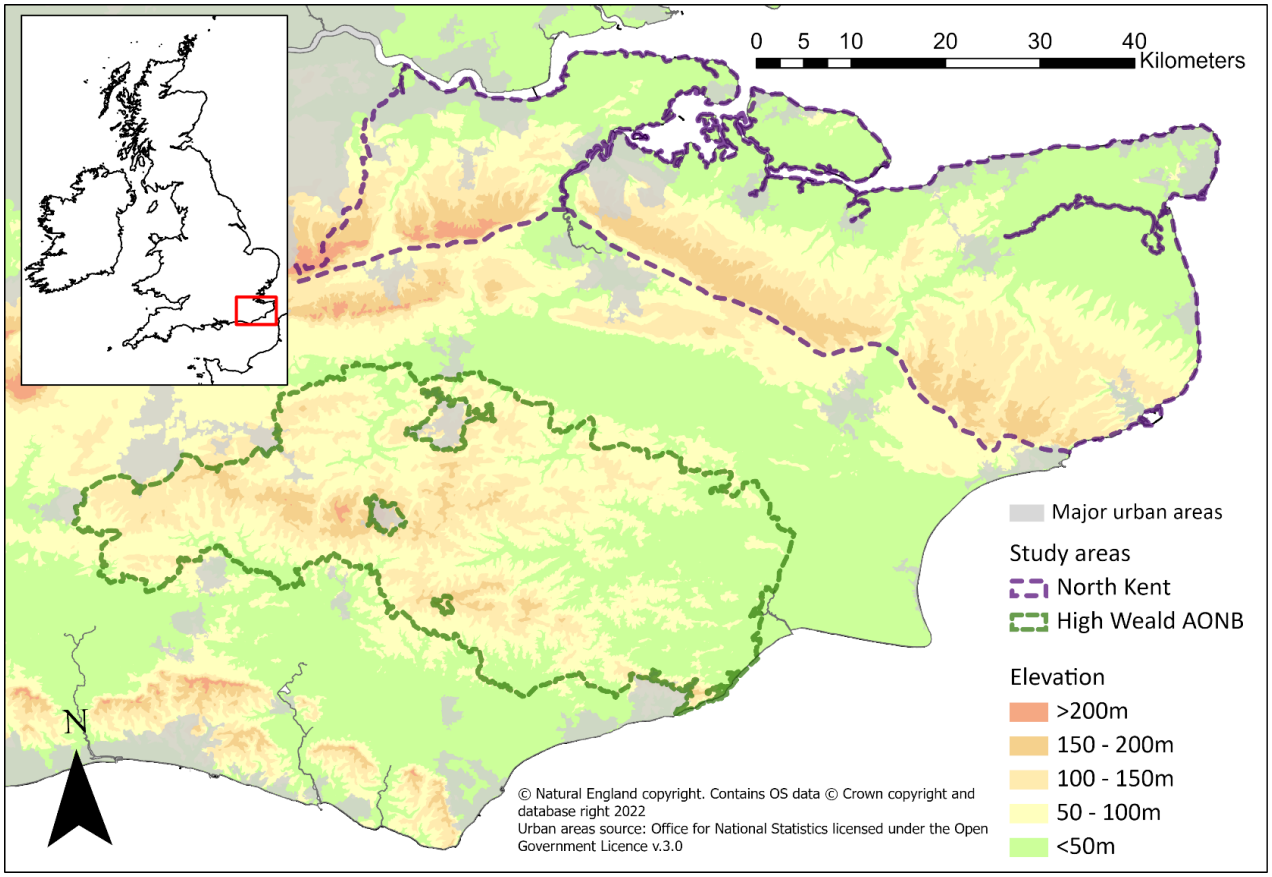

Figure 5.1. Map of south-east England, showing the locations of the two study areas for the sustainability assessment: North Kent and the High Weald AONB

5.2.2. Methodological approach

Drawing on the framework developed by Sheate et al. (2008) and Tzanopoulos et al. (2011), this methodology combined scenario analysis, qualitative impact mapping, and network analysis to assess the territorial sustainability of ecological farming. The need for close stakeholder involvement is recognised as vital for effective sustainability assessment (Fauré et al., 2017; J. B. Morris et al., 2011), so the process includes a strong participatory element, with stakeholder consultation required for each step, alongside interdisciplinary researcher discussion. The main features of this approach are summarised in Fig. 5.2 and explained in detail below.

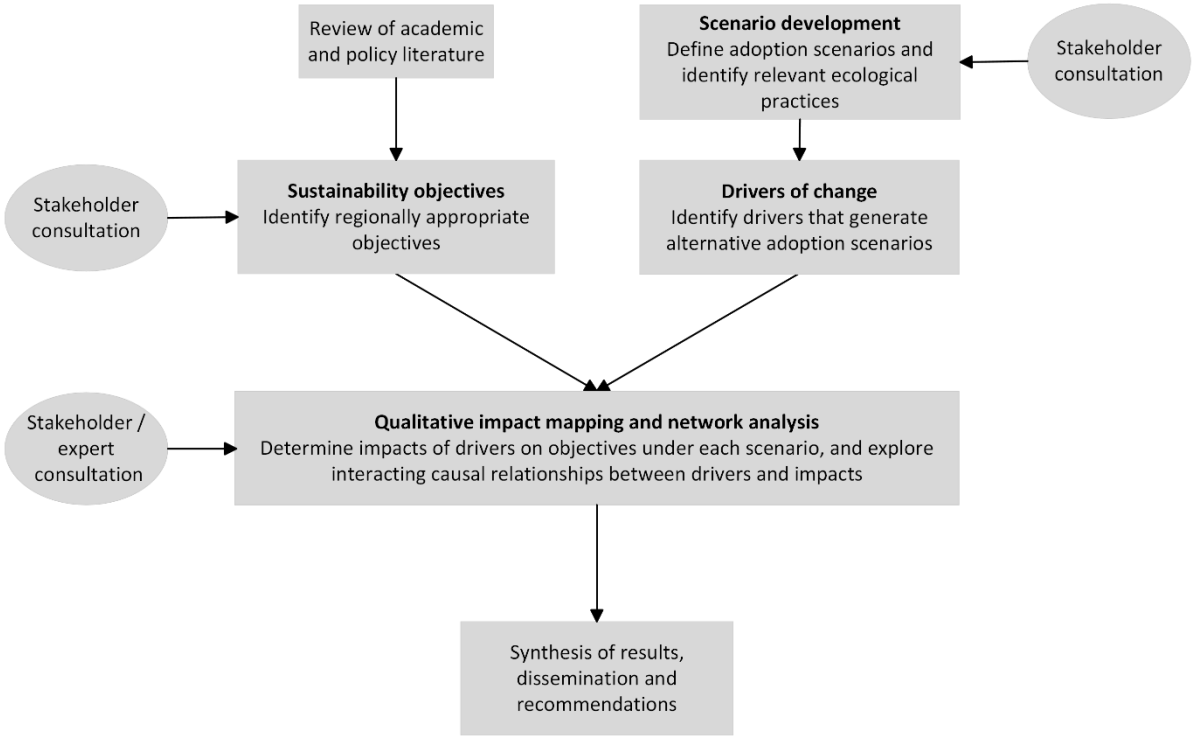

Figure 5.2. An overview of the sustainability assessment methodology, showing the how the different steps of the process fit together, and the role of stakeholder input

5.2.3. Defining the sustainability objectives

This assessment used a combination of conceptual models, tiering, and stakeholder consultation (Hacking & Guthrie, 2006), in a 3-stage process to generate specific and meaningful sustainability objectives relevant to the case study areas.

The first step involved screening the agricultural sustainability literature to compare the structure and content of objective and indicator lists in other assessments, identifying areas of overlap, and consolidating the different lists into a single generic set of agricultural sustainability objectives.

Next, the local context for the objectives was established by reviewing national, regional, and local policy documents that covered objectives for a range of environmental, economic, and social issues. These objectives were merged with the list of objectives from agricultural assessments to produce a draft list of 50 objectives for the study areas (Table S5.2, Table S5.3).

Finally, this long list of objectives was refined and prioritised using stakeholder input: 22 stakeholders gave their opinion on the significance of each objective for local sustainability. Stakeholders were chosen for their landscape-scale perspectives and knowledge of the study areas and represented a diversity of areas of expertise, including catchment managers, farmer cluster officers, members of countryside partnerships, local authority representatives, and social and environmental non-governmental organisations and charities (Table S5.4).

Since the two study areas were only about 20km apart, it was not always possible to identify stakeholders with an area of expertise tied to just one of the areas or make a clear distinction between stakeholders in terms of the area they were most familiar with. While some stakeholders were closely associated with one of the study areas, others operated in an area that overlapped both study areas. However, across all stakeholders, there was a high degree of consistency in the way they prioritised the objectives, so the decision was made to pool the input from all stakeholders to create one list of objectives that was relevant to both study areas.

Based on the significance assigned by the stakeholders to each objective, the most important objectives representative of 3 different sustainability dimensions (environmental, social, and economic) were selected to produce a short list of 20 objectives. The objectives were then subject to a final review by researchers, where the decision was made to merge 2 pairs of objectives with overlapping definitions, leaving a final list of 18 objectives for use in the assessment (Table 5.1).

Objective		Description
Biodiversity and ecosystem services		
O_1	Semi-natural habitat and biodiversity	To conserve and restore characteristic semi-natural habitats and the biodiversity they support, enhancing habitat connectivity to support functional and resilient ecological networks
O_2	Greenspace access and public use	To maximise accessibility to high quality, natural spaces that the public can use for the benefit of their well-being, and increase public understanding of/engagement with the natural environment
O_3	Flood risk reduction	To reduce the risk posed by flooding to people, the environment, and the economy
O_4	Water quality	To protect and improve water quality
O_5	Water availability	To protect and improve the availability and continuity of the local water supply, and adapt to anticipated risks of shortages in the water supply
O_6	Carbon storage and sequestration	To protect and restore natural carbon stores and increase carbon sequestration
Social development and institutional capacity		
O_7	Quality of life and public health	To increase the quality of life, health, and well-being of those living and working in the region, including minimising threats to public health
O_8	Health equality	To reduce inequalities in health and life expectancy
O_9	Housing equality	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
O_{10}	Natural beauty and scenic value	To ensure that the natural beauty and scenic value of the region is recognised, conserved, and enhanced
O_{11}	Biosecurity and disease control	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
O_{12}	Political democracy	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
O_{13}	Community wellbeing	To enable community members to support each other, according to their values, encouraging cohesion within diverse and distinctive communities, recognising the needs and contributions of all
O_{14}	Landworker rights and conditions	To protect labour rights and good working conditions for farmers and agricultural workers
Rural economic development		
O_{15}	Farm business resilience to crisis	To increase the resilience of farm businesses to crisis / external events
O_{16}	Reduced farm reliance on external inputs	To increase farm self-sufficiency in terms of resource use, minimising reliance on external inputs on the farm
O_{17}	Stable employment	To increase the level and stability of local employment and income, so everyone has the chance to benefit from economic growth in the region
O_{18}	Local resource-based livelihoods	To promote new livelihood opportunities based on local resources

Table 5.1. Final list of sustainability objectives identified for the High Weald and North Kent study areas, based on a review of academic and policy literature, and a stakeholder prioritisation exercise

5.2.4. Scenario development and identifying drivers of change

The subjects of the sustainability assessment were a set of 4 scenarios for ecological farming adoption. These scenarios had a 10-year time horizon and differed in terms of adoption rate and distribution:

- **Scenario 1**: **High** adoption (50% of farms) of ecological farming in a **clustered** pattern
- **Scenario 2**: **High** adoption (50% of farms) of ecological farming in a **dispersed** pattern
- **Scenario 3**: **Low** adoption (10% of farms) of ecological farming in a **clustered** pattern
- **Scenario 4**: **Low** adoption (10% of farms) of ecological farming in a **dispersed** pattern

The rates appropriate for high and low adoption scenarios were determined through stakeholder discussion regarding different feasible directions for ecological farming adoption in the study areas.

'Ecological' farming encompasses a range of approaches, so it was necessary to specify the farming approaches relevant to the scenarios. We achieved this using the aforementioned categories developed by Rega et al., (2021). For each study area, a panel of 10 expert stakeholders ranked farming practices according to their importance in defining an ecological farm within the context of the study area. Although the Rega et al., (2021) system was designed to classify farms based on farm-level data, because each type of farming approach is associated with a particular combination of practices, it is also possible to link the dominant practices in the ranking exercise with a certain farming approach, or mix of approaches (the different approaches are not mutually exclusive, so a single farm can belong to more than one approach). Therefore, the ranking exercise output (Tables S5.7 & S5.8), along with stakeholder feedback during the exercise, helped characterise ecological farming in the scenarios for each study area.

For the High Weald, the most important practices reflected a mix of integrated/circular farming, low-input, and conservation agriculture. However, stakeholders thought mixed farms would only constitute a minority of ecological farms in the High Weald, so integrated/circular farming would only play a minor role in the scenarios. Stakeholders settled on a mix of **conservation agriculture** and **low-input farming**, with a focus on livestock management, as the focus of ecological farming in the High Weald.

In North Kent, the dominant practices reflected a blend of practices in conservation agriculture and integrated/circular farming approaches. Again, however, subsequent discussion suggested that only a minority of ecological farms in the area would be mixed, so stakeholders settled on **conservation agriculture** as the best fit for ecological farming in North Kent.

With the scenarios defined, the rate and distribution of adoption in each scenario could be described as the product of drivers of change. A driver could affect the rate and/or distribution of adoption in different ways depending on the scenario.

The starting point for identifying the drivers of change was the set of themes generated from interviews with 18 farmers in the study areas (as described in chapters 2 and 3). Within these interviews, farmers were asked about how the perceived sustainability of local land management had changed over the course of their career, and their expectations for how this could change in the future and why. They were also asked to recount any major changes in their approach to farming, and the reasons they made these changes, as well as their ideal scenarios for the future of their farm and local area, and possible routes or barriers for achieving these scenarios. The responses to these questions provided a rich source of material to begin teasing out locally relevant drivers of change. Thematic analysis of the farmer responses identified many candidate drivers of change, and possible pathways to explain how they could deliver impact. To narrow down this list of drivers, expert opinion (academics with economic, social, and geographical expertise, alongside key local stakeholders) was consulted as to what drivers they thought would be most important in contributing to the differences between scenarios. This process produced a final shortlist of potential drivers, and an explanation for how each could contribute to the different patterns of adoption under the four alternative scenarios (Table S5.9).

5.2.5. Qualitative impact mapping and network analysis

With the scenarios, drivers of change, and objectives defined, the next stage of the assessment involved determining how the drivers of change impacted the objectives under each scenario. Network graphs, initially developed using expert discussion along with relevant academic and grey literature, were used to represent the cause-effect relationships linking drivers to impacts. In these graphs, the vertices, or nodes, represented the drivers of change, their impacts, and the objectives, while the lines represented the causal relationships between them. The graphs were refined using feedback from a final round of stakeholder consultation, targeting participants with strong knowledge or an overview of at least one of the sustainability dimensions in the study area.

In this final round of consultation, the network graphs were presented to small groups of stakeholders or experts (the participants for this exercise are listed in Table S5.10). The meaning of the network graphs, and the key causal pathways shown, were explained to the participants, who were then asked whether they thought these patterns of cause and effect made sense, and

whether there were any major omissions or errors. The networks were also used to generate a set of questions as prompts for discussion during these workshops, to help participants talk though the pathways to impact under each scenario. Based on the participant responses in these sessions, lines and nodes in the network graphs were altered, added, or removed to produce the final graphs, ready for network analysis. The construction of the network graphs, and their subsequent analysis, as described below, was performed using the network analysis software Pajek version 5.14 (de Nooy et al., 2018).

The finished networks and stakeholder feedback were used to complete a qualitative assessment matrix for each scenario, which summarised driver impacts on objectives, and indicated if these impacts were positive or negative, strong or weak, or uncertain. These impacts were aggregated to show the scenario's overall performance, with the results for all scenarios summarised in a scenario comparison matrix, following the process for qualitative impact aggregation described by (Sheate et al., 2008) and (Partidário et al., 2009).

The assessment matrices provide a basic representation of the direction and magnitude of impacts on objectives, but the inclusion of the network graphs made it possible to build a more nuanced understanding of the impacts on objectives under each scenario – allowing, for example, for the possibility of non-linear responses to change in the scenarios. Cause-effect links could be drawn from drivers of change to their consequences (i.e., the intermediate nodes in the graphs), but also from these consequences back to the drivers of change, which could be used to represent feedback loops – where state of the drivers of change under a certain scenario have effects that in turn reinforce or mediate the effects of these drivers.

Moreover, while the assessment matrices summarised the overall contribution of each scenario to the objectives, the network graphs created an opportunity to use network analysis to find key pathways and features underpinning the sustainability performance of the scenarios. Exploratory network analysis techniques assess vertex properties that characterise their role in the network structure and identify particularly well-connected vertices that play a disproportionately important role in the network (de Nooy et al., 2018). In the sustainability assessment, this means it is possible to identify those elements of the system that are primarily responsible for a scenario's performance.

The appropriate network analysis techniques depend on whether a network is directed (where the order between a pair of vertices does not matter) or undirected (where the order of the vertices is important) (de Nooy et al., 2018). In the networks for this sustainability assessment, the order of the vertices does matter, because in a pair of vertices, one represents the cause

and the other represents the effect. Therefore, these graphs were treated as directed networks, with arrows used to signify the direction of cause and effect. In directed networks, the relative importance of a vertex can be described in terms of structural prestige, where more prestigious vertices send or receive more connections to or from other parts of the network (de Nooy et al., 2018). The proximity prestige of a vertex is a useful measure of structural prestige that gives more weight to connections with closer neighbours (de Nooy et al., 2018; Zhao et al., 2015). Proximity prestige values were calculated for each node in the networks, and those nodes with the highest proximity prestige could be expected to play a pivotal role in scenario performance.

The output from the matrices and network analysis could then be used to build narratives that draw upon expert discussion, stakeholder feedback, and the wider literature, describing the processes of change that explain the sustainability performance of each scenario, and highlighting key messages relevant to policy. In this context, an objective-led assessment helps to simplify the process of communicating results to stakeholders and policy makers, succinctly demonstrating how to achieve policy targets and minimise trade-offs (Olsson et al., 2009; Pope et al., 2004). This assessment therefore provides a valuable tool for identifying options and making recommendations for strategic decision making for territorial sustainability in the study areas.

5.3. Results

5.3.1. Overall scenario comparison

The qualitative mapping of impacts on sustainability objectives showed how the rate and distribution of ecological farming adoption could shape territorial sustainability in North Kent and the High Weald. For ease of visualisation, the results from the scenario comparison matrices are presented using radar charts, by converting the assessment scores into a simple ordinal scale (Fig. 5.3 and Fig. 5.4).

Across both study areas, higher rates of ecological farming adoption were associated with more positive impacts on most environmental, social, and economic objectives, so an increase in the proportion of farms adopting ecological approaches could make a largely positive contribution to territorial sustainability in North Kent and the High Weald. With regards to the distribution of adoption, clustered adoption made a more positive contribution to territorial sustainability than dispersed adoption. Therefore, the high clustered adoption scenario was associated with the strongest sustainability performance in both study areas. This scenario positively impacted a range of objectives encompassing different dimensions of sustainability, indicating the potential to achieve many different objectives simultaneously under a high clustered adoption pattern.

While adoption clustering enhanced performance against a variety of sustainability objectives, its impact was particularly clear for the environmental objectives. Performance against most environmental objectives was stronger under clustered adoption, but the impact of adoption distribution was more variable for the social objectives, and largely absent for the economic objectives. This meant that the overall difference in sustainability performance due to adoption distribution was smaller than the difference due to adoption rate.

Although the high clustered scenario showed the strongest sustainability performance overall, it was not necessarily the best option for every objective, nor was it always associated with positive impacts on objectives. Some objectives showed a negative or negligible impact under one or both of the high adoption scenarios, and there were at least some objectives for which an alternative scenario performed at least as well as the high clustered scenario, and these objectives were not always the same in each study area.

In North Kent, housing equality was strongly positively impacted under low adoption scenarios, and negatively impacted under high adoption. This was primarily due to the association between urbanisation increasing availability of affordable housing, and a restructuring of the

agricultural sector that favoured the dominance of larger farms (profiting from the sale of land for housing) less likely to apply ecological approaches (as described in the network analysis interpretation below). Conversely, a lack of urban development and access to affordable housing characterised the high adoption scenario, so the benefits of high ecological farming adoption may need to be balanced against the detrimental impact on housing equality. Reconciling environmental and economic territorial performance with housing equality could therefore be a particular challenge for North Kent.

In some cases, participants could not conclusively determine how different scenarios would impact an objective. There was a lack of certainty over the link between ecological farming adoption and overall employment in both study areas. How the adoption of ecological approaches relates to regional employment levels may therefore be a priority area for research and engagement, to establish a consensus on whether the territorial performance of ecological farming in terms of employment aligns or conflicts with other objectives.

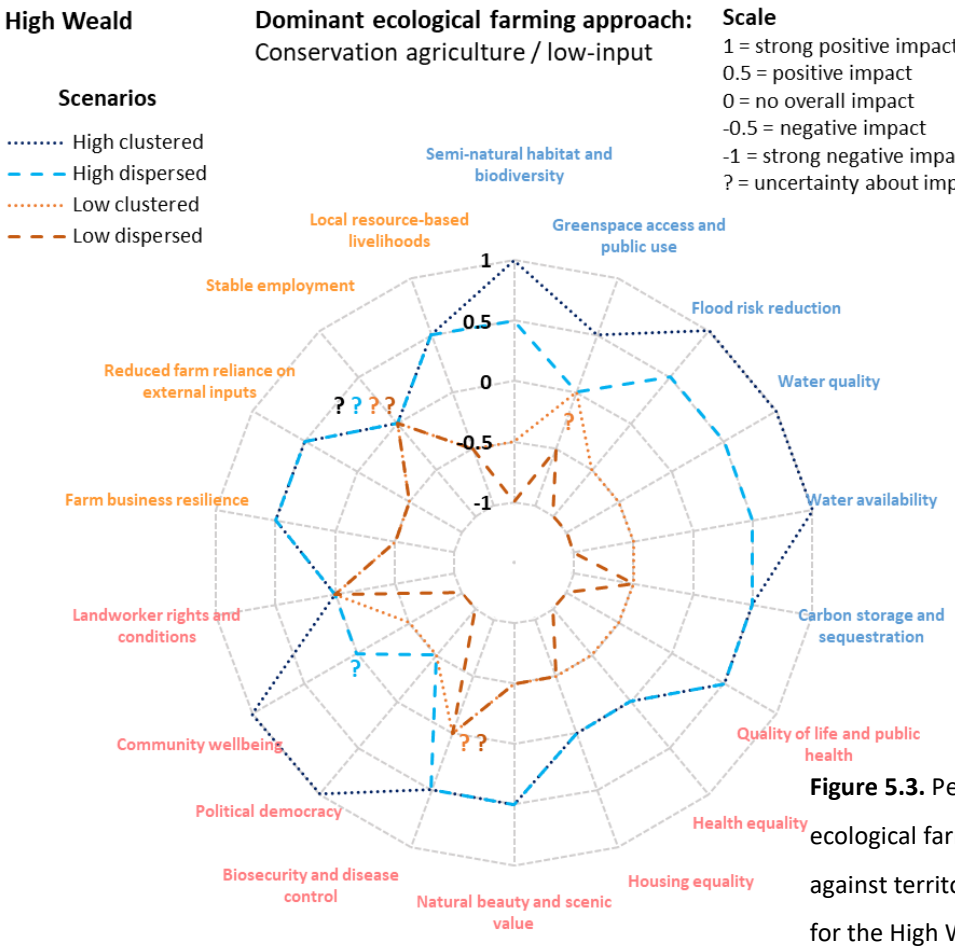

Figure 5.3. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for the High Weald

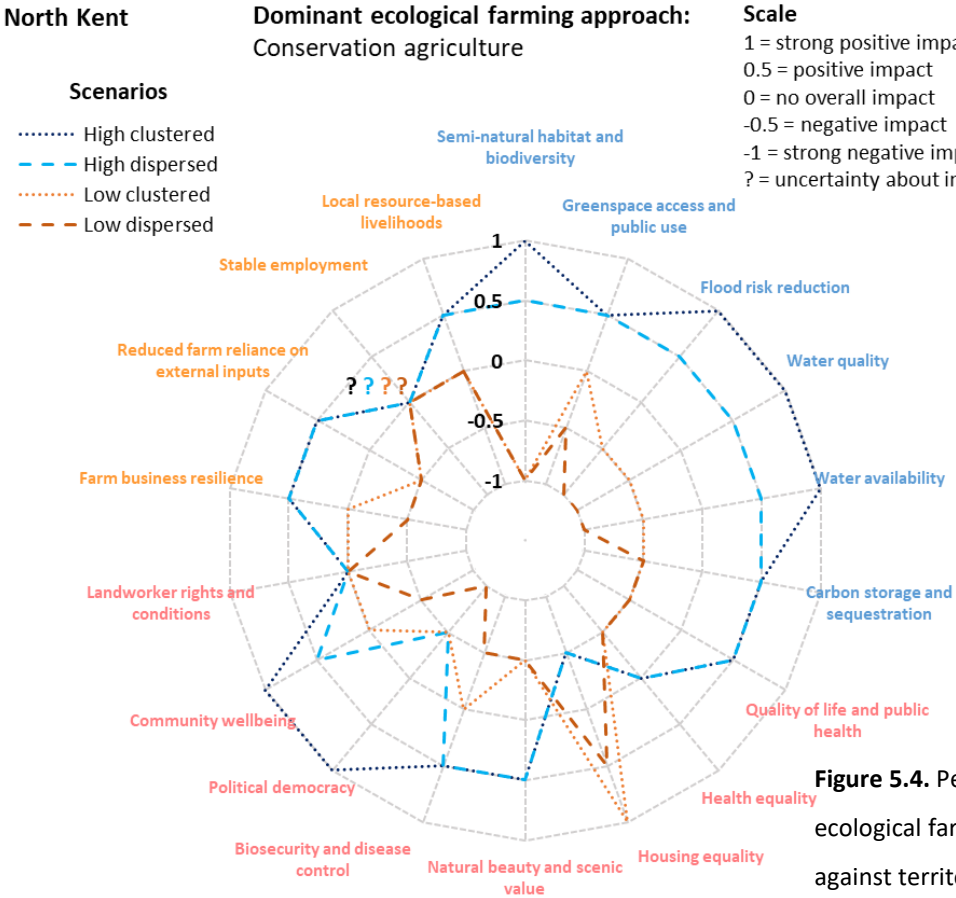

Figure 5.4. Performance of alternative ecological farming adoption scenarios against territorial sustainability objectives for North Kent

5.3.2. Network analysis – common features across both study areas

The processes explaining the differences in scenario performance, both at the overall level, and for specific objectives, can be explored by considering the network graphs for each scenario. While the networks show that the causal relationships underpinning the territorial sustainability of ecological farming approaches are complex and interdependent, by identifying the most influential nodes in the networks (those with the highest proximity prestige, highlighted in the graphs, Figs. 5.5 – 5.8, Figs. S5.9 – S5.12), it is possible to focus on some key insights from the results.

As reflected in the overall impact mapping results, within each study area, the greatest differences in network structure are seen when comparing the networks for the high and low adoption scenarios, with fewer differences in network structure due to adoption distribution. Therefore, the main causal pathways contributing to territorial sustainability performance are largely the same in the clustered and dispersed scenarios for a given adoption rate.

Moreover, the overall structures of the network graphs for the High Weald scenarios (Figs. 5.5, 5.6, S5.9, S5.10) resemble those for North Kent (Figs. 5.7, 5.8, S5.11, S5.12), with many of the same linkages and most prestigious nodes appearing in both study areas. These key nodes and pathways that are shared across the study areas may reflect general factors that are important for the territorial sustainability of ecological farming regardless of differences in local context and land use patterns.

Ecological farming practices and restoration of soils and habitats

In the high adoption scenarios (clustered and dispersed) for both study areas, the nodes reflecting farm-level features of the ecological approaches being adopted, namely the occurrence of conservation agriculture or low input practices, and associated soil or habitat restoration, occupy the most influential positions in the networks. Drivers of change were chosen in part for their potential to affect these aspects of agricultural land management, and so most drivers are directly or indirectly linked to these two nodes, which also positively impact a range of environmental, social, and economic sustainability objectives (Hobbs et al., 2008; Palm et al., 2014). Therefore, the farm level features of an ecological approach are central to the potential for the high adoption scenarios to reconcile positive performance across different aspects of territorial sustainability.

Conversely, in the low adoption scenarios, the intensification of agriculture, and degradation of soils and habitats, were the most important nodes, reflecting the absence of ecological

approaches, and the dominance of conventional practices associated with negative effects on environmental, social, and economic sustainability objectives (Campbell et al., 2017; Tilman et al., 2002).

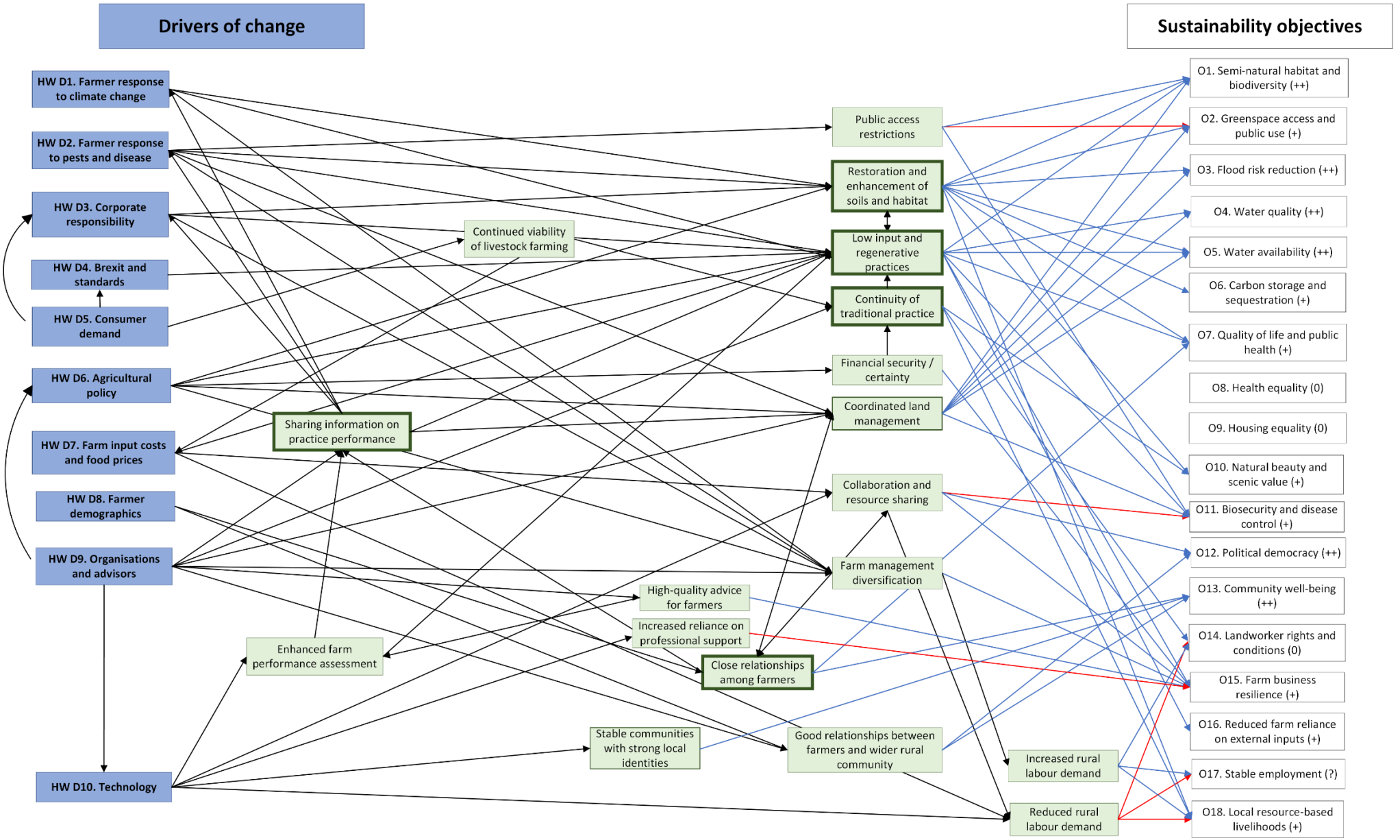

Figure 5.5. Network graph showing the key cause-effect relationships between the drivers of change, their consequences, and subsequent positive (blue lines) and negative (red lines) impacts on the sustainability objectives for the High Weald under **Scenario 1: high, clustered** adoption of ecological farming, which in this context is a blend of conservation agriculture and low-input farming, with a focus on livestock management (closely aligning with stakeholder views of regenerative agriculture). Boxes with thick outlines represent structurally key nodes in the graph (the top 25% of nodes with the highest proximity prestige values).

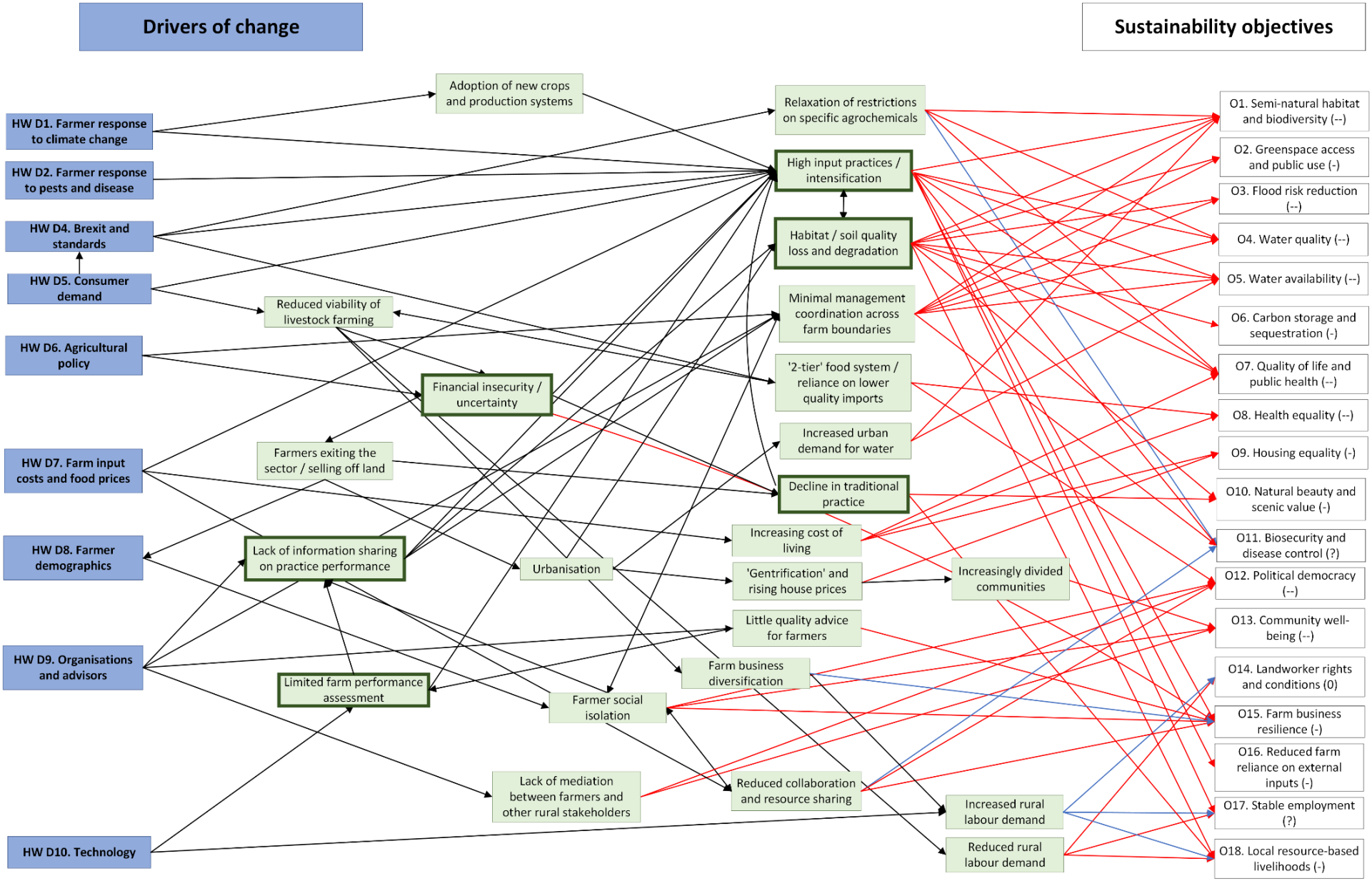

Figure 5.6. Network graph showing the key cause-effect relationships between the drivers of change, their consequences, and subsequent positive (blue lines) and negative (red lines) impacts on the sustainability objectives for the High Weald under **Scenario 4: low, dispersed** adoption of ecological farming, which in this context is a blend of conservation agriculture and low-input farming, with a focus on livestock management (closely aligning with stakeholder views of regenerative agriculture). Boxes with thick outlines represent structurally key nodes in the graph (the top 25% of nodes with the highest proximity prestige).

Access to information, farmer coordination, collaboration, and interpersonal relationships

While the aforementioned nodes represent farm-level features of this scenario with territorial-level sustainability implications, some of the other key nodes in the networks are associated with ways in which farmers across the landscape may interact to influence territorial sustainability.

One such node concerns farmer sharing of information on practice performance. The ability of farmers to learn for themselves how an ecological approach could benefit their own farm, due to this information sharing, was highlighted as vital to ensuring the high level of adoption that would deliver positive impacts across a range of objectives in this scenario. This information sharing was not only directly linked to the application of low-input and conservation agriculture practices, but also impacted the role of other drivers of change. Farmers may adopt ecological approaches as a strategy to increase resilience to climate change (D_1) or the spread of resistant pests and diseases (D_2) (Altieri et al., 2015; Altieri & Nicholls, 2017; Barzman et al., 2015), but would be unlikely to do so without some prior awareness of the performance of ecological approaches, which could come from the dissemination of knowledge from other land managers already implementing these approaches.

Two drivers directly contribute to farmer information sharing: use of technology (D_{10}), and support from organisations and advisors (D_9). In high adoption scenarios, enhanced and accessible technologies enable better assessments of farm performance that enable benefits of ecological approaches to be more clearly communicated to others (and farm inputs can be used more efficiently) (Dessart et al., 2019; Wandel & Smithers, 2000). External organisations and advisors, meanwhile, can mediate between farmers and facilitate information exchange (and help farmers access and use new technologies) (D'Emden et al., 2008; Kallas et al., 2010; Wossen et al., 2013).

The importance of information sharing was not just due to its role in increasing the adoption of ecological approaches, being also linked to adoption distribution. In particular, sharing spatial information on where different interventions are located, and how their combined impacts enhance ecosystem service delivery, can be an effective tool for communicating and engaging with farmers (Hauck et al., 2013), and support successful initiatives to coordinate management across different farms under a clustered adoption scenario. Clustered adoption makes it easier to coordinate practices across neighbouring farms, and this coordination can in turn be linked to further positive impacts on many of the environmental sustainability objectives, including biodiversity and habitat condition (O_1), greenspace access and public use (O_2), flood risk

reduction (O_3), and water quality (O_4) and availability (O_5) (Jarrett et al., 2015; Mckenzie et al., 2013).

Coordinated land management under clustered adoption directly contributes to environmental sustainability, but also indirectly links with social and economic aspects of territorial sustainability. Management coordination was associated with closer relationships between farmers, and closely connected farmers were in turn linked to improvements in quality of life for farmers and other rural workers (O_7), and more generally, rural community well-being (O_{13}) (Emery et al., 2017; Fandiño et al., 2006; Mills et al., 2011). Moreover, strong farmer relationships also promoted forms of collaboration that could support farm businesses in times of difficulty (O_{15}), and increase opportunities for farmers to get involved in collective action and represent their interests in decision-making processes (O_{12}) (Valentinov & Iliopoulos, 2013; Wynne-Jones, 2017).

In the high clustered scenario, close relationships between farmers are not only linked to coordinated management and collaboration, but also to the sharing of information on practice performance (Kroma, 2006; Risgaard et al., 2007). Therefore, the importance of the 'farmer relationships' node in this scenario's strong sustainability performance stems from its links with farmer collaboration and coordination, and its role in information exchange: connections between farmers are central to understanding how the clustering and rate of ecological farming adoption impacts territorial sustainability.

This linkage between farmer relationships and information sharing is missing when adoption occurs in a dispersed pattern, and so farmer access to information is less important for sustainability performance in the high dispersed scenario. Under this scenario, although farmers still benefit from accessible information on practice performance, the information primarily comes from advisors or use of technology for performance assessment. Access to information is no longer supported by close farmer relationships, and no longer contributes towards the coordination of management across farms, and so its role in the network is reduced.

The value of information for the territorial sustainability of ecological farming approaches is also illustrated by the importance of the inability of farmers to access information in the low adoption scenarios. In these scenarios, limited information sharing restricts farmer engagement with alternative ecological approaches, and instead reinforces the use of intensive practices, continued degradation of soils and habitats, and a focus on management within, rather than across, farms. Here, the failure to share information is the outcome of insufficient support from external organisations and advisors (D_9), a lack of technologies to help measure farm

performance (D_{10}), and demographic change disrupting farmer networks (D_8), increasing farmer social isolation. Therefore, the limited production and diffusion of information, contributing to farmer uncertainty over ecological farming performance (Dessart et al., 2019; Wandel & Smithers, 2000), becomes a key barrier to achieving territorial sustainability objectives.

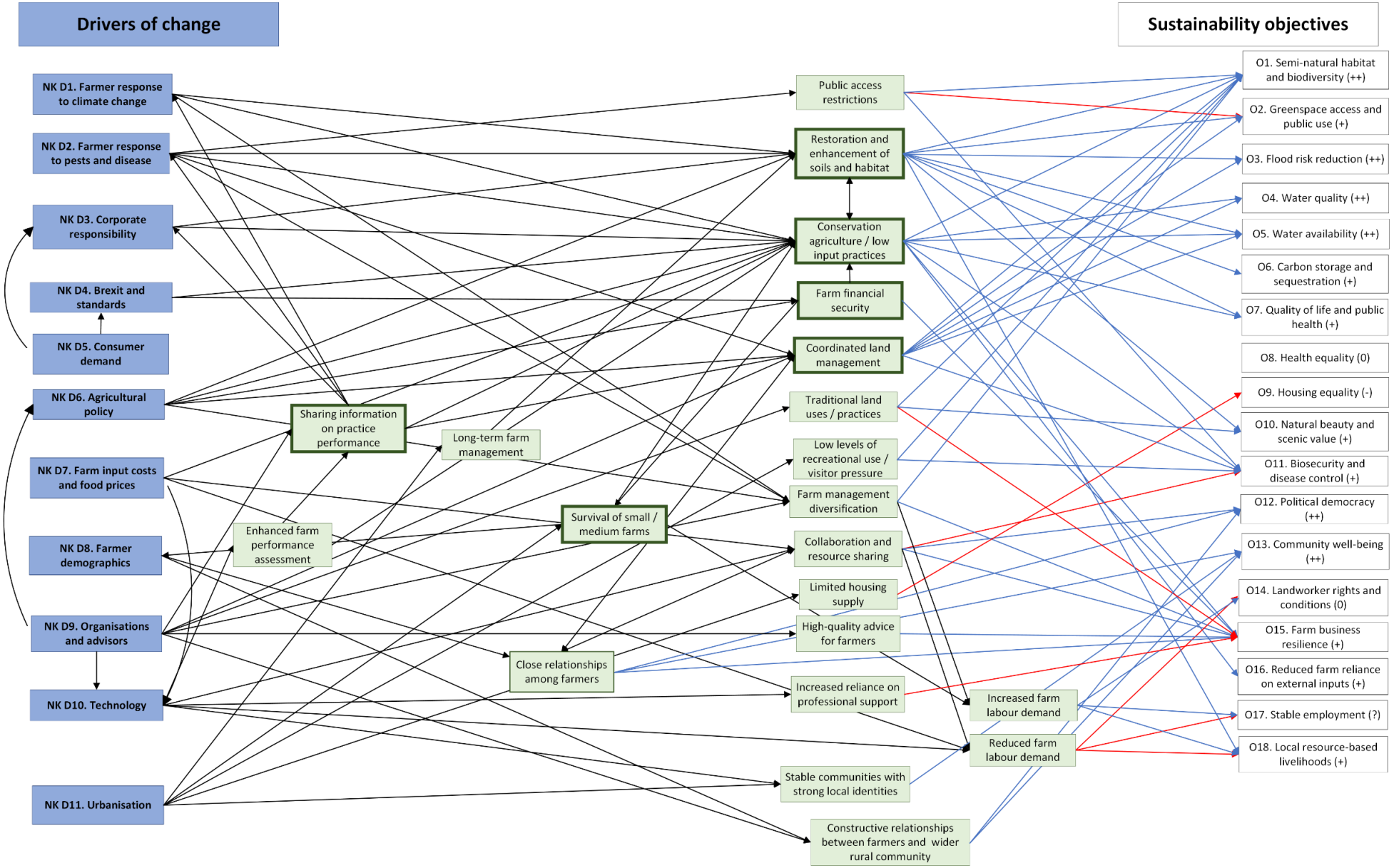

Figure 5.7. Network graph showing the key cause-effect relationships between the drivers of change, their consequences, and subsequent positive (blue lines) and negative (red lines) impacts on the sustainability objectives for North Kent under **Scenario 1: high, clustered** adoption of ecological farming, which in this context is dominated by a conservation agriculture approach. Boxes with thick outlines represent structurally key nodes in the graph (the top 25% of nodes with the highest proximity prestige values).

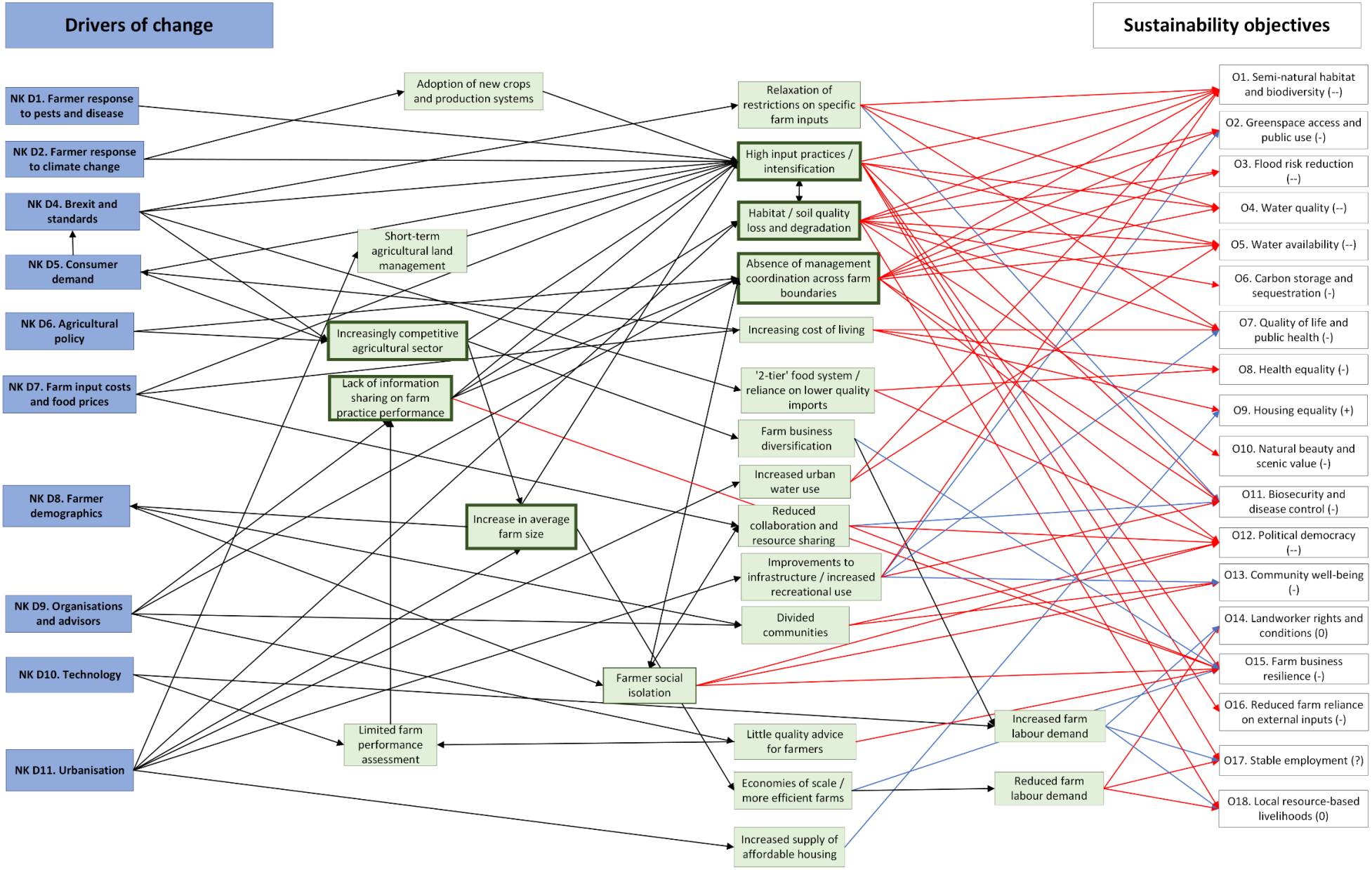

Figure 5.8. Network graph showing the key cause-effect relationships between the drivers of change, their consequences, and subsequent positive (blue lines) and negative (red lines) impacts on the sustainability objectives for North Kent under **Scenario 4: low, dispersed** adoption of ecological farming, which in this context is dominated by a conservation agriculture approach. Boxes with thick outlines represent structurally key nodes in the graph (the top 25% of nodes with the highest proximity prestige values).

5.3.3. Network analysis – differences between study areas

While network analysis identified several key nodes and pathways for the territorial sustainability of ecological farming approaches that were common to both areas, there were also factors that feature prominently in the scenarios for one study area but not the other. Some nodes were highly relevant to territorial sustainability in North Kent, but absent or downplayed in the High Weald, and vice versa. Equally, some influential nodes may appear in both study areas, but differ in terms of their connections to other parts of the network. These differences could suggest ways in which the territorial sustainability of ecological farming approaches may vary according to the local conditions.

Traditional land management practices

One of the most influential nodes for the high adoption scenarios in the High Weald concerns the continuity of traditional farming practices, while the decline of traditional practices dominated the networks in the High Weald's low adoption scenarios. This is primarily because achieving many of the sustainability objectives for the High Weald depends on the persistence of traditional extensive livestock farming that helped shape the region's distinctive landscape, underpinning its AONB designation (High Weald Joint Advisory Committee, 2019; Tubbs, 1997). Among other things, these low input livestock farms are important for the conservation of semi-natural habitats that depend on grazing (O_1), improving water quality (O_4), preserving the scenic value and landscape character of the area (O_{10}), and supporting land-based livelihoods that exploit the area's natural and cultural heritage (O_{18}) (Acebes et al., 2021; Agouridis et al., 2005; Derose et al., 2020).

However, while the continuity of traditional practices is key for sustainability in the High Weald, this was less important in North Kent. Outside the surviving areas of grazing marsh, North Kent lacks the strong association with a single type of traditional land use seen in the High Weald (Natural England, 2015). Under the high adoption scenario in North Kent, active conservation organisations (NK D_{10}) have the resources and relationships to promote low intensity farming systems, such as traditional orchards. However, while the maintenance of traditional orchards may be beneficial for biodiversity (O_1) and landscape character (O_{10}) (Burrough et al., 2010; Katayama et al., 2019; Špulerová et al., 2015), the overall impact on territorial sustainability was judged to be limited. Whereas the High Weald is notable for high rate of survival of historic grazing pasture, in North Kent, surviving traditional orchards now represent just a small proportion of current horticultural land use (Burrough et al., 2010; Kent Downs AONB, 2021). Compared to modern horticultural systems, traditional orchards are a less efficient use of land

for food production (Kent Downs AONB, 2021), and since much of North Kent is productive land with the potential to deliver higher yields (Natural England, 2015), traditional horticulture played only a minor role in the scenarios.

Part of the difference in the role of traditional practice between the High Weald and North Kent could also be attributed to the differences in ecological farming approaches chosen for the study areas. A low-input farming approach like that which was a feature of the High Weald scenarios is often compatible with traditional land uses (Acebes et al., 2021; Bignal & McCracken, 1996). However, in North Kent, adoption scenarios focused exclusively on conservation agriculture as the dominant ecological approach, and conservation agriculture has been acknowledged as requiring a radical change in farmer mindsets, breaking with long-standing traditions such as soil tillage and removal of crop residues (Lahmar, 2010).

The difference between the study areas regarding the role of traditional management practices in territorial sustainability reflected a divergence in participant views. For the High Weald assessment, the distinctive character of the AONB, as a nationally rare example of a relatively intact medieval landscape (High Weald Joint Advisory Committee, 2019; Tubbs, 1997), was cited as a reason to prioritise the preservation of traditional practices that maintain this landscape. By contrast, North Kent participants argued that a focus on traditional practice not only reduced the economic viability of farming businesses, but also prevented adoption of ecological approaches that may be new and innovative, but do not align with how farmers have operated in the past.

Farmer financial security

The network analysis for both study areas also identified farm-level financial performance as important for territorial sustainability. However, there were some differences between the study areas in terms of the precise causal pathways explaining why this should be the case.

In the High Weald scenarios, the role of farm financial security was due to its association with the persistence of traditional livestock management practices that are central to achieving many of the sustainability objectives for the area, as described above. In the low adoption scenarios, farmer financial insecurity, due to post-Brexit trading conditions (D_4), consumer demand (D_5), and the state of agricultural policy (D_6), threatens their ability to continue applying these practices.

Under the low adoption scenarios, poorly designed novel agri-environment measures, coupled with the phasing out of area-based subsidies (D_6), mean farmers no longer have the financial

certainty they had under the old policy regime. This has three major implications for territorial sustainability. Firstly, farmers may respond to greater uncertainty by prioritising short-term profitability over long-term performance (Pannell et al., 2014), favouring approaches that neglect the traditional low input practices. Secondly, without financial support that has 'no strings attached', farmers no longer have the luxury of conducting practices that contribute to the High Weald's cultural heritage which were overlooked by previous agri-environment measures (Vorley, 2013; Vorley et al., 2014). Thirdly, a lack of financial security may increase abandonment and neglect of agricultural land and encourage the sale of land for housing (Acebes et al., 2021), taking advantage of a growing interest in large-scale urban developments in the area (Dixon et al., 2017). The increased pressures on High Weald farmers resulting from policy changes are then compounded by changes in consumer demand and effects of Brexit. A continued reduction in red meat consumption (D_5) and trade agreements with countries with lower standards of food production (D_4) reduce the financial viability of domestic livestock production (Lee et al., 2021; Niamir-Fuller, 2016), and so drive further declines in extensive livestock systems. Therefore, under both low adoption scenarios, much of the low input farmland central to the High Weald's AONB designation, may be lost to land uses less sympathetic to the landscape character: drivers of change that reduce the rate of ecological farming adoption also threaten the wider environmental, social, and economic value of the High Weald landscape.

While the role of farm financial security in allowing farmers to continue less profitable traditional practices was less relevant in the North Kent scenarios, this factor also had a more general relevance to both study areas due to the potential business challenges associated with adopting an ecological farming approach. Participants agreed that transitioning from conventional to conservation agriculture involved a short-term loss of profitability for the farm. The cost of this transition can be a major barrier to the adoption of ecological approaches (Pannell et al., 2014; Vastola et al., 2017). Participants suggested that under the high adoption scenarios, meaningful financial support provided by agri-environment schemes (D_6) could mean insuring farmers against the risk to their business during this transitional period, and protection of British farming under trade agreements (D_4), would further help to mitigate the risk associated with this transition.

Farm business survival, restructuring of the agricultural sector, and urbanisation

One of the most important elements contributing to the difference in performance between the high and low adoption scenarios in North Kent concerned the changes in the structure of the

agricultural sector, reflected in the relative frequencies of different farm sizes. In the low adoption scenarios, the combination of increased trade with countries with lower production standards (D_4), consumer demand for cheap food (D_5), and an ineffective subsidy scheme (D_6), creates a more competitive agricultural sector, where the bottom line becomes increasingly important for business survival. At the same time, the combination of low farm input prices and high food prices (D_7) means farmers seek to increase profitability by maximising farm productivity under a high input, high output model (rather than focusing on cost savings through minimising inputs). Under these conditions, larger farming businesses that can exploit of economies of scale are able to outcompete and buy up small to medium-sized farms (Munton, 2009; Walford, 2005).

Meanwhile, growing pressure from urbanisation (D_{11}) makes the sale of land for development an increasingly attractive option for farm businesses, as farmers can get much more value from their land if they sell it for development rather than using it for food production (Munton, 2009). Tax breaks associated with selling land for development mean farmers can then reinvest profits from the sale to buy larger areas of farmland elsewhere, allowing them to expand. Therefore, as smaller or medium-sized farms are bought up by bigger and bigger farming businesses, North Kent becomes dominated by a few large farms (Munton, 2009; Walford, 2005). Compared to smaller or medium-sized farms, larger farms may be more likely to apply the more intensive, high input practices that are linked to negative impacts on many of the sustainability objectives (Bijttebier et al., 2017; Gilg, 1991). Therefore, an increase in average farm size is an important factor in the poorer sustainability performance of the low adoption scenarios in North Kent. However, the increased urbanisation that allows large farms to further profit from the sale of land for affordable housing developments does also mean that the low adoption scenarios perform strongly against the housing equality objective.

Under the high adoption scenarios, where British farmers are not undercut by imports from countries with lower production standards (D_4), and benefit from financial support associated with high engagement with agri-environment schemes (D_6), conditions favour the persistence of small or medium farms. Smaller farms can be associated with increased adoption of the practices that characterise an ecological approach to farming (Grasswitz, 2019; Tavernier & Tolomeo, 2004), to increase farm resilience (D_1 and D_2) and improve efficiency in the face of high input and low output prices (D_7). These practices positively impact a range of sustainability objectives, and so a higher frequency of small farms contributes to the strong performance of the high adoption scenarios.

The distribution of farm sizes also contributes to the difference in performance between the clustered and dispersed adoption scenarios. In the low dispersed scenario, the expansion of big farming businesses that lack close ties to the local area comes at the expense of small and medium farms that are more likely to be family-run. The concentration of farmland into the hands of a few large farms affects the demographics of farming communities (D_8), disrupting longstanding networks of farming families that have built close relationships from a history of working in geographic proximity (Pritchard et al., 2012). As a result, individuals responsible for management decisions on neighbouring farms may be less likely to be close to each other, reducing the ease of farmer cooperation that helps enhance sustainability performance in scenarios with clustered adoption (Emery, 2015; Emery & Franks, 2012; Mckenzie et al., 2013). On the other hand, while the dominance of larger farms may be associated with lower, more dispersed adoption, those few farms that do adopt ecological approaches can do so across a larger area and deliver the landscape-scale benefits that would otherwise require clusters of smaller farms. Moreover, with fewer separate farms, coordinating management across a given area to enhance ecosystem service delivery at the landscape scale requires may be easier, as it requires fewer partners and so is less logistically challenging.

The fact that changes in the distribution of farm sizes was important in North Kent but not the High Weald may be at least partly due to differences in landscape characteristics. North Kent already has a greater diversity of farm sizes than the High Weald, where there is a greater frequency of small farms compared to the national average (Vorley, 2013). In North Kent, a relatively open landscape (Natural England, 2015) means there are large contiguous areas of farmland that can easily be managed as a single unit. By contrast, the High Weald is more heavily wooded, broken up by steep valleys unsuitable for agriculture, which may limit field and farm sizes, and isolate pockets of grazing pasture (High Weald Joint Advisory Committee, 2019; Vorley, 2013). The more productive soils across much of North Kent also make it a more attractive environment for big farming businesses, which stand to gain more through maximising yields in this area.

5.4. Discussion

5.4.1. High clustered adoption of ecological farming maximises overall territorial sustainability, but may not be best for every objective

This study used a qualitative, objective-led approach to assess the territorial sustainability of ecological farming approaches in North Kent and the High Weald, specifically focusing on how the rate and distribution of adoption of conservation agriculture and low-input farming affect sustainability performance. In both areas, territorial sustainability was enhanced under scenarios with a higher rate of adoption and a clustered distribution of adoption (although adoption distribution tended to have a smaller and more variable impact on objectives than adoption rate): the high clustered scenario made the strongest contribution to sustainability objectives.

The same theme was seen when considering the environmental and social dimensions of sustainability separately, with the high clustered scenario performing best overall for environmental and social objectives. The positive impact of adoption clustering in the assessment results is supported by the considerable body of evidence in the literature that stresses the importance of management spatial distribution for environmental and social goals. Since drivers of ecosystem service provision operate across farm boundaries, joined-up management approaches spanning neighbouring farms can enhance environmental performance, with benefits for human health and well-being (Abler, 2004; Mckenzie et al., 2013; Renting et al., 2009), and cooperative initiatives associated with farm clusters have been linked to improved community cohesion, education, and engagement with local issues (Jarrett et al., 2015). Economic sustainability, however, tended to be impacted by adoption rate, but not distribution, so if the social and environmental benefits of clustered ecological farming adoption 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 approaches delivered positive impacts across most sustainability objectives indicates two key points. Firstly, the type of ecological approaches chosen for each study area tend to be appropriate for each area's sustainability requirements. Previous studies of conservation agriculture and low input farming performance have found that they are not equally suitable for all agroecosystems and socio-economic contexts, leading to variation in their potential to deliver intended environmental benefits, such as carbon storage and biodiversity conservation (Lahmar 2010; Craheix et al. 2016; Baccar et al. 2019; Jayaraman

et al. 2021; Bamière et al. 2022), so the choice of ecological farming approach does matter for territorial sustainability. Secondly, the adoption and spread of these ecological approaches may be able to deliver win-win outcomes for these regions, that reconcile performance in different aspects of sustainability. This is an idea that is also reflected in farm-level research, which suggests that under the right conditions, conservation agriculture has the potential to reconcile increased productivity with enhanced delivery of many provisioning and regulating ecosystem services, allowing it to meet a wider range of sustainability objectives than both organic and conventional farming (Chabert & Sarthou, 2020; Jayaraman et al., 2021). However, previous farm-level assessments of low input livestock systems have painted a more mixed picture of performance, with positive and negative impacts on different environmental criteria (Marandure et al., 2020). It is possible therefore, that if the High Weald scenarios had involved only low input farming, rather than low input and conservation agriculture combined, overall sustainability performance in the high clustered adoption scenarios would be reduced.

However, even if the scenario with high clustered adoption of ecological farming approaches had the strongest sustainability performance overall, it was not always the clear best option for achieving a given objective. There were objectives that performed as well or better under a lower rate, or dispersed distribution, of adoption (such as housing equality in North Kent), and objectives where participants were unable to determine differences in performance between scenarios (such as rural employment). Again, this resonates with farm-level research. While conservation agriculture may perform well in terms of environmental sustainability criteria, it has also been linked to some negative impacts on socioeconomic aspects of sustainability, including decreased agricultural employment associated with reduced tillage systems (Craheix et al., 2016). However, territorial impacts on employment will depend on the extent to which the resulting farm labour savings can be redirected to other rural activities (Craheix et al., 2016; Lahmar, 2010). The overall impact on employment was an area of ambiguity in this assessment, and so the interplay between farm labour savings in conservation agriculture systems and wider rural employment could be a priority area for further research.

Given these areas of variation and uncertainty in scenario performance, even if high clustered adoption makes a more positive overall contribution to territorial sustainability, if this scenario plays out in practice, policy makers may still have to manage trade-offs when considering objectives that would benefit under alternative adoption patterns. Navigating trade-offs may require an understanding of the relative desirability of the different objectives, which could be achieved through weighting objectives, through using more quantitative data collection methods to record preferences among a representative sample of stakeholders. However, there

is a risk that this could compromise some of the strengths of the qualitative assessment approach, encouraging non-technical audiences to overlook the need for compromise between different objectives and neglecting interdependencies among objectives.

5.4.2. Access to information and farmer relationships shape sustainability performance through farm- and territorial-level processes

While qualitative impact mapping shows how different adoption scenarios perform, illustrating the synergies and trade-offs among sustainability objectives, network analysis explores why these differences in performance may occur, identifying key pathways underpinning the territorial sustainability of ecological farming. In particular, the network analysis stressed the importance of sharing information among farmers for the sustainability of the high clustered adoption scenario. Access to easily observable and communicable information on practice benefits has long been recognised as important for the adoption of alternative approaches that enhance farm-level sustainability performance (Feder & Slade, 1984; Wandel & Smithers, 2000; Wossen et al., 2013). This appears to be especially true for conservation agriculture, which has been identified as a particularly knowledge intensive farming approach, that also requires farmers to embrace a fundamental shift in mentalities and engage with practices that can seem counterintuitive, if they are to realise the full potential of this approach for sustainability performance (Kassam et al., 2009). Farm-level assessments also indicate that the ability of conservation agriculture to enhance ecosystem service provision is highly variable, and strongly dependent on the level of farmer expertise for this approach (Chabert & Sarthou, 2020). Given that conservation agriculture partially or fully characterised ecological farming for both study areas, it is therefore not surprising that farmer information exchange and access should play such a key role in the sustainability performance of the scenarios in this assessment.

However, the value of information sharing in determining sustainability performance did not just stem from its role in farm-level adoption and performance. Network analysis also highlighted the role of information sharing in showing farmers how their own environmental management relates to that of their neighbours, something that farmers may otherwise have little awareness of (Riley et al., 2018), and helping to achieve the management coordination that enhances sustainability performance in clusters of ecological farms. Therefore, dissemination of information on practice performance can be important for territorial and farm-level sustainability.

The networks indicated how strong organisational and advisory support, use of technology, and high quality farmer relationships, all contribute to information exchange and therefore provide targets for cost-effective interventions to improve territorial sustainability. However, the network analysis results only describe the importance of these factors due to their position in the network and do not identify which of these factors may have the strongest impact on farmer access to information. A node may be well-connected, but these connections could reflect relatively weak cause-effect relationships, and this analysis does not consider the strength of causal links. Although participants agreed that organisations, technology, and farmer relationships all play a role in information accessibility, and therefore scenario performance, they differed in their views on the relative importance of each factor.

More generally, the network graphs illustrated how the territorial sustainability of ecological farming is the product of the cumulative effect of farm-level processes (such as low input practices and habitat restoration), and processes operating across the landscape (such as information sharing and management coordination). Moreover, the networks also suggest areas of interaction between farm and landscape-level processes, identifying important factors associated with both the rate and distribution of adoption. As an example, relationships among farmers provide a means for sharing information, which favours increased adoption of ecological approaches at the farm level, but also encourage management coordination and collaboration across farms, contributing to the positive environmental, social, and economic territorial sustainability impacts linked to adoption clustering. Spatial analyses and farmer surveys have shown how farmer interpersonal relationships can influence the distribution of agricultural approaches across a region (Dessart et al., 2019; Lastra-Bravo et al., 2015), and this assessment takes these ideas further by showing how these interpersonal relationships can relate to different aspects of territorial sustainability.

5.4.3. The methodology has the potential to be part of an integrated assessment tool to investigate agricultural sustainability at different spatial scales

Previous sustainability assessments combining qualitative impact mapping and network analysis focused on scenarios that explicitly reflected alternative policy directions (Boron et al., 2016; Tzanopoulos et al., 2011). Here, the scenario development process instead focused on the spread of a set of farming practices, rather than any particular policy philosophy, providing a methodology that could provide the starting point for comparing the territorial sustainability of alternative farming approaches.

A key challenge is to reconcile this methodology with assessments at other spatial scales, which may not come to the same conclusions about sustainability performance. While increasing uptake of ecological approaches can deliver positive impacts against local environmental objectives, it may also depress overall yields in the study area, necessitating increases in productivity elsewhere, meaning that negative environmental impacts of intensive, high-output agriculture may be exported to areas further afield (Bruckner et al., 2015; Chaudhary & Kastner, 2016; Seufert et al., 2012). Conversely, while intensification may be associated with negative impacts on environmental objectives in the study areas, the increases in yields may free up land for conservation in more environmentally sensitive areas elsewhere (Balmford et al., 2015; Phalan et al., 2011). Equally, the objectives prioritised at a territorial level may differ from national or international priorities, leading to differences in the way sustainability is assessed at different levels. Although food security and food chain resilience were not chosen as objectives for the study areas, they may figure more prominently in a national or international assessment (Chaudhary et al., 2018), which could change the relative sustainability of the different adoption scenarios. Therefore, there may be trade-offs between the performance of ecological agriculture at the national or international level, and the regional or territorial level.

Similar considerations apply for farm-level performance, so stakeholders may prioritise different objectives for farm and territorial-level sustainability. However, integrating farm and territorial assessments is complicated by the fact that while at the farm level, assessments can easily focus on a set of practices or an approach characterising a specific farm, a territory may contain a variety of farms applying a range of practices in different combinations. The High Weald scenarios were characterised by the adoption of a mix of low input and conservation agriculture, making it difficult for a territorial assessment to make conclusions about the performance of one farming approach in isolation.

If such challenges can be overcome, then using the framework described here to combine assessments at different scales could identify areas of alignment and disconnect between sustainability performance at these different levels. The need to study trade-offs across different spatial scales has been identified as a priority for research into the performance of agriculture and alternative land uses (Klasen et al., 2016; Seppelt et al., 2013), so developing an integrated assessment approach would make a meaningful and valuable contribution towards our understanding of agricultural sustainability.

5.4.4. Concluding remarks

This assessment has shown that alternative farming approaches involving the application of more 'ecological' management practices (conservation agriculture and low input farming), designed to address the negative environmental impacts of conventional intensive agriculture, have the potential to deliver positive outcomes for different aspects of sustainability at the territorial level. The territorial sustainability performance of these ecological farming approaches can be enhanced by measures that increase the rate and clustering of adoption. However, given that the rate of adoption had a more pronounced effect on sustainability performance than the distribution of adoption, policy interventions for these study areas may maximise their cost-effectiveness by prioritising measures to increase adoption rate over adoption clustering.

Despite the opportunity for ecological farming approaches to positively impact a variety of territorial sustainability objectives in south-east England, there were some objectives, particularly for socio-economic sustainability, including employment and housing equality, for which the impacts of ecological farming were uncertain or potentially negative. Therefore, if policy interventions are designed to promote a particular pattern of ecological farming adoption across the landscape, care should be taken to identify sustainability objectives that may be at risk and navigate trade-offs between conflicting objectives, helping focus the attention of decision makers on developing solutions to mitigate possible costs of ecological farming at the territorial level.

The results presented here also show how the territorial sustainability of an ecological farming approach is not just due to the management practices involved, and the rate and distribution of its adoption, but also the geographic context in which it is applied. Conservation agriculture and low-input farming may be a route for reconciling diverse aspects of territorial sustainability in south-east England, but it is important to consider the extent to which this is true for other regions individually.

The overall similarities in the assessment results across both study areas suggest it is possible to create generic, nationwide interventions to promote ecological farming adoption and clustering that will enhance territorial sustainability. However, the subtle differences in results between the study areas also mean that generic interventions cannot maximise sustainability performance everywhere: their effectiveness will vary between regions, having to deal with different trade-offs between objectives, and different patterns of cause-effect relationships underpinning territorial sustainability. Therefore, to optimise policy interventions so they can

produce the best result for sustainability in different regions, they must have the flexibility to be adapted or fine-tuned to the local context as required.

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5.6. Supporting Information

Table S5.2 Original list of objectives (prior to stakeholder consultation and prioritisation)

1	To conserve and enhance biodiversity
2	To conserve cultivated plants and animals and their associated genetic resources
3	To conserve and restore semi-natural habitats characteristic of the region, enhancing habitat condition and connectivity to establish and improve functional and resilient ecological networks
4	To increase the public's understanding of / engagement with the natural environment
5	To maximise accessibility to high quality, natural spaces that the public are encouraged to visit for the benefit of their health and well-being
6	To promote the sustainable use of agricultural land for supplying local markets, reducing the UK's dependency on non-sustainably managed land and the need for the long-distance transport of resources with its associated global, social, and environmental impacts
7	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
8	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
9	To adapt to anticipated risks of shortages in the water supply for agriculture
10	To maintain and restore natural functions / processes within river catchments, promoting benefits for water quality, storage, and flow regulation
11	To reduce the risk posed by flooding to people, the environment, and the economy
12	To ensure the sustainable / rational management of soils for agriculture, preserving and restoring soil quality and quantity
13	To promote the sustainable use of fertiliser / nutrients in a way that preserves and restores natural nutrient flows and cycles
14	To reduce waste generation by minimising waste disposal and increasing recycling and re-use of materials to support the development of a circular economy
15	To reduce greenhouse gas emissions through more efficient energy use and increasing the proportion of energy generated from renewable sources
16	To protect and restore natural carbon stores and increase carbon sequestration
17	To enable the agricultural sector, and wider society, to adapt to the effects of that climate change which is already unavoidable
18	To maintain / increase the quality of life, health, and well-being of those living and working in the region, including minimising threats to public health
19	To enhance the safety and nutritional quality of agricultural produce, increasing diet quality and consumer confidence in food
20	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
21	To ensure a sustainable supply of affordable, well-constructed housing, with an appropriate mix of types and tenures to reflect the demands, needs and means of all sections of society
22	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
23	To ensure equal human rights and security / sharing access to services and benefits of prosperity fairly
24	To protect / improve the resilience of rural communities to change
25	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
26	To give farmers the freedom to make their own management decisions, according to personal insights, capabilities, and desires

27	To enable people to have the freedom to choose whether they wish to stay or leave the area, and avoid situations where people are forced to leave
28	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
29	To promote the continued application of traditional agricultural knowledge, skills, and practices
30	To ensure that the natural beauty / scenic value of the region is recognised, conserved, and enhanced
31	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 region, encouraging people to support their conservation, with their cultural heritage acting as a source of inspiration and enjoyment
32	To protect the welfare, health, and well-being of livestock
33	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
34	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
35	To protect and promote the continued practice of traditional economic activities
36	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
37	To provide an environment that is attractive to starting and growing a business / helps new farmers establish and retains existing ones
38	To support development of a dynamic and knowledge-based economy that maximises opportunities for farm / business innovation
39	To support a heritage-led and environmentally responsible tourism sector
40	To increase the total farm profit / income that the farmer (and their household) has at their disposal
41	To reduce farm vulnerability to external events / increase the resilience of farm businesses
42	To increase the potential for farming to be an economically viable option for making a living / managing land
43	To reduce farmer reliance on subsidies and other forms of external finance
44	To enable farmers to increase self-sufficiency in terms of resource use, minimising use of external inputs on the farm
45	To ensure certainty over future funding to allow farmers to plan and invest for the future
46	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
47	To promote new livelihood opportunities based on local resources
48	To protect labour rights and good working conditions for farmers and agricultural workers
49	To encourage the active participation of local communities in local policy and decision-making processes, giving communities greater power in influencing the decisions that affect them, including in the planning, design, and long-term stewardship of their community
50	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

Table S5.3. Literature used to create the draft list of sustainability objectives

UK / England – national policy
• 2019-21 Agriculture Bill briefing paper (Finlay et al., 2020)
• Time for a Strategy for the Rural Economy (Select Committee on the Rural Economy, 2019)
• Fair Society, Healthy Lives: The Marmot Review (Marmot et al., 2010, 2020)
• Public Health England Strategy 2020-25 (Public Health England, 2019)
• A Green Future: Our 25 Year Plan to Improve the Environment (H.M. Government, 2018)
• Clean Air Strategy (DEFRA, 2019)
• The Clean Growth Strategy (Department for Business Energy & Industrial Strategy, 2017)
• UK Industrial Strategy (Department for Business Energy & Industrial Strategy, 2018)
• The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting (DEFRA, 2018b)
• Sustainable Communities: Building for the Future (Office of the Deputy Prime Minister, 2003)
• Local Growth: Realising Every Place's Potential (HM Government, 2010)
South-east England
• The Kent and Medway Sustainability and Transformation Plan (NHS) (Kent and Medway Sustainability and Transformation Partnership, 2016)
• Kent Environment Strategy (Kent County Council, 2016)
• Covid-19 and the South East Local Nature Partnership's principles for our economic recovery (Kent Nature Partnership, 2020)
• Sustainability Appraisal (SA) of the Kent Minerals and Waste Local Plan (URS, 2014)
• River Basin Management Plans (Environment Agency, 2016)
High Weald
• High Weald AONB Management plan (High Weald Joint Advisory Committee, 2019)
• River Ouse Catchment Flood Management Plan (Environment Agency, 2009)
• East Sussex Economic Development Strategy (East Sussex County Council, 2012)
• East Sussex Environment Strategy 2020 (East Sussex Environment Board, 2020)
• West Sussex Transport Plan Sustainability Appraisal (West Sussex County Council, 2011)
• Sustainability Appraisal of the Hastings Planning Strategy (Brenkley, 2012)
• National Character Area Profile: High Weald (Natural England, 2013a)
North Kent
• Sustainability Appraisal of Thanet District Council Local Plan (Thanet District Council, 2012)
• Sustainability Appraisal of the Canterbury District Local Plan (Amec Foster Wheeler, 2017)
• Sustainability Appraisal of the Swale Borough Local Plan (AECOM, 2016)
• National Character Area Profile: North Kent Plain (Natural England, 2015)
• National Character Area Profile: Greater Thames Estuary (Natural England, 2013b)
Objective-based sustainability appraisals in the academic literature
• Sustainability assessment for agriculture scenarios in Europe's mountain areas: Lessons from six study areas (Partidário et al., 2009)
• Agricultural decline and sustainable development on mountain areas in Greece: Sustainability assessment of future scenarios (Tzanopoulos et al., 2011)
• Achieving sustainable development in rural areas in Colombia: Future scenarios for biodiversity conservation under land use change (Boron et al., 2016)
Other agricultural sustainability assessment research
• Themes in the RISE 2.0 model (de Olde et al., 2016)
• Themes in the FAO's SAFA assessment tool (Soldi et al., 2019)
• Level 1 and 2 themes in the MOTIFS assessment tool (Meul et al., 2008)
• Themes and sub-dimensions in the SOSTARE assessment tool (Paracchini et al., 2015)
• Key principles in the SAFE integrated assessment tool (Van Cauwenbergh et al., 2007)
• Key public goods in the 'Public Goods' assessment tool (Gerrard et al., 2012)
• Objectives in the IDEA assessment tool (Zahm et al., 2008)
• Common themes from a review of 11 assessment methods (Payraudeau & van der Werf, 2005)

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Table S5.4 Stakeholders consulted for the prioritisation of sustainability objectives

Participant type	No. of participants
County council environmental managers	2
Area of Outstanding Natural Beauty (AONB) management	2
Utility company representative	7
Internal drainage board officer	1
Civil servant	2
Farmer cluster officer	1
Environmental non-governmental organisation (NGO) representative	2
Rural community development NGO representative	1
Countryside partnership representatives	4
Total	**22**

Table S5.7. Average rankings given by 10 High Weald expert participants for 12 farming practices according to their importance in ecological farming within the High Weald (where 1 is most important), and the most relevant farming approach, according to the typology developed by Rega et al. (2021).

Practice	Most relevant approach (from farm typology)	Average practice rank
Use of organic manure or compost	Integrated/circular farming	2.9
Low tillage use	Conservation agriculture	4.3
Integration of crop and livestock at farm level	Integrated/circular farming	4.7
Integrated Pest Management	Integrated/circular farming	5.1
Extensive use of cover crops	Conservation agriculture	5.2
Precision technologies	Low-Input	5.8
Number of crops	Conservation agriculture	5.9
Strip grazing / mob grazing	Conservation agriculture	5.9
Integrated Weed Management	Integrated/circular farming	7
Machine weeding	Low-Input	8.9
Alternative remedies for livestock disease management	Low-Input	9.8
Manual weeding	Low-Input	9.9

Table S5.8. Average rankings given by 10 North Kent expert participants for 12 farming practices according to their importance in ecological farming within the High Weald (where 1 is most important), and the most relevant farming approach, according to the typology developed by Rega et al. (2021).

Practice	Most relevant approach (from farm typology)	Average practice rank
Low tillage use	Conservation agriculture	3.4
Use of organic manure or compost	Integrated/circular farming	4.3
Integrated Pest Management	Integrated/circular farming	4.9
Extensive use of cover crops	Conservation agriculture	5.2
Integration of crop and livestock at farm level	Integrated/circular farming	5.2
Integrated Weed Management	Integrated/circular farming	5.7
Number of crops	Conservation agriculture	5.9
Precision technologies	Low-Input	6.3
Alternative remedies for livestock disease management	Low-Input	8.2
Strip grazing / mob grazing	Conservation agriculture	8.6
Machine weeding	Low-Input	9.3
Manual weeding	Low-Input	10.7

Driver		Scenarios			
		1. High clustered adoption	**2. High dispersed adoption**	**3. Low clustered adoption**	**4. Low dispersed adoption**
D_1	**Farmer response to climate change**	Farmers adopt ecological practices to increase farm resilience in response to increases in the frequency and severity of extreme conditions		Increased productivity under a changing climate improves the performance of high-input intensive practices	
D_2	**Farmer response to pests and disease**	Farmers adopt ecological approaches to deal with pest and disease resistance to conventional control methods, and cooperate to tackle their spread across farm boundaries	Farmers adopt ecological approaches to deal with pest and disease resistance to conventional control methods	Conventional control methods remain effective in suppressing agricultural pests and diseases	
D_3	**Corporate responsibility**	Companies pay farmers to mitigate environmental impacts and promote ecological practices		n/a	
D_4	**Brexit & standards**	The high standards associated with British farming are protected in post-Brexit trade agreements		Trade agreements with countries that have lower standards of food production results in a reduction in domestic standards in an attempt to maintain the competitiveness of British farming	
D_5	**Consumer demand**	Consumer demand for beef and dairy products is sustained at current levels (***High Weald only***); Consumer engagement encourages businesses and policy makers to support ecological farming		Reduced consumer demand for beef and dairy products (***High Weald only***); Consumer choices prioritise cheap produce from intensive farming	
D_6	**Agricultural policy**	New agri-environment schemes (AES) are effective at engaging farmers and delivering on the promise of 'public money for public goods', and landscape scale schemes encourage the development of ecological farming clusters	New AES are effective at engaging farmers and delivering on the promise of 'public money for public goods', but landscape scale schemes fail to encourage the development of ecological farming clusters	New AES are ineffective in engaging farmers despite the phasing out of area-based payments, but landscape scale schemes do encourage the development of some localised farm clusters.	New AES are ineffective in engaging farmers despite the phasing out of area-based payments, and landscape scale schemes fail to encourage the development of farm clusters.
D_7	**Farm input costs and food prices**	High input costs and low food prices mean farmers focus on making cost savings, favouring the adoption of low-input ecological and collaborative practices.	n/a	n/a	Low input costs and high food prices mean farmers focus on maximising productivity, favouring the adoption of high-input, intensive practices, with minimal collaboration
D_8	**Farmer demographics**	The continuity of established farming communities favours the persistence of close relationships among neighbouring farmers	Changes in the structure of the agricultural sector breaks up communities / networks of established farmers	The continuity of established farming communities favours the persistence of close relationships among neighbouring farmers	Changes in the structure of the agricultural sector breaks up communities / networks of established farmers
D_9	**Organisations and advisors**	Organisations and advisors effectively support farmers in adopting ecological practices and facilitate the creation of farming clusters.	Organisations and advisors effectively support farmers in adopting ecological practices	Organisations and advisors facilitate the creation of some farming clusters, but are only able to engage a small proportion of farmers	Organisations and advisors lack the resources or expertise to engage and support farmers with ecological practices
D_{10}	**Technology**	Increasingly accessible and affordable technologies automate otherwise labour-intensive ecological practices, help with the assessment of farm environmental performance, and improve connectivity and knowledge exchange among rural communities.		A lack of accessible and affordable technologies restricts automation of labour-intensive ecological practices, limits farmer ability to assess farm environmental performance, and limits connectivity and knowledge exchange among rural communities.	
D_{11}	**Urbanisation**	A lack of urban development / unfavourable planning conditions reduces opportunities to profit from the sale of land for development, ensuring the persistence of more small farms and long-term land management mindsets. (***North Kent only***)		Urbanisation / favourable planning conditions encourages bigger farms to use the profits from the sale of land for development to further expand the farm and promotes short-term land management mindsets. (***North Kent only***)	

Table S5.9. Drivers of change identified under each ecological farming adoption scenario for the High Weald and North Kent study areas, based on farmer interviews, stakeholder discussion, local literature, and expert opinion. Out of the 11 drivers, 9 are identical for both study areas, and 2 (consumer demand and urbanisation) differ between the study areas.

Table S5.10. Participants involved in the qualitative impact mapping and network analysis process

Participant type	Study area	No. of participants
Landscape ecologist	North Kent & High Weald	1
Agricultural economist	North Kent & High Weald	3
Rural geographer	North Kent & High Weald	1
Agribusiness consultant / agronomist	North Kent	3
Catchment manager	North Kent	1
Farmer	North Kent	4
Farmer	High Weald	4
Land management advisor	High Weald	1
Farmer cluster officer	High Weald	2
AONB management	High Weald	2
Total		**22**

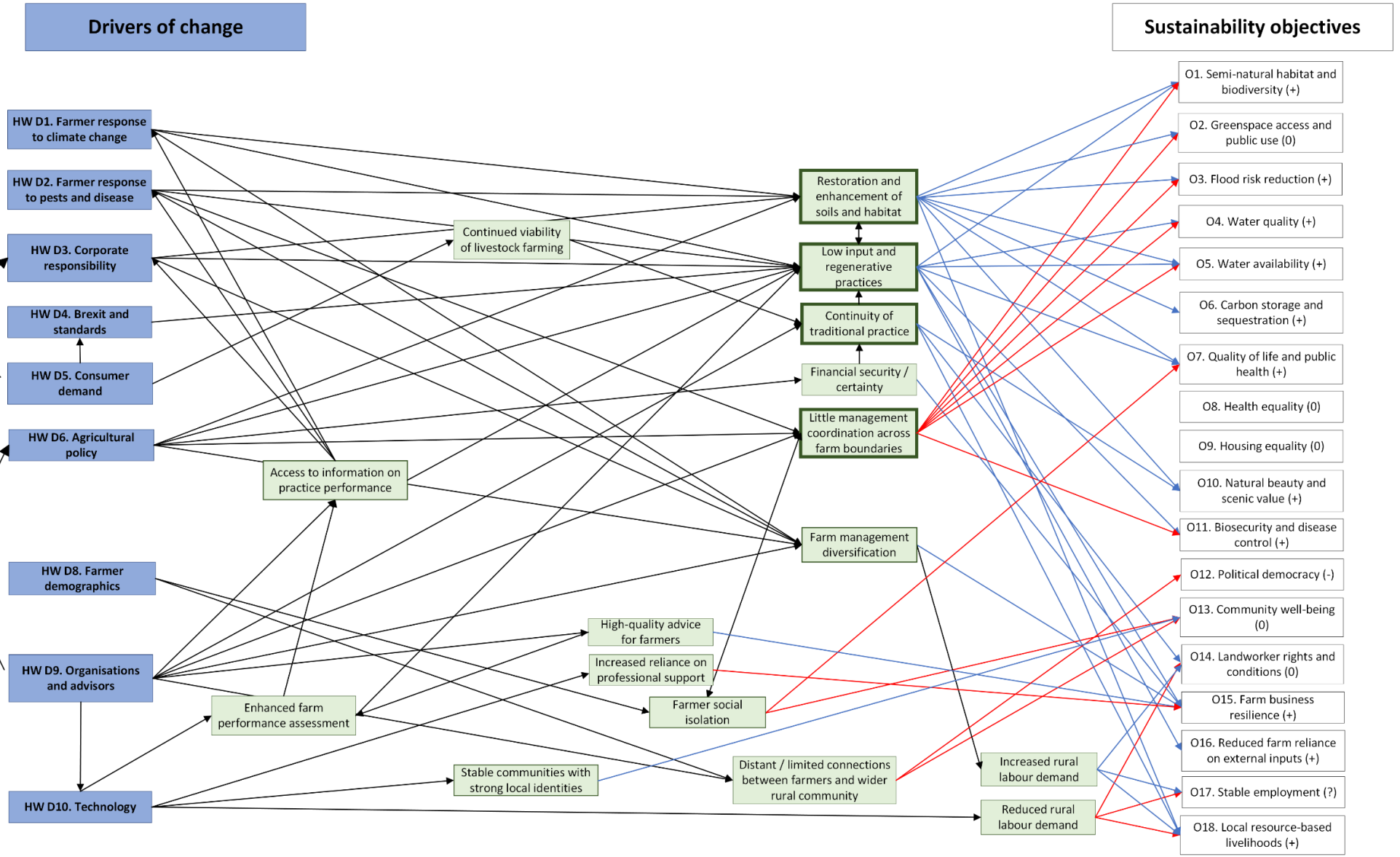

Figure S5.9. Network graph showing the key cause-effect relationships between the drivers of change, their consequences, and subsequent positive (blue lines) and negative (red lines) impacts on the sustainability objectives for the High Weald under **Scenario 2: high, dispersed** adoption of ecological farming, which in this context is a blend of conservation agriculture and low-input farming, with a focus on livestock management (closely aligning with stakeholder views of regenerative agriculture). Boxes with thick outlines represent structurally key nodes in the graph (the top 25% of nodes with the highest proximity prestige values).

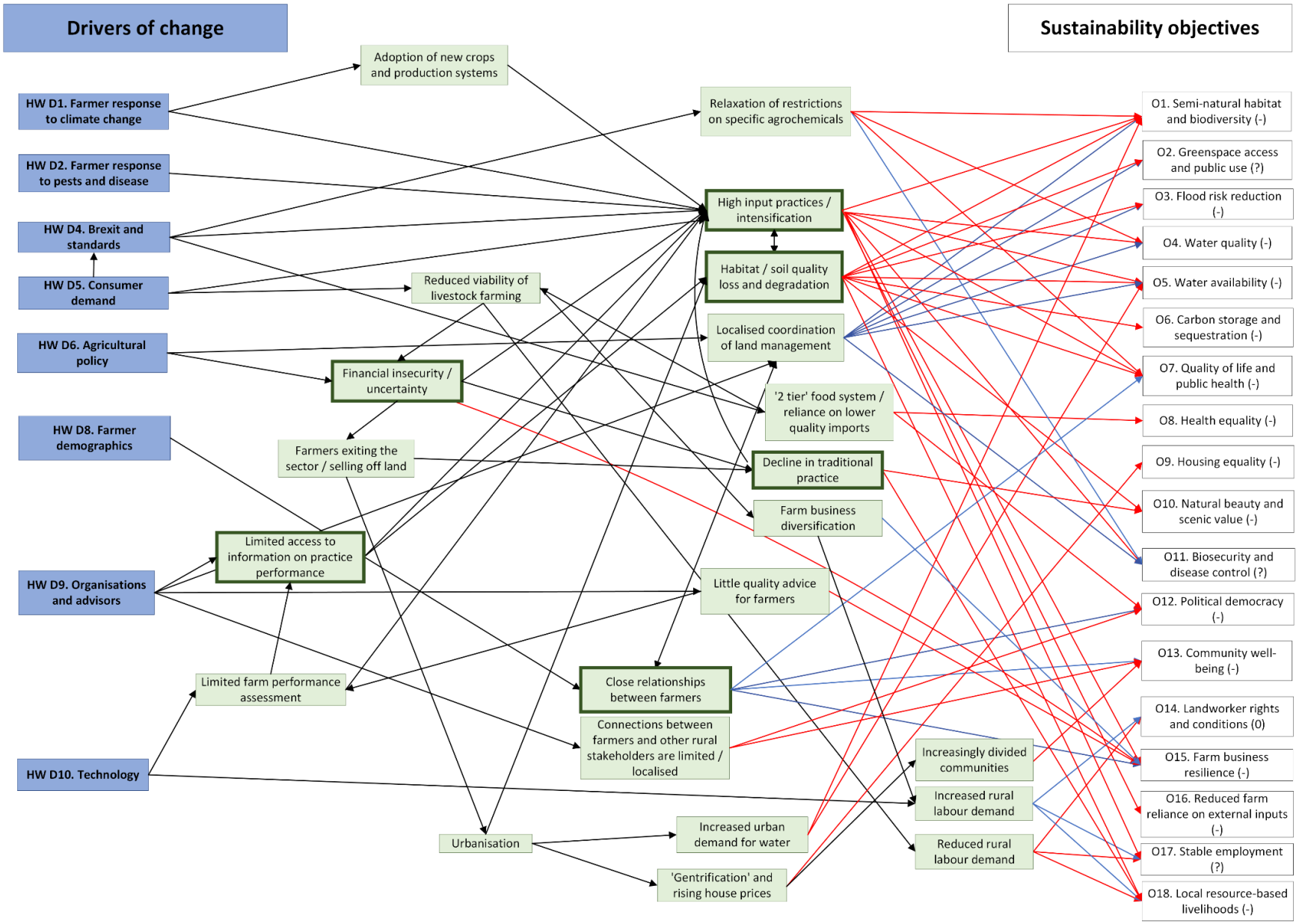

Figure S5.10. Network graph showing the key cause-effect relationships between the drivers of change, their consequences, and subsequent positive (blue lines) and negative (red lines) impacts on the sustainability objectives for the High Weald under **Scenario 3: low, clustered** adoption of ecological farming, which in this context is a blend of conservation agriculture and low-input farming, with a focus on livestock management (closely aligning with stakeholder views of regenerative agriculture). Boxes with thick outlines represent structurally key nodes in the graph (the top 25% of nodes with the highest proximity prestige values).

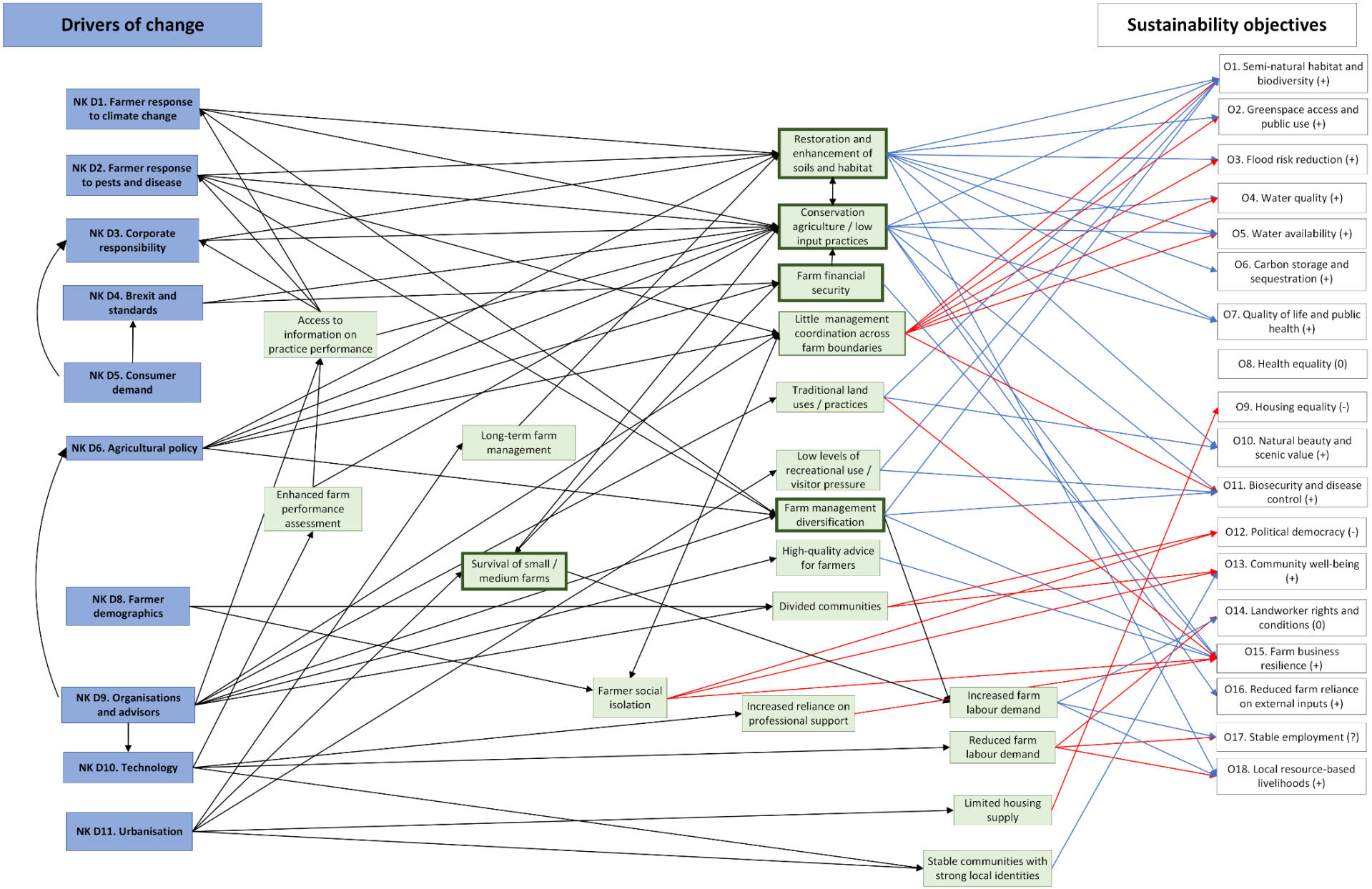

Figure S5.11. Network graph showing the key cause-effect relationships between the drivers of change, their consequences, and subsequent positive (blue lines) and negative (red lines) impacts on the sustainability objectives for North Kent under **Scenario 2: high, dispersed** adoption of ecological farming, which in this context is dominated by a conservation agriculture approach. Boxes with thick outlines represent structurally key nodes in the graph (the top 25% of nodes with the highest proximity prestige values).

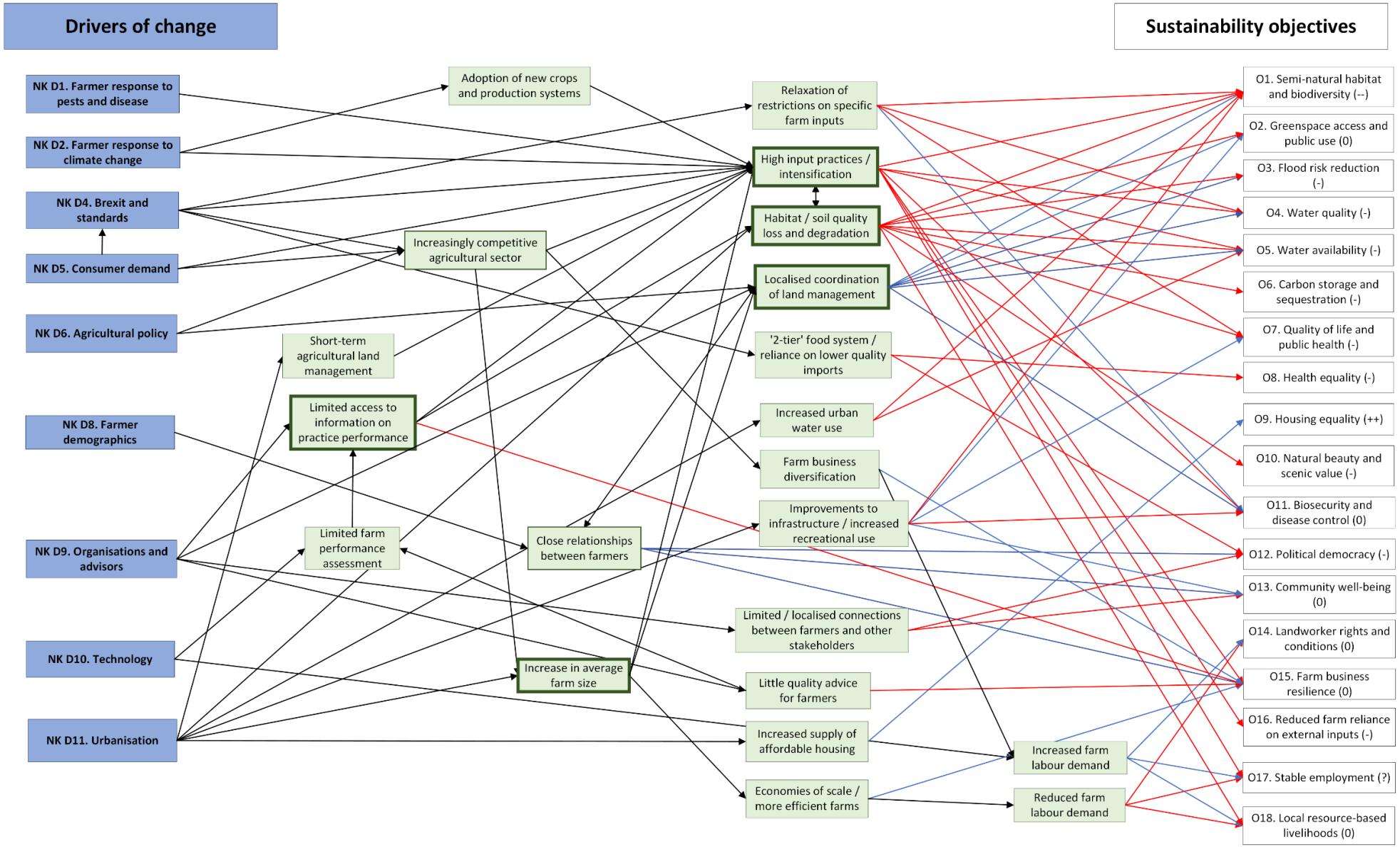

Figure S5.12. Network graph showing the key cause-effect relationships between the drivers of change, their consequences, and subsequent positive (blue lines) and negative (red lines) impacts on the sustainability objectives for North Kent under **Scenario 3: low, clustered** adoption of ecological farming, which in this context is dominated by a conservation agriculture approach. Boxes with thick outlines represent structurally key nodes in the graph (the top 25% of nodes with the highest proximity prestige values).

Chapter 6: Discussion

The aim of this thesis was to assess the challenges and opportunities for the adoption of alternative (i.e., 'ecological') farming approaches and agri-environment schemes (AES) to impact agricultural sustainability performance at the regional level, in the context of English agriculture post-Brexit. This was achieved using an interdisciplinary, mixed methods approach, combining semi-structured interviews, spatial analysis, scenario analysis, network analysis, and sustainability assessment, to approach this topic from multiple perspectives and gain new insights. In this final section of the thesis, I will first review the key findings from each of these methods, and then show how the results from these approaches complement each other to inform our understanding of factors influencing adoption and sustainability performance of ecological farming approaches and practices at the regional level.

6.1. Summary of key findings

6.1.1. Farmer identities and relationships with providing public goods

Thematic analysis of the semi-structured interviews conducted with a diverse sample of farmers in south-east England showed considerable variation in awareness of the idea of farming to provide public goods and highlighted the malleability and subjectivity in how the concept of public goods was used and understood. Farmers had their own interpretations of what was meant by 'public goods', which informed their views about the role of farming in society. Some reactions were influenced by scepticism of external intervention in farming, describing the public goods definition as manipulated by other parties to justify controlling farming to deliver certain outputs to suit their agendas. This control was feared because it was seen to deprive farmers of the opportunity to use their farm to demonstrate their 'good farmer' credentials based on acquired knowledge and experience.

Equally, farmers themselves manipulated the public goods concept to suit their purposes, choosing to interpret the idea of being a provider of public goods in a way that fit with their views about what their role as farmers meant. By defining public goods as things that are good for the public, farmers could use the public goods discourse to justify the value of their role as producers of sufficient healthy food. However, respondents also indicated that their identities were multidimensional: while many emphasised that they primarily identified as producers of food for profit, private goods, they often did so alongside acknowledgement that providing non-

food outputs outside of markets was a secondary aspect of their identity. Others refrained from compartmentalising their identity in this way, by describing the provision of private and public goods as two interdependent or inseparable features of their role that could not be traded off against each other.

Regardless of how respondents chose to incorporate public good provision in their identities, the idea of being a provider of public goods was closely linked to ideas around public perception of farmers. Given that public goods were often defined as being 'good for the public', farmer willingness to be seen as providers of public goods was connected to a desire for the public to recognise the value of these outputs from farming. While farmers therefore responded positively to opportunities to demonstrate their value to the public, these opportunities were generally limited for most. Research has highlighted the ability to generate symbolic capital that demonstrates a reputation as a 'good farmer' as an important determinant of farmer willingness to adopt novel practices. Given the importance of reputation among the wider public in farmer attitudes towards providing public goods, extending this perspective to consider the potential for symbolic capital to be recognised by individuals outside the farming community could be an important avenue for future research and an opportunity to influence adoption behaviours.

6.1.2. Farmer cooperation for public good delivery

Analysis of interview responses concerning attitudes to cooperative management suggested that while an understanding of the benefits of cooperation for public good delivery was widespread, this did not always translate into willingness to cooperate for this purpose. Several farmers expressed a preference for environmental management focused on their own farm rather than participating in cooperative projects that were seen as complex and onerous with relatively little reward. Finding ways to quantify and communicate the beneficial impacts of cooperative management was identified as a key requirement for altering this perceived cost-benefit ratio and therefore make cooperative management more appealing. This suggests that a major barrier to adoption of cooperative management may be its reduced suitability for generating symbolic capital compared to individual farm management, which may be exacerbated by difficulties in attributing signals of performance quality from cooperative management to individual farmers.

Another potential barrier preventing cooperation was the difficulty in connecting with farmers with contrasting self-identities, with different ideas about what constitutes good farming. However, some respondents sought to bridge these gaps by looking for common ground with potential partners by identifying those aspects of identity or symbols of quality that are shared

between them. Farmers with the willingness and ability to build these bridges are critical for the success of cooperative environmental initiatives, especially considering the need for cooperation to be farmer driven, given the reported farmer mistrust of top-down control. However, because the spatial configuration of cooperation is an important determinant of its effectiveness in delivering public goods, an element of coordination is needed to organise management across different farms, so landscape scale management still requires a (small) element of top-down coordination in combination with bottom-up collaboration.

This also means that the distribution of cooperative management will depend on the distribution of able and motivated farmers that can help with this coordination, resulting in localised clusters of cooperating farms focused on these key individuals. Equally, however, there will be some 'fuzziness' in these clusters, with not all farmers in the immediate vicinity engaging, because while proximity was important in determining choice of cooperative partners, differences in farmer cultures and networks meant that social relationships did not always map exactly onto geographic ones. Therefore, farmers' preferred partners may be slightly further afield than their immediate neighbours, and even in the presence of key individuals driving cooperation, farm clusters will likely contain gaps due to farmers with differing ideals or identities that may be harder to engage with.

6.1.3. Spatial distribution of agri-environment scheme adoption at the regional level in England

The application of spatial analysis to assess the distribution of Environmental Stewardship Scheme (ESS) uptake across the Local Authority Districts (LADs) of England provided further insight into processes affecting adoption distribution at the regional level. Exploratory spatial analysis indicated that ESS engagement was clustered at the LAD level, with LADs with similar ESS uptake rates concentrated close together. The location of clusters for ESS management options for different agri-environmental objectives showed considerable overlap, but there was a difference in cluster locations when comparing the distribution of Higher-Level Stewardship (HLS)-only and combined Entry Level Stewardship (ELS)-HLS schemes. Spatial econometric modelling identified variables contributing to this clustering. Out of the variables assessed, the coverage by protected areas for nature conservation was the most consistent predictor of ESS distribution, and the relationship was strongest when considering the distribution management options specifically for habitats and biodiversity. This suggests that the design of HLS schemes under ESS was effective in targeting appropriate management options towards areas of high conservation value. For other variables, their impact on distribution differed between HLS-only

and ELS-HLS schemes, contributing to the differences in cluster location between these two scheme types. For example, high productivity agricultural land was negatively associated with HLS-only scheme participation, but not for ELS-HLS schemes. This suggested that the different characteristics of each scheme attract different types of entrants and so different factors drive regional rates of adoption in each case. Not all the candidate explanatory variables tested had a significant effect on adoption rates, and some had unexpected effects compared to the literature. These differences may be partly due to the choice or availability of appropriate data to operationalise these variables but also likely reflect the importance of geographic context in shaping how a given variable influences adoption.

Equally, while the models identified variables contributing to the regional clustering of adoption, these variables often only had a slight effect on adoption distribution, and diagnostic tests comparing alternative models showed that this clustering was also driven by the occurrence of spatially correlated variables not included in the models (i.e., spatial error). Some of these missing variables may have been accounted for if the study was conducted at a different spatial scale where more agricultural survey data is publicly available. However, this result is consistent with other spatial studies that used a greater number of independent variables and mapping model error terms did not show any obvious underlying geographic pattern, so this spatial error effect would probably persist even if more variables were added to the model. It is probable that the spatial error reflects a complex mix of spatially correlated variables relating to factors not easily quantified or measured at the regional level. The diagnostic tests for spatial dependence also showed that the clustering was not due to any form of spillover effect between nearby regions (i.e., spatial lag), as has been reported by other studies for different areas and spatial scales. This means that high adoption in one LAD does not make adoption more likely in nearby regions: clustering is instead due to association with other explanatory variables that affect a region's suitability for adoption.

6.1.4. Regional Sustainability of Ecological Farming Approaches

For assessing the regional sustainability of ecological farming approaches (i.e., those designed to address the negative impacts of conventional intensive agriculture), a combination of scenario analysis, qualitative impact mapping and network analysis was used to compare adoption scenarios for two case study areas in southeast England. This is the first time this integrated assessment framework has been applied to agricultural assessment, having previously only been used to compare the consequences of different policy directions, and its usage here therefore demonstrates the untapped versatility of this method. The assessment

showed that the adoption of locally relevant ecological farming approaches (which included conservation agriculture and low-input farming) can positively impact overall regional sustainability.

Sustainability performance was enhanced in scenarios where the rate of adoption was high, and the distribution was clustered (although adoption rate had a stronger effect than distribution). The high clustered adoption scenarios were linked to positive impacts across a most sustainability objectives, indicating that the chosen ecological approaches were appropriate for the study area's requirements for sustainability, and that they can reconcile positive performance in different aspects of sustainability. However, the high clustered adoption scenarios were not the best option for every sustainability objective, with some objectives better served by a lower rate or more dispersed distribution of adoption. Therefore, even in the best-case adoption scenario, policy makers may still have to manage trade-offs when considering objectives better served under alternative adoption scenarios.

The inclusion of network analysis to describe the interacting cause-effect relationships between drivers of change and impacts on objectives identified key nodes and pathways that explained the sustainability performance of different adoption scenarios. This highlighted the importance of information access and sharing for regional sustainability of the ecological farming approaches. Having access to information on the benefits of ecological approaches increases farmer willingness to adopt and makes it more likely these approaches will be implemented effectively. Information sharing also facilitates the coordination across farms needed to optimise the spatial configuration of environmental management for public good delivery beyond the farm level. Strong organisational and advisory support, the use of technology, and the quality of social relationships also played pivotal roles in the networks, at least in part due to their contribution to information access. This example also illustrates the broader point that the regional sustainability performance was the product of both farm-level and landscape-level processes, and that there may be linkages between the pathways underpinning sustainability at different spatial scales.

6.2. Implications for adoption and sustainability performance of ecological farming approaches and AES at regional level

6.2.1. Farmer identities and resistance to change associated with 'public money for public goods' reform

The observation from the interviews that farmers adapt the public goods concept to fit with their own identities and views about what farming should be could present a challenge for the reform of agricultural policy to promote ecological farming approaches and practices. Policy reform may be weakened if agricultural stakeholders can reshape the meaning of 'public money for public goods' to make it align with the good farmer ideals under a productivist culture, rather than farmers adapting their identities in response to a new policy direction. If AES for public good provision can be designed to allow farmers to demonstrate skilled performance and so accrue cultural capital, these practices could become accepted as part of a good farming identity, but these benefits can take time to materialise and be recognised by other farmers (Riley, 2016), so there is a danger that hostility towards, or conflicting interpretations of, 'public money of public goods', lead to policy reform being watered down before it is able to effect meaningful change.

This conflict between the objectives of policy reform and farmer mindsets is nothing new. In the late twentieth century, many commentators in rural social science thought that reforms to the Common Agricultural Policy (CAP) would initiate a transition in the agricultural sector, from a productivist approach, centred on intensification and industrialisation of farming, where the priority was to increase productivity, to a post-productivist approach, with an alternative vision for a more multifunctional agricultural landscape (G. A. Wilson, 2001). However, this view was contested by subsequent research, as empirical evidence showed that productivism was still dominant in farming communities, with farmers tending not to change their production systems to the extent that they could be described as post-productivist (N. Evans et al., 2002; Walford, 2003; G. A. Wilson, 2001; Zomeni et al., 2008). Although agri-environment policy resulting from the CAP reforms became well-established in the UK and EU member states, studies continued to find that a large core of conventional farmers remained embedded in a mindset that placed maximising productivity at the centre of their identity, regardless of exposure to AES, or the prevalence of discussion around more conservation-oriented approaches to farming (Burton & Wilson, 2006; Saunders, 2016; Walford, 2003).

Given that the farmers interviewed here interpreted the 'provider of public goods' idea in a way that suits their productivist identities, it is possible that history will repeat itself with the current agricultural policy reform in England. Top-down policy reform may be insufficient or even counter-productive in reframing cultural identities to increase engagement with farming approaches to enhance public good provision. While interventions imposed on farmers may be enough to coerce them to adopt AES for financial benefit, deeper engagement may be limited, especially given the mistrust and scepticism that typifies farmer reactions to external interventions in the agricultural sector. Previous research has suggested that this control is unpopular among farmers in part because the application of prescribed measures under AES deprives farmers of opportunities to use symbolic capital that demonstrates their personal accrued knowledge and experience (Burton et al., 2008; Sutherland & Burton, 2011), and this conclusion is corroborated by the responses in these interviews. Farmer hostility to agri-environment policy due to concerns over the marginalisation of farmer knowledge has been a common theme in AES research (C. Morris, 2006), and an associated "*visceral distrust*" of institutions has been identified by other researchers as an important aspect of farmer identities in relation to Brexit and wariness of policy reform (Jones-Garcia & Touboulic, 2022).

Finding more ways to protect farmer autonomy, and respect their accrued wisdom, will therefore be important for new ELM schemes to realise their full potential in delivering public goods, and not repeat the same issues that have hindered AES performance in the past (Arnott et al., 2019). Otherwise, the new emphasis on public money for public goods, and the primarily financial perspective adopted by the new Agriculture Bill, may have only limited success in shifting agriculture post-Brexit onto a more sustainable trajectory (Howe & Ross, 2019). The government has signalled their intention to design the new ELM schemes so that they give farmers greater autonomy and independence in how they choose to deliver public goods (DEFRA, 2020a, 2020b), and if this is realised, ELM may be better able to produce effective, lasting change in farming communities compared to earlier schemes.

However, an entrenched productivist identity or a mistrust of external intervention is not an absolute barrier to adoption of practices as part of a 'public money for public goods' policy, given that farmers still reported adopting measures that they were not satisfied with, or doing so begrudgingly. Given this observation, it would help to better understand how conflicts with farmer identities affect the relationship between practice adoption and sustainability performance. This could be achieved by studying whether there is a difference in sustainability performance between farmers who adopt an environmental management practice primarily because it aligns with their view of their role as a farmer, and those who adopt the same practice

primarily out of economic necessity. Such research could help clarify the extent to which financial incentives could enhance sustainability performance compared to shifts in farming culture or social pressure.

Farmers may be able to reconcile adopting measures under AES with their identity as a productive farmer because these measures can fit around or alongside their current farming approach, particularly if the potential for generating and displaying symbolic capital varies between different practices or environments in the farm. Research into farmer environmental land management indicated that if other areas of the farm or farm practices can continue to provide the necessary opportunities for demonstrating symbolic capital, then there may be little cost (in terms of loss of prestige) from applying AES in certain areas of the farm (Thomas et al., 2019). However, adopting an entirely new ecological farming approach is a more radical change, which could affect the whole farm environment, and not just certain areas or practices, so issues around farmer cultural identity and symbolic capital may be a more significant barrier to adoption.

Therefore, financial incentives under AES may be enough to encourage farmers to adopt individual practices related to public good provision, but they may be unwilling to convert to a new farming approach and make radical changes to their role if they are not also compensated for social losses: otherwise, farmers are being asked to revise their self-perceptions and the meanings attributed to their actions, and lose status that may have accrued from generations of farm management (Burton, 2004). This idea is demonstrated by the networks created for the regional sustainability assessment: a scenario with high adoption of ecological farming approaches depended on many different drivers of change coming together to produce a shift in the farming community, with drivers relating not just to the economic aspects of farming decisions, but also to a farmer's social and cultural environment.

6.2.2. Local conditions and constraints on farmer adoption decisions

While an unhappiness with prescriptive interventions that conflict with 'good farming' ideals may not prevent AES adoption, the spatial analysis of ESS engagement in Chapter 4 did suggest other factors that may influence adoption rates at the regional level. Habitat quality (as reflected in the extent of designated protected areas) was associated with increased adoption for ELS-HLS and HLS-only schemes, while the land's potential to support highly productive agriculture was associated with reduced adoption of HLS-only schemes. Both variables could influence farmer decisions through their effects on the relative economic costs and benefits of adoption. In areas with high quality semi-natural habitat, land managers may have increased

opportunities for income through HLS schemes designed to target the management of specific habitats for conservation (Yang et al., 2014). Equally, in areas of high productivity, there is a larger opportunity cost involved in sacrificing potential yield in order to apply an environmental management practice such as reducing use of external inputs or taking some land out of cultivation (Espinosa-Goded et al., 2013).

These results show how farmer adoption behaviour can be constrained by the environmental conditions of the region they are in, so adoption patterns and therefore sustainability performance will vary across regions, as was seen when assessing the sustainability of ecological farming approaches in Chapter 5. Moreover, given that it is possible to identify factors that influence adoption distribution by affecting economic drivers of farmer decisions, there are clear opportunities for financial interventions to increase adoption rates and therefore the regional sustainability of agriculture, even if the proposed practices do not align with the existing dominant good farming ideals, as discussed above.

6.2.3. Adoption distribution and sustainability performance at different scales

While this thesis was designed to look at the regional performance of AES and ecological farming, 'regional' is not associated with a specific spatial scale, and the different methods in the thesis were applied at different scales. The farmer interviews focused on adoption and performance within individual farms, and in a farmer's neighbourhood, considering how adopting farms may be distributed within the landscape. The spatial analysis looked at adoption distribution across the whole of England, with the unit of study being districts rather than farms. The study areas for the sustainability assessment, meanwhile, were equivalent in size to just a couple of districts, so this method focused on a scale that was intermediate between the interviews and the spatial analysis. Therefore, the results of each method could tell us something about the implications of adoption distribution for sustainability at each scale.

The interviews indicated that at the local level, a tendency for loose clustering of farmer adoption around key individuals responsible for initiating cooperation and forming new connections, could be an opportunity for enhanced sustainability performance. Local clustering of ecological farming approaches and practices has been linked to enhanced delivery of ecosystem services and biodiversity conservation (Sutherland et al., 2012), and the sustainability assessment conducted here suggests this is also true for the overall sustainability performance of conservation agriculture and low input farming in the chosen study areas. In

both North Kent and the High Weald, regional sustainability was enhanced when farmers adopted ecological approaches at a high rate and in a clustered distribution, while low and dispersed adoption was linked to poorer sustainability performance.

Clustering of high adoption rates was observed in the spatial analysis of ESS engagement across the districts of England, but it may not be appropriate to scale up the results from the sustainability assessment and assume that clustered adoption also maximises sustainability at this scale. As discussed further below, different processes could affect the sustainability of ecological farming at different scales. It may be that the clustering of whole regions with low adoption, areas dominated by intensive agriculture, generates negative impacts on regional sustainability objectives that cancel out benefits from high adoption elsewhere in the country. Recent research has indicated that intensive agriculture has a stronger negative impact on biodiversity within regional clusters of high intensity farming, so clusters of districts with low adoption may make a disproportionate contribution to the negative impacts of intensive agriculture on the natural environment (Teillard et al., 2015). While clustering of adoption among individual farms has been closely linked to enhanced environmental performance, there is a debate in the literature over whether biodiversity conservation and ecosystem service provision at the regional or national level is better served by promoting ecological farming in regions where adoption rates are already high, thereby reinforcing clustering (Green et al., 2005; Kleijn & Sutherland, 2003), or by concentrating on regions where adoption rates are low, reducing clustering (Bengtsson et al., 2005; Tscharntke et al., 2005).

In any case, to further investigate whether the regional clustering of adoption rates should be a concern for high-level agricultural sustainability in England, it would help to repeat this spatial analysis to include ELS-only agreements, to see if they fill the gaps in the distribution of ELS-HLS and HLS-only agreements. It was not possible to address this question here because data on ELS-only agreements was not publicly available at the time of this research since all such agreements had already ended. However, in this respect, it is a positive sign that although regional participation rates in both ELS-HLS and HLS-only schemes were clustered, the cluster locations for the different types of schemes showed little overlap: there was no correlation between ELS-HLS participation and HLS-only participation in each region. If the design of different scheme types means that different factors affect their distribution at the regional level, then their adoption could complement each other to enhance sustainability performance at the regional level: areas with low adoption rates for one scheme type may have high adoption rates for the other.

This suggests that to maximise the contribution of AES to regional sustainability, it would be beneficial to provide a diverse range of complementary scheme types, designed to favour different conditions, to maximise overall adoption, and reduce gaps in adoption at the regional level. The fact that the new ELM scheme involves three different types of agreement, each designed to target different types of farmers with different levels of commitment to environmental management practices (DEFRA, 2020b), could therefore be a promising opportunity for improving the adoption and sustainability performance of AES at the regional level in England. More generally, having a diverse mix of policy instruments, that can accommodate the variation in farmer views on public good provision and motivations for adoption, has been identified as a requirement for lasting social acceptance of any agricultural policy changes for sustainability (de Boon et al., 2022). However, recent assessments of the post-Brexit agricultural policy transition suggest that despite the proposed multiple tiers of AES, more needs to be done to diversify policy design, if agricultural stakeholders are going to view this transition as effective and legitimate (de Boon et al., 2022; Pedersen et al., 2020). Other research into the factors affecting the perceived legitimacy of policy reform for agricultural sustainability has indicated that lasting, widespread social acceptance of any changes will be more likely if this transition is supported by a diverse mix of policy instruments (de Boon et al., 2022).

6.2.4. Challenges for optimising adoption clustering among farms

While the sustainability assessment indicates that the clustering of farms adopting ecological approaches could maximise sustainability performance for the chosen study areas, the farmer interviews and stakeholder discussions identified both challenges and opportunities for achieving this clustering. The interviews highlighted the importance of key individuals with the willingness and ability to initiate cooperation and build new connections with farmers for creating adoption clusters, so cluster distribution depends strongly on the occurrence of these key individuals and networks. Previous research into the diffusion of organic farming has illustrated the importance of pioneering farmers to champion novel approaches and use their central position within their social network to influence others and shape farmer's decisions to convert (Risgaard et al., 2007), and these pioneering farming champions appear to be also key for the development of cooperative environmental management in these study areas. Where these individuals are absent, external facilitators may be needed to support adoption and joined-up management but given the natural tendency of farmers to be sceptical of external intervention, care will need to be taken to ensure that this facilitation respects and

acknowledges local knowledge and farmer experience. This is a theme that has recently been highlighted by other researchers in the context of ELM implementation: identifying trusted individuals to act as intermediaries, with strong interpersonal skills and locally relevant experience, will be crucial for maximising engagement with policy reform and reaching less connected farmers (Hurley et al., 2022). Previous interview-based research also suggests that farmer receptivity to advisor and facilitator input will depend closely on the specific context and past and present relationships between the parties involved (Thomas et al., 2020). Moreover, while the reduced costs of cooperating across shorter distances, and strong relationships formed by a long history of working in proximity may favour close-knit adoption clusters, the interviews suggested that social networks do not always map neatly onto geographical patterns. Neighbours did not always have close bonds, or held conflicting ideals over good farming, so cooperative arrangements among adopting farmers may not necessarily be the ones that would be best for ecosystem service and public good delivery.

However, overcoming these challenges to optimise adoption clustering may be a lower priority for agri-environmental policy, at least in these study areas, given that the sustainability assessment showed adoption rate to be more important for overall sustainability than adoption distribution. Cost effective policy measures should therefore prioritise increasing adoption rate over increasing clustering. Although the interviews indicate that clustering of adoption, particularly in the context of cooperative management, may not always occur in a way that maximises environmental benefits, maybe this suboptimal clustering is 'good enough' given the lower importance of adoption distribution compared to adoption rate for sustainability performance. In this context, the primary benefit of farmer-driven cooperative initiatives may be more about increasing the local rate of adoption through sharing information, encouraging dialogue, and exposing farmers to new ideas about good farming and farmer identities, with improvements to ecological functioning by enhancing connectivity across the landscape being of secondary importance.

Equally, however, it is possible that the optimal focus of agri-environmental policy could depend on the level of funding available. Since the low clustered adoption scenario outperformed the low dispersed adoption scenario for several of the sustainability objectives, when funds are limited, being able to increase the rate of adoption by a small amount over a large area may be less effective than using these funds to focus on clustering adoption within a small area. If more funds are available, then the optimal strategy may be to promote higher rates of adoption, and adoption clustering may be a much lower priority.

6.2.5. Farmer reputations, connections, and information exchange as opportunities for promoting adoption and regional sustainability

While conflicting farmer ideals for good farming and cultural identity suggested possible sources of resistance to a closer engagement with ecological farming approaches and practices, analysis of farmer interview responses also linked these themes to opportunities for adoption and sustainability performance at the regional level.

By defining public goods as outputs that were 'good for the public', respondents made a connection between the idea of being a provider of public goods and the public's appreciation of this role. On the one hand, the fact that farmers feel they get little public recognition for their role in providing non-food outputs means that the label of 'provider of public goods' was seen as undervaluing their role, and therefore as an unattractive aspect of farming. However, this concern over public recognition also suggested an opportunity for promoting willingness to adopt by creating ways for the public to recognise the public good provision of individual farmers. Farmers are more willing to adopt practices if they feel these help contribute to their reputation among other farmers (Burton et al., 2008; Sutherland & Burton, 2011), and the interviews conducted here suggest that the same may be true if practices can enhance their reputation among the wider community. Finding ways to make information about farmer environmental management more accessible and transparent to the public may therefore encourage greater engagement with AES and ecological farming approaches.

Moreover, while farmers may be reluctant or dissatisfied with adopting prescribed measures that are imposed upon them by economic necessity, the interviews also suggest there may be greater enthusiasm for alternative approaches when these spread through bottom-up, cooperative projects. Farmer responses relating to cooperation for public good provision suggested that these may be most effective when there is a strong farmer-driven aspect to these types of projects. This has long been recognised in research into environmental management in general: previous studies, for example, have shown that informal social networks can be more important than formal institutions in ensuring compliance with environmental regulations (Bodin & Crona, 2009). At the same time, realising the full potential of cooperative projects means creating new partnerships for environmental management, not just sticking with members of already well-established networks. This means working with neighbouring farmers who may not necessarily approach farming or identify in the same way. Making these new connections with farmers with contrasting identities could be achieved through finding common ground and finding aspects of symbolic capital or good farming that partners do agree on. The

formation of these partnerships, besides being necessary for cooperative environmental management, can improve the adoption and sustainability performance of ecological farming approaches and practices in a variety of ways.

Firstly, building connections, by looking for those aspects of cultural identity or symbols of quality that unite rather than divide farmers, may help with internalising changes to the good farmer role, and therefore increase willingness to engage closely with alternative ecological farming approaches. Those members of the farming community who help drive or champion cooperative management due to their willingness and ability to make new connections are likely to play a disproportionately important role in the adoption and diffusion of alternative farming approaches and practices (Risgaard et al., 2007). This resonates with other research that has already suggested that farmer shifts in identity are most likely to come from dialogue with peers, rather than external intervention (McGuire et al., 2013). Therefore, by proactively building connections across the farming community, these individuals may be more able to initiate more widespread change in adoption behaviours compared to external interventions which may be frustrated by a lack of trust or sympathy from farmers (Hurley et al., 2022; Jones-Garcia & Touboulic, 2022).

However, the interviews and stakeholder discussions indicated that the value of farmer relationships is about more than just their potential to shift farmer identities. These connections were influential for other reasons related to the adoption and sustainability performance of ecological approaches. The interviews suggested that farmer social networks could dictate which farmers are willing to engage with each other and so have the potential to override the tendency of nearby farmers to work together, making farm clusters more diffuse. On the other hand, in the sustainability assessments for both areas, relationships among farmers were important for information exchange, which was a critical feature of the networks for high adoption scenarios. Sharing knowledge was valued because it helped farmers to be able to recognise the benefits of ecological practices and implement them successfully and enabled them to see how management on their farm fits into the wider landscape context and participate accordingly in cooperative projects. Recognition of the importance of accessible information for shifting attitudes and effective implementation on the farm has already led researchers to call for deficiencies in ELM proposals to be addressed by increasing the diversity and prominence of information sharing (de Boon et al., 2022), and the research here adds further support to this argument by emphasising the value of information for regional as well as farm-level performance. Knowledge exchanges are therefore important for sustainability performance of ecological farming at the different levels, and relationships (and technology) are

crucial in mediating these exchanges. The role of social networks for increasing access to information necessary to support adoption of ecological farming approaches is widely recognised in the literature (Rodríguez-Entrena & Arriaza, 2013; saint Ville et al., 2016; Šūmane et al., 2018). The assessment conducted here therefore builds on this understanding by showing the value of social networks for regional as well as farm-level performance across different aspects of sustainability.

While farmer connections and information sharing are therefore critical to regional sustainability directly through impacting adoption and performance of ecological farming approaches, they also provide avenues for greater support and resilience among the farming and wider rural communities, helping to enhance community well-being, and so have wider benefits beyond the environmental dimensions of sustainability. Bridging gaps and building connections may enhance public good delivery and sustainability performance at the regional level through both increasing the rate and clustering of ecological farming adoption, while also strengthening rural community cohesion and resilience.

6.2.6. Regional sustainability performance as the product of interacting processes at different scales

The network analysis illustrated how the factors impacting regional sustainability performance do so through a complex mix of interacting pathways, but also that pathways affecting performance at the farm and regional levels are interconnected. This means that a complete understanding of sustainability performance requires an integrated multi-scale approach that gives an oversight of the interactions between processes occurring at different spatial scales: this should be a target for future studies. A policy intervention could have different impacts on adoption and sustainability depending on the scale being considered, so it is important to be able to describe the degree of alignment between sustainability performance at different levels. Identifying connections between processes at different scales helps suggest priorities for interventions that will reinforce benefits at different scales, while areas of disconnect between the processes at different scales, could flag up where there is a risk that efforts to promote sustainability at the farm level may have negative impacts at the regional level, and vice versa.

The differences in processes impacting sustainability at different scales can also be seen when comparing the findings from the different methods in this thesis. The farmer interviews suggest some form of neighbourhood effect could drive clustering of individual ecological farms, where farmers may be more likely to engage because they are close (geographically and socially) to

key individuals driving collaborative efforts. Previous spatial analyses of the distribution of adoption among farms have provided quantitative evidence for such a neighbourhood effect for at least some ecological approaches or practice types, in the form of spatial lag models to explain observed spatial dependence in adoption (Bartolini & Vergamini, 2019; Boncinelli et al., 2016).

However, the research conducted here suggests that this effect does not scale up to influence the distribution of adoption at the LAD level across the whole of England. The spatial modelling of ESS engagement showed that a spatial lag model was not necessary to explain clustering at the LAD level: high adoption in one LAD did not automatically make high adoption more likely in nearby LADs, which instead was driven by other spatially correlated variables. In other studies that have assessed spatial dependence in adoption at the regional level, some support the results found here, showing no neighbourhood or spatial spillover effect in driving the clustering of regions with similar adoption rates, while others did find a significant spatial lag effect (Bartolini & Vergamini, 2019; Boncinelli et al., 2016; Kazakova-Mateva, 2020; Yang et al., 2014). Therefore, while adoption of certain practices may occur in a clustered distribution at both the local and regional level in England, different processes could be driving this clustering at different scales, and farmer social environment and information exchange may be less relevant for higher-level patterns in distribution. This indicates that the adoption and sustainability performance of ecological farming and AES at the regional or national level cannot always be understood by scaling up the processes occurring at lower levels.

The results of any agricultural sustainability assessments will therefore depend strongly on the scale at which they are conducted, and a holistic approach to understanding overall sustainability performance will have to integrate assessments at multiple levels, rather than extrapolating from an assessment conducted at a certain scale. The qualitative assessment framework applied here, using network analysis to describe the relationships underpinning sustainability performance, provides an opportunity to develop a multi-scale approach. If networks can be constructed for assessments at different scales, interactions between these scales can be described using analysis techniques that overlay and compare multiple networks (de Nooy et al., 2018). The analysis results can then highlight priorities for more focused quantitative research. This multi-scale approach could also be useful for communicating with stakeholders and promoting engagement with ELM. Researchers have raised concerns that the different components of ELM, relating to farm, local, and landscape-level action, are increasingly being treated as separate schemes by DEFRA, and a lack of clarity about how these components fit together could be a barrier to the legitimacy and social acceptance of the scheme (de Boon et al., 2022; Maguire, 2021). An framework that uses network analysis to integrate assessments

at different scales could help overcome this barrier by clarifying and communicating the linkages between these different components of ELM.

6.2.7. Trade-offs between different aspects of sustainability

Alongside differences between different scales, the possibility of trade-offs is also relevant when considering the performance of ecological farming approaches against different aspects of sustainability. The sustainability objectives defined via stakeholder combination, literature review, and theoretical frameworks, encompassed a range of environmental, social, and economic goals for the study areas. The subsequent assessment showed that while the adoption of conservation agriculture and low-input farming could positively impact many of these objectives, indicating that these farming approaches reconcile performance across different aspects of sustainability, there were still some objectives, including housing equality and employment, where impacts at the regional level were uncertain or negative under high adoption scenarios. Therefore, efforts to promote the adoption of conservation agriculture and low-input farming in these study areas should acknowledge that they will have to make decisions over prioritising conflicting objectives.

These trade-offs could be accommodated in agri-environmental policy through the spatially explicit zoning and targeting of payments, so that different areas are focused on delivering different objectives that may have been difficult to deliver simultaneously in the same location. This already occurs to some extent: the spatial analysis of ESS engagement in England provided some indication as to how these schemes have been effectively targeted towards priority areas with high nature value (which may reflect the division of the country into target areas and regional themes), and how the distribution of scheme management options varies depending on the chosen agri-environmental theme.

The extent to which adopting ecological approaches and practices involves trading different aspects of performance off against each other as opposed to delivering universally positive outcomes was also an issue relating to whether and how farmers reconciled the provision of public goods as part of their identity. Some described the provision of public goods as a secondary aspect of their identity, separate to their role in producing food for society for profit, which meant public good provision sometimes had to be sacrificed for them to fulfil their role as a productive farmer. Others saw public and private good provision as interdependent, and that these different aspects of their role could not be traded off against each other: producing food for profit was dependent on, and necessary for, the provision of public goods contributing to regional sustainability performance.

These different viewpoints are effectively a microcosm of a wider debate among research and policy circles, concerning the extent to which alternative farming approaches can deliver positive outcomes for all aspects of sustainability simultaneously. The new direction for English agri-environment policy post-Brexit was based on the position that the goals of protecting the natural environment, supporting rural development, and maximising agricultural productivity and profitability are fully compatible (Gove, 2018). Some commentators have argued that this is not always possible, and policy makers must prioritise and engage in trade-offs between these different goals (Whitfield & Marshall, 2017). Stakeholders have already expressed disagreement over the extent to which the new Agriculture Bill gives enough consideration to achieving an appropriate balance between food production and other objectives (EFRA, 2018; Finlay et al., 2020). Even proposed 'win-win-win' concepts such as sustainable intensification have been criticised for failing to recognise that strategies for agricultural and rural development can still result in winners and losers, so sustainability targets may be better served by managing these trade-offs rather than aspiring to an unrealistic goal of achieving everything at once (Whitfield et al., 2015; Whitfield & Marshall, 2017).

The sustainability assessment results here suggest that while ecological farming can reconcile strong performance across most aspects of sustainability, it is not always possible to deliver positive outcomes for every sustainability objective, with some trade-offs unavoidable. The methodology used was purely qualitative, no weights were assigned to the objectives, and so this approach does not tell us about the relative desirability of individual objectives, and which objectives should be prioritised over others in the case of conflicts. However, this qualitative assessment is still useful in making these trade-offs explicit and identifying the key pathways that give rise to conflicts between objectives, helping to focus the attention of decision-making on the most important issues for optimising regional sustainability performance.

However, it is also important to recognise that the assessments were specific to the case study areas. The assessment process highlighted the context-dependent nature of defining sustainability and sustainability performance, so repeating the assessment for different regions and farming approaches may lead to different conclusions. Therefore, it is unsurprising that the ability of ecological farming approaches and practices to deliver win-win-win outcomes for food production and other sustainability goals continues to be debated among farmers, researchers, and policymakers, because there is no single answer that is relevant across all contexts.

6.2.8. Geographic context and sustainability performance of ecological farming

The importance of local context for adoption and sustainability performance of alternative farming approaches and practices could be seen in both the spatial analysis and sustainability assessment results. The spatial modelling of ESS engagement showed some of the ways in which farmer adoption may be constrained by the conditions associated with the district they are based in. Farmers in districts with highly productive landscapes are less likely to adopt environmental management practices that involve sacrificing potential yield, while farmers in districts with high quality habitat may take advantage of extra income through AES.

Similar conclusions can be drawn from the sustainability assessment. On the one hand, there were broad similarities in overall impacts on sustainability objectives and key network pathways between the North Kent and High Weald study areas, suggesting that the regional sustainability of ecological farming, and the mechanisms underlying sustainability performance, may be similar in areas with different geographic characteristics. Therefore, interventions to favour the adoption of ecological farming could be expected to be generally applicable and deliver similar benefits across a wide area. However, although there were more similarities than differences in the regional sustainability of ecological farming across the study areas, the results were not identical, with some differences in impacts on sustainability objectives, generating different trade-offs, and different pathways or barriers for sustainability performance reflecting the local characteristics of the case study area.

The differences in study area characteristics also meant that initial stakeholder consultation placed a slightly different emphasis on which approaches would constitute ecological farming for the adoption scenarios in each study area. While the North Kent high adoption scenarios focused on conservation agriculture, in the High Weald, a mix of conservation agriculture and low-input farming was considered most appropriate. Previous farm-level assessments of conservation agriculture and low-input farming have found that they were not always appropriate for the ecological and socio-economic context (Baccar et al., 2019; Craheix et al., 2016; Jayaraman et al., 2021; Lahmar, 2010). The ability of certain ecological farming practices to deliver intended environmental benefits has therefore found to differ between regions (Bamière et al., 2022). The assessments performed here align with these observations from farm-level research, suggesting that choosing a locally appropriate ecological farming approach is relevant for maximising sustainability performance at the regional level as well as the farm level.

Furthermore, although the differences in the assessments between the study areas were relatively subtle, this was in part a reflection of the deliberate choice to choose two areas that were similar enough to make detailed comparisons. There are likely plenty of pairs of case study areas in England that would generate much greater differences in assessment results. Being only about 20 miles apart, North Kent and the High Weald have much in common in terms of both physical and human geography. Given that even with these two similar study areas, the assessments still produced different outcomes that could be linked to differences in local conditions, it is likely that ecological farming sustainability performance would show even stronger differences when comparing other, more contrasting areas in England.

This creates a challenge for policymakers seeking to promote the adoption of ecological farming to achieve sustainability goals. It may be possible to enhance sustainability performance to some degree by using the same strategies to promote the same approaches everywhere, but the context-dependent nature of sustainability means that if ecological approaches are to realise their full potential, there will not be one approach that will maximise sustainability performance everywhere. For policymakers to help optimise the regional sustainability of ecological farming approaches and practices, interventions need to have the flexibility to be tailored or adapted to suit local needs.

This observation echoes some of the suggestions raised by commentators and researchers concerning the potential effectiveness of policy reform at the farm level in England following Brexit, who have argued that scheme performance will be enhanced if it recognises the legitimacy of local knowledge and farmer perspectives on appropriate practices for the local conditions (Howe & Ross, 2019; Whitfield & Marshall, 2017). This will mean involving farmers in identifying the practices that are most ecologically appropriate for their land and requiring policy makers to be open to locally supported solutions (Howe & Ross, 2019). This approach not only ensures that the practices adopted will have a more positive impact on regional sustainability, but has the added benefit of respecting farmer autonomy, giving them greater freedom to display their quality as a good farmer (as discussed above in relation to farmer concerns over interventions to promote public good provision), and therefore encouraging greater engagement and adoption. Therefore, when these arguments from the literature are considered in combination with the results presented here, ensuring solutions for agriculture are locally relevant is clearly important for adoption and sustainability performance across different spatial scales.

The importance of geographic context may also help with interpreting the results from the spatial analysis of ESS engagement in relation to the wider literature on AES adoption. Not all the chosen independent variables behaved as expected based on the literature. The existing literature on spatial dependence in regional adoption rates already indicates that driver impacts can depend on location (Boncinelli et al., 2016; Mozzato et al., 2018; Yang et al., 2014), and the research presented here adds to the diversity of observed patterns in spatial dependence and roles of explanatory variables in regional adoption distribution. The other studies conducted so far at this scale show a lot of variation, even when comparing similar practices or farming approaches. Some variables are found to be important in some studies and not others, some show spatial dependence while others show random distribution, and sometimes spatial dependence is due to spatial error, sometimes spatial lag, and sometimes both. Therefore, the influence of different farm structural or territorial factors on adoption, and the types of processes shaping adoption distribution at the regional level, appear to vary across study areas.

This suggests that the next step in researching the drivers of adoption distribution at the regional level in England and beyond should also test how the effect of drivers varies with location. In spatial analyses, this can be studied using spatially weighted regression models, which allow for non-stationarity in the direction and magnitude of independent variable effects across space, to see if and how the factors affecting adoption vary spatially (Taus et al., 2013). The spatial analysis conducted here assumed that the independent variables operated in the same way across all of England. However, given that the sustainability assessment pointed to subtle local differences in the way drivers of adoption impacted sustainability performance, it is possible that this may not always be a valid assumption, even within a relatively small area. Applying a model that allows the effect of an independent variable to vary across space would therefore help to test the assumption that factors affect adoption the same way in different areas. However, the idea that the difference in driver impacts between this study and those conducted in other countries reflects actual geographic differences in how drivers of adoption operate should also be examined by conducting spatially weighted regression at a higher level, ideally internationally.

6.2.9. Data availability for researching adoption and sustainability of ecological farming at different scales

An international study of the type outlined above would improve understanding of spatial variation in adoption drivers. However, conducting an analysis that extends beyond England's borders would be complicated by the fact that different countries have different forms of AES,

and different agricultural datasets, making it hard to find data used consistently across multiple countries to support an international analysis. However, for those countries still within the EU, the EU's Farm Accountancy Data Network (FADN) provides promising opportunities for large scale research into ecological farming adoption and sustainability. The FADN has been designed to monitor and evaluate implementation of the EU's Common Agricultural Policy (CAP), by collecting detailed annual financial and economic information from a representative sample of farms across member states (Vrolijk et al., 2016). Researchers have previously used FADN data to proxy for environmental variables, and there are plans to extend the scope of the FADN to include data on other aspects of farm performance to reflect different aspects of sustainability (Vrolijk et al., 2016; Vrolijk & Poppe, 2021). Therefore, this dataset has the potential to be used for estimating ecological farming adoption rates and impacts across different countries. Moreover, if agricultural survey data in England could continue to be collected in a way that ensures compatibility with the FADN after Brexit, then the ability to make meaningful comparisons with other countries would also help improve understanding of the drivers of adoption and sustainability performance within England. However, because FADN data is only available for much larger spatial units than England's LADs, it would not be possible to assess spatial distribution at the same level of detail as considered here. The increased opportunity to test how drivers of adoption vary across space must be traded off against the coarser resolution of spatial analysis, and reduced power to detect and describe spatial patterns.

This trade-off shows how data availability limits our ability to apply quantitative methods to assess adoption and sustainability performance of alternative farming approaches beyond the farm level. Outside of AES (Bartolini & Vergamini, 2019; Yang et al., 2014) and certified organic farming (Blaće et al., 2020; B. Ilbery & Maye, 2011), there are few existing regional, national, or international datasets on the uptake of alternative ecological farming approaches. Conservation agriculture and low-input farming were the focus of ecological farming adoption scenarios for the High Weald and North Kent study areas, but to date, there is no formal classification of farms in these areas according to whether they have adopted these approaches. The interviews and sustainability assessment indicated that the spread of these approaches may be initiated by farmer-driven initiatives, rather than as part of any externally imposed scheme, so their adoption may go under the radar, limiting our ability to monitor their uptake as it happens. This means that evidence informing policy may be incomplete, and interventions may be poorly targeted, and not necessarily recognising the approaches that are in most need of support. In defining scenarios for the sustainability assessment, the current and possible future rate of occurrence of ecological farming approaches was estimated based on stakeholder and expert

knowledge. While this approach was sufficient for a purely qualitative assessment, it would help to be able to more accurately quantify the occurrence of these ecological approaches at the regional level to track and respond to future changes.

Although there is no official dataset of farmers practicing conservation agriculture or low input farming in England, if it is possible to characterise these different farming approaches according to proxy variables used in national and international datasets such as the FADN (Vrolijk et al., 2016), we could derive more reliable estimates of the actual spread of these ecological approaches. These estimates could then be compared to adoption levels in the sustainability assessment scenarios, helping to identify the potential consequences of the observed adoption patterns, and therefore which trade-offs between regional sustainability objectives need to be addressed. The typology for ecological farming approaches referred to in the sustainability assessment (Rega et al., 2021) could help achieve this. The typology characterises different ecological farming approaches in terms of different combinations of farming practices that can be described in terms of metrics that can be captured in FADN data, so it could be used for quantitative evaluations of the adoption and sustainability performance of ecological farming at the regional level. While such an approach would still be constrained by the available regional agricultural datasets, it would provide a useful complement to the results from qualitative methods.

6.2.10. Reflections on the sustainability assessment methodology

The specific combination of scenario analysis, impact mapping, and network analysis, as a tool for sustainability assessment, has only recently been developed, but this research demonstrates its value for future sustainability assessments that integrate processes across different spatial scales. This is the first time this methodology has been used in agricultural sustainability research, and as such, it would be useful to reflect on the process and identify lessons for future applications of this assessment framework.

Sustainability is a normative concept, and the results of this assessment are strongly dependent on the context in which it is conducted. The choice of sustainability objectives, drivers of change, and the patterns of cause-effect relationships will inevitably reflect the views of the specific participants involved in this assessment. This is illustrated by the mixed perspectives among participants on the role of organisations and advisors as a driver of change. Unsurprisingly, representatives of environmental organisations and land management advisors believed strongly in their ability to effect change. On the other hand, some farmers were highly sceptical of the potential for external parties to make a different to adoption patterns and regional

sustainability performance, arguing that this driver would only have a minor effect, and real meaningful change was more likely to come from other sources. The assessment results may also reflect certain narratives that stakeholders are trying to push. For example, the High Weald AONB management body was championing regenerative agriculture, and so the views of their representative, could in part reflect a desire to promote this farming approach to a wider audience. However, the fact that their contributions were largely consistent with other stakeholders and farmers with different agendas provided us with greater confidence in the reliability of their input.

Therefore, it was important that the participants for the various phases of stakeholder consultation were deliberately chosen from different sectors, backgrounds, and networks, to ensure, as best as possible, that we captured the broadest variety of stakeholder perspectives in this assessment (Tables S5.4 and S5.10). However, the qualitative nature of this assessment means that while their contributions may be illustrative of some of the types of stakeholder perspectives in these study areas, we cannot assume that the views of the participants are necessarily representative of the wider views of stakeholders across the study areas. It is possible that repeating assessment with a different set of participants would generate a different outcome.

Moreover, the assessment results reflect the stakeholders' views at a specific point in time. The concerns and priorities of stakeholders will change over time, such that the same group of stakeholders could come to different conclusions if the assessment was repeated a few years later. As an example, since the assessment was conducted in the winter of 2021-22, the changing geopolitical context associated with Russia's invasion of Ukraine in 2022 could mean a shift in the emphasis stakeholders place on the role of food security, input costs, and farm prices, changing the role of these factors in the scenarios.

When it comes to evaluating whether the assessment results do represent plausible and meaningful scenarios, a key factor to consider is the extent to which the contributions from different sources (expert opinion, literature, stakeholder consultation) reflect a common narrative, or provide contradictory accounts. The input from different stakeholders used in constructing the scenario assessment matrices and network graphs largely corroborated each other, with different stakeholders converging on common ground. Differences of opinion tended to be differences of degree (for example, over the extent to which organisations and advisors can help mediate information exchange among farmers), rather than differences concerning the direction or type of causal relationships between drivers and impacts. This

general coherence, and the fact that the key pathways highlighted by scenario analysis could also be derived from the academic literature, provide support for the validity of the main findings of the assessment.

However, there are some areas of uncertainty, where stakeholders did not come to a consensus about the nature of impacts on objectives under different scenarios, or where stakeholder input diverged slightly from academic evidence. For example, within the High Weald, there was widespread agreement that regenerative livestock farming would enhance carbon sequestration, but the evidence in the scientific literature is less definitive than stakeholder responses would suggest (Govaerts et al., 2009).

The relationship between farm size and uptake of environmentally friendly practices is another area where the links between the scenario narratives and other evidence could merit further investigation. Compared to smaller farms, stakeholders and experts perceived an increase in larger farms in North Kent as making the application of more intensive farming practices more likely, with associated negative impacts on environmental sustainability objectives. While there is evidence for this pattern in the literature (Bijttebier et al., 2017; Gilg, 1991), it has also been observed that larger farms, with higher turnovers, may have less difficulty in applying measures that require reductions in agricultural intensity, and be better able to absorb the fixed costs of adopting a new ecological practice (such as new equipment), giving them a greater capacity to invest in ecological farming approaches (Ducos et al., 2009; Trujillo-Barrera et al., 2016). Moreover, the results of the regional spatial analysis of AES participation in chapter 4 found that uptake rates were higher in regions where average farm size was greater. Adoption of AES alongside current farming operations is a distinct phenomenon from full conversion to an ecological farming approach, and could be expected to involve different drivers, but these different results suggest that the relationship between farm size and agricultural intensity may also vary depending on context. The negative impact of increasing farm sizes in North Kent on certain sustainability objectives may reflect the specific characteristics of large-scale farming operations in North Kent, rather than farm size per se. It could be informative, therefore, to investigate whether the relationship between farm size and high input practices varies between different regions in England, and what factors could be driving this variation.

Some topics, such as the overall impact on rural employment under the different scenarios, remained unresolved – but in this instance, this also reflects a recognition in the literature that the rural employment impact of ecological farming is a complex issue requiring consideration of many different socio-economic factors (Lobley et al., 2009; Mills, 2012). Nevertheless, this

assessment output can still 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, means 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 stakeholder engagement efforts and research using quantitative methods should be prioritised.

The design of the network graphs is well suited to representing the complexity of sustainability performance at the territorial level, allowing for the inclusion of complex interactions between different causal pathways. An extension to the network design, to further enhance the validity of the graphs, would be to introduce the possibility that the impacts of sustainability objectives could in turn affect the state of the drivers of change. The findings from the farmer interviews in chapters 2 & 3, and the spatial analysis in chapter 4, suggest some ways in which these feedbacks could occur. Under the high adoption scenarios, increasingly engaged and politically active rural communities, and the development of more constructive relationships between farmers, the public, and other rural stakeholders, associated with the delivery of the political democracy and community well-being objectives, could reinforce the impact of the consumer demand and organisations and advisors drivers. The farmer interview responses discussing the importance of feeling valued by consumers, and the quality of relationships with facilitators for cooperative management, for the adoption and clustering of ecological farming approaches, provide an indication of how this feedback could occur. Likewise, in scenarios where the biodiversity and habitat quality objective is positively impacted, this could mean that in the longer term, the area is prioritised for AES to protect the existing high-quality habitat. The investigation into the factors affecting AES uptake distribution at the regional level in England identified the quality of the natural environment as one of the most important factors determining uptake. Therefore, it is possible that improvements to local biodiversity and habitat quality could result in the area being designated as a target area for future AES, potentially reinforcing the impact of the agricultural policy driver.

6.3. Conclusion

Assessing the potential of ecological farming approaches and AES to meet the challenge of feeding the world's population without compromising our ability to feed future generations requires an assessment of their performance across all aspects of sustainability. To date, most such assessments have focused on the farm scale, but we must consider how these approaches

perform at all scales for a full understanding of their performance: the processes shaping adoption and performance can vary with scale, so results cannot just be extrapolated from one scale to another. The limited availability of consistent quantitative datasets on the adoption and impacts of different types of ecological farming, mean that sustainability assessments beyond the farm scale are scarce. This thesis addressed this gap with an interdisciplinary approach to show that for south-east England, ecological farming approaches do have the potential to positively impact performance across different aspects of sustainability at the regional level and that performance is maximised when the adoption rate is high and spatially clustered. The methods used also complemented each other to identify key drivers and barriers for achieving this high and clustered adoption configuration, showing how farmer identities, interpersonal relationships, information accessibility, local geographies and the diversity of available policy instruments, all had important roles to play in improving regional agricultural sustainability.

However, this result does not suggest that adoption of ecological farming by itself is a panacea for sustainability. High clustered adoption of appropriate ecological approaches can still generate some trade-offs between regional sustainability objectives, and how a given ecological approach impacts sustainability, particularly in terms of its ability to reconcile performance across different objectives and minimise the need for trade-offs, depends on the geographic context. In this respect, the diversity of ecological approaches and practices presents an opportunity for sustainable agriculture. Since there is no one option that will work best everywhere, it will likely be necessary to utilise the full diversity of ecological approaches to optimise regional sustainability performance. It is therefore important for agri-environment policy to recognise this diversity: different approaches will perform better in different areas and under different adoption scenarios, so farmers should be supported to adopt the approach that is most appropriate for their location. The case for policy intervention that gives farmers the flexibility to adopt farmer-driven, locally supported solutions is further supported by the pivotal role of farmer communities and information exchange for adoption and sustainability performance highlighted in the farmer interviews and sustainability assessment.

Given the findings presented here, the initial proposals for ELM schemes are encouraging for the future of English agriculture. Support for practices characteristic of ecological farming approaches have featured prominently in ELM proposals, alongside landscape-scale action, the flexibility to allow farmers to select options relevant to local conditions, and complementary scheme types suitable for different types of farmers (DEFRA, 2020b). As per the findings discussed here, all these features provide opportunities for enhancing the regional sustainability of agriculture. Equally, this research shows that mechanisms to encourage information sharing

and build new relationships with farmers will also be crucial to sustainability performance, supporting the arguments of recent publications that have argued for greater emphasis on these processes in ELM design (de Boon et al., 2022; Hurley et al., 2022). At the time of writing, it remains to be seen what impact the government's announced ELM review will have and whether this will result in a downgrading of the more ambitious elements of ELM (Benwell, 2022; EFRA, 2022). As the farmer interviews illustrated, while the idea of 'public money for public goods' may prompt a re-evaluation of the role of farming in society, it is also possible that this public goods concept is manipulated by farmers to make it fit identities that are centred around the production of food for profit. Therefore, while ELM could be used to support the more widespread, spatially clustered adoption of ecological farming necessary to improve the regional sustainability of agriculture in England, conflicts with farmer identities may be a factor contributing to resistance among agricultural stakeholders that influences political reluctance to progress with these reforms.

Regardless of the final shape of England's agri-environmental policy, being able to monitor its performance in terms of farmer adoption and impacts on regional sustainability will be useful to ensure that policy can continue to be refined and adapted to optimise agricultural sustainability at every level. Understanding the overall sustainability of alternative farming approaches requires us to combine the results of assessments conducted at different spatial scales: this is one of the next big challenges for agricultural sustainability research. Limitations in data accessibility means that agricultural adoption and sustainability research often uses methods that are specific to a particular scale or area. The methodology used here for the sustainability assessment, however, helps address this challenge by providing a framework to integrate sustainability research across different scales, bridging the gap between farm-level and regional-level research. By demonstrating the versatility and utility of this framework for agricultural assessments, this research helps pave the way for an integrated approach necessary for a complete understanding of agricultural sustainability accounting for the interactions between different scales.

6.4. References

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