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FoPIA-Surefarm 2 Case Study Report United Kingdom

Work Performed by CCRI

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D5.5 Impacts of future scenarios on the resilience of farming systems across the EU assessed with quantitative and qualitative methods

Supplementary Materials L. FoPIA-SURE-Farm Case Study Report United Kingdom

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1 Introduction

1.1 Main indicators, resilience attributes and challenges

The case study area is in the East of England, a large arable farming area. There was some discussion amongst participants as to what arable farming constituted here. For example, some areas of land have less fertile soils than others and so grow a rotation of wheat and oil seed rape (OSR). However, the richer soils where historically peaty wetlands have been drained have rotations of wheat with vegetables. It was decided that the area of land with wheat and OSR rotations would be focused upon, as the vegetable growing areas are more akin to horticulture than arable.

Table 1. Main indicators and their performance and development. Source: FoPIA Country Report United Kingdom

Main indicators	Current level (score 1:5)
Productivity (per ton/ha)	3.6
Net farm income	3.0
Soil quality (erosion/stability)	2.6
Biodiversity	2.9
Happiness index (OECD) of rural population	2.8
% of products with higher animal welfare	3.7

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Table 2. Main resilience attributes and their presence in the farming system. Source: de Grunne et al. (2019; FoPIA Country Report United Kingdom)

Main indicators	Current level (score 1:5)
Reasonably profitable	2.3
Related to local and natural capital (production)	1.9
Diversity of farms types	1.1
Socially self-organized	2.2
Connected with relevant stakeholders outside the farming system	1.9
Infrastructure for innovation	2.0

Main challenges for the farming systems are:

- Low prices: This means that farmers struggle to be profitable and therefore struggle to look after their natural capital / resources and is caused by global market competition.
- Land ownership model and high rents: The UK model of land ownership is still archaic and means that land owners often have strong influence over how the landscape is managed. It also means many farms are tenanted to farmers, who are subject to high rents from land owners due to the high value of land. This means farmers struggle to make a profit and are not able to care for the natural resources.
- Transitioning from use of manufactured chemicals: This is a challenge due to the lack of support in advice, innovative solutions and financial help needed whilst transitioning to lower chemical use or organic systems. As the soil becomes reliant on chemicals without organic inputs and crops are bred to be used alongside chemicals, there is a lag period when reducing their use in which soil life needs to be reactivated and crops need to adjust to different sources and levels of nutrients.
- Winter crops: The cost of winter cover crops to keep soil healthy and protected from winter weather can be high and therefore a challenge. Killing these off and or sowing through them in spring can also be a challenge. Wet autumn weather further poses a difficulty in sowing them.

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- Changes in environmental payments: The uncertainty around how these may change and how much money is available to them under a 'public money for public goods' scenario is a challenge and source of stress for farmers. Not having enough funding for them also may mean a challenge in increasing natural capital resource health.
- Climate change: This could negatively affect most natural resources and creates uncertainty in crop yields as well as through transitioning to more environmentally friendly practices.

1.2 Participation in the workshop

For the workshop, a range of stakeholders from different backgrounds were invited, including farming, the UK's largest national farming organization, science and government. There were 5 stakeholders altogether (originally more had accepted the invitation, but due to the politically turbulent time of year, 10 stakeholders cancelled at short notice). The participants consisted of a relatively small-scale land owner and agricultural consultant; a second agricultural advisor, an NFU regional director; a representative of the Country Land and Business Association (CLA) and a government Defra (Department of Environment, Food and Rural Affairs) Natural Science Monitoring & Evaluation representative for the new Environmental Land Management Scheme. No participants had taken part in FoPIA 1.

The workshop ran from 10 am – 3 pm in a location close to the UK SURE-Farm study region (East of England) in order to attract those with the right knowledge and background. The SURE-Farm project was introduced. The objectives and geographical scope of the project were briefly introduced. The three concepts defining resilience were then explained as set out in Meuwissen et al. 2019:

Robustness: the capacity to withstand (un)anticipated shocks and stresses and to main previous levels of functionality without major changes.

Adaptability: the capacity to identify and adapt to constantly changing conditions, to learn from them and emerge even stronger from disturbances, but without changing the main function of the farming system.

Transformability: the capacity to change the main function of the farming system in response to either severe shocks or enduring stress that make business as usual impossible.

The participants agreed on the main challenges and indicators of both farm function and resilience. They further agreed on the scoring from FoPIA 1. Some explanation was needed to introduce and explain the context of each indicator.

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2 Results

2.1 Maintaining the status-quo

2.1.1 Introduction

In order to keep the current system as it is, participants provided minimum or maximum levels of indicators, resilience attributes and challenges.

2.1.2 Indicators

Soil health

As soil health in the UK generally, and perhaps more so in East Anglia, declines due to heavy use (exhaustion due to lack of organic matter returning to the soil and short rotations), it is becoming an increasing problem for producing food and sustaining above and below ground biodiversity.

Soil health was thought to be a difficult aspect to measure due to the inability to easily measure microbial diversity and abundance due to high costs and complex methods. Despite this, it was recognised that a wide range of physical soil properties can be measured as well as macro-biology such as earthworms. As a minimum threshold, a baseline of soil health should be recorded on all farms from which to measure changes in subsequent years. A suite of soil health measurements including organic matter, texture, colour, moisture, nutrients and earthworms should be taken to track change. Alongside this, the % of cover crops, % spring crops, rotation length and seedbed preparation techniques (till / soil disturbance) should also be tracked in order to take a holistic approach to preventing further decline of soil health. This would also help farmers and other stakeholders understand soil health better and therefore manage it more sustainably.

Biodiversity

As with soil health, biodiversity is undergoing decline due to lack of habitat with larger fields and less plant diversity, causing low insect and animal diversity. In order to maintain the status quo and again prevent this ongoing decline in biodiversity, it was thought that a threshold would be a minimum % of crops which require pollinators should be incorporated into rotations. It was also thought that, following on from the above mentioned 5-year tenancies, rotations should be 5 years as a minimum threshold. Other farm elements such as having hedgerows on all field boundaries and diverse hedgerow species should be incorporated.

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Happiness index of farmers

Happiness is key to mental and physical health in farming, as well as in encouraging new entrant farmers. It is currently a challenge with physical isolation on large farms with very few employees increasingly common, as well as financial pressures.

The initial title here was 'happiness index of the rural population', however as this is diverse, the most important was thought to be that of the farmer. Currently, social isolation through lone working has a negative impact on mental health and is an issue. As there are many happiness indexes, this referred to the OECD example, which incorporates many questions measuring happiness. With the short amount of time available to discuss this, it was thought that the most important may be the farmer feeling valued in that they are contributing positively to society. This threshold could be measured on a % or scale basis, with a minimum threshold that they felt as though they are contributing. A maximum was not given by the group.

Percent of products certified higher welfare standards

Welfare standards (certified by government or an independent body) are at risk of declining depending on future trade deals with the EU and internationally. It was felt important to clarify that UK welfare standards are relative to those in the rest of the world, as Brexit has caused an assumption that we have some of the highest standards globally, which participants felt is not necessarily true. As above, there has been discussion amongst government, farming and environmental organizations that welfare standards could fall if certain trade deals are made internationally, however it is still the case that the UK should recognise that its welfare standards need to be improved from their current level regardless of trade deals. In order to keep the status quo, then the threshold could be the minimum currently in place (including red tractor certification and those that are in higher standards such as organic) should stay as they are. However, it was felt that with Brexit, under a scenario where we do not import lower welfare standard products, the threshold should be that 100% of British products should be higher welfare.

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2.1.3 Resilience attributes

Diversity of farm types

Farms have seen a move away from diversity on individual farms in terms of produce. This also has been a regional diversity decline, with some regions seen as better at producing one crop than another linked to soil and climate type.

In order to keep the status quo of farm diversity, current measures should be kept. Within East Anglia this farm diversity is low but includes mainly wheat in rotation with oil seed rape as well as wheat in rotation with vegetables in areas of more fertile soil. There are also a few farms who are now integrating livestock to graze cover crops sown over winter ahead of spring sown wheat. However, with current declining soil health, a move towards more mixed farming in East Anglia would help stabilise (and eventually increase) the current diversity. It was noted that farms do not need to be small to be mixed (which is a common presumption), as big estates do incorporate different farming types as well as a current move towards arable farmers cooperating with livestock farmers to graze off cover crops in winter. A need for more abattoirs and other mixed farming infrastructure was expressed. With regards to non-agricultural diversity, big estates often have non-farm enterprises such as renting out buildings in order to stay profitable. Opportunities for these estates to do so need to be kept open as we progress through Brexit. The workshop participants were not able to think of a suitable threshold for future systems however.

Socially self-organized

Social self-organization is increasingly a challenge for farmers who are physically and socially isolated and stressed by a range of factors ranging from financial to political and environmental. This means there is little time to make associations with other farmers and facilitate group meetings.

In order to maintain status quo, current farmer facilitation and advice groups such as Agri-tech E, Farming and Wildlife Advisory Group (FWAG) should be supported and more capacity given for new ones in order to prevent decline in farmer facilitation post-Brexit. It was thought that these are often of varying sizes and scales, for example, across catchments, soil types and parishes. New cooperatives could be set up around water sharing to deal with drought concerns. Farmer-group facilitation was thought to be vital for the success of the industry in helping advice and knowledge to be exchanged, particularly in relation to dealing with upcoming change and challenges relating to the environment, Plant Product Protection bans and Brexit. As a minimum threshold, participants thought that every farmer should have access to an advisory group such as FWAG within their region or locality.

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Connected to relevant stakeholders outside of the farming system

Connections outside of the farming system are a challenge for farmers who are experiencing isolation and the range of stressors mentioned above. There has also been a general movement of understanding about where food comes from and the farming system. This has come from environmental organizations and some media who aim to create public awareness and education around food and farming, especially in light of more people living in urban areas and therefore being less connected to rural areas where most food is produced.

There was some debate over who relevant external stakeholders are, and it was decided that they include environmentalists, researchers and publics. It was thought that farmers and environmentalists now more closely cooperate towards more sustainable farming practices. Therefore, there could be an indicator measuring the percentage of farmers collaborating with environmentalists. It was also thought that publics have a better understanding of farming than 10 years ago due to environmental organizations, however there is still a lot of understanding to gain about the nuances of farming, e.g. when there is a ban of a chemical product from public pressure, farmers may have to use multiple other chemicals because government and research have not provided another solution, thus making the situation worse for the environment. Some people do not want or feel they cannot relate and engage with farming perhaps due to a lack of time, other life pressures and potentially lack of education. Another indicator here could therefore be the percentage of publics with positive attitudes towards farming. Despite coming up with indicators, the participants were not able to decide on a minimum or maximum threshold here.

Infrastructure for innovation

Where agricultural budgets are currently squeezed, infrastructure (including a broad range from advice to buildings) has been pressured and seen a decline.

In the group discussion, infrastructure was thought to cover a wide range of things from advisors to technology. Advisors and farmer group facilitators (which can often be the same) were thought to be key as these people support the adoption of new innovation through group discussions, knowledge exchange and farm demonstrations. Therefore, it was thought that the indicator could be number of advisors per farm, and that as a minimum threshold all farms should be connected to advisors and groups (as above in ‘socially self-organized’).

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2.1.4 Challenges

Low prices

Prices for crops are a challenge more generally due to their unpredictability and fluxes in the global market. Low prices were seen as a more defined challenge within this, as they are relative to the input cost of producing a yield which can often be high. A minimum threshold was thought to be a low price of £140 / t for winter wheat, however this can depend upon the yield which is obviously unknown when sown.

Winter crops (OSR & wheat)

Winter crops are a challenge due to weeds such as blackgrass and the weather causing poor yields. It was noted that the 'chemical toolbox' of options for tackling pests, disease and weeds is growing ever smaller due to bans with concern for the environment e.g. glyphosate. The status quo is that there are no alternatives when these are banned, and farmers are finding it difficult and stressful to deal with these issues which may mean crop and therefore financial losses. It was decided in this case that farmers need a minimum threshold of one viable alternative available before another is banned. There should also be a minimum time threshold of 5 years notice before a ban is enacted, giving farmers time to adjust and perhaps reduce their usage and put into practice other cultural methods which may help to mitigate the effects of not using the product.

Changes in environmental payments

Environmental payment may be subject to a decrease as the UK leaves the EU, which is juxtaposed by the need to increase the amount and quality of environmental farm management. Increasing this is necessary to mitigate climate change and enhance resilience in terms of soil health and above and below ground biodiversity.

It was thought that farmers need at least a minimum compensation payment for environmental management to deal with losing money on the crops that they would otherwise produce, and that this would actually need to be more than a minimum in order for them to run as viable businesses. For example as a minimum threshold, a rough figure for payment would be (as above under 'low prices') £140 / t and then the Basic Payment Scheme on top of this in order to make environmental stewardship viable.

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Climate change

Climate change is a challenge for crop yields often causing a decrease and altering timings for farm operations such as seed sowing. It was felt that the type of extreme weather and its impact on crops differed depending upon the time of year. The most challenging weather regarding spring cropping was thought to be flooding or prolonged rain from August until October. Therefore, the minimum threshold would be that there are no prolonged wet periods during this time, every year. It was noted that this may not be the ideal minimum threshold outside of East Anglia, or for different farming types e.g. some arable areas in East Anglia on richer soils grow vegetables during their rotations. These farmers may have a different minimum threshold at a different time of year.

Transition from manufactured fertilisers

The transition from manufactured fertilisers to organic systems, or a significant reduction in their use, is likely to be necessitated in order to decrease environmental pollution and increase the uptake of alternative sources of nutrients such as nitrogen fixing plants and long rotations. It would probably be initiated by a limit on how much can be applied to a certain area.

The main factor, which was also decided to be a minimum threshold, needed for farmers to help in transitioning away from fertilisers was advice on how to do this. Advice needs to incorporate introducing livestock in the farm system and nitrogen fertilising crops in to the rotation, as well as financial and risk planning. This needs to be on an individual basis. A need for financial support was also voiced. Financial support would be needed to cover any yields losses in transition as well as the cost of other environmental measures, such cover crop / legume seeds to add nitrogen and increase soil health, which are more expensive than the cash crop.

Land ownership and tenancies

Land ownership and tenancies can be an issue due to the short tenancy length and lack of transparency on whether land owner or tenant decides to undertake good land management and gets paid for it.

The minimum current tenancy can be 1 year, or sometimes less if the area of land is only licenced to a contractor. It was observed that it is increasingly common for 1 year or less contracts or licences. This leads to a lack of incentive and commitment to manage it sustainably, which is a factor in the progression towards poor soil health. Therefore, the threshold was decided to be a minimum tenancy length needed of5 years, ideally 10. Rent prices were also thought to be increasing due to an increase in farm diversification away from food production, for example into Anaerobic Digestate plants (which used to be incentivised by government). As a threshold, rents were therefore thought to need to be a minimum of 50% of a farmer's net margin in order for them to be able to stay in farming. It was noted that diversifications such as these actually take

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money out of the system, towards the land owners and not into the agricultural system or to farmers.

2.2 Alternative systems

2.2.1 Introduction

The alternative systems discussed included 'status quo', 'desirable' and 'likely' scenarios. Given that during the workshop, the UK was about to exit the EU, these two scenarios seemed most appropriate given the high uncertainty. This also enabled participants to think holistically about future scenarios, not simply focusing on one aspect of how a system may be run e.g. as with precision agriculture. Participants felt that a holistic view, where whole system change is to be implemented, needed to be discussed e.g. including advisory services, infrastructure, technology, farmer welfare etc. Expected developments and boundary conditions for future systems are presented in Table 3 and Table 4.

2.2.2 Desirable farming system

A desirable future farming system was summed up to be a regenerative one. This was defined as arable systems incorporating livestock into rotations in order to add manure (organic matter) back to the soil to increase its health. This would also entail greater across farm cooperation and collaboration, with livestock moving across 3 or 4 arable farms. It was also thought that within this system, subsidies should not prop up production, but that farming should be a viable business within itself, as well as having positive environmental impacts. As is the current trajectory for farming post Brexit, 'Public Money for Public Goods' was thought to be a part of this desirable system. Food prices were considered to be kept affordable in order to be accessible to all, however welfare standards would be kept high.

The likelihood of this scenario was rated as 2 out of 5, but more likely to be less than 2.

2.2.3 Likely farming system given current political and environmental situation

A farming system that is likely to happen given the current political and environmental situation was considered after thinking about a desirable system. This was thought to be one that is only changed slightly, "tweaked" from the current system. Such a scenario would incorporate 'public money for public goods' which has been under discussion over the last few years, and would manifest only as more emphasis and extending the use of existing agri-environmental stewardship features such as hedgerows and wildflower margins. It would therefore miss the opportunity to be a broader, more holistic landscape scale change.

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In terms of payments for this, it was thought that a 'volatility payment' should be put in place, in order to cushion farmers against weather and global trade uncertainties. The current Basic Payment System (BPS) was thought to be susceptible to change and being decreased by government despite current reassurances that this would not happen. There were also concerns that money set aside for tackling climate change through carbon neutrality plans may in reality be part of the same budget as the public money for public goods agricultural system, therefore putting much greater strain on this spending with less for farmers. An example was given for this regarding the UK's peat strategy.

The desirability of this scenario was rated in two ways. The first was against the status quo, which was 3 out of 5. The second was desirability in its own right, which was only given1 out of 5.

Table 3. Current perceived performance of main functions and presence of resilience attributes (FoPIA-SURE-Farm 1) and their expected change in future systems.→ implies no change, ↗ implies moderate positive change, ↑ implies strong positive change, ↘ implies moderate negative change, ↓ implies strong negative change,

Indicator	Current level	Status quo	System decline	Desirable system	Likely system
Diversity of farm types	Low	→	→	↗	↘
Socially self-organized	Moderate	→	↓	↑	↘
Connected to relevant stakeholders outside of the farming system	Moderate - low	↘	↓	↑	→
Infrastructure for innovation	Low	↘	↓	↑	
Soil health	Low	↘	↓	↑	→
Biodiversity	Low	↘	↓	↑	↘
Happiness index of farmers	Low	↘	↓	↑	↘
Percent of products certified higher welfare standards	Moderate	→	→	↗	→

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Table 4 'V' implies that a boundary condition is relevant for a future system. Arrows and tick marks in bold font are results obtained in the workshop. Arrows and tick marks in normal font are deductions from what has been said in the workshop.

Boundary conditions	Dimension	Status quo	System decline	Desirable system	Likely system
Keep or increase farm diversity	Environmental	V		V	
% farmers in socially self-organized groups	Social	V	V	V	V
% of farmers collaborating with outside stakeholders	Institutional	V	V	V	V
Advisors per farm	Institutional	V	V	V	V
Soil health maintained or increased and the % of cover crops, % spring crops, rotation length and seedbed preparation techniques (till / soil disturbance)	Environmental	V		V	
minimum % of crops which require pollinators, minimum 5-year rotations, hedgerows and field margins maintained	Environmental	V		V	
Minimum 5-10-year tenancies	Environmental			V	
% or scale of farmer feeling valued in that they are contributing positively to society	Social	V	V	V	V
% produce in higher welfare standards	Environmental	V	V	V	V

In Table 3 and 4, the current system / status quo across almost all indicators are low, with only some being moderate and none high. Most indicators would be negative for the status quo to remain as it is, as this is their current trajectory. Diversity of farm types, social self-organization and welfare standards would remain neutral however, as a negative or positive change would lead to the system coming out of the status quo to either decline or improvement.

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As could be expected, most of these indicators would undergo negative change to lead to system decline. However, the diversity of farm types and moderate level of welfare standards if kept at the current level will eventually lead to system decline as overall, they are not good enough to maintain the system. Soil health and biodiversity are currently low, however there is new advice and management practices which are reaching some arable farmers and therefore being implemented (e.g. cover crops, minimum tillage, collaborations with livestock farmers for grazing and organic matter input). Therefore, whilst these indicators are low they would still need to decrease across the whole of East Anglia to see decline. Similarly, some farmers are happy with the new knowledge they are gaining relating to the latter practices, whilst others have not received good management advice. This range in knowledge and happiness therefore means overall a decrease would be needed to implement a system decline.

Every indicator in the desirable system would need to see some degree of increase due to the low-moderate nature of the current system. Unfortunately, the low and moderate nature of current system indicators alongside the weak political will to radically improve the farming system means that the likely scenario would lead mostly to negative changes in the indicators.

As in Table 3 and 4, across all systems, % farmers in socially self-organized groups, collaborating with outside stakeholders, advisors per farm, % or scale of farmer feeling valued in that they are contributing positively to society and % produce in higher welfare standards boundary conditions are deduced to be applicable from the participants discussion. To ‘keep or increase farm diversity’ is a boundary condition for maintaining the status quo and for a desirable future system as a decrease would cause changes to the landscape, possibly creating more environmental damage if more monocrop arable farms are created. Similarly, the boundary condition ‘Soil health maintained or increased and the % of cover crops, % spring crops, rotation length and seedbed preparation techniques (till / soil disturbance)’ and ‘minimum % of crops which require pollinators, minimum 5-year rotations, hedgerows and field margins maintained’ are necessary to keep the status quo or move to a desirable system as otherwise soil health could further decrease causing lower and failing yields, biodiversity and exacerbating issues such as flooding etc.

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2.3 Strategies towards the future

The shared vision for the future is the desirable scenario discussed in the workshop and shared above. This is a regenerative system that includes more cooperation amongst farmers and outside stakeholders, environmental practices for regeneration rather than just conservation, respect and awareness of farming by publics and a level of protection from volatile global markets without undercutting farms as businesses which need to self-innovate and create profit. The likely scenario was also agreed on and moves towards a similar positive future for farming, but at a much slower pace due to low political will to make change as is currently evident. Therefore, the strategies are of varying degrees (Table 5), rather than being inherently different, and the regret only lies in the slow pace of change with the likely scenario compared to faster change with the holistic desirable scenario. The indicators that are marked as moderate in Table 1 may allow space to fail, however others that are low are likely to be less lenient. With biodiversity and soil health being key factors for food security and climate change it is unlikely there is room to fail here. This will also depend upon the status of individual farms. The biggest impact would be on all those indicators and resilience that are currently marked as low. In thinking holistically, all actors need to be involved in supporting the farm system to evolve out of its current low resilience into a system with greater resilience.

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Table 5. Current strategies and future strategies for different future systems. Current strategies are based on FoPIA-SURE-Farm 1. Bold font indicates that these strategies were mentioned during the workshop for a specific system. Normal font indicates that, based on the discussions during the workshop, it seems likely that strategies will be applied in certain systems.

Strategy (current/past)	Domain	Current strategy	Future strategies		
			Status quo	Desirable system	Likely system
Land tenure arrangements	Agronomic		V	V	
Reintroduction of livestock	Agronomic			V	V
Responsible management	Agronomic			V	
Agricultural diversification	Economic		V		V
Increased area farmed	Economic	V	V		
Non-agricultural diversification	Economic	V			V
Adoption of agri-environmental schemes	Environmental	V	V	V	V
Adoption of conservation farming	Environmental			V	
Collaboration	Institutional		V	V	V
Knowledge Exchange	Institutional	V	V	V	V
Farmer led exchange	Social	V		V	

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Peer Learning	Social	V	V	V	V

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3 Interpreting results

3.1 Tipping points

For the UK, it is evident with Brexit that the system is already moving through the tipping point into change caused by politics (Bateman and Balmford, 2018). This will have knock on effects for the social, economic and environmental aspects of the farming sector too however. It is also evident with increasing arable weeds such as blackgrass and the increase in occurrence of floods and droughts that environmental tipping points are being breached.

Regarding soil health, if measured parameters such as organic matter, texture, colour, moisture, nutrients and earthworms decrease it could be seen that a tipping point is being reached towards the inability of soil to produce food (Guardian, 2017). However, figures for these boundaries are farm baseline dependent i.e. each farm will differ in respect of their own local environmental conditions. Alongside this, if as suitable for the farm, measures such as % of cover crops, % spring crops, rotation length and seedbed preparation techniques (till / soil disturbance) are not taken, a tipping point of soil degradation could also be reached.

Regarding good farm advisory services, a tipping point towards poor farm management and degradation of the agro-ecology of an area might be the lack of connection of a farmer to an independent soil health and natural capital related advisor. This would depend upon their current farm management strategies and access to other sources of information, however (Holden et al., 2017). Equally, poor farmer happiness may cause farmers to drop out of the profession, potentially causing a decrease in overall farmer numbers and smaller farms which may then also lead to environmental degradation. However, this again is subject to each individual and could in some circumstances lead to more positive farming practice.

It is perhaps easier to consider profitability and the minimum price dropping below £140 / t as suggested by participants. This was thought to be a tipping point at which farmers can no longer cope financially, and likely also health-wise (a stress burden which is to great). They may therefore also drop out of the profession, or seek a new crop type, different management practices etc. if the support and information is in place to do so. This will also depend upon whether and how much a support payment, such as public money for public goods, will be paid to farmers in lieu of the Basic Payment Scheme or Agri-environment Scheme. These payments have also been found to enhance or constrain the resilience of the arable sector (see Grant, 2016).

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3.2 Thresholds exceeded

If thresholds are exceeded positively, then the desirable system will be enabled to happen, however if they are exceeded negatively, the system will head towards decline. Figure 1 illustrates these interactions, with a reinforcing effect on negative factors leading towards decline.

As disucssed above, positive changes in social, enviornmental, economical (mostly in regard to farmers saving money through lessening chemical inputs) and political indicators will lead to greater farmer health and wellbeing, protected and enhanced natural resources, greater proift and a more supportive policy envrionment. Conversley, negative changes in the latter indicators would lead to decline and system failure through greater social isolation, farmers dropping out of farming, degraded natural capital, loss in profitability and poor political support. This could eventually lead to a decline in arable farming or much more intense systems with very few farmers. The strain on the natural capital and isolated farmers could then cause system collapse.

The current system is dominated by both environmental and political challenges. A lack of political support across the indicators could lead to the described system decline, including the environmental challenges. In this way, it is the most important challenge currently facing UK arable farmers. Environmental challenges including climate change are more difficult to predict the timing of, although we are already experiencing great pressure from this. However, this could

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lead to system collapse eventually if farmers are not supported to better protect and to enhance natural capital (Figure 1).

The indicators / variables used were enough to highlight the challenges encompassing the whole farming system as it currently stands.

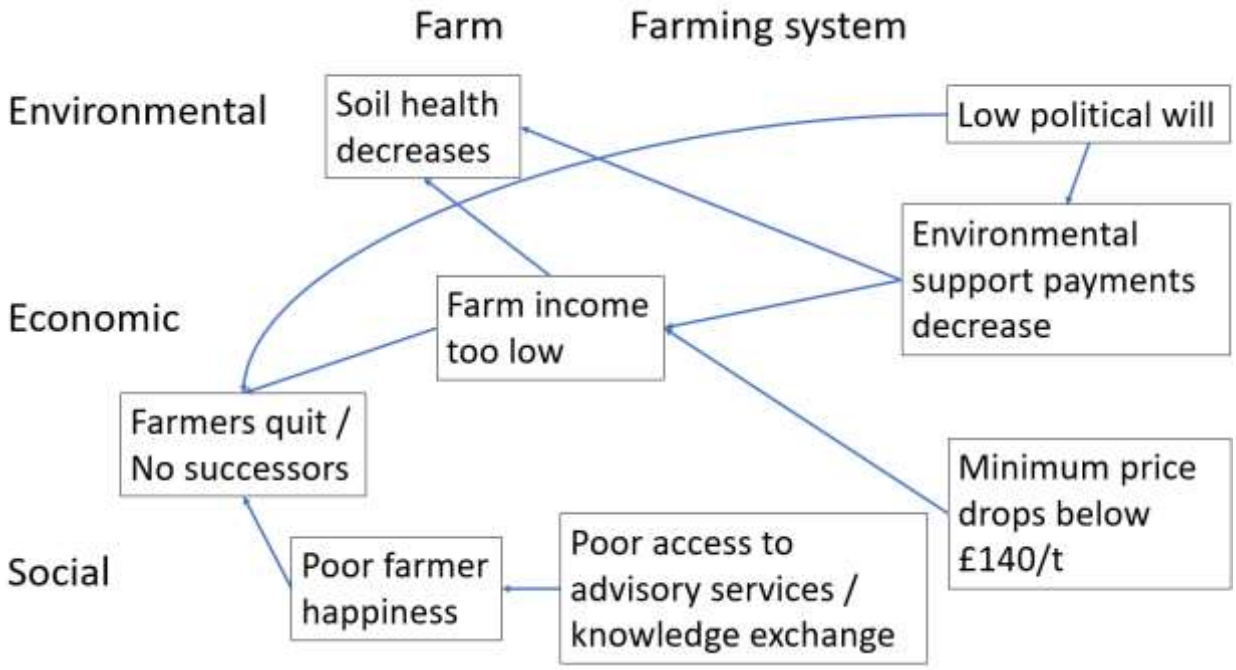

Figure 1. Interacting thresholds in the farming system under pressure of various challenges.

3.3 Alternative systems

The main indicators change towards positively supporting farmers and the environment at varying rates depending upon the scenario (desirable = fast change, likely = slow change).

In the likely scenario, the changes are most likely to be seen as adaptations from the current system implemented gradually over time. The desirable scenario is most likely to be seen as a transformation of the current system as the changes are more radical, long-term and fundamental. For example, they cause farmers to join discussion groups and access knowledge and support where otherwise they would be isolated and cause collaboration and farm diversity change and therefore landscape-scale changes by livestock entering arable farms and diverse cover crops being planted over winter. They may also encourage smaller-scale farms or large farms incorporating agroforestry and more hedgerows therefore changing the landscape.

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3.4 Causal loop diagram

The below diagrams were produced after the workshop with participants. The challenges, indicators of function and resilience were discussed in the workshop as in the previous sections, the diagrams have therefore been interpreted in relation to these discussions. Two CLDs have been produced, one focusing on indicators of functions and one on indicators of resilience. Having two CLDs allows to better observe the relationships, otherwise unclear when combined as one diagram.

3.4.1 Indicators of functions

In Figure 2, transition from chemical use has a negative effect on both animal welfare and happiness, with the stresses of needing to find new ways to deal with pests and disease. However, this would likely be short term and assumes that government would not provide enough support (financial, innovation, advice) during the transition. It has a positive effect on biodiversity and soil health which will be less impacted by toxins. Environmental payments would also benefit that latter to functional indicators by protecting and enhancing them. Environmental payments also look to boost net farm income by paying the minimum crop price plus basic payment scheme allowance, which the participants deemed necessary. However, in reality the government may not undertake this. Land ownership and high rents for tenancies negatively affect happiness (farmer welfare), biodiversity and soil quality through putting pressure on producing more to be able to pay rent and bills. In a desirable scenario rents would decrease, however there has been little discussion on this at government level and so looks unlikely to change.

If environmental payments are high enough to warrant farmers applying for them, this will have a positive and reinforcing effect (R1, Fig. 2) between the payments, soil health and biodiversity. Equally, if they are not then this would be a negative reinforcing loop where biodiversity and soil health continue to decline. If winter crops are 'cover crops' planted to increase soil health and nutrition, this will have a positive effect on the soil and biodiversity. However, if this is a wheat crop, the benefit will be less strong as harvesting it will mean less organic matter return to the soil. Despite this, some cover over winter will benefit the soil. Increasing biodiversity could also help with the transition from chemical use as a better ecological balance is reached, and natural predators come into play. However, this may take time to happen. In the short term, this transition could cause stress and unhappiness. Biodiversity will also have a positive reinforcing impact on animal welfare, assuming this includes growing more diverse forage, as will soil quality and the transition from chemical use (R2).

These positive reinforcing cycles may be balanced by low prices and productivity, which constrain the transition from chemical use through lack (or need) of capital (B1 and B2, Fig. 2).

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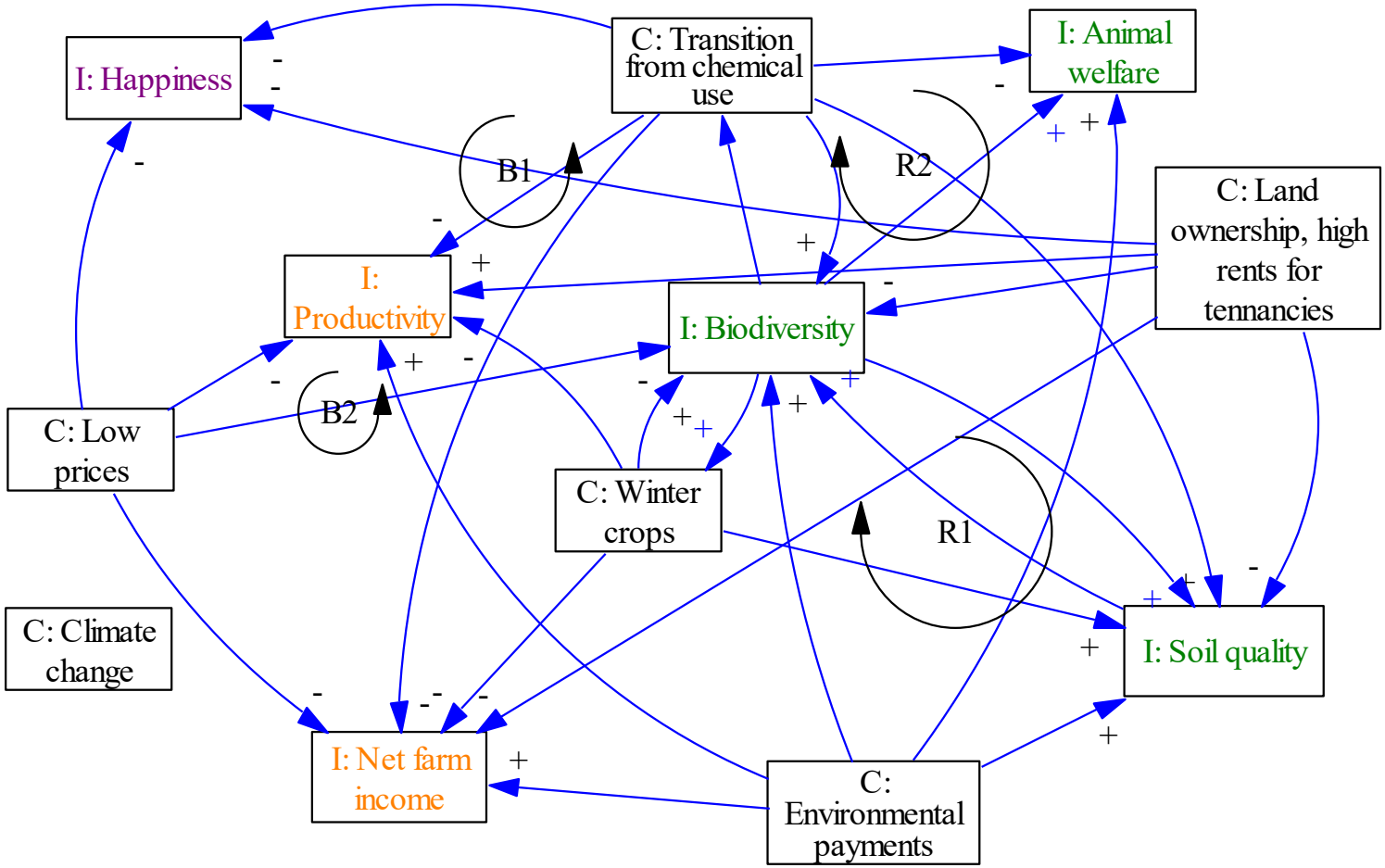
Figure 2. Causal loop diagram of the farming system in the UK. A + implies a positive cause-effect relationship and a - implies a negative cause-effect relationship. B stands for a balancing feedback loop and R stands for a reinforcing feedback loop. I indicates an important system indicator related to the system's functions. C indicates a system challenge. A indicates an indicator related to a resilience attribute. S indicates a strategy applied to maintain current functionality of the system.



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3.4.2 Indicators of resilience

In Figure 3, the transition from chemical use would have a positive effect on natural resource capital and social self-organization as it would avoid soil contamination and necessitate farmers working better together and innovating in order to cope with a lack of or reduced 'chemical toolbox', which may cause short-term issues with pests, disease, soil changes and lower yields. R1 and R2 show the positive reinforcing loop between these indicators and challenges. It would have a negative effect on profitability (likely only short-term) as investment in new methods and seeds for cover crops etc. would be needed. Environmental payments have a positive effect on all related indicators as they help to create diversity, increase natural capital health, create a point of farmer knowledge exchange, connect to outside stakeholders through the need to gain outside knowledge. They were thought to have a negative effect on being reasonably profitable however, as in effect they prevent cash crops from being grown. Climate change also has a positive effect on diversity, innovation and connection to outside stakeholders as the vast changes that this brings necessitates these actions. Again, there are positive reinforcing loops here (R1 and R3). Low prices have a positive effect on innovation as this will be necessary to find less costly practices or more profitable crops etc., although obviously has a negative effect on reasonable profitability. Winter crops (such as cover crops which don't create a product) and low prices have a negative effect on profitability. However, they do have a positive effect on infrastructure innovation as they necessitate this.

Climate change will likely have a negative effect on crops as new pests and disease arise, and weather events such as drought and flood become more frequent and intense. It also likely to negatively impact profitability and prices, therefore ultimately creating a negative balancing effect (B1 and B2) to the positive reinforcing effects described above.

If a good amount of support across the farming system is given (i.e. the desirable scenario), this would likely initiate positive feedback loops strengthening the farming community, connections outside as well as environmental health and natural capital. However, if not enough support is given, perhaps particularly to supporting good environmental practices resulting in soil health, water quality and biodiversity declines, this could create negative feedback loops which eventually lead to the inability to produce food.

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Figure 3. Causal loop diagram of the farming system in the UK. A + implies a positive cause-effect relationship and a - implies a negative cause-effect relationship. B stands for a balancing feedback loop and R stands for a reinforcing feedback loop. I indicates an important system indicator related to the system's functions. C indicates a system challenge. A indicates an indicator related to a resilience attribute. S indicates a strategy applied to maintain current functionality of the system.

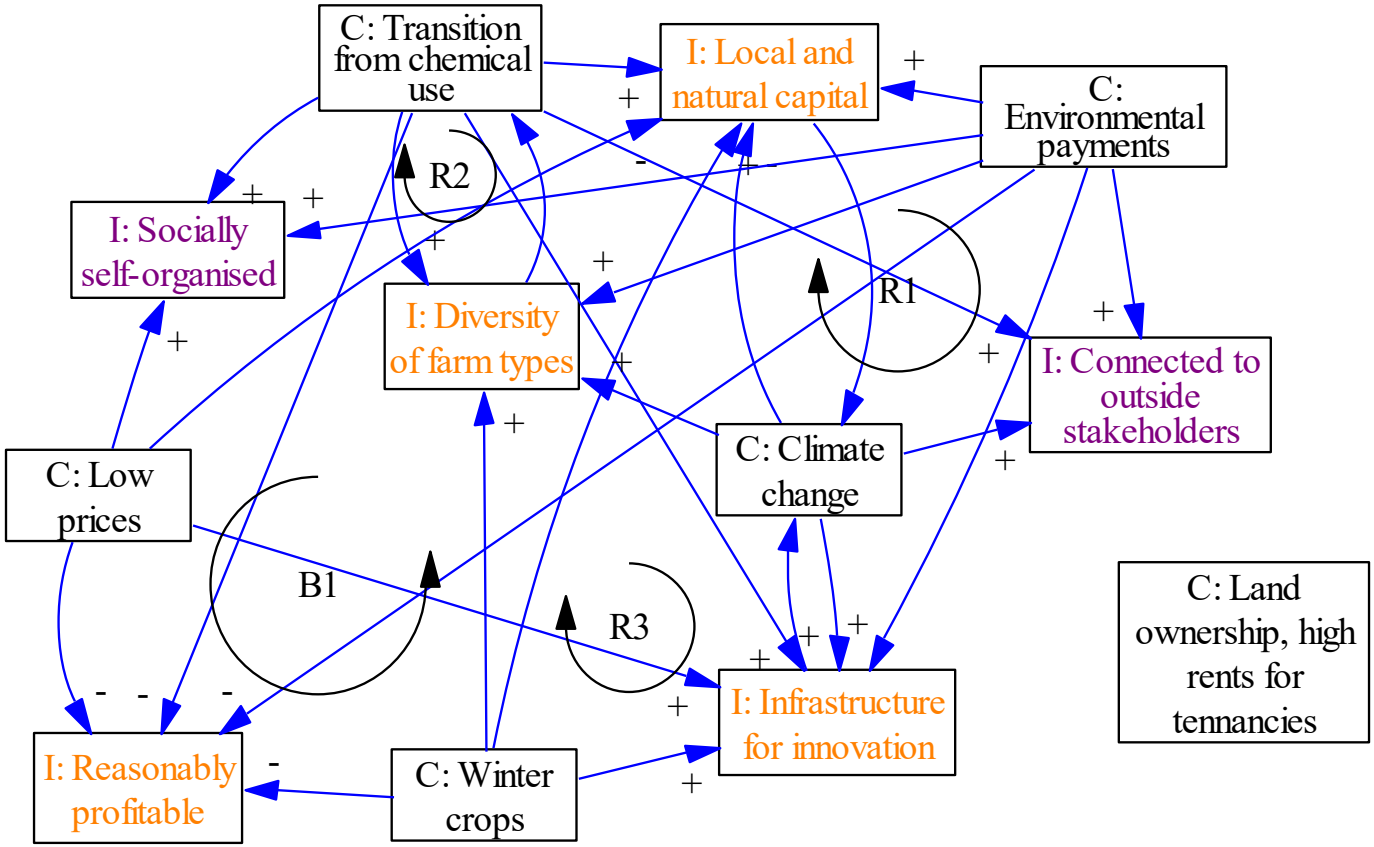

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Figure 4 shows a full representation of the above two CLD's, i.e. with all challenges and indicators included. This shows a much more complicated set of relationships due to the number of factors involved, however it highlights the main causal reinforcing and balancing attributes within the system. The main reinforcing factors are between biodiversity, soil quality, natural capital, animal welfare, diversity, self-organization, access to knowledge, innovation and the transition from chemical use which all positively interact to create a more enabled farmer and environmentally friendly farming system. However, the main balancing factors which may act against these positive reinforcing factors are climate change, net farm income, low prices and the need to be profitable.

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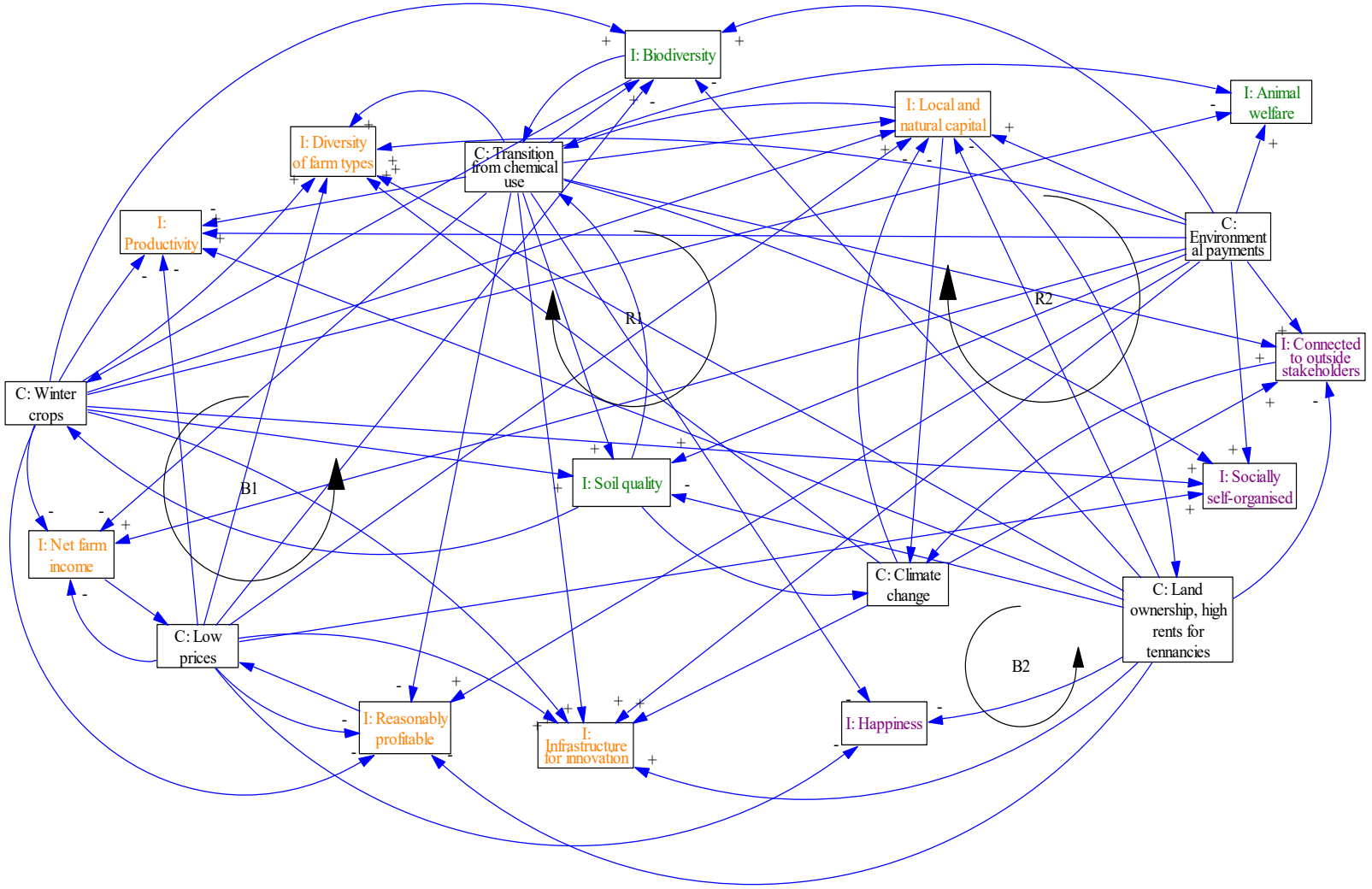
Figure 4 A more complex version of the CLD showing all relationships between all challenges and indicators as in the previous two figures.



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3.5 Linking alternative systems to scenarios

In maintaining the status quo, it is important to halt the decline of soil health and biodiversity. This therefore requires a better advisory system, technology that works for the farmer and to reduce the use of chemicals and fossil fuels. There will be a point at which the latter progresses from maintaining the status quo to creating first the likely scenario (as participants had some positivity about this scenario moving towards a more sustainable system, albeit slowly) and then the desirable scenario. The desirable scenario would require a more holistic view of the farming system and therefore a good provisioning of well-trained soil health and biodiversity focused independent advisors. It would also require not just advancement in agri-technology (the 'likely' scenario), but advancement where farmers were leading the ideas and work as partners alongside researchers. Trade is also likely to change as the UK leaves the EU, and to maintain the status quo the current trade relationship will need to be maintained. Participants did not discuss the details of trade relationships, but it was thought that any new international trade deals would need to proceed with caution in protecting farmers in the UK being able to produce high welfare standard and high-quality produce.

Table 1. Compatibility of alternative systems with different Eur-Agri-SSPs. Where values -1 to -0.66: strong incompatibility, -0.66 to -0.33: moderate incompatibility, -0.33 – 0: weak incompatibility, 0-0.33 weak compatibility, 0.33-0.66: moderate compatibility, and 0.66-1: strong compatibility.

	Scenarios				
Systems	**SSP1**	**SSP2**	**SSP3**	**SSP4**	**SSP5**
Status quo	0.60	0.11	-0.74	0.07	0.23
Desirable system	0.78	0.31	-0.83	0.03	0.05
Likely system	0.70	0.18	-0.78	-0.05	0.02

There is a fairly strong compatibility between SSP1 (Sustainability pathway) and all future scenarios. The desirable system is most compatible with SSP1 as the participants see the need for a more sustainable agricultural system which incorporates greater environmental awareness amongst society, public money for public goods (i.e. soil health, water quality, biodiversity) and increasingly high welfare standards for production. It also recognises the need of technological support – however, this will only be effective if developed with farmers taking a lead role in what technology they actually need. It also carries the caveat of farmers needing the time and advisory / social support to transition away from chemicals which can otherwise cause a huge stress burden. Lowering meat consumption further needs to imply that high welfare standards are met through smaller herds / flocks, healthy soils and a diverse forage mix including trees for livestock to feed from. The likely system is also thought to be progressing towards SSP1, due to current

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environmental pressures, growing public awareness of these and pressures on politicians and companies to act. However, participants thought that it would take much longer to achieve, crucially missing out a broader landscape and holistic opportunity to progress with sustainability. Similarly, the status quo is thought to be progressing towards SSP1, however still needs work to achieve a holistic system.

A weak compatibility is seen between all the future scenarios and SSP2 (Status-quo). This is likely due to the fact that the UK is exiting Europe and therefore will potentially move away from its current support schemes, e.g. CAP. Infrastructure in rural areas, diversity in agricultural supply chains, reduction of relatively lower prices for natural resources and stopping resource depletion scored particularly low. The latter two are not important in the desirable system, as it is assumed natural resources are valued and therefore given priority.

Despite the UK separating from Europe, and therefore 'renationalising', the participants were positive that in all future scenarios cooperation between the two would prevail. They were also positive that regional rivalry within the country will be minimal and that regardless of the future system, cooperation will carry on (or increase) as the current and future circumstances dictate (e.g. financial constraints, environmental and social pressures). The participants were hopeful that new subsidies or public money for public goods would be directed towards environmental measures, therefore in this respect the scenarios are not compatible with SSP3 (Regional rivalry).

Here again, there is a weak compatibility between SSP4 (Inequality pathway) and the future scenarios. There currently exists some multi-level cooperation but this has yet to be developed more strongly. International trade is ongoing but trade between the EU and the UK is strong and it is hoped that this would not alter drastically. It is also hoped by participants that investment in rural infrastructure, education and environmental standards would all increase, if only slowly in the status quo and likely scenarios, which is in opposition to SSP4.

SSP5 (Technological pathway) again shows weak compatibility with all three future scenarios. Whilst there is hope for greater technological advancement in the future, this is not dependent on fossil fuels, rather towards reducing environmental resource use and having a net positive (or regenerative) impact upon the environment. Any developed international trade agreements would still look to protect and enhance UK welfare standards, albeit to different levels or at different timescales depending upon the scenario. Although direct payments are likely to reduce and change as the UK leaves the EU, in all scenarios they are thought to encourage environmental protection (and regeneration in the case of the desirable system).

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3.6 Strategies

3.6.1 Desirable system strategy

As previously discussed, the need for good, well trained advisors for holistic farm management (with an emphasis on soil health and resource use as underpinning factors of the system) was expressed. Training would need to be well structured towards the latter. Current tests and trials on farms that are helping to develop the post-Brexit farm system are a good example of this advice, however it was thought that as well as government extension services giving advice, more independent advisors are needed. This would also mean a change away from advisors that are connected to a company selling products who therefore have an ulterior motive. It was mentioned that some farmers have experienced a lack of knowledge and expertise on soil health through such current advisors.

Farm clusters (groups of farmers sharing knowledge and experiences together) were said to be an effective way of reaching more isolated farmers and creating a supportive base for those transitioning between systems. These groups can be self-organized and / or with the help of a facilitator, for example Farming and Wildlife Advisory Group (FWAG) or Catchment Sensitive Farming (CSF) officers who help to organize meetings and the progression of the group. This can also help advise the next generation or new entrants to farming.

Additionally, it was thought that enough time for changes to be put in place would be needed, this was decided to be a minimum of 5 years. This is a threshold and environmental boundary condition, under which farm resilience will decline.

In order to fund the above, the public money for public goods system was thought to be essential, as well as results-based payments (on increases in water quality, soil health etc from each farm's baseline) and reverse auction (where the budget for environmental payments is low, farmers can reveal the minimum payment they are willing to receive from the government). In reality, it was thought that payments may come from a diverse set of these payment strategies. Funding could also come from private companies, such as water companies, but there is a risk here of them becoming a private good, rather than a public good. Despite underlying payments, the need for farms to function as independent businesses in their own right was stressed, and so there is still a balance to be found between support and independence for farmers.

As above, a 'volatility payment' was mentioned again in relation to supporting farmers through a transition period of a few years where yields may suffer due to changing soil conditions, redeveloping microbial life and previous reliance of crops on chemical inputs. Again, alongside this tailored advice would be needed for all farms (covering different soil types, crops etc). Mentoring from farmers who have already undergone the transition, for which there currently

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exists a small pool, was thought to be very beneficial and potentially necessary for new farmers entering transition into the more desirable system.

Another part to the strategy for implementing the desirable system was greater multi-stakeholder engagement, e.g. local communities being involved with helping farmers clear waterways to increase water quality and biodiversity, whilst creating a greater connection to where their food comes from and personal relationships between local communities and farmers.

A government-led assurance scheme which promotes landscape-scale environmental land management would help with promoting and creating public awareness around a new system.

In relation to farm tenancies and new entrants accessing land to farm on, it was thought that these need to be at least 10 years in order to implement and motivate farmers towards a sustainable strategy. Difficulties in sustainable management can also arise between land owners, tenants and the government; with private land owners able to make the ultimate decision on management practices. It was thought that a well facilitated 3-way conversation between these parties may better enable sustainable practice and increase transparency on who is being paid for what type of management. Land owners need to be regulated by government regarding making transparent their responsibilities towards tenants and land management. Ultimately this would aim to better hold private land owners to account for managing lands in an environmentally friendly way. Potentially independent advisors such as FWAG representatives could help facilitate this process and 3-way conversations.

Regarding technology to promote sustainable land management, it was felt that there is a great gap between that which is being produced by companies and researchers and that which farmers have access to and understanding of. Therefore, a need for technical 'translators' and a government-led programme to undertake knowledge exchange would be beneficial. This could lead to a more efficient uptake of technology. The need for more user-friendly and farmer-led technology and research (ideas from farmers which is then experimented with by farmers) was also expressed. If current initiatives or models could be rolled out on a national scale, incorporating independent or government facilitators, this could lead to more useful technology development for farmers.

Alongside technology, more infrastructure is needed in arable East Anglia in order to promote farm collaboration and landscape regeneration. For example, the reintroduction of livestock to arable fields (a collaboration between arable and livestock farmers) to graze off cover crops and add soil organic matter and nutrients is seen as desirable for a more holistic landscape management. In order for this to expand, more investment in small-scale abattoirs are needed

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for livestock farmers in the area. This may need to come from government money and / or incentives towards planning permission and feasibility.

3.6.2 Likely system strategy

In discussions, despite the 'likely' system being developed, it was thought that the government still needs to provide a committed vision in order for it to take place and avoid staying at the status quo or seeing further decline in environmental health. This commitment therefore forms part of the strategy for implementing the gradual and perceived minor change as describe above.

In relation to tenancy agreements, these were thought to need to increase as above, but would only do so gradually.

Technology was also thought to be limited to developing as it currently is, e.g. via precision technology to cut down chemical use, and which would still need a more structured government-supported plan for.

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4 Conclusion

The current East of England arable system is dominated by both environmental and political challenges. While the most likely system is thought to be slowly progressing down a sustainability pathway due to current environmental pressures and growing public awareness, a lack of political support could lead to system decline, particularly in relation to environmental challenges which are especially pertinent to UK arable farmers. Climate change is more difficult to predict and we are already experiencing great pressure from this. The most likely scenario is therefore considered to be an adaption from the current system implemented gradually over time.

A more desirable future farming system is deemed to be a regenerative one, defined as arable systems incorporating livestock into rotations in order to add organic matter back into the soil to increase its health. This would include measures such as % of cover crops, % spring crops, rotation length and seedbed preparation techniques (till / soil disturbance) to assess the closeness to thresholds of soil health. This would also entail greater across farm cooperation and collaboration, with livestock moving across three or four arable farms. Every farmer being linked to advice and knowledge sharing groups would act as a threshold of which to monitor. In this system, subsidies should not prop up production, but rather farming should be a viable business within itself, as well as having positive environmental impacts. A minimum price threshold would need to be £140 / t to allow this system to be viable. This would see strong positive change in the resilience of most attributes, most notably provision of public goods, biodiversity and high welfare standards from their currently low-moderate base. Strategies to achieve the desired system include results-based payments and reverse auctions; knowledge sharing amongst farmers at various stages of transition; greater multi-stakeholder engagement and community connections, government-led assurance schemes to promote landscape-scale environmental land management; longer farm tenancies to implement and motivate farmers towards a sustainable strategy; and programmes to facilitate technological change and take up, and the development of infrastructure such as abattoirs and grazing regimes.

This desired system - which is seen as a transformational as the changes are more radical, long-term and fundamental - is most compatible with a sustainability pathway (SSP1) which incorporates greater environmental awareness amongst society, public money for public goods and increasingly high welfare standards for production. In order to take a leading role in their technology requirements, farmers may seek to join discussion groups and access knowledge and support where otherwise they would be isolated and cause collaboration and farm diversity change and therefore landscape-scale changes by livestock entering arable farms and diverse cover crops being planted over winter. They may also encourage smaller-scale farms or large farms incorporating agroforestry and more hedgerows therefore changing the landscape.

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If thresholds are exceeded positively, then the desirable system will be enabled to happen, however if they are exceeded negatively, the system will head towards decline. Postive changes in social, enviornmental, economic and political indicators will lead to greater farmer health and wellbeing, protected and enhanced natural resources, greater proift and a more supportive policy envrionment. Conversley, negative changes in the latter indicators would lead to decline and system failure through greater social isolation, farmers dropping out of farming, degraded natural capital, loss in profitability and poor political support. This could eventually lead to a decline in arable farming or much more intense systems with very few farmers.

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