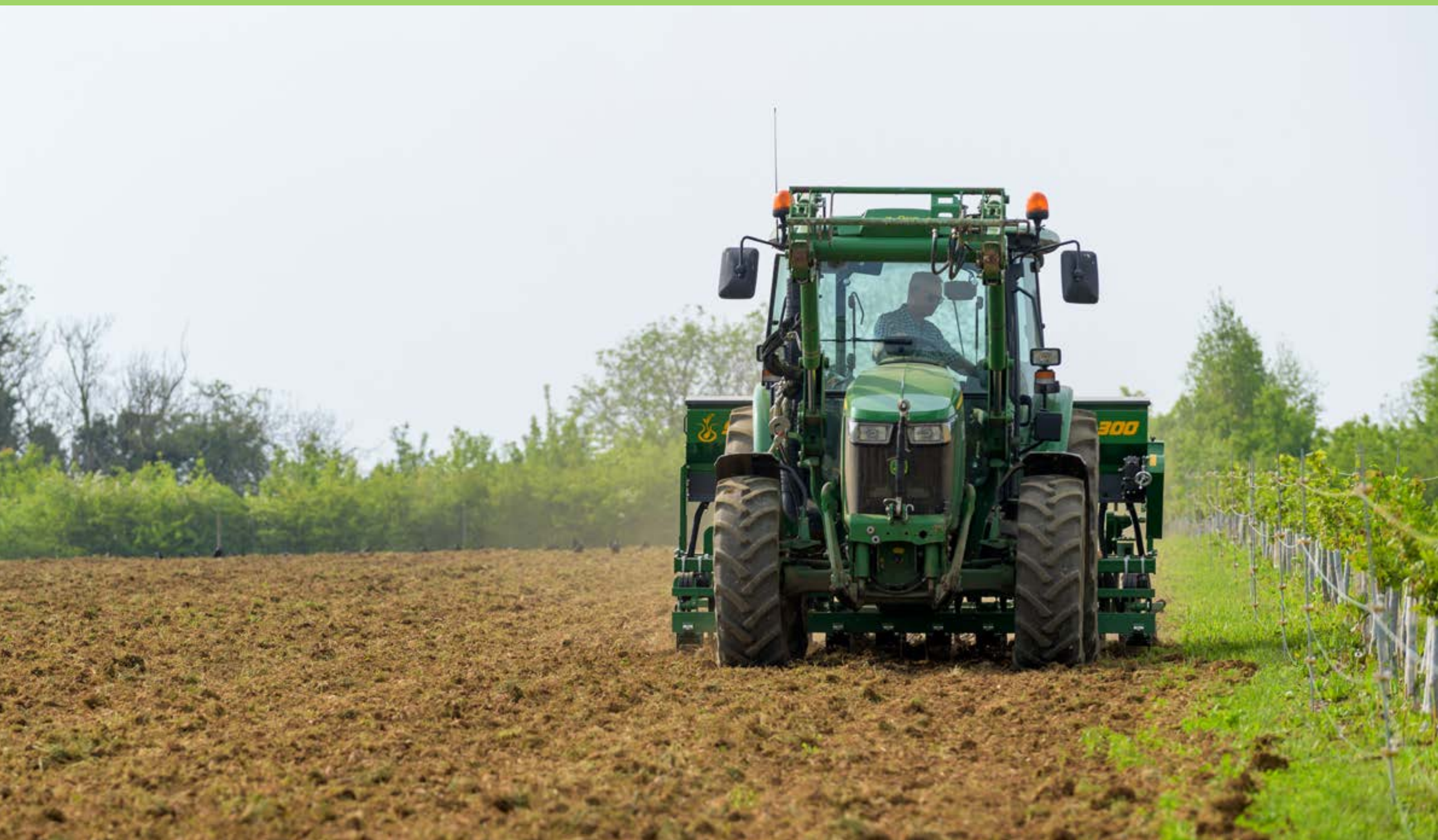
Regenerative Agriculture in the UK

An ecological perspective



Through science we can

Contents

The **authors** of this report were: Bridget Emmett (UK Centre for Ecology & Hydrology), Lucie Büchi (University of Greenwich), Barbara Smith (Coventry University), Romina Rader (University of New England), Kate Randall (Northumbria University), Jed Soleiman (University of Oxford), William Thompson (University of Oxford), Ruth Wade (University of Leeds), Roy Neilson (James Hutton Institute), Nicola Randall (Harper Adams University), Adenike Amoo (North-West University), Hannah Cooper (University of Nottingham, Emily Magkourilou (University of Sheffield), Andy Neal (Rothamsted Research), Hannah Wright (Independent), Lisa Norton (UK Centre for Ecology & Hydrology), Alfy Gathorne-Hardy (University of Edinburgh), Philip Donkersley (Lancaster University), Jennifer Dodsworth (University of Oxford), Kathryn Powell (Butterfly Conservation), Philip Donkersley (Lancaster University), Alexandra Tomlinson (Independent), Alice Midmer (Game & Wildlife Conservation Trust), Alastair Leake (Game & Wildlife Conservation Trust), Edward Baxter (Independent), Charlotte Curtis (Progressive Agriculture).

This report was edited by a **Steering Group** including Rick Stafford (Bournemouth University), Richard Bardgett (Lancaster University), Kaley Hart (Institute for European Environmental Policy), Lisa Norton (UK Centre for Ecology & Hydrology), Lynn Dicks (University of Cambridge), Douglas Christie (Durie Farm, Fife) and Andrew Watkinson (University of East Anglia); the **BES Policy Team** (Joanna Bromley, Phil McCluskey, Rob Booth, Rebecca Walley, Sarah McKain) and former BES staff Daniela Russi, Nick Harvey Sky and India Stephenson.

ACKNOWLEDGEMENTS
The authors would like to acknowledge the contribution of:
Debanjana Dey (Indian Institute of Science), Willams Oliveira (Federal University of Pernambuco), Elisée Bahati Ntawuhiganayo (African Leadership University), Mohamed Mounir Mfonden Poumie (University of Dschang), Jenny Rhymes (UK Centre for Ecology & Hydrology), Cathy Hawes (James Hutton Institute), Sacha Mooney (University of Nottingham), Fabrizia Ratto (Royal Holloway, University of London), Sally Westaway (Independent), Robert Patchett (University of St Andrews), James Robinson (University of Edinburgh).

The authors and the BES would also like to thank the academic reviewers for their comments and feedback.

SUGGESTED CITATION
British Ecological Society (2025). Regenerative Agriculture in the UK: An Ecological Perspective. London, UK. ISBN 978-1-0369-1546-9
Available at: https://www.britishecologicalsociety.org/our-policy-work/

CONTACT DETAILS
Email: policy@britishecologicalsociety.org
Address: British Ecological Society, 42 Wharf Road, London, United Kingdom, N1 7GS

Foreword

by Jake Fiennes

In my 30-year career working on large rural estates, I have seen the effects farming has had on our natural capital; from the soil beneath our feet, the water in our rivers, to the nature that shares the space in which we produce food. The intensification of food production and the ability to increase yield has happened with little or no consideration for the wider environmental impact. We ploughed, we sprayed, we shortened our rotations and left no time for the land to breathe. And we witnessed an increase in pests and diseases that, overtime, became immune to the products we produced to control them.

How can we provide for an ever-growing global population and develop a system that works alongside nature; a system that has a set of principles that effectively mimics nature whilst still providing our food?

The organic movement began in the 1940s as a reaction to agriculture's growing reliance on synthetic fertilisers and pesticides. It had all the potential but delivered little in terms of uptake: yields were low and premiums were high. It also came with a set of daunting? standards and regulations. For the majority of farmers, intensive agriculture (or conventional) was just too attractive with its high yields and low cost (initially) for inputs. A term I have heard from many a farmer is 'Yield is king.'

A little after the turn of this century, the concept of regenerative agriculture started to gain a foothold. It appealed to farmers and growers looking for alternative ways to grow food in an ever-changing climate that was less reliant on large amounts of synthetic inputs and worked in synergy with nature. For many, the primary goal was ensuring that their soils were alive and functional with the ability to hold moisture in drought but also drain freely in flood. A food system that could be available to all but had the flexibility to be adapted to individual circumstances; a system that didn't see a loss in yield.

For the first time in years, farmers talked to one another about what worked and what didn't; learning from each other's experiences and adapting for their own farms. With a set of objectives, principles and practices, regenerative agriculture can be flexible and adaptable to individual circumstances. This enthusiasm from farmers has captured the imagination of politicians and policy-makers where we now see support for best practise and alternative methods.

Regenerative agriculture is not a new form of agriculture, it is about learning from the past and implementing for the future. We have a once in a generation opportunity to create a food system that is fit for people, place and planet with actions that are backed by robust science and ecological expertise.

Executive summary

More than two-thirds of land in the United Kingdom (UK) is used for agriculture. Over recent decades, the industrialisation of agriculture has accelerated and intensified the impact of farming on the environment. In 2023, the *State of Nature* report suggested that farming in the UK was a leading cause of habitat loss and species decline, on a par only with climate change. Our soils and their diverse ecosystems are also under threat. Another 2023 report, by the House of Commons Environment, Food and Rural Affairs Committee, found that current agricultural approaches are putting the future of our soils 'at serious risk'. Furthermore, around 40% of food eaten by residents of the UK is grown elsewhere, according to 2024 statistics. Land use for food and feed imported into the UK have had significant impacts on ecosystems from Brazil to Indonesia and New Zealand. If we are to reverse the decline of biodiversity and soil health, both in the UK and internationally, then improvements to the way we produce food are urgently needed.

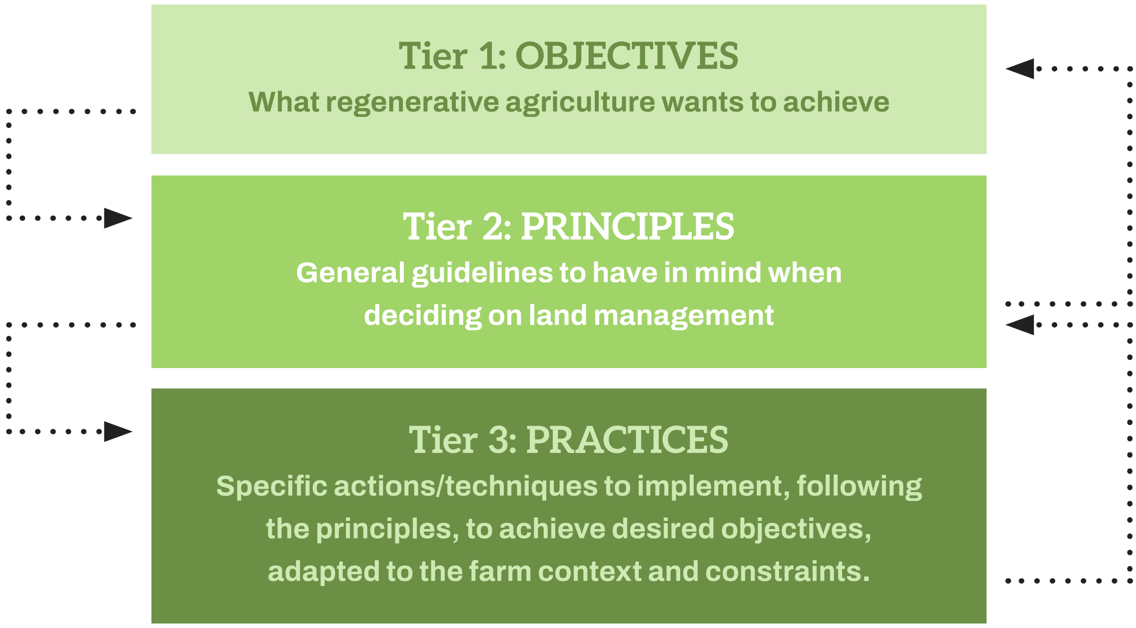
Throughout the 2010s and into the 2020s, the concept of 'regenerative agriculture' has begun to attract increasing discussion and consideration. This attention comes not just from farmers, but also from governments and the corporate supply chain. Ongoing public and scientific discussions of regenerative agriculture concern both the evidence supporting the benefits of agricultural practices associated with regenerative agriculture, and debate over the impacts of labelling, defining and certifying certain ways of farming as 'regenerative'. This report represents the British Ecological Society's efforts to bring together diverse expertise in order to address these issues. It poses, and answers, two key questions: first, how should regenerative agriculture be understood by ecologists, farmers, policy makers, the public, food processors, food retailers and those within the food supply chain? And second, what do the principles and practices associated with this understanding offer in terms of farming systems that might both feed people and protect, or even restore, our shared ecosystems in the future?

Defining regenerative agriculture: Objectives, principles and practices

Regenerative agriculture is frequently framed as a farmer-led movement that offers a viable alternative to so-called conventional agriculture. It emphasises the need for farmers and land managers to focus on soil restoration. Yet no codified definition of, or standards for, regenerative agriculture currently exist in the UK. Many overlapping definitions are used concurrently, and disagreement persists on some important points.

The British Ecological Society proposes a definition based on a three-tier approach: objectives, principles and practices:

Regenerative agriculture: Three-tier definition



This approach builds on the commonalities of existing definitions and adds nuances where definitions diverge in order to promote a more inclusive definition that both agricultural practitioners and policy makers across the nations of the UK may be able to share. A less flexible definition based on prescribed practices could exclude many practitioners that are embarking on a journey to make their agricultural practices more regenerative. Equally, too flexible an interpretation of these principles risks approaches being labelled 'regenerative' within farming systems or supply chains which are not working towards the improvement of agricultural ecosystems.

Tier 1: The objectives are to produce nutritious food and restore soil health and functions while also increasing biodiversity, improving water quality, and mitigating and adapting to the effects of climate change. Retaining farmer's' autonomy and profitability is also significant, given the farmer-led dimension of regenerative agriculture's development.

Tier 2: Principles are guidelines to have in mind when selecting practices and are not prescriptive of any specific practice, as the selected practices will depend on the specific context. They are a 'direction of travel'.

Tier 3: No single practice can be labelled as 'regenerative' per se, as its impact will depend on the farm context and constraints, and on the outcome of the interactions with other practices adopted. However, more than one practice needs to be adopted to follow the regenerative agriculture principles and to meet the objectives stated above.

Our definition includes the five principles below, with example practices:

	Principles	**Example practices**
1	Minimise soil disturbance **where appropriate**	Fallow land, reduced tillage, rotational grazing of livestock
2	Minimise bare soil and keep living roots year round	Mulching, cover crops, undersowing, resting pasture, living roots
3	Increase diversity on the farm	Diverse cropping, alley cropping, diverse or wider, less managed hedgerows
4	Integrate livestock **or approaches that deliver the same functions**	Introducing mixed farming (depending on context), rotational grazing
5	Reduce synthetic inputs **and favour ecological approaches**	Animal manures, cover crops, better rotations, multi-species cover crops

Although it is not included in this report as a principle alongside those listed above, the emphasis regenerative agriculture puts on farmers knowing and understanding their context is also important and reoccurs throughout the report.

Ecological evidence: Assessing benefits and indicators

Research shows that implementing the principles of regenerative agriculture has the potential to provide environmental benefits. However, the practices selected should be tailored by the farmer to each individual farm to avoid undesirable outcomes. It is likely that the benefits and success of implementing the practices will depend on multiple contextual factors, including the principles and practices adopted, the farmer's knowledge and skills, the farming system, the contemporary ecology of the farm and its location. There is some evidence for a synergistic effect of some management practices on several ecosystem services. Despite the contextual complexity, there is evidence that minimising soil disturbance can over time improve soil structure and support greater biodiversity, thereby improving soil function. Similarly, eliminating bare soil and keeping living roots in the soil all year round increases soil organic matter and biodiversity, as well as improving soil structure and nutrient availability.

Incorporating greater diversity in farm systems (by using multiple crop mixtures and rotations and incorporating livestock, especially when coupled with reduced inputs) can support greater biodiversity and potentially yields. It can also increase resilience to environmental variability such as summer droughts, or to fluctuations in commodity prices. Although there are concerns regarding greenhouse gas emissions and inefficient land use, integrating livestock on arable land can also have multiple benefits, including increased soil organic matter and biodiversity, and increased on-farm economic margins.

Identifying the outcomes of implementing the principles and practices of regenerative agriculture requires a good understanding of the context of the farming system – for example, the soil type, climate, starting point and desired trajectory of change – and a robust means of measuring change. Indicators regarding regenerative agriculture can be practice-based (by considering the practices being used) or outcome-based (by considering the observed benefits of said practices). The report finds that a consensus is emerging among experts that a combination of practice- and outcome-based indicators may be the best option for future assessment of regenerative agriculture.

Potential long-term consequences and trade-offs

Benefits associated with regenerative agriculture will vary over time and are context dependent; trade-offs are also likely.

While trade-offs between biodiversity and yield can be challenging, there is evidence that initial yield reductions in transitioning to regenerative agriculture may reduce or even reverse over the longer term through enhanced ecosystem services. However, the evidence for this is variable, and realising these potential benefits takes time. A greater understanding of these impacts requires long-term experiments.

During the transition phase (medium term), which spans three to six years, positive benefits appear to become more detectable. However, there is a need for careful management to prevent issues like competitive weeds and pests. Despite increased risks during this phase, some research indicates that integrated management can maintain yields comparable to those of conventional systems.

In the long term, the enhancement of biodiversity and ecosystem services through regenerative practices may lead to maintained yields with less reliance on external inputs and improved soil health.

Despite ongoing debates about the effectiveness of a regenerative approach, navigating the complexities may help to achieve sustainability goals, although evidence of trade-offs and of yield impacts is still limited, and more funding and commitment to long-term studies are needed.

Opportunities and barriers for farmers

From existing research, and interviews with eleven farmers who already practice regenerative agriculture and one independent agronomist, we explored the opportunities and challenges associated with a transition towards regenerative farming methods across the UK.

Our expert interviewees identified three key opportunities associated with the effective deployment of regenerative agriculture: increased productivity and profitability, heightened resilience against external factors, and improved levels of farmer satisfaction and wellbeing. Where some have experienced increased productivity and profitability, others have seen a decrease in productivity but an increase in profitability due to a reduction in spend on inputs such as fertiliser or feed. The reduced reliance on fertiliser was also cited as part of an increase in farm resilience against external factors. Farming by regenerative principles can provide a wellbeing benefit to practitioners, who feel a greater connection to the land and biodiversity.

Barriers to the uptake of regenerative agriculture were also identified around five themes: technical knowledge and skills, changes in mindset, agricultural policy, finance and business structure, and land ownership and tenancies. Exacerbating the challenge with knowledge and experience is the fact that regenerative agriculture often requires a system redesign of the farm rather than a straightforward substitution of produce or practice. Interviewees reflect on how these challenges can be overcome through training, networking, external technical advice and peer-to-peer support. Some barriers may require systemic changes, and this is discussed with regard to the agricultural policy landscape in the UK and farm business structures.

Policy recommendations

Finally, we draw together key findings and a range of policy recommendations to help further the transition towards regenerative agricultural principles and practices across England, Wales, Scotland and Northern Ireland. Some of these recommendations are explicitly rooted in scaling up practices associated with regenerative agriculture. Others are more holistic, taking inspiration from the principles of regenerative agriculture and the collaborative, farmer-led movement which has supported its rise in popularity in the UK. The recommendations look to create knowledge exchange and collaboration between farmers, land managers, policy makers and the ecological and broader scientific community as a whole.

1. Increase support and advice to help farmers make the transition to regenerative agriculture

Both the accessibility and the quality of support and advice available to farmers need to be upgraded for regenerative agriculture's positive principles and practices to become more widespread across the UK. To help farmers navigate through the complexity of the landscape towards regenerative agriculture, it is' essential to establish a robust network of mentors and facilitators who can offer context-specific advice and support.

2. Ensure farmer-led innovation is placed alongside scientific evidence to inform agricultural policy and practice

Success in regenerative agriculture will require recognition of different kinds of expertise and the development of a collaborative environment that builds strong institutions and rewards.

3. Use regenerative agriculture principles to co-design impactful and measurable agricultural policy

Integrating regenerative agriculture principles directly into agri-environment policy could further propel the uptake of sustainable practices. By recognising and leveraging farmers' expertise, providing comprehensive support, and maintaining sustained engagement, policy could effectively drive the transition to a more sustainable agricultural future.

4. Advance innovation in regenerative agriculture

Innovative practices, experimentation and technological advancements are needed to propel the regenerative agriculture movement forward. To ensure continuous progress in regenerative agriculture, it is crucial to develop a comprehensive and forward-looking research agenda.

5. Ensure the credibility, transparency and consistency of regenerative agriculture initiatives across the whole supply chain

There is an important role for governments as well as the private sector to play in ensuring that such approaches remain rigorous, transparent and fair to producers and consumers.

Chapter 1: Introduction

Authors: *Bridget Emmett, Rob Booth*

1.1 A critical moment for agriculture & ecology

If we are to reverse the decline of biodiversity across the world, then improvements to the way we produce food are urgently necessary. The effects of agriculture on the ecology of the UK are diverse, significant and longstanding. As of 2024, 69% of the UK's land is used for agriculture (Defra, 2024). However, over recent decades the industrialization of agriculture has accelerated and intensified the impact of farming on the countryside and its ecosystems. In 2023, the *State of Nature* report produced by a coalition of leading environmental organizations suggested that farming in the UK was a leading cause of habitat loss and species decline, on a par only with climate change. Once familiar farmland birds are now rarely seen in some parts of England, Wales, Scotland and Northern Ireland. The British Trust for Ornithology states that numbers of corn bunting, grey partridge and turtle dove have each fallen by over 90% since the 1970s.

Yet, it is not only visible and recognizable bird species which have been affected. Our soils and their diverse ecosystems are also under threat. A 2023 report summarizing an inquiry by the House of Commons Environmental, Food and Rural Affairs Committee synthesizes the issues associated with soil degradation and associated emissions and biodiversity loss. The report finds that current approaches are putting the future of our soils 'at serious risk' making change 'critically important'. Furthermore, around 40% of food eaten by residents of the UK is grown elsewhere according to 2024 statistics. Land use for food and feed imported into the UK has had significant historical impacts on the ecologies of vast and rich ecosystems from Brazil to Indonesia and New Zealand. The effects of these impacts continue to this day.

Yet it hardly needs stating that farming is essential for our food security, and indeed our survival. And as the world's population continues to grow, farming necessitates ever more ecological disturbance. Producing sufficient amounts of affordable food has been an objective of British government policy for longer than environmental protection has even registered as a concern. In the 2020s, farmers themselves are increasingly feeling the tensions between the expectation to produce food and the need to protect and enhance the natural environment of the land that they manage. Recent protests by farmers across the UK and beyond underline the sentiment created by being put in this difficult position. These tensions are also driven by the current moment of growing political and economic volatility, with price spikes resulting from COVID-19 and the war in Ukraine affecting farmers worldwide. In the United Kingdom, food producers face the added impact of the ongoing transition away from European Union agricultural policy and the guaranteed income that European subsidies provided. Climate change and the uncertain and extreme weather it is increasingly creating are also already a reality for the agricultural supply chain. Whereas 2024 saw large amounts of rainfall, 2022 saw temperature records broken across the country. As the Department for Environment, Food and Rural Affairs' Food Security Report for 2024 put it: "extreme weather events continue to have a significant effect on domestic production". This will get worse.

This complex and uncertain moment has been harnessed by some involved in food production and its governance to argue for a continuation of the status quo. Others, however, have been working towards refining and promoting different visions of farming that they argue will make for a better, more resilient and nature-friendly agricultural future. These alternative approaches to so-called 'conventional' agriculture bring together farmers, scientists, policy makers, campaigners, supermarkets and consumers in various configurations and under various banners. A range of these approaches is explored further in this report's next chapter. However, this report focuses on exploring and evaluating one such approach in particular: regenerative agriculture. What exactly constitutes regenerative agriculture in practice remains open to interpretation. That is a question addressed directly by Chapter 2. What this introductory chapter will do, however, is further establish the origin, objectives and scope of the report, as well as establishing the key themes and main arguments which emerge.

1.2 Origin, objectives and scope

Regenerative agriculture has existed as a concept since the 1970s but has grown in popularity over the last decade. During the time this report was compiled it has continued to attract discussion and consideration globally. This attention comes not just from farmers, but also from governments and the corporate supply chain. Ongoing public and scientific discussion of regenerative agriculture concerns both the evidence supporting the benefits of agricultural approaches associated with regenerative agriculture, as well as debate over the impacts of labelling, defining and certifying certain ways of farming as 'regenerative'. This latter point is demonstrated by a recent statement from the UK's Advertising Standards Authority setting out what can be said to constitute regenerative agriculture from a marketing perspective in Britain.

This report represents the British Ecological Society's efforts to bring together diverse expertise in order to address two questions which follow from this public discussion. Firstly, how should regenerative agriculture be understood by ecologists, farmers, policy makers and the public? And, secondly, what do the approaches associated with this understanding offer in terms of farming systems that might provide longer-term food security, sustainability and resilience: to both feed people and protect, or even restore, our shared ecosystems for future generations? This report answers both questions. It focuses specifically on the application, prospect and definition of regenerative agriculture in the context of the UK, its geography and ecologies. Although food produced all over the world is consumed in the United Kingdom every day and regenerative agriculture is practiced and discussed worldwide, the ambition and scope of this report is limited to its application and potential in England, Wales, Scotland and Northern Ireland.

Further, this publication follows the weight of existing evidence and ongoing scientific discussions in terms of the types of food production it considers, whilst recognising evidence gaps and uncertainties and where there is a lack of consensus. Much of the focus, where specified, concerns the production of crops. Grazing livestock too, notably cattle and sheep, are discussed throughout. Little attention, however, is given specifically to other forms of animal agriculture, such as pigs and poultry. Equally, horticulture (in the various forms in which it is practiced across the UK) is addressed indirectly where principles may be relevant, however rarely explicitly.

This perspective also speaks to how this report approaches the question of regenerative agriculture in a way which is grounded in ecological principles. Accordingly, recognition is given throughout to the reality that different agronomic approaches will work differently in different contexts, from different starting points and within different ecosystems. This ecological sensibility is a noted dimension of regenerative agriculture, as discussed in Chapter 2. It rejects a 'one-size-fits-all' logic via which the same crops, approaches and outcomes can be reproduced across different contexts with the aid of fertilisers, herbicides and other chemically-derived inputs. The recognition of context-specificity promoted by advocates of regenerative agriculture is a key starting point for moving towards more nature-friendly forms of farming.

Another reason that regenerative agriculture attracted the interest of the British Ecological Society and its members is the extent to which its proclaimed ecological principles have been proving increasingly popular with farmers themselves. Much of the organising around, and promotion of, regenerative agriculture in the UK has come from farmer-led groups such as BASE-UK and the annual festival Groundswell. It is fair to say that farmers and ecologists are not often portrayed as two professions likely to agree on everything. This report represents an effort by the ecological community, many of whom work regularly with land managers, to engage directly and positively with an approach to agriculture being championed by farmers themselves. In this regard, during the production of the report we engaged directly with farmers from different walks of life and from different sectors across the country. The British Ecological Society recognises the need for the societal changes required to address the twin nature and climate crises to involve, engage and empower the people they will affect most. In this case, any just transition in food production must not alienate farmers.

In summary, this report retains the rigorous scientific approaches associated historically with the British Ecological Society and its members. This report draws on the professional credentials of our members and stakeholders to bridge the gap between different ways of producing practical knowledge about our ecosystems, and the report has also been subject to independent external review from the wider community. Foundationally, however, it relies on existing peer-reviewed literature to evidence claims about regenerative agriculture and its application. This led to some creative tensions during the writing of the report around the science of farming and the everyday ecology practiced by land managers themselves. How can we take first-hand evidence from food producers seriously whilst simultaneously looking to abstract their findings and ensure their reproducibility using scientific principles and processes - particularly in a field as context-specific as agriculture? This is a difficult question, and this report does not claim to answer it. Chapter 6 does, however, offer practical and institutional suggestions for improving the relationships between farmers and ecologists in the future that might help mediate this tension and ensure the approaches taken towards agricultural change are both supported by people and supported by evidence. There are also questions raised by this report which have complicated answers which exceed its scope, yet have significant environmental and ecological resonance. This includes the ongoing use of agricultural inputs like the herbicide glyphosate within regenerative agriculture systems and the prospective increase in extensive livestock that regenerative agriculture could create given its focus on returning mixed farming systems. Relatedly, questions of carbon emissions and sequestration and dietary change are also bracketed given the focus and expertise of the authors brought together to produce this report.

Finally, for a report by the British Ecological Society, much of this publication does not approach in detail familiar questions about habitat creation or agri-environment schemes and their possibilities and pitfalls. Instead, there is much engagement with more literature that has, at its heart, a concern for the restoration and regeneration of the soil and the mitigation and minimisation of environmental externalities associated with food production. Emergent from this editorial choice is an argument about land use. Much discussion has gone towards the divergence between so-called 'land-sharing' and 'land-sparing' approaches to agriculture. This debate is relevant in the UK and beyond: it is important, for example, to ensure that nature recovery is not contained to hedgerows and wildflower margins, but encompasses every hectare of agricultural land in order that species can move through a landscape to disperse and migrate due to climate change. This is arguably advocating for land-sharing in its purest form. Some farmed landscapes will always produce more than others in terms of a certain conception of agricultural productivity. However, all agricultural land and soils should be contributing towards ecosystems recovery and biodiversity renewal to the greatest extent possible. It is laudable that the approach outlined here as 'regenerative agriculture' encourages that. Further, in engaging in this way this report looks to show that ecologists are acutely aware of the need for food security and future resilience to be achieved globally. This can neither morally or biophysically come at the expense of the ecosystems which support human life.

1.3 Overview & structure

The following report consists of five chapters, each with a different focus. Chapter 2 addresses the question of defining regenerative agriculture. It does so in a way which explores the environmental claims associated with regenerative agriculture. It establishes an important differentiation between principles, practices and objectives. Ultimately, it sets out a principle-based definition of regenerative agriculture from an ecological perspective. Chapter 3 starts by evaluating the benefits associated with each principle of regenerative agriculture and the practices which stem from them, cross-referencing these against objectives outlined in Chapter 2. It continues with an exploration of the advantages and disadvantages of different ways of assessing the outcomes of applying regenerative agricultural practices via outcome-based and practice-based indicators. Chapter 4 extrapolates some of the previous discussion into a consideration of the prospective impact regenerative agriculture may have on yields and food security. Chapter 5 uses interviews with expert-practitioners involved with regenerative agriculture to map out the social and economic benefits associated with its implementation, as well as the barriers and pitfalls it creates. Chapter 6 brings the report to a conclusion in analysing the relationship between regenerative agriculture and the current policy landscape across the United Kingdom. It ends with a series of policy recommendations inspired by the regenerative agricultural movement designed to create the conditions for a more collaborative and ecological British agricultural sector in the future.

The report also contains several central, interlinked arguments. Firstly, the definition of regenerative agriculture in Chapter 2 asserts the need for a broader horizon of possibility for regenerative agriculture. This comes from the expansion of the principles around introducing livestock and reducing synthetic inputs. Furthermore, the ecological sensibility inherent to the additional principle of *know your context* also requires reiteration and support. Chapter 3 establishes that many of the principles and practices associated with regenerative agriculture have a firm basis in terms of evidence regarding their environmental advantages. Minimising bare soil, retaining living roots all year round and embracing greater on farm agri-biodiversity are, in particular, principles of regenerative agriculture with demonstrable ecological benefits.

This report highlights, however, that some benefits purported to be associated with applying regenerative agriculture principles require further examination via long-term and collaborative research which brings together farmers, ecologists, social scientists and policy makers. This research agenda, and the institutions and investment required to support it, are highlighted in Chapter 6. Finally, the arguments around food security presented throughout, and notably in Chapter 4, show that there remains uncertainty around the prospects of these methods, yet there is some scope for cautious optimism. Regardless, there is a need for future farming systems to mitigate and adapt to climate change whilst creating resilient supply chains and contributing to nature recovery. All of this must be achieved in an increasingly unstable world. Regenerative agriculture shows there is an appetite for such change amongst farmers and land managers and, although the systems which emerge may not mirror exactly what is discussed in this report, it is incumbent upon all scientists, including ecologists, to help work towards an evidence-led, collaborative and just transition.

Chapter 2: Defining regenerative agriculture

Authors: *Lucie Büchi (co-lead), Barbara Smith (co-lead), Romina Rader, Kate Randall, Jed Soleiman, William Thompson*

Contributors: *Debanjana Dey, Willams Oliveira, Elisee Bahati Ntawuhiganayo, Mohamed Mounir Mfonden Poumie*

Summary

Regenerative agriculture is frequently framed as a farmer-led movement that offers a viable alternative to conventional agriculture. In its current forms, it emphasises the need for farmers and land managers to focus on soil restoration. This prioritisation is often accompanied by additional objectives linked to increasing biodiversity, improving water quality, reducing environmental externalities, and alleviating the negative effects of climate change via both emissions reduction and increased agricultural resilience. In contrast to organic agriculture, no codified definition of, or standards for, regenerative agriculture currently exist in the UK. Many overlapping definitions are used concurrently; however, disagreement persists on some important points. The approach adopted here builds strongly on the commonalities of existing definitions and adds nuances where definitions diverge in order to promote a more inclusive definition that both agricultural practitioners and policy makers across the nations of the UK may be able to share. Accordingly, the definition of regenerative agriculture used in this report is articulated around three tiers: objectives, principles and practices. International case studies are included throughout the chapter to provide perspectives from other countries.

2.1 Introduction

Advocates of a transition to regenerative agriculture argue that following its principles and applying its practices means working with ecosystems and nature to help efficiently produce agricultural goods. They also argue that a regenerative approach not only minimises environmental and ecological harms, but also builds or restores ecosystems and/or natural capital. This chapter draws on existing approaches and evidence to provide an inclusive definition of regenerative agriculture. The intention of this is to encourage uptake of beneficial practices associated with regenerative agriculture and, accordingly, to help shape future agri-environmental policies which recognise these benefits. As set out in this report's introduction, the growing land use pressures and environmental uncertainties facing UK farmers and land managers make this a timely exercise.

Defining regenerative agriculture is complicated by the fact that it has taken inspiration from multiple agricultural movements (O'Donoghue et al., 2022; Bless et al., 2023), such as organic farming, agroecology and conservation agriculture (each discussed further below). The term 'regenerative agriculture' was first used by Medard Gabel towards the end of the 1970s, before being adopted and developed by the Rodale Institute in Pennsylvania in the 1980s. These considerations initially focused on organic agriculture and, ultimately, culminated in a document called *Seven tendencies for regeneration* (1989). This work was one of the first formal outputs that helped shape the contemporary movement, and it outlined many of the key principles that define regenerative agriculture today. The scope of this movement now extends beyond the agronomic into the social, cultural and even spiritual. In addition to this, the economic dimensions of farming have remained of central interest to producers who wish to farm regeneratively while retaining profitability.

In recent years in the UK, the adoption of methods associated with regenerative agriculture has been driven to a notable extent by farmer-to-farmer knowledge exchange through gatherings such as Groundswell and the Oxford Real Farming Conference, and networks such as Pasture for Life, BASE (Biodiversity, Agriculture, Soil & Environment) UK and the Nature Friendly Farming Network. Many farmers investigating and trialling these ideas and techniques are also drawing from their own practical experiences to determine the ways farming regeneratively can work best in their specific context, as few practices are completely generalisable and many draw on agronomic common sense or past understandings of best practice (Beacham et al., 2023).

Yet, while 'regenerative agriculture' is now a widespread term used across scientific articles, grey literature, farmers' associations and both conventional and social media, there is little consensus on a precise definition (Newton et al., 2020; Schreefel et al., 2020; O'Donoghue et al., 2022; Tittonell et al., 2022). Some sources present a complete definition of regenerative agriculture, while others focus on the principles to follow, the management and cropping practices involved, or the objectives these aim to achieve. All these approaches have advantages and disadvantages and emphasise different aspects of regenerative agriculture. Understanding the history of the term and its associated practices allows for the creation of a more robust and meaningful definition and is essential for ensuring the incorporation of regenerative agriculture into policy agendas in a way that represents diverse lineages of alternative approaches to agriculture (Sands et al., 2023).

So, what does it mean for farming to aim to be 'regenerative'? The term 'regenerative' indicates an aspiration to continuously improve the soil, biodiversity and environmental starting point of landscapes without a specific end goal. This idea of continuous improvement can be associated with the ambition to restore lost soil fertility and ecosystem services.

Building on commonalities from existing definitions – and adding nuance when definitions diverge – this chapter aims to offer a definition that ecologists, practitioners and policy makers can embrace. Central to these efforts is the delineation of objectives, principles and practices that can contribute towards a more regenerative future for agriculture across the UK. First, however, it is necessary to further contextualise regenerative agriculture in comparison with other paradigms.

2.2 Comparisons and contestations

Regenerative agriculture is one mode of farming among multiple alternative approaches being forwarded as a means to move beyond existing 'conventional' forms of agricultural land management. Importantly, defining what does or does not constitute regenerative agriculture may affect potential future agri-environment payments or private certification schemes. This will have financial impacts for farmers and consumers. The appropriateness of connecting regenerative agriculture with approaches like subsidies or certification is taken up throughout this report, notably in Chapter 6.

In looking to establish what regenerative agriculture means in principle and practice in the UK, comparison and definition by association with other notable movements or paradigms are useful. Different agronomic approaches may manifest differently depending on contexts, but the most important terms for comparison are outlined below in Table 2.1. This list is not exhaustive of current understandings of agricultural change movements but represents the most relevant comparisons in the British context. Regenerative agriculture is not included at this stage given the discussion to follow.

Table 2.1: Paradigms and key principles

Paradigm	Key principles
Organic agriculture	Organic agriculture forbids the use of certain synthetic inputs such as chemical fertilisers, veterinary medicines or pesticides. Standards and practices are defined by certification bodies, with assurance and compliance measurements rooted in legislation. Organic agriculture is certified and assured in the UK by bodies such as the Soil Association.
Agroecology	Like other paradigms, agroecology emphasises the need to diversify farming practices according to the local ecological context. Agroecology emphasises the articulation between agronomic questions, supply chain transformation and social and environmental justice. Its key ideas have been popularised in the UK by the likes of Miguel Altieri via academic study and NGO involvement.
Conservation agriculture	Conservation agriculture is defined by the Food and Agriculture Organization of the United Nations (FAO) as promoting minimum tillage, soil cover and crop diversification. These are similar principles to those discussed here regarding regenerative agriculture; however, regenerative agriculture goes further while attempting to retain further flexibility and the capacity for broader application (see Box 2.1).
Sustainable intensification	Sustainable intensification seeks to maximise agricultural productivity while minimising environmental externalities. It is often associated with the need to farm productive land as efficiently as possible. It differs from other paradigms in this table in that it can be considered more of a goal or objective, rather than a way of farming in and of itself (Dicks et al., 2018).
Biodynamic agriculture	According to a 2022 review by Santoni et al. (2022), biodynamic agriculture shares many principles and rules with organic production but goes further in some areas. For example, Santoni et al. (2022) point to the definition of the International Federation of Organic Agricultural Movements, which suggests biodynamic agriculture necessitates rearing animals on farm, leaving land for ecological infrastructure, and the application of specific preparations intended to improve crops and soils. Like organic agriculture, biodynamic production is certified by an international federation, Demeter.

Organic farming is the most widely known touchstone for comparison. It was the first significant agricultural movement to emerge in the modern era, followed by biodynamic agriculture in the 1920s. The first iteration of agroecology emerged during the 1930s, and between the 1970s and 1990s transitioned into a scientific discipline. It was during this time that the terms 'regenerative agriculture' and 'regenerative farming' appeared (Giller et al., 2021). Nowadays, while some regenerative agriculture movements are also organic, like Rodale Institute's Regenerative Organic Agriculture, the main difference between regenerative and organic agriculture is the more prescriptive nature of organic agriculture and its total ban of synthetic inputs. Ultimately, regenerative agriculture has evolved from a combination of existing paradigms (Giller et al., 2021; Oberč and Schnell, 2020).

Box 2.1: Conservation agriculture

According to the FAO, conservation agriculture is 'a farming system that promotes minimum soil disturbance (i.e. no tillage, maintenance of permanent soil cover, and diversification of plant species). It enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increased water and nutrient use efficiency and to improved and sustained crop production' (FAO, n.d.). These three pillars of conservation agriculture are therefore identical to three principles of regenerative agriculture described below. The objectives of conservation agriculture are similar, too.

'Conservation agriculture' is a popular umbrella term which pre-dates regenerative agriculture, but many farmers and associations that used to use the conservation agriculture label now practise and promote regenerative agriculture, while some have retained the term 'conservation agriculture'. Compared with conservation agriculture, regenerative agriculture has an additional focus on livestock integration, whereas conservation agriculture is widely practised on stockless farms. Both organic agriculture and conservation agriculture claim enhanced benefits for soil conservation, the former thanks to the absence of herbicides and the latter through minimising tillage. Fundamentally, regenerative agriculture can be seen as inclusive of conservation agriculture principles.

Many publications have raised concerns that the lack of a unified, transparent and legal definition of regenerative agriculture is problematic (IFOAM Organics Europe, 2023; Newton et al., 2020). Relatedly, as the global need for sustainable agriculture intensifies, regenerative agriculture as a concept has become increasingly politically and economically loaded. Much mainstream discourse and many claims regarding the future prospects for such approaches require a greater and longer-term scientific evidence base to reduce the prospect of superficially motivated actors using the flexibility associated with the term with little accountability or explanation of their practices. Accordingly, many corporate actors in the food system have integrated the discourses and practices of regenerative agriculture into their supply chains, leading to accusations of greenwashing (see, for example, Wilson et al., 2024).

For example, in a recent publication, Tittonell et al. (2022) defined three broad types of regenerative agriculture: philosophy, development and corporate. Regarding the 'corporate' type, the authors say that it 'comprises the approaches followed by large enterprises, from local to multinational (farming operations, banks, chemical input companies, food processors, etc.), that place emphasis on agronomic practices such as conservation tillage. Companies often present regenerative agriculture as part of their corporate sustainability programs.'

The fact that many multinational companies, such as Unilever, Syngenta and PepsiCo, mention regenerative agriculture on their websites and in their guidelines to growers poses the question of how strict and prescriptive the definition of regenerative agriculture should be to avoid greenwashing, while not deterring farmers from adopting it. Some sources advocate that a focus on the outcomes, as opposed to the practices adopted, would allow better control of what is done and ensure tangible results. However, measuring outcomes poses a number of methodological challenges and, in general, increases costs (see Chapter 3). The risks of 'greenwashing', 'greenwishing' or 'regenwashing' are further explored in Chapter 6.

A question also emerges regarding duration: for how long must a farmer have adopted regenerative agriculture principles to be practising 'true' regenerative agriculture? Soil restoration, water and biodiversity preservation are all long-term objectives that cannot be achieved in just a few years of practice. However, while results after a change of practices may initially be minimal, regenerative agriculture is a journey where positive impacts are expected to increase over time. This is a question taken up in depth in Chapter 4. For the sake of this report, a farm may only need to start moving in the right direction to be considered regenerative.

Box 2.2: View of BASE UK, a farmer-led knowledge exchange organisation

'BASE' stands for 'Biodiversity, Agriculture, Soil & Environment'. BASE UK was founded in 2021 as a sister organisation to BASE France, and at that time it was encouraging the three principles of conservation agriculture discussed above. Among BASE members, some are now using the term 'regenerative agriculture' to describe their systems, while others have retained the 'conservation agriculture' label and others reject labels altogether. Nowadays, the BASE committee sees the role of its organisation as guiding farmers along the journey to adapt practices and improve soil health. The organisation aims for inclusivity in its approach to encouraging a more sustainable or even regenerative way of farming among other farmers. It is believed that avoiding the exigencies of a label helps members to grow in confidence in their practices. An increase in membership recently suggests regenerative agriculture may be striking a chord with the farming community in a way that conservation agriculture did not. Accordingly, the farmers of BASE UK reject the idea that certification schemes, similar to those used for organic agriculture, would be an appropriate pathway for the sector.

International case study 1:

Australia

Author: Romina Rader, Associate Professor in Community Ecology, University of New England, Australia

We interviewed three Australian livestock farmers to gain insight into regenerative practices of importance to their production systems. Key messages include: (i) practice holistic management principles to maintain soil fertility and groundcover; (ii) few external inputs; (iii) maintain high plant and animal diversity in the landscape; (iv) minimise broad-scale disturbance to soil and vegetation.

Robert Watson (Mungalli Creek Dairy, North Queensland) advocates working with biological and formative processes rather than chemical additives, continuously improving the condition of the farm with minimal inputs and cost, maintaining biodiversity on the farm and maintaining a low environmental impact.

Bruce Maynard (Stress-free Stockmanship, New South Wales) implemented a wide range of regenerative practices to build complexity and function on farm, including no-kill cropping and stock self-herding to reduce grazing pressure on over-used areas, and encourage cattle to graze previously underused areas. He advocates increasing farm complexity by maintaining diversity of vegetation on farm, including mixed grasslands with shrubs and woodlands that provide edible shrubs and shelter for stock, and reinstate system function.

Norm Smith (Glenwood Merinos, New South Wales) practices holistic management principles of long rest, short graze periods, low inputs and maintenance of high ground cover. This ensures rainfall water is retained and supports a high diversity of perennial plants.

2.3 Objectives

The European Academies' Science Advisory Council notes in its report on regenerative agriculture in Europe:

> *'In contrast to other related concepts, regenerative agriculture is not viewed as defined a priori by a given set of rules and practices; instead, the goals that should be achieved are set and then practices and new technologies are adopted over time which contribute to achieve these goals.'*

Defining the goals or objectives of regenerative agriculture, and the time frame in which they need to be achieved, is a necessary first step. Shared understandings of the objectives of regenerative agriculture have come to influence various definitions of the paradigm. One of the most comprehensive definitions of regenerative agriculture, based on a systematic review of the literature, was provided by Schreefel et al. (2020), who describe regenerative agriculture as:

> *'An approach to farming that uses soil conservation as the entry point to regenerate and contribute to multiple provisioning, regulating and supporting ecosystem services, with the objective that this will enhance not only the environmental, but also the social and economic dimensions of sustainable food production.'*

In the UK context, this definition is echoed by Groundswell, a significant organisation in terms of promoting first conservation agriculture and subsequently regenerative agriculture in England. Its public-facing communications offer the following encapsulation:

> *'Regenerative agriculture is quite simple: it is any form of farming, i.e., the production of food or fibre, which at the same time improves the environment. This primarily means regenerating the soil. It's a direction of travel, not an absolute.'*

The primary objective of any farming system, as these definitions acknowledge, is to **produce food, drink, feed or fibre**. As already recognised, there is also, of course, an economic rationale for farmers interested in applying regenerative agriculture, and its adoption will not be widespread if it is associated with a significant drop in either income/profitability or yield.

Yet while beyond that touchstone most definitions emphasise slightly different aspects of regenerative agriculture, the one common factor in most definitions is **soil health**. Interest in soil health has increased significantly in recent years and it is generally seen as the 'soil's continuing capacity to function as a vital ecosystem that sustains plants, animals and humans' (Bünemann et al., 2018). Restoring and improving soil health is therefore integral to any future truly sustainable forms of agriculture, and at the heart of much discussion and deployment of regenerative agriculture.

Additional objectives emerge across both the relevant literature and the public positions of the movement's advocates. For example, the **reversal of biodiversity loss**, or at least the increase of biodiversity at a local scale, is also one of the most cited objectives of regenerative agriculture (Newton et al., 2020; Giller et al., 2021). Important here, however, is recognising the distinction between developing greater agricultural diversity, a principle of regenerative agriculture, and increasing the biodiversity of species which reside in agricultural landscapes, like farmland birds.

Another widespread objective concerns improving **water quality** (Newton et al., 2020; Schreefel et al., 2020) and the general reduction of other environmental externalities associated with agriculture, such as farming's impact on air quality. **Mitigating and adapting to climate change** also appears as an ambitious overarching objective in some of the literature (Schreefel et al., 2020). For the purposes of this report, these can be considered the core objectives of regenerative agriculture. As highlighted and explained in this report's introduction, however, the question of mitigating the effects of and adapting to climate change, for example via emissions reduction, is not addressed directly throughout the report, with the exception of considerations of soil improvements and increased soil organic matter. Equally, the question of biodiversity is usually attended to via evidence pertaining to immediate agronomic interventions, such as the effect of certain practices on soil invertebrates or microbial communities. The connection between these realities and the presence of larger fauna on British farms, notably birds, requires further exploration and substantiation (see Chapter 6).

These objectives are ambitious and play into a broader societal moment of competing pressure over land use. This report looks to assess the extent to which these objectives are reconcilable via exploration of the principles mobilised in order to achieve them and the practices these principles manifest when applied on farms. This chapter then provides a foundation for the assessment to follow of the evidence for regenerative agriculture's ecological prospects and the future trajectories for the movement, the mindset and its application.

International case study 2:

Brazil

Author: Willams Oliveira, Universidade Federal de Pernambuco, Brazil

Rizoma Agro is developing regenerative agriculture in three farms in Brazil, which have a size of over 2,000 hectares. Its objective is to reduce the environmental impacts of agricultural production, while ensuring comparable yields to conventional agriculture. The production of grains occurs in a crop rotation system to keep the soil covered almost all year. Additionally, it produces fruits in agroforestry systems designed for carbon sequestration and to increase biodiversity, but it also cultivates woody species for sale and annual crops. It adopted the principle of self-sufficient systems in one of the three farms, where the manure from more than 2,000 chickens is used to fertilise the land where grains are produced. This company also implemented a carbon negative livestock system by integrating cattle into forest strips. In 2022, it reported a significant improvement in environmental indicators related to carbon sequestration, biodiversity and water retention. According to the report, the agricultural system adopted was capable of sequestering 45 tonnes of C02 equivalent per hectare per year. It also tripled the number of species of pollinators and natural enemies of pests, and led to the retention of 49,000 litres of water.[1]

Pasto Vivo is a regenerative agriculture project that integrates livestock and agroforestry, contributing to soil conservation, climate protection and biodiversity. This project is also committed to some key targets of the Sustainable Development Goals, such as no poverty, clean water and sanitation, decent work, responsible consumption and production, and climate action. The project has been developed on one farm that comprises a total area of 1,200 hectares, where 744,45 hectares are destined for pasture.[2]

1. RizomaAgro (2022) Relatório de impacto: *Uma imersão em agricultura regenerativa*. Available at: https://rizomaagro.com/
2. https://pastovivo.com/

2.4 Principles

Many efforts to define regenerative agriculture take a principles-based approach (Giller et al., 2021). For example, a 2024 report by Linking Environment and Farming (LEAF) brings together six principles the organisation sees as typifying regenerative farming. Although existing lists of principles differ in how they communicate these principles, there is often overlap. In this section, we bring together the principles most commonly advocated for in the British context. This results in a focus on five central principles:

1. **Minimise soil disturbance**
2. **Minimise bare soil**
3. **Keep living roots/plants in the soil all year round**
4. **Increase diversity on the farm**
5. **Integrate or bring back livestock**

Many sources also highlight the significance of context dependency ('know your context'), sometimes as an additional principle. This is a key consideration, as both principles and, more importantly, practices need to be tailored to the specific context of the farm (climate, soil type, production type, social and economic constraints) to achieve the desired objectives (O'Donoghue et al., 2022). This idea, underpinned as it is by an ecological sensibility, reoccurs throughout this report. The need for recognising context specificity also complicates the implementation of certain practice-based incentive structures or indicators and the potential desirability and application of certification schemes for regenerative agriculture.

This section now expands upon these main principles of regenerative agriculture and describes their ecological rationale before considering the practices associated with them. The evidence base behind many of the claims associated with regenerative agriculture is established further in Chapters 3 and 4.

2.4.1 Minimise soil disturbance

This principle is about reducing or abandoning soil tillage, the main source of physical and mechanical disturbance of agricultural soils. The reduction of chemical disturbance, like the use of chemical inputs, may also be considered. This is important as the reduction of tillage, and in particular no-till farming, in different types of agriculture is generally accompanied by a higher reliance on herbicides, in particular glyphosate, to control weeds. In contrast, organic farming relies on intense mechanical weeding to replace herbicides, which can have a negative impact on soils.

This principle can be extended to 'rebuilding soil after a tillage event' (LaCanne and Lundgren, 2018), which allows the inclusion of root crop cultivation in regenerative agriculture if integrated in a diversified rotation with measures to minimise its impact on the soil and environment (see examples in Gordon et al., 2011 and Lemann et al., 2019).

Ecological rationale:

It is argued that, when applied correctly in the correct context, minimising soil disturbance ensures the maintenance of soil structure, which is vital for the preservation of soil organic matter. Preserving soil organic matter contributes to nutrient supply, water holding capacity and carbon sequestration (Hijbeek et al., 2018; Johnston et al., 2009), and supports soil life, including beneficial soil organisms (de Graaff et al., 2019). Reducing soil disturbance is also argued to minimise soil erosion, promote enhanced soil microbial activity and fungal mycelial networks, and improve nutrient cycling.

2.4.2 Eliminate bare soil and keep living roots/plants in the soil

This section agglomerates principles 2 and 3. Three complementary and overlapping principles are usually found in the literature regarding this principle:

1. Keep the soil surface covered by live plants or residues (sometimes called 'soil armour'), for example straw after harvesting
2. Maintain living roots in the soil
3. Keep plants in the ground year round

In conventional arable agriculture, bare soil is often present during the period between two main crops (after harvest if crop residues are exported), after tillage interventions and in the early stages of crop growth. This principle thus aims to address field management practices to avoid exposed soil and the absence of living plants whenever possible.

Ecological rationale:

Eliminating bare soil can reduce soil erosion by wind, rain and surface water by introducing a barrier between the soil surface and these perturbations (Kaspar and Singer, 2011). This helps to preserve soil structure and reduces leaching of nutrients (Reicosky and Forcella, 1998). The coverage of soil with organic matter or vegetation effectively retains water, as well as minimising evaporation, and therefore can enhance moisture levels for plant growth (Bodner et al., 2007) while contributing to nutrient cycling. Moreover, soil cover can contribute to temperature regulation by providing a protective layer that buffers against extreme heat or cold events (Mendis et al., 2022). Furthermore, the elimination of bare soil promotes biodiversity by creating a favourable habitat for diverse organisms; this can be useful for both weed and pest control (Fageria et al., 2005).

2.4.3 Increase diversity on the farm

This principle concerns cultivated crops, the wild species which occur with them, and plant diversity in general. It can be achieved by diversifying the crop rotations, through intercropping or cover cropping, through the use of flower mixes in field margins, and through diversified hedgerows. Some definitions include animal biodiversity in terms of insects, birds or below-ground biodiversity. However, in contrast to crop or plant diversity, this increase in fauna diversity is usually a desirable emergent property of regenerative practices rather than something that practitioners can increase directly. In other definitions, 'diversity' is widened to include diversity in production systems (e.g. horticulture, livestock, arable, agroforestry), diversity of ownership/managers or diversity of income streams for farmers.

> **Ecological rationale:**
> Increasing cropping diversity in field has been shown to lead to increased crop and forage yield in some contexts (Smith et al., 2008). This is achieved through the establishment of diverse plant species that have complementary nutrient requirements and support beneficial interactions (Beillouin et al., 2021). Crop diversity can also improve yield stability by reducing the risks associated with monocultures and susceptibility to pests, diseases and climate shocks (Raseduzzaman and Jensen, 2017). Furthermore, increased on-farm biodiversity can provide a greater range of habitats to support pollinators, crucial for the success of some crops and fruit trees (Nicholls and Altieri, 2013; Pywell et al., 2015). Increased biodiversity promotes natural pest suppression, as a diverse range of predators and beneficial organisms helps regulate pest populations (Gurr et al., 2003; He et al., 2019; Nicholls and Altieri, 2013). Increased crop diversity or the use of cover crops can also suppress weed pressure, as diverse plant communities compete with and inhibit weed growth (Isbell et al., 2017). Increased diversity in grassland has been shown to be associated with higher levels of soil carbon and nitrogen, and invertebrate abundance in soils (Norton et al., 2022).

2.4.4 Integrate or bring back livestock

This principle focuses on the integration of grazing animals into cropland, as may have been the norm in mixed farming systems typical of past British agriculture. Today, food production in the Global North tends to be highly specialised, and many farms no longer include grazing animals. One of the main effects of bringing back grazing animals in croplands is to enable the integration of perennial crops and permanent or rotational leys, which are known to promote soil organic matter and can contribute to plant diversity on the farm. Livestock help control weeds by breaking the cycle of specialised arable weeds and grazing leys and perennial crops, providing organic amendments that increase soil fertility.

Reintroducing livestock is a significant transformation that may not be easily economically and logistically achievable in some geographical contexts. However, rotational leys, cover crops and organic amendments (e.g. compost, manure and woodchip application) do not necessitate the presence of livestock but may have a comparable effect on soil health through, for example, increased organic matter and breaking weed and pest cycles. Integrating livestock by allowing animals from neighbouring farms to graze on their land can also be a way for stockless farmers to acquire the benefits of animal grazing when constraints for direct integration prevent it.

Significantly, this report recognises the tensions associated with this principle and the foreseen environmental benefits of reduced meat consumption, particularly in light of the ecological impacts of intensive livestock production. This publication, however, does not look to definitively assert the role of animals in future agricultural systems but does, however, recognise the centrality of livestock to the regenerative agriculture paradigm.

> **Ecological rationale:**
> Integrating livestock into arable farms can enhance within-farm nutrient cycling by moving nutrients between and within fields via grazing and producing manure (Soussana and Lemaire, 2014). However, grazing livestock merely move nutrients around and do not represent a net input of nutrients to the soil when they feed on plants that are sourced on the farm. Rotating between cropped land and grassland has also been shown to enhance soil carbon storage in some contexts (Zani et al., 2022). Furthermore, reduced soil erosion, via increased soil cover, and enhanced nitrogen fixation through leguminous plants, for example within a grazed ley, can increase soil nutrient stocks. Additional ecologically derived benefits of incorporating grass leys for livestock into a cropping rotation include breaking weed and pest cycles (Lemaire et al., 2014).

2.4.5 Reduce synthetic inputs

Some sources list the reduction or banning of synthetic chemical inputs as an additional principle of regenerative agriculture (Newton et al., 2020). Synthetic inputs can be broken down into separate categories, each of which play a fundamentally different role in modern agriculture:

1. Mineral fertilisers

2. Pesticides (e.g. herbicides, insecticides and fungicides) and growth regulators

3. Veterinary medicines in livestock systems

Whereas a complete move away from using a range of conventionally employed chemical inputs may be a desired objective for proponents of organic agriculture, the elimination of such inputs, notably herbicides, may not be immediately compatible with other recommended principles and practices associated with regenerative agriculture, such as a reduction of tillage.

In this regard, consideration of herbicides should be bracketed from reductions in insecticides and fungicides. This is because herbicides will be the hardest type of pesticides to transition away from (Triantafyllidis et al., 2023), given that the minimum or no-tillage systems promoted by regenerative agriculture are currently highly reliant on broad-spectrum herbicides such as glyphosate (see Box 2.3).

Some sources have suggested that integrated pest (and weed) management should be promoted as a replacement, as these are well-defined methods that can be taught, followed and monitored, though they are knowledge- and time-intensive for farmers (Giller et al., 2021). The relationship between regenerative agriculture and integrated pest management (IPM) is evolving, with some regenerative agriculture principles and practices arguably consistent with IPM (e.g. diversification) and others incompatible (e.g. no-/minimum-till). How technology will bridge these gaps also remains to be seen (for more information see Maclaren et al., 2020).

As regards fertilisers, the use of organic inputs such as compost and manure enables the recycling of nutrients within systems, but does not replace nutrients lost through production export. Many natural levers exist to reduce losses and promote nutrient accumulation and cycling in agricultural soils, but the move to regenerative systems that employ these levers will involve a transformational shift from current systems, which involve massive exports of nutrients from the soils. In the first instance, measures improving the management of fertilisers and avoiding overuse, for example via the promotion of integrated soil fertility management, are more likely to be taken up by land managers while aligning with regenerative agriculture principles.

Ecological rationale:

It has been suggested by Tripathi et al. (2020) that eliminating chemical inputs can enhance the functioning of the soil microbiome, promoting nutrient cycling and improving soil health. Elimination or an interim reduction, in particular of nitrogen fertilisers, can contribute to lowering greenhouse gas emissions (both from their production and their use) and leaching. In terms of phosphorus fertilisers, as for nitrogen, there is a need for research into how ecological production methods can reduce the requirement for phosphorus addition. In transitioning to regenerative approaches, favouring recycled sources of phosphorus such as sewage sludges would be beneficial as there is only a finite amount of the source rock phosphate, which is a major global sustainability issue of the 21st century (Cordell and White, 2014). Such approaches, however, necessitate consideration of related contaminants.

Restoring ecological function to production systems will reduce the need for pesticides. In turn, this will lower their deleterious effects on biodiversity in general and in particular on beneficial organisms, such as pollinators and natural pest predators (Bakker et al., 2020; Zaller and Brühl, 2019). However, as for fertilisers, there is a need for strategies to redress the loss of beneficial organisms in agricultural systems and a need to understand how to manage the use of pesticides in a transition towards regenerative farming approaches.

Box 2.3: Considering glyphosate

In an article regarding farmers' 'perspectives on regenerative agriculture, Beacham et al. (2023) recount examples from interviews where farmers suggested that their approaches to regenerative arable agriculture in the UK would become incredibly difficult without herbicides like glyphosate. Usage of such products was considered to be worthwhile given the benefits it made possible, resulting in a reduced tillage regime which would otherwise make management of weeds like blackgrass impossible. The issue of how to approach glyphosate reoccurred throughout the discussions which led to the development of this report.

On the one hand, research by Duke (2017) has pointed to the ecological advantages offered by glyphosate in comparison with other herbicides, resulting from its shorter half-life and water solubility. And further, despite much political contestation, in 2023 the European licence for the chemical was extended a further 10 years to 2033. By contrast, studies have explored the relationship between increased glyphosate use and herbicide resistance (Mortensen et al., 2012), impacts on ecologies (Zaller and Brühl, 2019) and absorption into soils (Battaglin et al., 2014). The prospective impact on human health is also significant according to the International Agency for Research on Cancer (IARC), which in 2015 assessed glyphosate as 'probably carcinogenic to humans' (IARC, 2015).

What is certain, however, is the extent to which arable agriculture in the UK currently relies on glyphosate and similar products. Equally, the principle of regenerative agriculture that calls for reduced use of synthetic inputs is a significant horizon for a move towards a more ecological mode of pest management (Maclaren et al., 2020), fertility maintenance and farming in general. Embedding and enabling this trajectory across the UK requires further discussion, evidence and policy beyond the scope of this report.

2.4.6 Limitations and trade-offs

While regenerative agriculture's principles are grounded in ecological rationale, this report asserts throughout that there are limitations to what this collection of principles can deliver. In agriculture, there are no silver bullets. In addition, it is important to note that there are inevitable trade-offs between practices, and between desired outcomes, that require consideration in the design and implementation of a regenerative agriculture strategy for any specific farm. Importantly, these trade-offs will vary between different agroecosystems and management contexts. For example, reduced tillage strategies, which follow the principle of 'reduced soil disturbance', have been shown to enhance soil fertility and pest control, but they tend to result in reduced water quality regulation and weed control (Tamburini et al., 2016).

Eliminating bare soil, for example by utilising cover crops, can enhance nutrient cycling, but also increase the favourability of microclimates for certain crop pests, such as plant parasitic nematodes (Daryanto et al., 2018). Additionally, increasing plant diversity in fields and farms can increase populations of pest natural enemies, but can also provide habitat for other crop pests, as well as for disease vectors (Ratnadass et al., 2012). For livestock integration, there are several key trade-offs, including the potential increased production of greenhouse gases via enteric fermentation, and increased water usage against any climate mitigation benefits of enhanced soil carbon fixation through improved grazing (Prairie et al., 2023). Finally, a key trade-off for reduced chemical input use is linked to indirect land use change when, in some contexts, lower use of synthetic fertiliser and pesticides can lead to decreased crop yields, with this decrease in food supply being compensated for by the expansion of agricultural land in other countries (Meyfroidt et al., 2018). These trade-offs, limitations and risks are considered in further detail in the chapters to come.

2.5 Practices

So far this chapter has established the objectives of regenerative agriculture and the principles widely associated with delivering on those objectives. To do this, principles must inform agricultural practices. Practices, however, as the additional or floating principle of context specificity establishes, are not applicable universally due to the variety of geographical, ecological, geological and climatic contexts present across the UK. This is an idea explored in case study 2.1.

Case study 2.1: Regenerative agriculture in the peatland context

Author: Jenny Rhymes, Greenhouse Gas Flux Scientist, Centre for Ecology & Hydrology, UK

In the UK, carbon-rich lowland peat soils provide some of the most productive land for food production, with approximately 40% of UK grown vegetables produced on lowland peat. However, lowland peat soils are also responsible for the highest carbon emissions per unit area of any land use in the UK. Greenhouse gas emissions from agricultural peatlands are particularly high due to drainage practices, which cause the peat to oxidise. Water table depth (i.e. the volume of peat in an aerobic environment) is the key control on greenhouse gas fluxes on peat, rather than land use, land management or crop type per se. As a result, there is a risk that agronomic practices rooted in regenerative principles developed on mineral soils may provide only marginal emissions savings on organic soils if they do not involve wetter management practices, albeit while still delivering other environmental benefits such as improved biodiversity. Regenerative farming practices for peat therefore must include wetter soil management in combination with conventional regenerative principles (e.g. reducing soil disturbance). Context specificity is key here in ensuring that land use becomes a way to sequester carbon, with the blanket application of certain agronomic practices risking creating greater emissions instead.

The **practices that contribute to soil health** can be broadly divided into those that seek to minimise direct mechanical disturbance of the soil, such as reducing tillage or low stocking rates, and those that protect soil from erosion by covering the soil through the use, for example, of mulching or cover crops. Cover crops are also one way of keeping 'living roots' in the soil, and using them is a key practice for many regenerative farmers. Keeping living roots in the soil feeds the soil microbial community, encourages soil macro-biodiversity, plays a role in carbon sequestration, and in some circumstances conserves water. Keeping the soil covered with living material also contributes to increasing above-ground biodiversity on the farm. The integration of nitrogen-fixing plants is an important practice to manage nutrients, whether it is through their incorporation into permanent pasture or in leys, in arable fields as main or intercrops, or as under-sown cover crops.

Further **promotion of biodiversity** can be achieved through a range of practices, for example by changes to cropped areas (e.g. increasing crop diversity; increasing grassland diversity; diversifying rotations; introducing multi-species cover crops; diversifying leys; or incorporating perennials or trees) or by introducing non-crop biodiversity, for example through the sowing of diversified field margins, encouraging billowing hedgerows or managing semi-natural non-crop areas on the farm for biodiversity. Integrating livestock into cropping systems (e.g. for grazing arable leys) is another route to diversification and is a frequently cited principle of the regenerative approach. However, grassland systems themselves may also be regenerative and include practices such as rotational or mob grazing, or the adoption of integrated farming systems such as silvopasture. The diversification of plants and crops on site, both temporally and spatially, will facilitate ecosystem services, and farmers may use bespoke seed mixes to encourage the natural enemies of pests for pest regulation (to reduce pesticide use) or pollinators for pollination services, or convert some land to agroforestry.

Water preservation, a key objective (but not directly associated with any one practice), is indirectly facilitated by several practices such as cover cropping or ridge farming, or incorporation of deep rooting herbs in pasture which enhance water infiltration and prevent excessive run-off. Watercourse protection beyond the farm gate can be delivered through practices such as riparian buffers. In regenerative agriculture, a suite of practices function synergistically to deliver multiple outcomes.

Likewise, **mitigation of and adaptation to climate change** can be addressed by implementing practices that reduce the use of chemical inputs (thereby reducing greenhouse gas emissions) and interventions that increase the amount of carbon added back into the soil and prevent further losses. A range of regenerative practices aim to facilitate the latter, including reduced tillage, cover crops, perennial planting (herbaceous and woody species) and improved grazing management.

International case study 3:

India

Author: Debanjana Dey, DST-Centre for Policy Research, Indian Institute of Science, Bengaluru, India

Regenerative Agriculture lacks a clear definition in India. The National Institution for Transforming India (NITI Aayog), a public policy think tank of the Government of India, defines natural farming as chemical-free and agroecology-based, with diversified farming systems that integrate crops, trees, livestock, and functional biodiversity, but it does not define regenerative agriculture specifically. According to NITI Aayog, around 2.5 million farmers in India practice regenerative agriculture, including organic farming and natural farming.[1]

In Andhra Pradesh, a state in Southern India, almost a million small holder farmers have adopted Andhra Pradesh Community Managed Natural Farming (APCNF) to make agriculture economically viable, agrarian livelihoods profitable and climate-resilient. APCNF is inspired by regenerative agriculture and focus on crop diversification, soil cover, use of natural bio-stimulants, agroforestry, system of root intensifications, pre-monsoon dry sowing to boost the soil quality and productivity. Major challenges identified in adopting APCNF include lower and fluctuating yields in some crops; marketing challenges for APCNF produce; and non-availability of biological inputs to prepare on- site bio-stimulants. An annual study to assess the performance of six APCNF crops showed that four crops had higher yields than those under chemical agriculture.[2] The study also showed that about 94% of APCNF farmers in the state perceive that the quality of soil in their fields have improved along with soil softening, presence of earthworms and improvement in greenery. More than half of the studied group consider APCNF crops as more resilient than those under chemical farming and believe that they eliminate health risks associated with the usage of fertilizers and pesticides.

1 'An unprecedented participatory foresight initiative to foster the agroecological transition in India'. March, 2023. Available at: https://www.cirad.fr/en/cirad-news/news/2023/participatory-foresight-initiative-in-india-agroeco2050

2 Gulab, S. et al. 2020. Impact Assessment of APCNF. Rabi-2019-2020 report. Institute for Development Studies, Andra Pradesh.

Table 2.2: Examples of practices contributing to the main principles and objectives of regenerative agriculture

Regenerative principles	Examples of practices	Associated benefits
Minimise soil disturbance	**Direct soil disturbance:** No-till (no-dig in smallholder/ market garden systems); reduced tillage; strip tillage; direct drill; precision drilling; contour tillage; controlled traffic; wind breaks; fallow land **Livestock management:** Appropriate stocking rates; rotational grazing; mob grazing; self-herding	Water preservation; soil biodiversity improvements; carbon sequestration (context dependent); enhanced nutrient cycling
Eliminate bare soil	Mulching; cover crops; undersowing; catch crops; riparian buffers; wind breaks; contour hedgerows; living roots; resting pasture; minimise reseeding pastures	Water preservation; above- and below-ground biodiversity restoration; carbon sequestration
Increase diversity on the farm	**Crops:** Diverse cropping; diverse crop rotations; alley cropping; intercropping; relay cropping; multi-species cover crops; legume integration; rotational leys; incorporate perennials and trees; increase grassland/ pasture diversity **Other plants:** Diverse field margins; diverse hedgerows; wider, less managed hedgerows; restoring natural habitat	Water preservation; soil restoration; above- and below-ground biodiversity; natural pest and weed control; biological fixation of nitrogen to reduce inputs; carbon sequestration
Livestock integration	Introducing mixed farming (context dependent); livestock-only systems; rotational grazing; silvopasture mob grazing; holistic grazing; adaptive multi-paddock grazing; animal trains (poultry)	Biodiversity; carbon sequestration; nutrient cycling; water preservation
Reduce chemical inputs	**Biological nutrient cycles:** Animal manures; compost; green manures; cover crops; living roots; legume integration; rotational leys; integration of livestock **Biological pest control:** Diverse field margins; multi-species cover crops; alley cropping (agroforestry); intercropping; catch crops; action threshold for pesticide application **Weed management:** Better rotations; judicious use of glyphosate; emergent technological approaches associated with 'precision' agriculture	Soil restoration; above- and below-ground biodiversity; nutrient cycling through microbial function; carbon sequestration

Adapted from Khangura et al. (2023); Newton et al. (2020); Giller et al. (2021); Abram (2020); Jansson et al. (2021); Elevitch et al. (2018); Jordon et al. (2022); Mosier et al. (2021); Lal (2020).

International case study 4:

Rwanda

Author: Elisée Bahati Ntawuhiganayo, Research associate, Circular Economy Programme, African Leadership University, Rwanda

In Rwanda's higher altitudes, regenerative agricultural practices address challenges including the small agricultural land size, lack of crop diversity, land degradation, soil nutrient depletion, and reliance on inorganic fertilizers.[1] Due to a hilly topography that exacerbates farmland susceptibility to landslides and soil erosion, regenerative agricultural practices complement soil and water conservation measures already. These include ditches, and planting agroforestry trees on radical and progressive terraces. Agroforestry is therefore among the dominant regenerative agricultural practices in higher altitudes of Rwanda.[2] For instance, by 2019, agroforestry contributed 85% of Rwanda's target to restore 2,000,000 hectares of degraded land.[3] Other practices include the application of green leaf biomass, compost application, crop rotation, and intercropping.[4]

Rwanda's farming community has embraced regenerative agricultural practices due to the numerous benefits it offers. The adoption rate of regenerative agricultural practices is currently dominated by farmers who implement low capital and labour-requiring practices such as crop rotation and intercropping.[2] In addition, farmers who participated in training on regenerative agricultural practices are more likely to adopt regenerative agricultural practices, thus highlighting the need for capacity building to accelerate the adoption of regenerative agricultural practices among farming communities Of Rwanda.

1 Cyamweshi, R. A. et al. (2023). Farming with Trees for Soil Fertility, Moisture Retention and Crop Productivity Improvement: Perceptions from Farmers in Rwanda. Small-scale Forestry. https://doi.org/10.1007/s11842-023-09547-x

2 Ntawuhiganayo, E. B. et al. (2023). Assessing the adoption of regenerative agricultural practices in Eastern Africa. Frontiers in Sustainability. https://doi.org/10.3389/frsus.2023.1105846

3 Dave, R. et al. (2019). Second Bonn Challenge progress report. Application of the Barometer in 2018. Gland, Switzerland: IUCN.

4 Murindangabo, Y. T. et al. (2021). Adoption of Conservation Agriculture in Rwanda: A Case Study of Gicumbi District Region. Agronomy. https://doi.org/10.3390/agronomy11091732

2.6 Towards a definition of regenerative agriculture

We argue that an operational yet flexible definition of regenerative agriculture could encourage uptake of regenerative agriculture and make it more accessible to stakeholders, including both farmers and policy makers. It could also help more clearly assess and evaluate the ecological prospects and potential of regenerative agriculture.

For this reason, we propose a principle-based definition of regenerative agriculture which recognises the role that a farmer-led movement has played so far in shaping and promoting regenerative agriculture across the nations of the UK and beyond over recent decades. The principles established below offer guidelines to farmers interested in a transition towards regenerative agriculture. They are not, in and of themselves, prescriptive of any specific practices, as these will depend on the context and constraints of each farm.

The principles take the existing approaches to regenerative agriculture described above as a starting point. The main differences with existing definitions are, however, the broadening of the principle on livestock integration to recognise that regenerative agriculture can also be practised on stockless farms, and the inclusion of a principle regarding reducing synthetic inputs.

As this chapter has established, our definition is based on a three-tier approach (Figure 2.1), organised around:

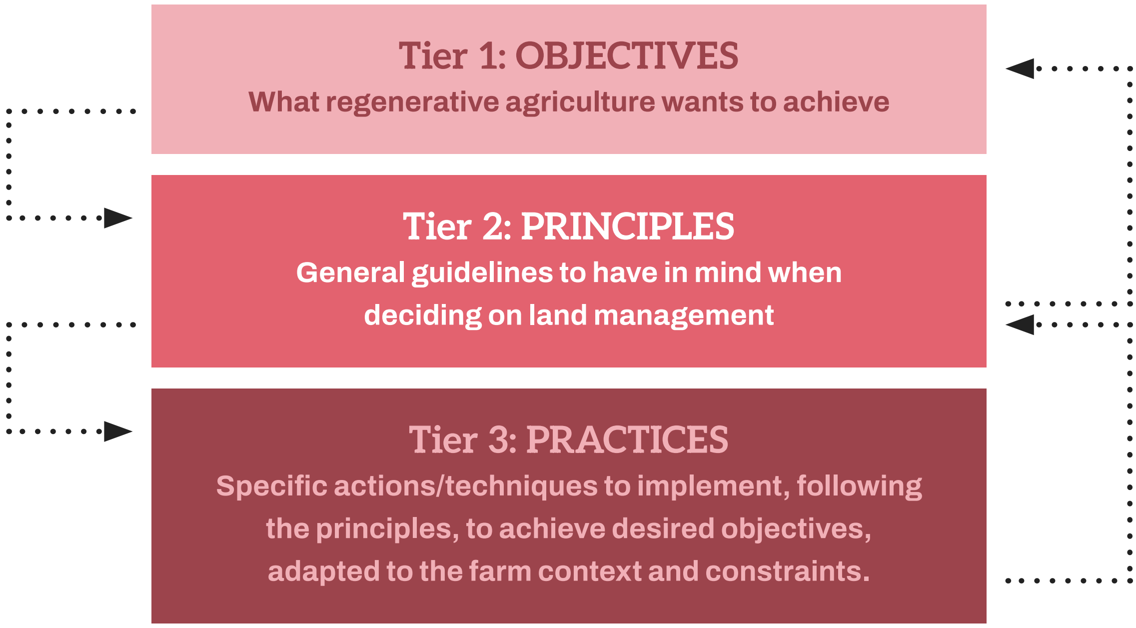
1. The aims and objectives of regenerative agriculture

2. The underlying or guiding principles

3. An indicative list of practices potentially allowing the objectives to be reached, recognising that practitioners innovate and adapt existing practices to their context, constraints and needs

A less flexible definition based on prescribed practices could exclude many practitioners that are embarking on a journey to make their agricultural practices more regenerative. Equally, too flexible an approach risks approaches being labelled regenerative within farming systems or supply chains that are not working towards the improvement of agricultural ecosystems.

Figure 2.1: Regenerative agriculture: Three-tier definition



Objectives: Regenerative agriculture is an approach to farming that aims to produce nutritious food and restore soil health and functions (such as soil organic matter, soil fauna, nutrient cycling, carbon sequestration and water filtering) while also increasing biodiversity, improving water quality, and mitigating and adapting to the effects of climate change. Retaining farmer's' autonomy and profitability is also significant, given the farmer-led dimension of regenerative agriculture's development so far, and this is considered throughout the report, notably in the recommendations in Chapter 6.

Principles: Our definition includes the five following principles. Principles are guidelines to have in mind when selecting practices and are not prescriptive of any specific practice, as the selected practices will depend on the specific context. In other words, they are a 'direction of travel':

1. Minimise soil disturbance **where appropriate**
2. Minimise bare soil and keep living roots year round
3. Increase diversity on the farm
4. Integrate livestock **or approaches that deliver the same functions**
5. Reduce synthetic inputs **and favour ecological approaches**

Important to note is the combination of the principles around bare soil and living roots. In addition, amendments have been suggested to principles 1, 4 and 5 which reflect the need for context specificity, the complexities associated with livestock introduction, and the sensitivities discussed regarding synthetic inputs. As regards the fifth principle, to favour ecological approaches regards biologically based weed control methods (Maclaren et al., 2020) and alternative modes for fertility maintenance as being in line with previous principles.

Practices: No single practice can be labelled as 'regenerative' per se, as its impact will depend on the farm context and constraints, and on the outcome of the interactions with other practices adopted. However, more than one practice needs to be adopted to follow the regenerative agriculture principles and to meet the objectives stated above. See above for a non-exhaustive list of example practices that may be used to follow the principles of regenerative agriculture.

International case study 5:

Cameroon

Author: Mohamed Mounir Mfonden Poumie, University of Dschang, Cameroon

Cameroon's ecological diversity promotes regenerative agriculture practices that are adapted to each zone's unique climate, soils, and cropping systems.

The Soudano-Sahelian zone of Northern Cameroon is characterized by a dry, semi-arid climate with limited and erratic rainfall, favoring crops like millet, sorghum, cotton, and cowpea. Farmers use contour plowing, and water harvesting techniques (micro-dams) to conserve scarce water, integrating cover crops and organic amendments (compost and green manures) to rebuild soil organic matter and improve moisture retention. Trees for the Future, through their Forest Garden Approach promotes the incorporating drought-tolerant trees (nitrogen fixing species) that help manage grazing systems, stabilize soils and enhance nutrient cycling.[1]

The Guinea Savannahs zone, mainly located in parts of the Adamaoua region, has a monomodal rainfall regime with moderate moisture levels and is used for both food and cash crops (e.g., maize, yams, cassava, and cotton). Earth Rising Foundation and Wandusoa Organic Cameroon help farmers capitalize on intercropping and crop rotations to improve soil fertility and break pest cycles, planting native trees along field boundaries to serve as windbreaks and improve water infiltration.[2] Minimum tillage is done using locally made hoes to maintain soil structure and protect microbial life.

Regenerative practices are location specific and for this reason, their uptake requires robust research, training, extension and implementation schemes that are context-specific.

1 https://training.trees.org/en/resource

2 https://wandusoa.org/

References

Abram, M. (2020). Regenerative agriculture. *Farmers Weekly*.

Bakker, L. et al. (2020). Neonicotinoids in global agriculture: Evidence for a new pesticide treadmill? *Ecology and Society*. DOI: 10.5751/ES-11814-250326

Beacham, J. et al. (2023). Contextualising farmer perspectives on regenerative agriculture: A post-productivist future? *Journal of Rural Studies*, 102: 103100. https://doi.org/10.1016/j.jrurstud.2023.103100

Beillouin, D. et al. (2021). Positive but variable effects of crop diversification on biodiversity and ecosystem services. *Global Change Biology*. DOI: 10.1111/gcb.15747

Bless, A. et al. (2023). A genealogy of sustainable agriculture narratives: Implications for the transformative potential of regenerative agriculture. *Agriculture and Human Values*. DOI: 10.1007/s10460-023-10444-4

Bodner, G. et al. (2007). Cover crop evapotranspiration under semi-arid conditions using FAO dual crop coefficient method with water stress compensation. *Agricultural Water Management*. DOI: 10.1016/j.agwat.2007.06.010

Bünemann, E. K. et al. (2018). Soil quality – A critical review. *Soil Biology and Biochemistry*. DOI: 10.1016/j.soilbio.2018.01.030

Cordell, D. and White, S. (2014). Life's bottleneck: Sustaining the world's phosphorus for a food secure future. *Annual Review of Environment and Resources*. DOI: 10.1146/annurev-environ-010213-113300

Daryanto, S. et al. (2018). Quantitative synthesis on the ecosystem services of cover crops. *Earth-Science Reviews*. DOI: 10.1016/j.earscirev.2018.06.013

de Graaff, M.-A. et al. (2019). Chapter One – Effects of agricultural intensification on soil biodiversity and implications for ecosystem functioning: A meta-analysis. *Advances in Agronomy*, 155: 1–44.

Dicks, L. V. et al. (2018). What agricultural practices are most likely to deliver 'sustainable intensification' in the UK? *Food Energy Security*, 2019, 8: e00148. https://doi.org/10.1002/fes3.148

Elevitch, C. R. et al. (2018). Agroforestry standards for regenerative agriculture. *Sustainability*. DOI: 10.3390/su10093337

European Academies' Science Advisory Council. (2022). *Regenerative agriculture in Europe: A critical analysis of contributions to European Union farm to fork and biodiversity strategies*. https://easac.eu/fileadmin/PDF_s/reports_statements/Regenerative_Agriculture/EASAC_RegAgri_Web_290422.pdf

Fageria, N. K. et al. (2005). Role of cover crops in improving soil and row crop productivity. *Communications in Soil Science and Plant Analysis*. DOI: 10.1080/00103620500303939

FAO. (n.d.). *Conservation agriculture*. https://www.fao.org/conservation-agriculture/en/#:~:text=Conservation%20Agriculture%20is%20a%20farming,and%20diversification%20of%20plant%20species

Giller, K. E. et al. (2021). Regenerative agriculture: An agronomic perspective. *Outlook on Agriculture*. DOI: 10.1177/0030727021998063

Gordon, R. J. et al. (2011). Impact of modified tillage on runoff and nutrient loads from potato fields in Prince Edward Island. *Agricultural Water Management*. DOI: 10.1016/j.agwat.2011.07.007

Gurr, G. M. et al. (2003). Multi-function agricultural biodiversity: Pest management and other benefits. *Basic and Applied Ecology*. DOI: 10.1078/1439-1791-00122

He, H. et al. (2019). Crop diversity and pest management in sustainable agriculture. *Journal of Integrative Agriculture*. DOI: 10.1016/S2095-3119(19)62689-4

Hijbeek, R. et al. (2018). Evidence review indicates a re-think on the impact of organic inputs and soil organic matter on crop yield. *Proceedings International Fertiliser Society*.

International Agency for Research on Cancer. (2015). Q&A on Glyphosate. https://www.iarc.who.int/featured-news/media-centre-iarc-news-glyphosate/#:~:text=In%20March%202015%2C%20IARC%20classified,of%20%E2%80%9Cpure%E2%80%9D%20glyphosate).

IFOAM Organics Europe. (2023). *Regenerative Agriculture & Organic*.

Isbell, F. et al. (2017). Benefits of increasing plant diversity in sustainable agroecosystems. *Journal of Ecology*. DOI: 10.1111/1365-2745.12789

Jansson, C. et al. (2021). Crops for carbon farming. *Frontiers in Plant Science*.

Johnston, A. E. et al. (2009). Chapter 1 – Soil organic matter: Its importance in sustainable agriculture and carbon dioxide fluxes. *Advances in Agronomy*, 101: 1–57.

Jordon, M. W. et al. (2022). Can regenerative agriculture increase national soil carbon stocks? Simulated country-scale adoption of reduced tillage, cover cropping, and ley-arable integration using RothC. *Science of The Total Environment*. DOI: 10.1016/j.scitotenv.2022.153955

Kaspar, T. C. and Singer, J. W. (2011). The use of cover crops to manage soil. In *Soil management: Building a stable base for agriculture*. John Wiley & Sons Ltd: 321–337.

Khangura, R. et al. (2023). Regenerative agriculture—A literature review on the practices and mechanisms used to improve soil health. *Sustainability*. DOI: 10.3390/su15032338

Kibblewhite, M. G. et al. (2007). Soil health in agricultural systems. *Philosophical Transactions of the Royal Society B: Biological Sciences*. DOI: 10.1098/rstb.2007.2178

LaCanne, C. E. and Lundgren, J. G. (2018). Regenerative agriculture: Merging farming and natural resource conservation profitably. *PeerJ*. DOI: 10.7717/peerj.4428

Lal, R. (2020). Regenerative agriculture for food and climate. *Journal of Soil and Water Conservation*. DOI: 10.2489/jswc.2020.0620A

LEAF. (2024). *Regenerative agriculture: What is it and where do I start?* https://s3-eu-west-1.amazonaws.com/leaf-website/Regenerative-in-a-Nutshell.pdf

Lemaire, G. et al. (2014). Integrated crop–livestock systems: Strategies to achieve synergy between agricultural production and environmental quality. *Agriculture, Ecosystems & Environment*. DOI: 10.1016/j.agee.2013.08.009

Lemann, T. et al. (2019). The effect of the Dyker on infiltration, soil erosion, and waterlogging on conventionally farmed potato fields in the Swiss Plateau. *CATENA*. DOI: 10.1016/j.catena.2018.10.038

MacLaren, C. et al. (2020). An ecological future for weed science to sustain crop production and the environment. A review. Agronomy for Sustainable Development, 40, 24. https://doi.org/10.1007/s13593-020-00631-6.

Mendis, S. S. et al. (2022). Effects of cover crops on soil thermal properties of a corn cropping system. *Soil Science Society of America Journal*. DOI: 10.1002/saj2.20409

Meyfroidt, P. et al. (2018). Middle-range theories of land system change. *Global Environmental Change*. DOI: 10.1016/j.gloenvcha.2018.08.006

Mosier, S. et al. (2021). Adaptive multi-paddock grazing enhances soil carbon and nitrogen stocks and stabilization through mineral association in southeastern U.S. grazing lands. *Journal of Environmental Management*. DOI: 10.1016/j.jenvman.2021.112409

Newton, P. et al. (2020). What is regenerative agriculture? A review of scholar and practitioner definitions based on processes and outcomes. *Frontiers in Sustainable Food Systems*.

Nicholls, C. I. and Altieri, M. A. (2013). Plant biodiversity enhances bees and other insect pollinators in agroecosystems. A review. *Agronomy for Sustainable Development*. DOI: 10.1007/s13593-012-0092-y

Norton, L. R. et al. (2022). Can pasture-fed livestock farming practices improve the ecological condition of grassland in Great Britain? *Ecological Solutions and Evidence*. DOI: 10.1002/2688-8319.12191

Oberč, B. P. and Arroyo Schnell, A. (2020). *Approaches to sustainable agriculture*. IUCN.

O'Donoghue, T. et al. (2022). Regenerative agriculture and its potential to improve farmscape function. *Sustainability*. DOI: 10.3390/su14105815

Prairie, A. M. et al. (2023). Restoring particulate and mineral-associated organic carbon through regenerative agriculture. *Proceedings of the National Academy of Sciences*. DOI: 10.1073/pnas.2217481120

Pywell, R. F. et al. (2015). Wildlife-friendly farming increases crop yield: evidence for ecological intensification. *Proceedings: Biological Sciences*. DOI: 10.1098/rspb.2015.1740

Raseduzzaman, M. D. and Jensen, E. S. (2017). Does intercropping enhance yield stability in arable crop production? A meta-analysis. *European Journal of Agronomy*. DOI: 10.1016/j.eja.2017.09.009

Ratnadass, A. et al. (2012). Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: A review. *Agronomy for Sustainable Development*. DOI: 10.1007/s13593-011-0022-4

Reicosky, D. C. and Forcella, F. (1998). Cover crop and soil quality interactions in agroecosystems. *Journal of Soil and Water Conservation*.

Rodale Institute. (1989). *Seven tendencies of regeneration*. https://rodaleinstitute.org/wp-content/uploads/7-TENDENCIES-REGENERATION.pdf

Rodale Institute. (2020). *Regenerative agriculture and the soil carbon solution*.

Sands, B. et al. (2023). Moving towards an anti-colonial definition for regenerative agriculture. *Agriculture and Human Values*. DOI: 10.1007/s10460-023-10429-3

Santoni, M. et al. (2022). A review of scientific research on biodynamic agriculture. *Organic Agriculture*, 12: 373–396. https://doi.org/10.1007/s13165-022-00394-2

Schreefel, L. et al. (2020). Regenerative agriculture – The soil is the base. *Global Food Security*. DOI: 10.1016/j.gfs.2020.100404

Smith, R. G. et al. (2008). Effects of crop diversity on agroecosystem function: Crop yield response. *Ecosystems*. DOI: 10.1007/s10021-008-9124-5

Soussana, J.-F. and Lemaire, G. (2014). Coupling carbon and nitrogen cycles for environmentally sustainable intensification of grasslands and crop-livestock systems. *Agriculture, Ecosystems & Environment*. DOI: 10.1016/j.agee.2013.10.012

Tamburini, G. et al. (2016). Soil management shapes ecosystem service provision and trade-offs in agricultural landscapes. *Proceedings of the Royal Society B: Biological Sciences*. DOI: 10.1098/rspb.2016.1369

Tittonell, P. et al. (2022). Regenerative agriculture—Agroecology without politics? *Frontiers in Sustainable Food Systems*.

Triantafyllidis, V. et al. (2023). Herbicide use in the era of farm to fork: Strengths, weaknesses, and future implications. *Water, Air, & Soil Pollution*. DOI: 10.1007/s11270-023-06125-x

Tripathi, S. et al. (2020). Chapter 2 – Influence of synthetic fertilizers and pesticides on soil health and soil microbiology. In *Agrochemicals detection, treatment and remediation*, ed. Prasad, M. N. V. Butterworth-Heinemann: 25–54.

Wilson et al. (2024). A buzzword, a 'win-win', or a signal towards the future of agriculture? A critical analysis of regenerative agriculture. *Agriculture and Human Values*. https://doi.org/10.1007/s10460-024-10603-1

Zaller, J. G. and Brühl, C. A. (2019). Editorial: Non-target effects of pesticides on organisms inhabiting agroecosystems. *Frontiers in Environmental Science*.

Zani, C. F. et al. (2022). Effects of integrating grass-clover leys with livestock into arable crop rotations on soil carbon stocks and particulate and mineral-associated soil organic matter fractions in conventional and organic systems. *Soil Use and Management*. DOI: 10.1111/sum.12754

Chapter 3: Ecological evidence: Assessing benefits and indicators

Authors: *Ruth N. Wade (co-lead), Adenike Amoo, Hannah Cooper, Emily Magkourilou, Andy Neal, Hannah Wright, Lisa Norton, Jennifer Dodsworth, Roy Neilson (co-lead)*

Summary

Appropriately implementing regenerative agriculture principles has the potential to provide many environmental benefits. However, regenerative practices should be tailored by the farmer to each individual farming system to avoid potential undesirable outcomes. The perception that environmental benefits delivered by individual regenerative agriculture practices are maintained when several regenerative agriculture practices are concurrently adopted, resulting in additive benefits, is not yet well evidenced. It is likely that the benefits of regenerative agriculture and the success of implementing the practices will depend on multiple factors, including the principles and practices adopted, the farmer's knowledge and skills, the farming system, the contemporary ecology of the farm and its location. As highlighted in Chapter 2, context is fundamental.

Despite these multiple influencing factors, there is evidence that minimising soil disturbance, wherever possible, can over time improve soil structure and support greater soil biodiversity, thereby improving soil function. Similarly, eliminating bare soil and keeping a living root all year round via practices such as leaving crop residue on the surface and including cover crop and perennial plant rotations confer benefits such as increasing soil organic matter and biodiversity, as well as improving soil structure and nutrient availability. Incorporating greater diversity in farm systems by using multiple crop mixtures and rotations and incorporating livestock, especially when coupled with reduced inputs, can support greater biodiversity and potentially yield and increase resilience to climatic variability such as summer droughts, extreme rainfall events or to fluctuations in commodity prices. Notwithstanding concerns regarding greenhouse gas emissions, integrating livestock on arable land can also have multiple benefits, including increased soil organic matter and biodiversity, and increased on-farm economic margins.

Identifying the outcomes of regenerative agriculture requires a good understanding of the context of the farming system – for example, the soil type, climate, starting point and desired trajectory of change – and a robust means of measuring change. Indicators used to assess the benefits of regenerative agriculture can be practice-based (by considering the practices being used), outcome-based (by considering the observed benefits of said practices) or a combination of both indicator types. A consensus is emerging among experts that the best way to measure the impact of regenerative agriculture is a combination of practice- and outcome-based indicators.

3.1 Environmental benefits of regenerative agriculture

In recent years, regenerative agriculture has attracted increased interest in scientific circles, among farmers and in public-facing media. This publicity has been accompanied by a range of claims about the potential of regenerative agriculture systems to improve biodiversity, increase carbon sequestration and mediate the ecological harms associated with conventional agriculture. This chapter will assess the current understanding of the extent of such environmental benefits as established by existing research and expertise and measured against the objectives and principles included in this report's previous chapter.

Importantly, although regenerative agriculture offers much promise, its potential benefits can be greatly impacted by numerous factors relating to the principles and practices adopted, the farmer's knowledge and skills, the farming system and its location. As outlined in Chapter 2, the environmental benefits of regenerative agriculture may only be realised if multiple regenerative agriculture principles are adopted and implemented together, but there is a lack of evidence to support this. Ultimately, each benefit described in this chapter should be considered as a 'potential benefit', which will be realised only if practices are suitable for the production system and implemented appropriately. If wrongly implemented or used in a system that is unsuitable for them due to the combination of local environmental and on-farm factors, a practice (or the interaction of several practices) can result in negative consequences for the agricultural system, the environment and/or the farm business.

Box 3.1: Mediating factors to benefits of regenerative agriculture

The success of regenerative agriculture practices is greatly influenced by a variety of factors, including:

- Economics (e.g. level of required capital investment, profit margins)
- Environment (e.g. soil type, climate, length of growing season, proximity to non-cropped habitats)
- Infrastructure (e.g. availability of specialist equipment and proximity to processors)
- Knowledge and skills to successfully implement regenerative agriculture practices
- Management (e.g. required inputs, diversity of rotation, sowing date)

Table 3.1 maps the potential benefits of successfully adopting overlapping regenerative agriculture practices alongside the principles established in Chapter 2. The potential benefits in the column on the far left of the top half of the table reflect and extend upon the objectives established in the previous chapter. The final column regarding favouring nature-based methods is a corollary of the principle regarding reducing synthetic inputs. The number of asterisks in a cell indicates the likely impact of any potential benefit. The colour of the asterisks represents the certainty of the assertion based on the available scientific literature discussed in further detail throughout this chapter. A minus sign indicates potentially negative impacts. The rows in the bottom half of the table highlight the indicators via which the benefits associated with each principle can be assessed, as well as the conditions upon which successful delivery of these objectives will depend and the prospective socio-economic benefits for farmers or land managers who adopt the practices concerned.

There is some evidence for a synergistic effect of some management practices on several ecosystem services. For example, a collation of 95 different meta-analyses of global crop diversification studies showed that crop diversification, achieved through a number of practices, enhances not only crop production but also the associated biodiversity of non-cultivated plants and animals, as well as several other ecosystem services including soil quality, water quality, and pest and disease control, although results were variable between practices (Beillouin et al., 2021). It is important to consider the benefits of regenerative agriculture principles rather than looking at individual practices.

This first section of the chapter expands methodically upon Table 3.1 with reference to the evidence regarding potential progress in relation to each principle where available in relation to the assertions made. The risks associated with each objective are also considered. This discussion on the potential benefits of regenerative agriculture is followed by related consideration of how best to measure and evaluate the progress being made towards relevant objectives associated with regenerative agriculture. As discussed in the preceding chapters of this report, the focus of much of the evaluation below is arable systems, or arable systems becoming mixed farming systems. However, the prospective benefits and differences associated with grassland or pastoral agriculture are introduced where possible.

Finally, there are emergent methodological and research issues associated with ongoing transitions to regenerative agriculture. A lack of harmonised methods to characterise the outcomes of the adoption of regenerative agriculture principles or practices could create uncertainty or an inconsistent knowledge base. Additionally, harnessing results from agricultural systems not applicable to the UK may lead to unintended consequences when applied on UK farms. Wherever possible, in this chapter, we have used evidence sourced from UK systems. Caution should therefore be exercised when considering conclusions generated from meta-analyses that may represent only a few studies applicable to UK conditions. More research is needed in the UK to fill in recognised knowledge gaps and support the wide transition towards more sustainable agriculture.

Table 3.1: Table assessing objectives, indicators, variables and potential benefits of the implementation of principles of regenerative agriculture established in Chapter 2

Objectives	Principles: Minimise soil disturbance	Minimise bare soil and keep living roots year round	Increase on-farm diversity	Integrate livestock or approaches that deliver the same functions	Favour nature-based methods over synthetic inputs
Increase in soil organic matter	* (Low certainty)	** (High certainty)	** (Low certainty)	** (Medium certainty)	** (Medium certainty)
Improved soil structure	** (Low certainty)	*** (High certainty)	** (High certainty)	—	?
Improved nutrient availability	* (Low certainty)	** (Medium certainty)	** (Low certainty)	* (Medium certainty)	—
Increased biodiversity	* (Low certainty)	** (Medium certainty)	** (Medium certainty)	* (Medium certainty)	** (Medium certainty)
Weeds, disease and pest suppression	?	* (Low certainty)	* (Low certainty)	** (High certainty)	* (Medium certainty)
Reduced environmental externalities	* (Low certainty)	* (Low certainty)	* (Low certainty)	—	*** (High certainty)
Commercial yields (including business resilience)	?	* (Medium certainty)	* (Medium certainty)	** (High certainty)	?

— Negative impact * Small impact ** Medium impact *** Large impact

? Uncertain Low certainty Medium certainty High certainty

Principles

	Minimise soil disturbance	Minimise bare soil and keep living roots year round	Increase on-farm diversity	Integrate livestock or approaches that deliver the same functions	Favour nature-based methods over synthetic inputs
Indicators	Water holding capacity Bulk density Infiltration rate Organic matter Wet aggregate stability Soil organic carbon content Plant available nutrients Earthworm abundance	Percentage of soil exposure Root biomass	Plant diversity within rotation and between rotation Soil biota (micro-, meso- and macro-fauna) e.g. earthworm abundance	Soil organic matter Animal health and welfare	Nodulation of legumes Insect pest abundance
Dependent variables	Access to specialist machinery Depth, type and timing of tillage Years of minimum cultivation Waterlogging Underlying geology Soil type Annual weather variability	Agronomic decision Climate Annual weather variability Soil type Legacy of effects of previous cropping Termination of cash or cover crop timing and method	Crop mixture used Economic margins Access to specialist machinery Market needs Past management Climate	Plant species Grazing rotation Ruminants used Trade-offs with nitrogen and phosphorus On-farm infrastructure and availability of local services for integrating animals into the farming system	Integrated pest management Availability of waste-derived organic matter Plant–soil and plant–plant interactions Soil biodiversity
Socio-economic benefits	Reduced fuel costs associated with tillage	Systemic resilience to extreme weather	Diversification of income streams Potential access to subsidy payments	Diversification of income streams Increased soil fertility	Reduced purchasing of external inputs

3.2 Minimise soil disturbance

Minimising soil disturbance means introducing less intensive tillage practices. This refers to a range of practices including 'conservation tillage', 'minimum tillage' ('min-till'), 'reduced tillage' or zero tillage ('no-till'). Changes in tillage are predominantly associated with arable agriculture and general cropping, activities which define around one-third of the UK's agricultural landscape (Defra, 2024). Yet in addition to this, in many intensive grassland systems farmers plough and re-sow predominantly grass mixtures in a way comparable to arable systems, although on a five-yearly rather than annual basis.

Multiple potential benefits of reducing soil disturbance in relation to Table 3.1 are listed below. Across the objectives, however, the level of certainty is relatively low and the potential extent of the benefits modest. The ambiguous question of yields (explored further in the following chapter) and the overall question of relative environmental benefits are not discussed further here. These remain an area where more research and evidence are required.

Increase in soil organic matter:

- Rating: **Small Impact / Low Certainty** *

- Soil organic matter is around 58% carbon, and the effect of reducing agricultural disturbance on soil carbon storage is a question of growing interest to ecologists, agronomists, farmers and society. Using the Rothamsted Carbon model (see rothamsted.ac.uk/rothamsted-carbon-model-rothc), Jordon et al. (2022) reported that, compared with conventional full-inversion[1] tillage, adopting reduced tillage practices would have only a minor impact on UK soil organic carbon stocks, with a likely average increase of 0.36% over 30 years, and potentially a decrease of 0.72% when no-till is implemented. This is consistent with assessments of short-term (four to 10 years' duration) tillage studies that noted a limited benefit in using shallow minimum tillage or zero tillage practices in the UK to increase soil carbon storage when a soil profile to a depth of 60 cm was considered (Brown et al., 2021). Similarly, Cooper et al. (2020) concluded that conservation tillage alone did not significantly improve soil organic carbon during the first five years of adoption as part of a Defra Demonstration Test Catchment, although yields did improve compared with conventional tillage.

  Even when no-tillage is introduced, the evidence is not clear. For example, a meta-analysis from boreo-temperate regions showed a significant increase in soil carbon in surface layers (0–15 cm) as a result of no-tillage when compared with high or intermediate intensity tillage. Soil carbon was also significantly higher in soils with intermediate tillage than those with high intensity tillage, but there were no significant impacts of tillage on soil carbon elsewhere in the soil layer, and effects were more likely to be found in long-term studies (more than 10 years) (Haddaway et al., 2017). The debate in this area is ongoing – for example, see Cai et al. (2022, 2023) and Simpson et al., (2023) – and more

1 Full-inversion tillage is a tillage method where the entire soil is inverted up to depths of 30 cm.

long-term studies are needed to distinguish between natural fluctuations and real outcomes of no-till (Cusser et al., 2020), as is consideration of subsoils (Button et al., 2022).

Data on carbon stocks in livestock grassland typical of regenerative agriculture approaches indicate that low intensity and more biodiverse grasslands with low inputs have higher soil carbon, higher soil nitrogen levels and higher abundances of soil macro-fauna (Norton et al., 2022).

Improved soil structure:

- Rating: **Medium Impact / Low Certainty** **
- Minimising soil disturbance leads to an improvement in soil structure, supporting soil biodiversity and soil macro-aggregate formation (the collection of silt/clay particles and organic matter) as well as increasing soil porosity. It can increase the proportion of water stable aggregates and thereby mitigates soil erosion (Figure 3.1). However, if large machinery continues to pass over undisturbed soil, resulting compaction can restrict root growth. For this reason, planting cover crops and plants with different rooting systems may be critical in maintaining good soil structure.

Improved nutrient availability:

- Rating: **Small Impact / Low Certainty** *
- Notwithstanding that disturbance stimulates a short-term increase in nutrient availability via briefly enhanced nitrogen mineralisation, minimising soil disturbance can reduce nutrient use and no-tilled soils tend to have greater soil moisture due to increased crop residue on the soil surface. A global meta-analysis of 203 studies (Lv et al., 2023) reported that, compared with conventional tillage with and without straw stubble covering and no-tillage with and without straw stubble covering, reduced and minimum tillage without straw stubble covering significantly increased a range of soil parameters, including topsoil (0–15 cm) organic matter, organic carbon, nutrient concentrations (carbon, nitrogen, phosphorus and potassium) and available nutrients (nitrogen, phosphorus and potassium).

Increased biodiversity:

- Rating: **Small Impact / Low Certainty** *
- Tillage has an ecological effect on the soil (Kladivko, 2001). Minimising soil disturbance leads to a spectrum of biodiversity outcomes within the soil. In general, adopting regenerative agriculture practices that minimise soil disturbance

can mitigate the negative impacts on soil diversity of previous production methods, and thereby enhance the abundance and diversity of key groups of soil organisms, such as earthworms, mycorrhizal fungi and nematodes (Levin, 2022). Furthermore, for those agricultural systems where no-till results in more fungal-based food webs (Chen et al., 2020), this could result in enhanced nutrient cycling efficiency and resistance to perturbations, such as drought (de Vries et al., 2012). Moreover, a review by Tamburini et al. (2020) found reduced tillage contributed to below-ground biodiversity. In addition, less disturbed grassland soils harbour different soil microbial communities, including soil fungi which strongly interact with above-ground plant communities (Seaton et al., 2022).

Practices such as minimum tillage show mixed results for its effect on biodiversity, mainly depending on biological grouping, region and soil type. For example, de Graaff et al. (2019) found an increase in soil bacteria and faunal biodiversity following minimum tillage, but no effect on fungi. Wilkes et al. (2021) concluded that zero tillage systems are beneficial for arbuscular mycorrhizal fungi, the enhancement of soil glomalin and soil erosion mitigation. Griffiths et al. (2012) noted that tillage effects on nematodes were secondary to season and year. Evidence has shown that no-till can also offer benefits for climate change mitigation.

However, outcomes depend on which soil organisms are being assessed, the methodology of assessment, soil type, the aspects of biodiversity of interest being assessed (e.g. diversity at individual site scale, or larger scales; diversity for its own sake or for how it contributes to agricultural production) and the agricultural system under study. For example, a meta-analysis reported that reduced tillage significantly increased total phospholipid fatty acids, fungal and bacterial abundances compared with conventional tillage, whereas no-tillage had only a positive effect on fungi (Morugán-Coronado et al., 2022). Yet using environmental DNA (eDNA) to assess the impact of reduced tillage on bacteria, fungi and eukaryotes, Frøslev et al. (2022) reported that richness was only weakly correlated with tillage, and more influenced by where in the field the sample was taken.

Risks:

- Application of minimum or no-till in inappropriate contexts may have a negative impact on soil structure and crop establishment. For example, poorly implemented no-till regenerative agriculture practices could lead to the generation of an impenetrable soil pan in some agricultural landscapes (Peixoto et al., 2020).

3.3 Minimise bare soil and keep living roots year round

Agricultural practices which minimise bare soil by keeping the soil covered include retaining crop residue such as straw or grass/herbal ley cuttings at harvest and planting cover crops. Cover crops are plants grown between cash crops – normally between a winter crop and a spring crop – that provide ground cover during the autumn and winter months. Where the production system allows, spring-sown cover crops are an option, as too is planting 'catch crops' which provide short-term cover for approximately six to 10 weeks between cash crops, normally two winter crops. Finally, companion cropping involves introducing a range of crop species which are planted alongside the planned cash crop and can be retained during the harvest of the cash crop. In addition, keeping living roots all year round includes practices such as planting perennial crops and herbal leys in a rotation or using perennial companion cropping.

Minimising bare soil and keeping living roots year round can provide multiple benefits, including:

Increase in soil organic matter:

- Rating: **Medium Impact / High Certainty** **
- Practices that retain crop residue as well as growing species with a cover crop or companion crops that have different root structures and root lengths can increase soil organic matter (Jian et al., 2020). The amount of soil organic matter accumulated depends on how the cash crop or cover crop is terminated; if the above-ground biomass is left on the soil or returned to the soil later as farmyard manure, then it is likely to increase soil organic matter.

Improved soil structure:

- Rating: **Large Impact / High Certainty** ***
- Practices that minimise bare soil make soil aggregates stable and structural, by binding them together. Soil aggregates are clumps of soil particles that are held together by moist clay, roots, gums from bacteria and fungi. Root systems of cover crop species can improve soil structure at different depths by breaking up compacted layers and adding organic matter. Advancements in root phenotyping and trait selection will be essential in improving further ecosystem service delivery by cover crops (Griffiths et al., 2022). Keeping the soil covered, particularly over winter, reduces soil erosion and topsoil losses by wind and water, especially in soils with sloping topography (Storr et al., 2019). Furthermore, increasing soil water holding capacity and water infiltration through improved soil structure and the addition of organic matter reduces run-off and ponding of water on the soil surface and helps soils better cope with drought and intense rainfall events. Improved soil structure also reduces nutrient and chemical run-off from agricultural land into water systems (Hallett et al., 2016).

Improved nutrient availability:

- Rating: **Medium Impact / Medium Certainty** **

- Cation exchange capacity is a measure of the soil's ability to hold positively charged ions, which has an important impact on soil structure stability and nutrient availability. Increased cation exchange capacity can reduce nutrient leaching and thus increases the availability of these nutrients to the plants. Long-term use of cover crops, particularly woody or fibrous plants, can increase the build-up of stable forms of organic matter humus containing several nutrient minerals, which are more slowly released, improving the health and fertility of the soil (Storr et al., 2019). The inclusion of legumes in cover or companion crops fixes nitrogen from the atmosphere and provides biological nitrogen to the soil; however, more research is needed to determine the quantities of nitrogen added by different legumes under low nitrogen fertiliser regimes.

Increased biodiversity:

- Rating: **Medium Impact / Medium Certainty** **

- Minimising bare soil and keeping living roots year round can improve biodiversity through an increase of water-filled pore spaces and channels for movement of below-ground organisms (Kim et al., 2020). Increased soil organic matter through crop residue retention and growing cover and companion crops gradually releases nutrients, providing substrate for soil biota such as micro-organisms, fungi, earthworms, nematodes and insects (Hao et al., 2023). Selection of flowering cover and companion crop species can enhance beneficial insect habitats and promote pollinators. A co-benefit of some cover and companion crops is that they can also be used for grazing, which, if managed correctly, could increase on-farm biodiversity. Both the Scottish Government (n.d.) and the Agriculture and Horticulture Development Board (n.d.) suggest integrating cover cropping to increase on-farm biodiversity.

Weed, pest and disease suppression:

- Rating: **Small Impact / Low Certainty** *

- Besides supporting pollinators, cover and companion crops support a broad spectrum of beneficial insects through creation of habitats during the growth and senescence phases of the crop. Furthermore, companion crops can be used to divert insect pests away from the main cash crop and could also act as barriers against fungal pathogen spread throughout the cash crop (Huss et al., 2022). There is potential to reduce herbicide and pesticide use if weeds, pests and diseases are successfully suppressed through companion cropping (Osipitan et al., 2019). This can be achieved through biofumigation, the post-crop termination process of macerating and incorporating certain

Brassicaceae or related plant species into the soil, leading to the release of isothiocyanate compounds through the hydrolysis of glucosinolate contained in plant tissues (Kirkegaard and Matthiessen, 2004). Furthermore, during plant growth, Brassicaceae roots release glucosinolates into the soil in a process known as 'partial biofumigation'. Both practices can result in a suppressive effect on a range of soil-borne pests and diseases, for example nematodes (Brennan et al., 2020; Waisen et al., 2020). An indirect consequence of incorporating high amounts of readily degradable organic matter is competition for oxygen in the soil, generated by increased soil biotic activity. Therefore, it is generally acknowledged by farmers and agronomists that caution should be exercised when planting or sowing a new crop immediately following the incorporation of green manure.

Commercial yields:

- Rating: **Small Impact / Medium Certainty** *
- A recent review reported that the use of cover crops can result in a 4% reduction in cereal yields, though this can be both mitigated and transformed into a more than 10% overall yield increase through the adoption of mixed cropping (Abdalla et al., 2019).

Risks:

- The use of cover crops may increase greenhouse gas emissions as a result of the selection of plant genotypes that through their interaction with soil microbiomes increase greenhouse gas efflux from soils, as has been demonstrated for grass genotypes (Giles et al., 2023).
- Cover cropping may incur extra costs without producing additional commercial yield.

3.4 Increase diversity on farm

For the purposes of this analysis, we focus on agricultural diversification in the sense of broadening the variety of different types of plants grown on farms. This can be achieved through practices like intercropping and agroforestry. Intercropping involves growing a mixture of more than one crop species at the same time and in the same area of land. Agroforestry – both in-field and as silvopasture – can take different forms including shelterbelts, widely spaced trees, groups of trees, hedgerows and woodland grazing (Perks et al., 2018) that are typically grown in combination with crops (silvo-arable systems) or combined with pasture for livestock (silvo-pastoral systems) (Cardinael et al., 2017). Silvo-arable and silvo-pastoral systems are not yet widespread in the UK, partly because they have not been incentivised as they have in the European Union (Saunders et al., 2016; Torralba et al., 2016). The adoption of integrated cropping systems can result in reduced environmental impacts without negatively impacting crop yields (Hawes et al., 2018).

Agroforestry is another way of increasing ground cover and diversity, and can be carried out in numerous ways. Ecosystem service dynamics will vary according to the type of agroforestry system and the underlying farming system, and will change from one year to the next as the trees grow, but the establishment of agroforestry, especially in arable systems, has been shown to increase soil carbon content, biodiversity, pest control and water regulation, while reducing soil erosion (Torralba et al., 2016; Staton et al., 2019; Pardon et al., 2020).

Increasing the diversity of grassland swards is a key regenerative agriculture practice for grassland farmers. As discussed above, higher species diversity is positively linked to higher soil carbon and nitrogen and to invertebrate numbers. It is also linked to higher resilience to extreme events such as flooding and drought (Lüscher et al., 2022). Other benefits of increased diversity include positive impacts on animal welfare and on food quality from livestock (Zanon et al., 2022). These relationships, like regenerative agriculture practices, are context dependent as well as dependent on livestock breeds and management.

In general, increasing diversity on farm could have multiple benefits, including:

Increase in soil organic matter:

- Rating: **Medium Impact / Low Certainty** **
- In this instance, the focus is very much on soil organic carbon. Rotational leys are known to enhance soil organic carbon (Montgomery et al., 2022), though this is optimally achieved as part of an integrated management practice (Al-Kaisi and Lal, 2020) with the inclusion of several different plant species (King and Blesh, 2018). The positive impact of afforestation associated with agroforestry on soil organic carbon stocks is more pronounced in cropland soils than in pastures, however, where there can be a net loss in the years following tree establishment (Laganière et al., 2010; Upson et al., 2016).

Improved soil structure:

- Rating: **Medium Impact / High Certainty** **

- Leys, compared with arable soil, increase earthworm abundance, soil infiltration rates, soil physical measures (including macropore flow) and saturated hydraulic conductivity. They also reduce compaction (bulk density), resulting in improved yields (Berdeni et al., 2021).

Improved nutrient availability:

- Rating: **Medium Impact / Low Certainty** **

- Potential benefits from mixed crops include the maintenance of crop yields with reduced inputs, such as herbicides and pesticides (see the subsection discussing yields in Chapter 4), and greater resilience to environmental variability such as summer droughts (Weih et al., 2022).

Increased biodiversity:

- Rating: **Medium Impact / Medium Certainty** **

- On-farm diversification of crops is known to enhance biodiversity and a range of ecosystem services such as supporting pollinators, pest control, nutrient cycling, soil fertility and water regulation, without compromising crop yields (Brooker et al., 2015; Tamburini et al., 2020). The results of a meta-analysis of 53 individual European studies on the effects of agroforestry on ecosystem services showed a strong positive effect of agroforestry on biodiversity, with the effect size varying depending on the taxa and systems studied; the strongest positive effects were seen for birds and silvo-arable systems (Torralba et al., 2016). The effects were often more apparent at a landscape and regional scale than at a farm scale.

Weeds, disease and pest suppression:

- Rating: **Small Impact / Low Certainty** *

- Regenerative agriculture practices that can increase diversity on farms, including through crop rotation, typically grass, have been a cornerstone of UK arable production for decades, especially to mitigate weed, pest and disease burden and to improve soil structure (Ball et al., 2005).

Commercial yields:

- Rating: **Small Impact / Medium Certainty** *

- Under Scottish conditions, crop mixtures when compared with monocultures in 32 trials between 2020 and 2022 showed that yield gains from growing a crop mixture were approximately 20% based on Crop Performance Ratio (SEAMS, 2023; Brooker et al., 2024). While mixture composition resulted in varied mixture performance, irrespective of management, climate and composition effects, crop mixtures always performed at least as well as expectations based on monocultures. Furthermore, in the same study, detected reductions in soil organic matter in upper soil layers suggest a future research priority.

Risks:

- A lack of valuable markets for selling diverse crops may lead to reduced on-farm profits.

3.5 Integrate livestock or approaches that deliver the same functions as livestock

Grazing and browsing animals have co-evolved with a range of flora and fauna and, through careful management, livestock can be used to mimic aspects of this 'natural' grazing, and through this support substantial biodiversity. Most existing research into the role of livestock in maintaining biodiversity has focused on rangelands, giving mixed results; see Alkemade et al. (2013) and Filazzola et al. (2020). Within the UK, inappropriate livestock grazing (primarily overgrazing) has historically resulted in substantial ecosystem degradation in upland regions (McGovern et al., 2011; Marrs et al., 2018). However, appropriate and regeneratively oriented livestock management can increase species richness compared with improved grassland grazing systems; see, for example, Norton et al. (2022). Schipanski et al. (2014) argue that adoption of ruminant-based ley-arable systems can lead to soil carbon sequestration, prevention of run-off and soil erosion, weed suppression and a reduction in nitrogen leaching.

Proponents of regenerative agriculture suggest that livestock integration or equivalent actions can deliver a variety of benefits in line with the principles and objectives highlighted above. These benefits are elaborated upon below. Importantly, however, livestock integration also comes with trade-offs and creates potential difficulties for farmers with no background in livestock production, as well as environmental externalities associated with livestock production.

Increase in soil organic matter:

- Rating: **Medium Impact / Medium Certainty** **
- In this instance, the focus is very much on soil organic carbon. Rotational leys are known to enhance soil organic carbon (Montgomery et al., 2022), though this is optimally achieved as part of an integrated management practice (Al-Kaisi and Lal, 2020) with the inclusion of several different plant species (King and Blesh, 2018). The positive impact of afforestation associated with agroforestry on soil organic carbon stocks is more pronounced in cropland soils than in pastures, however, where there can be a net loss in the years following tree establishment (Laganière et al., 2010; Upson et al., 2016).

Improved nutrient availability:

- Rating: **Small Impact / Medium Certainty** *
- The addition of farmyard manures in arable and ley fields add nutrients that can replace some artificial fertiliser (predominantly produced using non-renewable resources) applications.

Increased biodiversity:

- Rating: **Small Impact / Medium Certainty** *

- Introduction of leys into arable rotations allows for the development of a denser plant root system that encourages increases in microbial biomass and earthworm and mesofaunal activity, which in turn enable soil aggregate stability (Martin et al., 2020). Reintroduction of livestock into arable systems is often promoted for regenerative agriculture systems; however, there has been little attention to the potential biodiversity benefit of livestock within previously arable systems.

Reduction in weeds and pests:

- Rating: **Medium Impact / High Certainty** **

- Temporary grass leys and integration of livestock into arable rotations can be very important for reducing weeds and pests (Schut et al., 2021), particularly those for which herbicide resistance is increasing such as blackgrass (*Alopecurus myosuroides*).

Commercial yields:

- Rating: **Medium Impact / High Certainty** **

- These approaches offer farmers a new income stream, with research by the Agriculture and Horticulture Development Board (n.d.) showing potential for increased revenue for farmers when integrating beef into arable rotations of up to £250 per hectare, with further opportunities created via articulation with agri-environment schemes.

Risks:

- Integration of livestock may require investment in infrastructure such as fencing, handling areas or upskilling, which could be costly. In addition, as mentioned earlier in this report, an increase in livestock numbers has knock-on effects in terms of emissions and other environmental externalities, as is acknowledged in Table 3.1.

3.6 Reduce synthetic inputs and favour ecological approaches

This regenerative agriculture approach aims to design landscapes and cropping systems that can decrease invertebrate pest, weed and disease pressures. The idea is to optimise on-farm decision-making so that unnecessary chemical interventions are avoided, non-chemical pest control options are the preferred choice, and the efficiency of pesticide treatments, if required, is optimised. However, in practice in arable systems, many efforts in respect of moving towards regenerative agriculture systems still rely heavily on synthetic inputs for weed control, particularly the herbicide glyphosate. Nevertheless, there are potential benefits in this area that could be further enhanced with greater research, experimentation and collaboration.

In livestock-oriented pastoral systems, uses of pesticides and fertilisers are most significant in intensively managed grassland, particularly dairy systems. Their use is intrinsically linked to the species sown (primarily ryegrass) and to the breeds and types of livestock which utilise them, with herbicides primarily used to kill off broadleaved weeds. Ryegrass and dairy animals have been bred to be more productive within high nutrient systems, outcompeting other species and breeds. Regenerative agriculture practices in grassland promote reductions in inputs because these help to maintain diversity in swards as well as reducing costs, tractor usage and negative impacts of inputs within and beyond the farm. Positive impacts on animal health and on livestock food production have been found for pasture-based beef and sheep systems and for dairy systems (Davis et al., 2022; Stypinski, 2011). However, the drive for 'more' product, rather than for high-quality product, remains dominant. Adoption of regenerative agriculture practices in dairy is currently small scale, and involves a shift in system emphasis, including changing grassland composition and changing animal breeds. A reduced volume of production may be offset by reduced costs and higher prices for quality products.

There are also emerging opportunities in this space. These include the utilisation of arbuscular mycorrhizal fungi that form symbiotic relationships with the roots of many crop species. However, plant response to arbuscular mycorrhizal fungi is variable and is affected by abiotic and biotic factors (Yang et al., 2015). Such inconsistent results may also be a consequence of the type of management interventions explored, context-specific responses of arbuscular mycorrhizal fungi (Pulleman et al., 2022) and poor quality of inoculants (Salomon et al., 2022). Biostimulants are biological or biologically derived fertiliser additives and similar products that are used in crop production to supplement and enhance existing agricultural practices and crop inputs, or to improve nutrient use efficiency. To date, further research on the use of biostimulants in the UK is required (Owen et al., 2015).

Increase in soil organic matter:

- Rating: **Medium Impact / Medium Certainty** ✱✱
- Any ecological approaches that fulfil some or all of the principles of regenerative agriculture e.g. increase on-farm diversity, have the potential to increase soil organic matter as described in previous sections.

Improved nutrient availability:

- Rating: **Negative** —
- Inorganic fertilisers can be replaced with organic materials with high nutrient content (e.g. slurry, composted material, digestate from anaerobic digestion). Slurry represents a potential co-benefit of livestock integration, and offers potential for the slow release of nitrogen to soils, reducing nitrous oxide emissions and nitrate leaching, with additional soil health benefits associated with increasing soil carbon stocks. However, there are recognised caveats associated with the replacement of mineral fertilisers. The use of alternative fertilisers can result in reduced yields, at least in the early years of transition (Hinson et al., 2022). In addition, replacing mineral fertilisers with organic fertilisers may lead to pollutant swapping associated with unintended excess nutrient application (e.g. phosphorus); transportation of bulky organic materials, resulting in increased greenhouse gas emissions; impacts on local air quality from in-field volatilisation (e.g. ammonia); and potential for contaminants associated with the organic materials that impact soil health (e.g. antibiotics, antibiotic resistance genes, microplastics).

Increased biodiversity:

- Rating: **Medium Impact / Medium Certainty** ✱✱
- A review of evidence found that IPM was widely seen to improve biodiversity (Adamson et al., 2020).

Weed, disease and pest suppression:

- Rating: **Small Impact / Medium Certainty** ✱
- Regenerative agriculture can reduce on-farm costs related to pesticide use. Chemical usage on arable crops in the UK is dominated by fungicide applications (48%), followed by herbicides (around 34%) and growth regulators (14%) (Wildlife Trust, 2021). Among these, it has been argued that herbicides would be the most difficult to reduce without compromising agricultural yield quantity and quality (Lechenet et al., 2017; Triantafyllidis et al., 2023), as the weed burden in regenerative agriculture systems is particularly high, with heavy reliance on

glyphosate to terminate cover crops and weeds. However, for some crops, such as winter cereals, a reduction of herbicides (by 25–30% on average) had no effect on either production or profitability (Catarino et al., 2019). Pest and disease suppression can be enhanced further through the adoption of IPM approaches, which aim to manage the impact of pests, pathogens and weeds while achieving environmental and economic sustainability (Hillocks, 2012; Barzman et al., 2015). IPM combines available methods (tools) for monitoring, predicting risk and controlling pest, pathogen and weed populations into programmes (toolboxes) where the tools operate synergistically to reduce environmental impact and economic risk. However, some minimal use of pesticides is considered viable within IPM approaches, provided that no alternative intervention is available and successful. The reality is that synthetic inputs for the purposes of weed suppression will remain necessary for agricultural continuity in the UK. However, aspects of both regenerative agriculture and IPM offer hopeful trajectories for reduction in their uses in years to come.

Risks:

- Efforts to replace or reduce synthetic inputs may present new problems, such as the introduction of pollutants like microplastics through the application of alternative fertilisers generated from domestic feedstocks. Increased carbon emissions associated with the transport of alternative fertilisers from source to farm also need to be taken into account when considering options. Furthermore, as discussed above, the systemic agronomic changes associated with transitioning arable farms towards regenerative agriculture methods may result in an increased use of herbicides, due to increased weed burden stemming from a move away from tillage.

So far, this chapter has looked to map the evidence for regenerative agriculture principles against the objectives already established in this report. It has shown that assessing the extent of benefits producing desired outcomes is complicated by the reality of delivering principles in practice in different agricultural contexts. Evaluating and assessing this progress requires indicators, particularly when benchmarking for future reference or when connecting the delivery of ecosystem services to the provision of public money or private finance. As such, it is to the question of indicators that this chapter now turns.

3.7 Indicators for regenerative agriculture

It is critically important to measure the environmental impacts, beneficial or otherwise, of regenerative agriculture for a variety of stakeholder needs, including the design and assessment of agri-environment schemes (Natural England, 2019); analysis of the impact of supply chain practices (Sustainable Soils Alliance, 2021); and consumer awareness and support of regenerative agriculture (Newton et al., 2020).

Assessing the impact of regenerative agriculture is context dependent and will operate at different spatial scales (field, farm, landscape) and temporal scales (time of year, number of assessments throughout the year, length of evaluation).

Spatial scales	Temporal scales
Field	Time of year
Farm	Number of assessments
Landscape	Length of evaluation

Thus, the indicators used to measure impact may need to differ depending on farm, soil and practice type, as well as farm history and baseline (the starting point of regenerative agriculture practice or monitoring). Furthermore, the utility of any indicator is arguably determined by the availability of robust baseline data that act as a comparator to determine the trajectory of change.

Indicators that are used to measure the impact of agricultural practices on environmental quality can be broadly defined as 'practice-based' or 'outcome-based'. This section of the report introduces these concepts and highlights their strengths, weaknesses and complexities. This serves to connect the above discussion of benefits with consideration of how to assess progress associated with adopting regenerative agriculture principles. It does not represent an exhaustive account of these two approaches, however, but serves to introduce a key debate regarding future agricultural change.

> **Practice-based indicators** are those that refer to a list of management practices or actions for which evidence exists that they deliver the desired outcomes in certain contexts.
>
> **Outcome-based indicators** refer to an environmental impact which is measured directly.
>
> For example, the use of grazing livestock would be a practice-based indicator, where the management action of using animals to graze livestock is understood to improve soil organic matter. An outcome-based indicator here would be a direct measure of the soil organic matter through a soil test.

There are two closely related and important differences to acknowledge when considering the use of practice- or outcome-based indicators. The first of these relates to **monitoring**: for a practice-based indicator, comprehensive records may need to be kept to ensure that the approved or recommended actions are being followed correctly. By contrast, for an outcome-based indicator, the result itself is the only necessary evidence; the methods that a farmer has used to achieve the outcome is not considered. The second important difference therefore relates to **management**: for a practice-based indicator, it is vital that prescribed actions are followed clearly to ensure consistency and accuracy in indicator measurements. By contrast, for an outcome-based scheme, the management choices of the farmer are not relevant to the indicator; only the assessment result is important to record.

When environmental measures are operationalised to incentivise farmers to enhance the environmental quality of their land, such as through an agri-environment scheme, it is vital that the appropriate indicators are used to create mechanisms which simultaneously provide meaningful improvements to the environment and value for money, while encouraging uptake among land managers.

In some cases, practice-based indicators are preferable, particularly where the desired environmental benefit may be difficult to achieve or measure, there is no standard starting point from which to measure change, or where there is a single approved approach for achieving the desired goal. In these instances, a set of prescribed actions may enable farmers to feel more confident that they will complete the requirements and deliver the desired environmental impact. An additional advantage of practice-based indicators is that they do not entail a risk for farmers, who will receive the payment if they adopt the required practices. On the other hand, outcomes may depend on factors outside the farmers' control, for example weather conditions.

Where the success of an environmental goal varies considerably based on context, and there are a variety of management practices which may reasonably be used to achieve this goal, an outcome-based indicator will enhance the flexibility and agency for practitioners, who decide how to achieve the desired outcome based on their experience, the characteristics of their farm and the local context. This may encourage empowerment and creativity of practitioners to innovate to find new solutions and potential cost-efficiencies to achieve the desired outcome, based on the characteristics of the farm system.

There is no consensus yet regarding which outcomes should be measured for regenerative agriculture and which techniques should be used to measure the outcome(s); nor is there consensus on spatial and temporal scales and the frequency of measurement(s). These are likely to remain an important focus of future research as experts attempt to baseline existing environmental quality and utilise a variety of approaches to measurement according to different farm types, budgets and governance structures.

When measuring outcomes is too expensive or methodologically challenging, proxy indicators can be used that are considered to be correlated to the desired outcome. For example, where environmental targets such as bird species may be outside the control of the farmer or landowner, the more definitive, measurable indicator is based on habitat quality rather than species count. Such proxy indicators have been trialled in the UK (in Wensleydale, North Yorkshire), where farmers used a results-based scheme to deliver upland habitats for breeding waders.

Another challenge with outcome-based indicators is that there is no consensus on the values to be achieved in different systems. As such, a farmer who has been regenerating land for many years with high baseline measurements may be penalised for not measuring large changes in future years. Conversely, a farmer with a lesser record of agri-environmental action may see more opportunities for financial reward. Similarly, soil and climate can have large impacts on the success of regeneration, and therefore any outcomes need to consider the starting point and inherent characteristics of the system.

Direct outcome-based indicators have also been effective and popular among practitioners in some recent UK pilots. Direct outcome-based measures were used in a Natural England pilot on arable plots for winter bird food and pollen and nectar mixes, where a tiered assessment system evaluated plots and paid farmers based on the number of desirable species present (Natural England, 2019). This direct 'outcome as evidence' approach is also simpler to manage for practitioners, as providing specific evidence of practices is more complex and often relies on intensive records which do not necessarily align with the more holistic management principles of regenerative agriculture.

Box 3.2: Hybrid approaches in agri-environment schemes: Balancing actions and outcomes

Hybrid approaches blend both result-based (or 'outcome-based') and practice-based payments for farmers rather than taking one approach over the other.

Recommendations for hybrid approaches

1. **Initial funding and ongoing incentives:** Provide upfront payments for adopting new practices, followed by performance-based bonuses for achieving specific environmental outcomes. This encourages initial uptake and continuous improvement.

2. **Tailored to context:** Design schemes that are adaptable to local contexts, allowing farmers to select actions that align with their unique conditions while being rewarded for achieving broader environmental goals.

3. **Monitoring and measurement tools:** Invest in developing and disseminating tools for accurate monitoring and measurement. This supports both farmers and policy makers in assessing the effectiveness of implemented practices.

4. **Stakeholder engagement:** Ensure ongoing dialogue with farmers, ecologists and other stakeholders to refine and improve schemes. This co-design process enhances the relevance and acceptance of policies.

Importance of hybrid approaches

- Flexibility for farmers: Hybrid models offer flexibility, allowing farmers to choose actions that suit their specific context while being incentivised for achieving desired outcomes. This flexibility respects farmers' knowledge of their own land and operational constraints, leading to higher engagement and compliance.
- Immediate and long-term benefits: By combining payments for actions with rewards for observed results, hybrid approaches ensure immediate actions are taken towards regenerative practices, while also encouraging ongoing improvements and long-term sustainability. This dual focus helps in building a robust and resilient agricultural system.
- Risk mitigation: Hybrid schemes mitigate risks associated with purely result-based models, where external factors (such as weather) might affect outcomes. Action-based payments ensure that farmers are supported regardless of these uncontrollable variables, while result-based incentives promote continual improvement.
- Encouraging innovation: Such approaches promote innovation by providing initial funding for new practices and technologies. Farmers can experiment with regenerative methods without the fear of immediate financial loss, fostering a culture of continuous learning and adaptation.
- Building capacity: Hybrid approaches help build the capacity of farmers to monitor and measure the impacts of their practices. This not only improves farm management but also contributes to a more comprehensive understanding of the effectiveness of regenerative practices on a larger scale.

Barriers to adoption

- Lack of consensus: it remains unclear which combination of practice and outcome-based indicators should be adopted.

As we continue to see a rise in the uptake of regenerative approaches across a variety of farming systems, a combination of practice- and outcome-based indicators is likely to be the most effective means through which we can measure the impact of regenerative agriculture. A key goal of utilising these indicators in the short term will be to achieve a greater understanding of regenerative agriculture benefits among practitioners and to develop more comprehensive baseline data. An increased understanding could lead to more targeted approaches and potentially improved outcomes in the longer term. Integrating practice- and outcome-based indicators will involve allowing for flexible approaches that have sufficient capacity for adaptation to local geological, climatic, social and economic contexts.

References

Abdalla, M. et al. (2019). A critical review of the impacts of cover crops on nitrogen leaching, net greenhouse gas balance and crop productivity. *Global Change Biology*, 25: 2530–2543.

Adamson, H. et al. (2020). *Review of evidence on integrated pest management*. Defra.

Agriculture and Horticulture Development Board. (n.d.). *An introduction to cover crops*. https://ahdb.org.uk/cover-crops

Al-Kaisi, M. M. and Lal, R. (2020). Aligning science and policy of regenerative agriculture. *Soil Science Society of America Journal*, 84: 1808–1820. https://doi.org/10.1002/saj2.20162

Alkemade, R. et al. (2013). Assessing the impacts of livestock production on biodiversity in rangeland ecosystems. *Proceedings of the National Academy of Sciences*, 110: 20900-20905.

Ball, B. C. et al. (2005). The role of crop rotations in determining soil structure and crop growth conditions. *Canadian Journal of Soil Science*, 85: 557–577.

Barzman, M. et al. (2015). Eight principles of integrated pest management. *Agronomy for Sustainable Development*, 35: 1199–1215.

Beillouin, D. et al. (2021). Positive but variable effects of crop diversification on biodiversity and ecosystem services. *Global Change Biology*, 27: 4697–4710. https://doi.org/10.1111/gcb.15747

Berdeni, D. et al. (2021). Soil quality regeneration by grass-clover leys in arable rotations compared to permanent grassland: Effects on wheat yield and resilience to drought and flooding, *Soil and Tillage Research*, 212: 105037. https://doi.org/10.1016/j.still.2021.105037

Brennan, R. J. B. et al. (2020). Biofumigation: An alternative strategy for the control of plant parasitic nematodes. *Journal of Integrative Agriculture*, 19: 1680-1690. https://doi.org/10.1016/S2095-3119(19)62817-0

Brooker, R. et al. (2024). Crop mixtures: Yield responses to climate and management and impacts on seed and soil chemical composition in a Scottish-based study. *Plant and Soil*. https://doi.org/10.1007/s11104-024-06987-y

Brooker, R. et al. (2015). Improving intercropping: A synthesis of research in agronomy, plant physiology and ecology. *New Phytologist*, 206: 107–117.

Brown, J. et al. (2021). Variable impacts of reduced and zero tillage on soil carbon storage across 4–10 years of UK field experiments. *Journal of Soils and Sediments*, 21: 890–904.

Button, E. S. et al. (2022). Deep-C storage: Biological, chemical and physical strategies to enhance carbon stocks in agricultural subsoils. *Soil Biology and Biochemistry*, 170: 108697.

Cai, A. et al. (2022). Declines in soil carbon storage under no tillage can be alleviated in the long run. *Geoderma*, 425: 116028.

Cai, A. et al. (2023). Reply to Simpson et al. Short-term no tillage reduces soil carbon stocks but longer duration can alleviate the initial decline. *Geoderma*, 430: 116308.

Cardinael, R. et al. (2017). Increased soil organic carbon stocks under agroforestry: A survey of six different sites in France. *Agriculture, Ecosystems & Environment*, 236: 243–255.

Catarino, R. et al. (2019). Experimental and empirical evidence shows that reducing weed control in winter cereal fields is a viable strategy for farmers. *Scientific Reports*, 9: 9004. https://doi.org/10.1038/s41598-019-45315-8

Chen, H. et al. (2020). Global meta-analyses show that conservation tillage practices promote soil fungal and bacterial biomass. *Agriculture, Ecosystems & Environment*, 293: 106841.

Cooper, R. J. et al. (2020). Conservation tillage and soil health: Lessons from a 5-year UK farm trial (2013–2018). *Soil and Tillage Research*, 202: 104648.

Cusser, S. et al. (2020). Long-term research avoids spurious and misleading trends in sustainability attributes of no-till. *Global Change Biology*, 26: 3715–3725.

Davis, H. et al. (2022). Nutritional benefits from fatty acids in organic and grass-fed beef. *Foods*, 11: 646. DOI: 10.3390/foods11050646

de Graaff, M.-A. et al. (2019). Chapter One –- Effects of agricultural intensification on soil biodiversity and implications for ecosystem functioning: A meta-analysis. Advances in Agronomy, 155: 1–44.

de Vries, F. et al. (2012). Land use alters the resistance and resilience of soil food webs to drought. *Nature Climate Change*, 2: 276–280.

Defra. (2024). *Agricultural Evidence Pack*.

Feeney, C. J. et al. (2023). Development of soil health benchmarks for managed and semi-natural landscapes. *Science of The Total Environment*, 886: 163973.

Filazzola, A. et al. (2020). The effects of livestock grazing on biodiversity are multi-trophic: A meta-analysis. *Ecology Letters*, 23: 1298–1309.

Frøslev, T. G. et al. (2022). The biodiversity effect of reduced tillage on soil microbiota. *Ambio*, 51: 1022–1033.

Gaba, S. et al. (2016). Herbicides do not ensure for higher wheat yield, but eliminate rare plant species. *Scientific Reports*, 6: 30112.

Giles, M. E. et al. (2023). Grass variety selection of microbial community composition is associated with differences in soil CO2 emissions. *Applied Soil Ecology*, 190: 104968.

Griffiths, B. S. et al. (2012). Bioindication potential of using molecular characterisation of the nematode community: Response to soil tillage. *European Journal of Soil Biology*, 49: 92–97.

Griffiths, M. et al. (2022). Optimization of root traits to provide enhanced ecosystem services in agricultural systems: A focus on cover crops. *Plant, Cell & Environment*, 45: 751–770.

Gross, A. and Glaser, B. (2021). Meta-analysis on how manure application changes soil organic carbon storage. *Scientific Reports*, 11: 5516.

Haddaway, N. R. et al. (2017). How does tillage intensity affect soil organic carbon? A systematic review. *Environmental Evidence*, 6: 1–48.

Hallett, P. et al. (2016). *Effect of soil structure and field drainage on water quality and flood risk*. CREW. Aberdeen, Scotland, UK.

Hao, X. et al. (2023). Are there universal soil responses to cover cropping? A systematic review. *Science of The Total Environment*, 861: 160600.

Hawes, C. et al. (2018). Plant responses to an integrated cropping system designed to maintain yield whilst enhancing soil properties and biodiversity. *Agronomy*, 8: 229. https://doi.org/10.3390/agronomy8100229

Hillocks, R. J. (2012). Farming with fewer pesticides: EU pesticide review and resulting challenges for UK agriculture. *Crop Protection*, 31: 85–93.

Hinson, P. O. et al. (2022). Organic transition in dual-purpose wheat systems: Agronomic performance and soil nitrogen dynamics. *Agronomy Journal*, 114: 2484–2500.

Huss et al. (2022). Benefits and risks of intercropping for crop resilience and pest management. *Journal of Economic Entomology*, 115: 1350–1362.

Jian, J. et al. (2020). A meta-analysis of global cropland soil carbon changes due to cover cropping. *Soil Biology and Biochemistry*, 143: 107735. https://doi.org/10.1016/j.soilbio.2020.107735

Jordon, M. W. et al. (2022). Can regenerative agriculture increase national soil carbon stocks? Simulated country-scale adoption of reduced tillage, cover cropping, and ley-arable integration using RothC. *Science of The Total Environment*, 825: 153955.

Kim, N. et al. (2020). Do cover crops benefit soil microbiome? A meta-analysis of current research. *Soil Biology and Biochemistry*, 142: 107701. https://doi.org/10.1016/j.soilbio.2019.107701

King, A. E. and Blesh, J. (2018). Crop rotations for increased soil carbon: Perenniality as a guiding principle. *Ecological Applications*, 28: 249–261.

Kirkegaard, J. A. and Matthiessen, J. N. (2004). Developing and refining the biofumigation concept. *Agroindustria*, 3: 233–239.

Kladivko, E. J. (2001). Tillage systems and soil ecology. *Soil and Tillage Research*, 61: 61–76.

Laganière, J. et al. (2010). Carbon accumulation in agricultural soils after afforestation: A meta-analysis. *Global Change Biology*, 16: 439–453.

Lechenet, M. et al. (2017). Reducing pesticide use while preserving crop productivity and profitability on arable farms. *Nature Plants*, 3: 1–6.

Levin, B. (2022). Regenerative agriculture as biodiversity islands. In Biodiversity islands: Strategies for conservation in human-dominated environments, ed. Montagnini, F. *Topics in Biodiversity and Conservation*, 20. https://doi.org/10.1007/978-3-030-92234-4_3

Lüscher, A. et al. (2022). Using plant diversity to reduce vulnerability and increase drought resilience of permanent and sown productive grasslands. *Grass and Forage Science*, 77: 235–246.

Lv, L. et al. (2023). Impact of conservation tillage on the distribution of soil nutrients with depth. *Soil and Tillage Research*, 225: 105527.

Marrs, R. H. et al. (2018). Effects of removing sheep grazing on soil chemistry, plant nutrition and forage digestibility: Lessons for rewilding the British uplands. *Annals of Applied Biology*, 173: 294–301.

Martin, G. et al. (2020). Role of ley pastures in tomorrow's cropping systems. A review. *Agronomy for Sustainable Development*, 40: 17.

McGovern, S. et al. (2011). Identifying drivers of species compositional change in a semi-natural upland grassland over a 40-year period. *Journal of Vegetation Science*, 22: 346–356.

Montgomery, D. R. et al. (2022). Soil health and nutrient density: Preliminary comparison of regenerative and conventional farming. *PeerJ*, 10: e12848. https://do,.org/10.7717/peerj.12848

Morugán-Coronado, A. et al. (2022). The impact of crop diversification, tillage and fertilization type on soil total microbial, fungal and bacterial abundance: A worldwide meta-analysis of agricultural sites. *Agriculture, Ecosystems & Environment*, 329: 107867.

Natural England. (2019). *Pilot results-based payment approaches for agri-environment schemes in arable and upland grassland systems in England (JP0031)*. https://publications.naturalengland.org.uk/publication/6331879051755520

Newton, P. et al. (2020). What is regenerative agriculture? A review of scholar and practitioner definitions based on processes and outcomes. *Frontiers in Sustainable Food Systems*, 4: 577723.

Norton, L. et al. (2022). Can pasture-fed livestock farming practices improve the ecological condition of grassland in Great Britain? *Ecological Solutions and Evidence*, 3: e12191. https://doi.org/10.1002/2688-8319.12191

O'Donoghue, T., Minasny, B. and McBratney, A. (2022). Regenerative agriculture and its potential to improve farmscape function. *Sustainability*, 14: 5815.

Osipitan, O. A. et al. (2019). Impact of cover crop management on level of weed suppression: A meta-analysis. *Crop Science*, 59: 833–842. https://doi.org/10.2135/cropsci2018.09.0589

Owen, D. et al. (2015). Use of commercial bio-inoculants to increase agricultural production through improved phosphorus acquisition. *Applied Soil Ecology*, 86: 41–54.

Pardon, P. et al. (2020). Juglans regia (walnut) in temperate arable agroforestry systems: Effects on soil characteristics, arthropod diversity and crop yield. *Renewable Agriculture and Food Systems*, 35: 533–549.

Peixoto, D. S. et al. (2020). Occasional tillage in no-tillage systems: A global meta-analysis. *Science of The Total Environment*, 745: 140887.

Perks, M. et al. (2018). *Agroforestry in Scotland – Potential benefits in a changing climate*. ClimateXChange.

Pulleman, M. M. et al. (2022). Soil biodiversity and nature-mimicry in agriculture; the power of metaphor? *Outlook on Agriculture*, 51: 75–90. https://doi.org/10.1177/00307270221080180

Pywell, R. F. et al. (2015). Wildlife-friendly farming increases crop yield: Evidence for ecological intensification. *Proceedings of the Royal Society B: Biological Sciences*, 282: 1740.

Rubio, V. et al. (2021). Quantifying soil organic carbon's critical role in cereal productivity losses under annualized crop rotations. *Agriculture, Ecosystems & Environment*, 321: 107607.

Salomon, M. J. et al. (2022). Global evaluation of commercial arbuscular mycorrhizal inoculants under greenhouse and field conditions. *Applied Soil Ecology*, 169: 104225. https://doi.org/10.1016/j.apsoil.2021.104225

Saunders, M. et al. (2016). *Can silvo-pastoral agroforestry systems contribute to Scotland's emission reduction targets*. ClimateXChange. https://www.climatexchange.org.uk/wp-content/uploads/2023/09/cxc-woodlands_agroforestry_policy_brief.pdf

Schipanski, M. et al. (2014). A framework for evaluating ecosystem services provided by cover crops in agroecosystems. *Agricultural Systems*, 125: 12–22.

Schreefel, L. et al. (2022). How to make regenerative practices work on the farm: A modelling framework. *Agricultural Systems*, 198: 103371. https://doi.org/10.1016/j.agsy.2022.103371

Schulte, L. A. et al. (2022). Meeting global challenges with regenerative agriculture producing food and energy. *Nature Sustainability*, 5: 384–388.

Schut, A. G. T. et al. (2021). Reintegration of crop-livestock systems in Europe: An overview. *Frontiers of Agricultural Science and Engineering*, 8: 111–129.

Scottish Government. (n.d.). *Use of cover crops: Practical guide*. https://www.fas.scot/downloads/practical-guide-use-of-cover-crops/#:~:text=All%20cover%20crops%20help%20to,of%20microbes%20in%20the%20soil.

SEAMS. (2023). SEAMS – Sustainability in education and agriculture using mixtures. https://www.hutton.ac.uk/sites/default/files/files/SEAMS%20final%20report_final%20version.pdf

Seaton, F. M. et al. (2022). Pasture age impacts soil fungal composition while bacteria respond to soil chemistry. *Agriculture, Ecosystems & Environment*, 330: 107900. DOI: 10.1016/j.agee.2022.107900

Sekaran, U. et al. (2021). Role of integrated crop-livestock systems in improving agriculture production and addressing food security—A review. *Journal of Agriculture and Food Research*, 5: 100190.

Simpson, Z. P. et al. (2023). No-tillage does not on average reduce soil carbon storage compared to conventional tillage. Comment on Cai et al. Declines in soil carbon storage under no tillage can be alleviated in the long run. Geoderma, 430: 116307

Staton, T. et al. (2019). Evaluating the effects of integrating trees into temperate arable systems on pest control and pollination. *Agricultural Systems*, 176: 102676.

Storr, T. et al. (2019). A UK survey of the use and management of cover crops. *Annals of Applied Biology*, 174: 179–189. https://doi.org/10.1111/aab.12488

Stypinski, P. (2011). *The effect of grassland-based forages on milk quality and quantity*. Agronomy Research, 9: 479-488

Sustainable Soils Alliance (2021). *Soil in the UK supply chain*. Bristol, UK: 1–21.

Tamburini et al. (2020). Agricultural diversification promotes multiple ecosystem services without compromising yield. *Science Advances*, 6: eaba1715.

Torralba, M. et al. (2016). Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. *Agriculture, Ecosystems & Environment*, 230: 150–161.

Triantafyllidis, V. et al. (2023). Herbicide use in the era of farm to fork: Strengths, weaknesses, and future implications. *Water, Air, & Soil Pollution*, 234: 94.

Upson, M. A. et al. (2016). Soil carbon changes after establishing woodland and agroforestry trees in a grazed pasture. *Geoderma*, 283: 10–20.

Waisen, P. et al. (2020). Effects of biofumigant crop termination methods on suppression of plant-parasitic nematodes. *Applied Soil Ecology*, 154: 103595. https://doi.org/10.1016/j.apsoil.2020.103595

Weih, M. et al. (2022). Intercropping systems for sustainable agriculture. *Agriculture*, 12: 291.

Wildlife Trust. (2021). *Sustainable use of pesticides: Draft national action plan. The Wildlife Trusts' Preliminary Analysis*. https://www.wildlifetrusts.org/sites/default/files/2021-02.21JAN_NAP_PRELIM_FINAL.pdf

Wilkes, T. I. et al. (2021). Zero tillage systems conserve arbuscular mycorrhizal fungi, enhancing soil glomalin and water stable aggregates with implications for soil stability. *Soil Systems*, 5: 4.

Wiltshire, S. and Beckage, B. (2023). Integrating climate change into projections of soil carbon sequestration from regenerative agriculture. *PLOS Climate*, 2: e0000130. https://doi.org/10.1371/journal.pclm.0000130

Yang, H. et al. (2015). Effects of arbuscular mycorrhizal fungi on plant growth depend on root system: A meta-analysis. *Plant and Soil*, 389: 361–374.

Zani, C. F. et al. (2022). Effects of integrating grass-clover leys with livestock into arable crop rotations on soil carbon stocks and particulate and mineral-associated soil organic matter fractions in conventional and organic systems. *Soil Use and Management*, 38: 448–465.

Zanon, T. et al. (2022). Diverse feed, diverse benefits – the multiple roles of feed diversity at pasture on ruminant livestock production. *A review. Journal of Veterinary Science and Animal Husbandry*, 10: 101.

Chapter 4: Potential long-term consequences and trade-offs of regenerative agriculture

Authors: *Nicola Randall, Alfy Gathorne-Hardy, Cathy Hawes, Sacha Mooney, Fabrizia Ratto, Sally Westaway*

Summary

As Chapter 3 demonstrates, regenerative agriculture practices are likely to improve soil structure, fertility and biodiversity. However, these benefits will vary over time and are context dependent, while trade-offs are also likely. While trade-offs between biodiversity and yield can be challenging, there are some indications that initial yield reductions in transitioning to regenerative agriculture may reduce or even reverse over the longer term through enhanced ecosystem services as the system stabilises. However, the evidence for this is variable, and realising these potential benefits takes time. A greater understanding of these impacts requires long-term experiments.

During the transition phase (medium term), which spans three to six years, positive benefits appear to become more detectable. However, there is a need for careful management to prevent issues like competitive weeds and pests. Despite increased risks during this phase, some research indicates that integrated management can maintain yields comparable to those of conventional systems. In the long term, the enhancement of biodiversity and ecosystem services through regenerative practices may lead to maintained yields with less reliance on external inputs, and improved soil health. Livestock integration, when managed carefully, can also support biodiversity by mimicking natural grazing patterns, but attention to the use of veterinary medicines is necessary.

Concerns about land area requirements and potential conflicts with biodiversity and environmental targets highlight the need for careful land management. Despite the potential benefits of regenerative agriculture, there may be consequences for food security and prices, but their direct link to socio-economic factors requires further evidence. Studies suggest mixed outcomes, with translation of ecosystem improvements directly into socio-economic benefits largely dependent on the wider system context. Economic benefits may include decreased labour and energy requirements alongside potential yield increases. However, broader socio-economic impacts are complex and under-researched, with potential shifts in the diversity and availability of farmed products impacting both local and global food chains. Regenerative agriculture in the UK may have global implications through indirect land use change (ILUC), and this is another area that requires further research.

4.1 Introduction

The five overarching principles of regenerative agriculture outlined in Chapter 2 may be summarised as improving soil quality and health for better productivity with fewer synthetic inputs, and increased diversity for resilient ecosystem functioning (Giller et al., 2021). Within these broad areas, regenerative management will aim to enhance soil physical properties, including soil structure and biological function (e.g. by direct drilling of arable crops to reduce soil disturbance from cultivation, incorporating livestock and increasing soil organic matter inputs); minimise reliance on agrochemical use (e.g. through use of integrated pest management strategies and legume, companion and cover cropping); and enhance biodiversity for ecosystem services (e.g. through diversified field margins, in-field weed management and habitat creation). The impact of regenerative agriculture approaches on productivity and on environmental factors varies according to the specific management practice (or combination of practices) applied and the timescale over which the system is assessed. There may also be broader implications and trade-offs, for example on the wider food chain. This chapter investigates some of the synergies and trade-offs that may occur over time when implementing regenerative agriculture principles together. It attempts to consider these trade-offs over the short, medium and long term, as well as considering some more systemic ramifications of a transition towards regenerative agriculture across the UK.

4.2 Potential impacts on productivity and other ecosystem services

A key concern for farmers considering moving towards more regenerative agricultural systems is the potential impact on farm productivity (often in the form of a reduction in crop yields). In approaching the question of food production ecologically via the paradigm of regenerative agriculture, this report has tried to recognise the centrality of this concern. Managing production systems for enhanced biodiversity and reduced environmental impact is often seen as conflicting with a primary goal of farming – to maximise food production. Evidence for these trade-offs is often limited and mixed, and may change depending on timescale and context. For example, the establishment of agroforestry systems can play a role in helping farmers adapt and become more resilient in the face of climate change through impacts such as microclimatic modifications, increased system diversity, provision of shade for livestock, and a reduction in the risks from flooding and wildfires (Cole et al., 2020; Jose, 2009; Torralba et al., 2016; Tsonkova et al., 2012; Atkin-Willoughby et al., 2022; Pritchard et al., 2021). However, some of these studies indicate that competitive interactions between trees and crops for resources can also result in overall yield reductions, especially at the interface between the trees and the crops. Other studies indicate that agroforestry can increase overall yields in arable systems (e.g. by up to 40% relative to monoculture arable and woodland systems (Graves et al., 2007)). However, yields vary widely depending on species, site and growth conditions, and overall yields (tree plus crop) ranged from 2% lower to 140% higher in the agroforestry system when compared with the trees and crops grown in monocultures.

Many apparent trade-offs in regenerative agriculture practices are predominantly based on short-term (typically two- to three-year) studies of low input organic systems, with yield penalties compared with those of intensive farming practices. However, the yield penalties from organic systems may differ from those of non-organic, integrated systems, and the length of time it takes for soil to reach equilibrium following transition to a new system may not always be accounted for in these studies.

Some evidence appears to show that regenerative agricultural practices may result in short-term yield loss due to initial disruption in the first few years following changes in management of functional processes and the balance between different functional types of organisms in the farming system. These disturbance impacts on yield and yield stability during the first few years following implementation of a new management system are, however, highly variable depending on environmental conditions and farming system (Achankeng and Cornelis, 2023; Palomo-Campesino et al., 2018; Röös et al., 2018).

For longer-term impacts, the research evidence is mixed and limited, but early findings appear to show that the drop in yield initially for some regenerative agriculture practices (e.g. reducing tillage) can be followed by a gradual improvement as populations and processes stabilise. These trends are illustrated in Table 4.1.

For example, in contrast with organic arable cropping systems, where yield impacts can persist according to the system and management (Röös et al., 2018), some regenerative practices appear to re-stabilise to a state where yields can be maintained with fewer inputs, probably due to better internal regulation of the production system. Examples of specific practices where this improvement to yields over time has been illustrated include cover cropping, reduced tillage and organic amendments (see Table 4.1 for further examples and associated references). More long-term data on indicators of whole-system function are needed to quantify these trends over time.

Depending on the management changes implemented, yield impacts may be influenced by increased nutrient turnover by soil invertebrate and microbial activity, detoxification of agrochemicals by the soil microbiome, better rooting in soil with a more diverse pore structure, stable natural enemy populations for the control of crop pests, and pollinator diversity for improved quality of insect-pollinated crops (Hawes et al., 2021).

Other biodiversity benefits may not have direct long-term yield benefits, but are still desirable as a management goal due to positive impacts on the wider farmland habitat. Soil health may take longer for benefits to outweigh initial costs, but could offer a positive effect on yield. Biodiversity measures tend to result in a more rapid, immediate positive impact on wildlife, but can have a bigger initial trade-off against yield and less of a long-term yield benefit.

Some of the short-, medium- and long-term yield trade-offs are detailed below. A systematic review or meta-analysis comparing specific practices over different timescales would be useful to add to this evidence base.

Table 4.1: Impacts on yield

Management practices	Short-term (1-3 years)	Medium-term (3-6 years)	Long-term (6+ years)
Organic matter (OM) amendments	neutral (improvements slow to develop), or negative where OM boosts soil borne pathogens (see below)	some positive (better soil water and temperature conditions allowing faster early season crop growth)	positive (continued improvement in soil microclimate conditions, linked to biological processes)
Reduced tillage/direct drilling	negative (benefits slow to compensate for negative effects due to poorer establishment, compaction and increased weed competition)	neutral (better rooting as soil structure improves compensates for establishment issues)	positive (better crop performance in extreme weather compared to disturbed/ploughed systems)
Winter cover cropping	positive (immediate effect on retention of nutrients over winter)	positive (continued improvement in nutrient retention/release)	positive (continued improvement in nutrient retention/release)
Management to improve soil microbial biodiversity and function (interventions as above)	negative (soil structure takes time to improve and an initial boost in OM can stimulate populations of soil borne pathogens)	positive (microbial community reasonably quick to stabilise and beneficial organisms provide functional benefits)	positive (continued improvement in soil function as soil foodwebs diversify)
Cover cropping/ continuous cover	positive (immediate impact of cover crops on subsequent crops through release of nutrients retained over winter)	positive (continuous improvement, especially where plant species are selected for allelopathic effects)	positive (maintained benefit over time)
Legumes	positive (immediate effect from BNF allowing maintained yields with less N)	positive (maintained benefit over time)	positive (maintained benefit over time)

Diverse understorey vegetation	neutral (diverse but non-competitive understorey community difficult to achieve and microbial community takes >4 yrs to respond); or negative (if non-crop plant densities are too high and compete with crop)	positive impact via above processes if non-crop plant densities can be managed at ca. 10% with a high proportion of beneficial, dicot species	positive if previous conditions met (potential benefit maintained over time)
Reduce crop protection inputs and non-target effects through threshold monitoring and forecasting	neutral (yield maintained at same levels as conventional ag but with less inputs), but greater potential risk	neutral (yield maintained but with less inputs), greater risk	neutral (yield maintained but with less inputs), greater risk
Improve crop resilience to pests and disease through biofortification	neutral (yield maintained but with less inputs)	neutral (yield maintained but with less inputs)	neutral (yield maintained but with less inputs)
Co-cropping/inter-cropping - diversity for resource use efficiency, over-yielding	potential for positive effect depending on type, location and management (immediate effect within a growing season)	positive (but improved agronomy required to compensate for potential compaction and weed burden)	positive if previous conditions met (benefit maintained)
Diverse understorey vegetation and field margins for ecosystem services (soil processes, natural enemy control of pests, pollination)	neutral for effect on crop via soil organisms (as above) since these take time to respond; some positive effect via natural IPM from mobile organisms (enhanced pollination, pest control), but mixed results for impact on yield	neutral/ small positive (improvements in soil biodiversity and aerial invert populations over time) - beneficial effects on wider system function rather than yield per se	neutral/small positive (benefits maintained provided in-field weeds are managed below competition threshold) - beneficial effects on wider system function rather than yield per se

Colours represent impact over time:
green for positive; amber for neutral; red for negative

4.2.1 Short-term impacts

Short-term impacts of regenerative agricultural practices vary depending on the practice, location, crop type and outcome being investigated. Reduced tillage, a key principle of regenerative agriculture, results in two common concerns that can impact yields: soil compaction and weed burdens. Other concerns include the increased reliance on glyphosate, and the loss of production associated with reduced arable production due to, for example, rotational grazing.

A switch from ploughing to direct drilling can lead to denser, more compact soil (Blanco-Canqui and Lal, 2008; Martinez et al., 2016; Nunes et al., 2019). However, these impacts can be mitigated over time as soil fauna and vegetation reduce compaction and improve soil porosity. A useful review of some of these mechanisms is provided by Cavalaris et al. (2023). Soil organic matter amendments can boost populations of soil micro-organisms, with pathogens responding more rapidly than other functional groups (Brierley et al., 2020).

Weed pressure in reduced or no-tillage systems is often higher than in conventional inversion tillage systems, which can result in increased herbicide applications (Holland, 2004; Van Capelle et al., 2012; Armengot et al., 2015; Reimer et al., 2019), especially during the transition phase.

For example, many no-till farmers rely on glyphosate, a broad-spectrum herbicide, which is subject to regulatory scrutiny across the world. Glyphosate use may have impacts on beneficial invertebrates; for example, Zaller et al. (2021) found decreased earthworm activity associated with glyphosate use when compared with hand weeding.

Weed management, especially of blackgrass, might not be economically viable without glyphosate, which could see no-till farmers returning to conventional tillage and the benefits to soils and the wider environment being lost. However, increasing research over the last decade into reduced tillage on organic farms demonstrates the potential for reduced tillage with minimal yield penalties in systems that do not use glyphosate or comparable herbicides (Krauss et al., 2020; Lehnhoff et al., 2017; Ingraffia et al., 2022), although it is important to note that the baseline yields in these studies are the lower yields of organic systems. Combining different management strategies may mitigate these negative effects; for example, occasional tillage reduces the build-up of weed seeds at the soil surface (Peixoto et al., 2020) and cover cropping over winter minimises weed seed return (Osipitan et al., 2019). Alternative weed management strategies can take longer to stabilise, resulting in an initial surge in seedlings emerging from the buried weed seed bank before cultural weed suppression measures take effect (Bastiaans et al., 2008). However, evidence from organic reduced tillage trials suggests that higher weed populations do not have the expected detrimental impacts on yields (Lehnhoff et al., 2017).

Insect biodiversity may respond rapidly and immediately to the absence of agrochemical inputs, but pest and disease populations may increase more rapidly than the natural enemies needed to control them in the absence of crop protection chemicals (Brzozowski and Mazourek, 2018). These disruptions, and a resulting increase in the cost of interventions to manage them, can result in a drop in financial margins and an apparent trade-off between economics and environmentally sensitive management in the short term (Roberts et al., 2023).

Other management strategies can have short-term positive effects on yield (although it is important to note that yield and profit do not always correlate). Winter cover cropping, for example, reduces losses of soil and nutrients from fields from the first year of implementation and can therefore provide immediate benefit (Wittwer et al., 2017; Kaye and Quemada, 2017), provided that the negative effect of soil cultivation or herbicide use to terminate the crop in the spring can be mitigated or avoided. Integration of long-term fertility-building legume-rich ley and legume intercropping can also have rapid benefits in terms of renewable nutrient inputs to the system through biological nitrogen fixation and a reduction in reliance on mineral fertilisers (Brooker et al., 2015; Iannetta et al., 2016).

Individual best practice options implemented in isolation are rarely sufficient to deliver the multiple benefits needed to meet wider targets for sustainable production (Hawes et al., 2021). Single-issue interventions in isolation are also unrealistic as real-world production operates within the context of the wider agricultural landscape and cropping rotation. The reverse of this can apply too: specific interventions that give negative outcomes, when used together, can deliver positive outcomes (the Parrondo paradox; see Gokhale and Sharma (2023)). A whole-systems approach is therefore needed where single interventions can be seen as building blocks to wider system change, integrated in an iterative way over time to resolve system-wide trade-offs and conflicts (Hawes et al., 2019).

For example, initial negative effects of no-till on yield may be overcome, even in the early stage of conversion, by combining no-till with cover cropping, especially in low weed pressure environments where herbicides are not relied on for cover crop termination (Büchi et al., 2018; Reimer et al., 2019), or where the subsequent crop can be direct drilled into the previous cover crop (Habib et al., 2016). Intercropping cereals with legumes or using undersown clovers also helps to mitigate the negative effect of no-till on weed burden through better weed suppressive effects (Fisk et al., 2001). Organic matter inputs (e.g. green waste compost) can mitigate the compaction effects of no-till by promoting better soil structure, earthworm activity and soil microbial function (Sradnick et al., 2013; Sun et al., 2020), though this effect via improvement in soil properties takes longer to be realised (Coudrain et al., 2016).

Short-term profit reductions due to yield drops are often balanced by lower production costs in low input, reduced tillage systems (Chen et al., 2022), although the extent to which this occurs depends on the specific management strategies employed. Additional requirements for seed (e.g. for cover crops) and bought-in organic matter may counteract this benefit in the early stages before yield improvements are evident (Roberts et al., 2023).

Some practices that directly take land out of production (e.g. flower strips, agroforestry) result in immediate reduced agricultural output. However, some of these could generate longer-term advantages – for example, introducing agroforestry to livestock systems will reduce the grazing area but may also provide shelter for livestock, better grass growth, and more liveweight gain. Additionally, yield reductions may be compensated for by output from the tree component: farm forestry and agroforestry systems can offer some farmers increased economic stability, mitigating some of the risks associated with climate variability and fluctuating market prices (e.g. of fruit, nuts, timber and fuel) (Schoeneberger et al., 2012; Smith et al., 2019).

4.2.2 Medium-term impacts during transition

Given that most studies comparing low input and regenerative systems with intensive production are short term, results can be biased towards the initial (often negative) impacts of the new cropping system or management approach on yields during the early stages of conversion. In the medium term (e.g. between three and six years from conversion), more positive benefits are detectable, but the key goal here is careful management to prevent the build-up of competitive weeds, pests and disease during the transition towards a more stable, self-regulating system. During this phase, positive benefits will still be gained from cover cropping and legume inclusion, but the negative effects of changes to soil management and biodiversity will reduce as soil structure improves and populations of antagonists and beneficial organisms start to regulate the abundance of pest and pathogen species. So, although there is still increased risk in terms of yield stability, integrated management of weeds, pests and disease to threshold levels can maintain yields at levels comparable to those of conventional systems during this phase of transition (Cardinale et al., 2003; Crowder and Jabbour, 2014; Ponisio et al., 2015; Synder, 2019).

4.2.3 Long-term implications

In the long term, regenerative agroecological systems aim to maintain yields by:

(i) enhancing ecosystem services for internal system regulation (Tilman, 2001; Loreau, 1998);

(ii) regenerating soil functions (Altieri et al., 2017; Pretty, 2008); and

(iii) increasing the efficiency of production relative to inputs and losses (Pearson, 2007; Struik and Kuyper, 2017).

Research indicates that this leads to maintained yield from the same cultivated area, but relying less on external inputs (Bonmarco et al., 2013; Ponisio et al., 2015) or reducing physical damage such as to soil structure, which is enhanced by a soil fauna undisturbed by cultivation (Büchi et al., 2017; Cooper et al., 2021).

According to Franzluebbers et al. (2020), long-term studies indicate that regenerative agricultural practices that include these biodiversity-based approaches can meet both food production and environmental needs through a whole-system approach that supports all ecosystem services, not just crop productivity. The response of biogeochemical cycles, environmental fluxes, and the relation between biodiversity and system function to changes in land management are often slow and require longer timescales for their impact to be properly assessed (Peterson et al., 2018). Cooper et al. (2021) showed in a UK-based study that global warming potential was reduced by 30% under long-term (more than 10 years) no-till, largely due to reduced $CO2$ emissions, which they attributed to the soil structure that emerges when left undisturbed. Long-term experiments are therefore essential for understanding the impact of management on environmental and biological processes (George et al., 2014).

There are currently around 600 long-term experiments of more than 20 years' duration worldwide (Korschens, 2006), the majority of which were originally set up to answer a specific question relating to single issues such as fertiliser rates, organic versus mineral fertiliser types, tillage, soil carbon dynamics or cropping sequence, and were continued after answering the initial hypothesis as their more general long-term value was realised.

A key emerging feature is that the management interventions represented in these long-term experiments rarely operate in isolation from the wider production system. To address concerns about food security, loss of biodiversity and the long-term future sustainability of managed systems, there is a need for whole-system experimentation within a rotational and landscape context. A number of new research platforms have been established that are designed to assess whole-system responses to new management approaches and to identify trade-offs, conflicts and synergies across different components of agricultural systems. These experiments use contemporary management, setting them apart from older experiments, and have longer-term intended lifespans than the two- or three-year experiments that dominate soil management and plant breeding research.

Although data are currently lacking on long-term trends in regenerative and agroecological approaches, early evidence from some of these newer platforms has shown that, once the transition period is over, the system can reach a new stable state, with improved soil structure and fertility, and a balance of beneficial species and antagonists that regulate pest populations below threshold levels. This reduces the yield gap, even in the absence of chemical control, and the trade-off between yield and biodiversity may eventually disappear. Realistic assessment of the effects of regenerative approaches on yield and productivity should therefore be based on data gathered beyond the transition phase when the new system has stabilised.

4.3 Conclusions: Potential landscape and global trade-offs from regenerative agriculture

There are a range of complications arising from any extrapolation of agricultural change into the future, given the complexity of the food system. For example, one barrier to achieving productive regenerative systems may be the management and practical constraints associated with regenerative agriculture approaches. The trend of simplification in modern agricultural systems has been supported by technologies to facilitate this. Typical of this is the way machinery has generally become larger and heavier, while mechanisation has supported increases in farm size and in productivity (Schmitz and Moss, 2015); however, this reliance on mechanisation may make it more difficult for farmers to introduce more regenerative systems, particularly where this requires in-field diversification. This trade-off between practical considerations and the theoretical benefits of regenerative agriculture may need to be overcome with new developments in technologies. Box 4.1 provides an example.

Box 4.1: Overcoming trade-offs between regenerative principles and management barriers

One of the principles of regenerative agriculture is to maximise crop diversity, in order to improve the resilience of agroecosystems to biotic and abiotic stresses such as pest outbreaks and weather extremes. Intercropping or polyculture (growing several crops together) offers this greater diversity and can support natural pest control (including of diseases and weeds) and soil protection (Brooker et al., 2015).

One method of intercropping is strip intercropping, where different crops are grown in the same field but in strips. Crops can be sown and harvested at different times (relay cropping), meaning there is no need for post-harvest separation. The spatial and genetic diversity disrupts the lifecycles of weeds, pests and diseases, and increases resilience. Relay crops also benefit from temporal complementarity (Wang et al., 2023) in their use of resources (light, water and nutrients). An example would be growing winter barley with spring beans, which allows each plant the best access to available resources at the most appropriate time (late spring for winter barley when the neighbouring spring bean plants are small, and mid-summer for the beans). Relay cropping also avoids having the whole field bare at the same time, achieving two additional principles of regenerative agriculture – living roots in the soil for much of the year, and cover of the soil.

One of the problems with strip cropping, as with many methods to reintroduce diversity within productive systems, is that modern farm machinery is better focused towards supporting monocultures. Narrower strips (one to two metres) may provide greater benefits, as a higher proportion of plants are in edge rows, but conventional farm machinery imposes a minimum strip width of at least four metres (the narrowest commercial combine header width).

This trade-off between farm management pressures and diversification needs to be addressed in order to support a wider-scale movement towards regenerative agriculture approaches. One approach is further technological development. For example, autonomous vehicles such as small robots may offer a solution, with several working as a swarm to replace one larger manned vehicle, or smaller, lighter unmanned vehicles that can run independently so do not add additional workload. Autonomous vehicles and the use of drones may facilitate much narrower strips (for example, trials at Harper Adams University in Shropshire are enabling two-metre strips). Use of smaller, lower mass machines operating in a controlled traffic farming strip cropping system may also contribute to greater soil health through reduced soil compaction.

A general transition towards regenerative agriculture may have implications for wider landscapes or other aspects linking to sustainability. For example, concerns (Ewer et al., 2023) exist regarding whether any reductions in productivity may mean farming expands into previously unfarmed areas to compensate for any losses in supply. The global impacts of such processes are known as indirect land use change (ILUC), and occur when changes in supply or demand in one region drive changes in land use elsewhere – mediated through the global agri-food commodities market. Awareness of ILUC grew with the development of biofuels: these created a new demand for food crops, generating ILUC as the supply side of agriculture expanded to meet this new demand (Searchinger et al., 2008; Fargione et al., 2008).

The relationship between regenerative agriculture and ILUC is still under-researched, and relevant literature often tends to focus on land close to the land undergoing change (see, for example, Kremen (2015), who focuses on ILUC in the context of the land sparing and land sharing debate). However, if, for example, a move towards more regenerative approaches reduces UK cereal production due to lower yields or a shift in land use (e.g. to agroforestry or livestock), this could have a knock-on impact on cereal import requirements, driving increased conversion of natural habitats elsewhere to agricultural land. Conversely, if production consistently increased through regenerative agriculture, this would result in 'reduced' indirect land use change, and consequent reduced biodiversity loss and greenhouse gas emissions. Putting figures to this change is difficult, with different models generating contrasting results (Gerssen-Gondelach et al., 2017; Valin et al., 2020). UK cereal production of wheat, barley and oats is less than 1% of global production (based on calculations from FAO (2023)), but the carbon and biodiversity impacts of even a small increase in tropical deforestation are so substantial that they prove small changes in 'local' production can have large impacts. This notion is explained in a paper by Smith et al. (2019), although that focuses on organic rather than regenerative agriculture production.

The carbon and biodiversity impacts associated with ILUC are essentially a 'one-off'. Even if, for example, production is consistently 10% down, the ILUC impact will only occur in year 1, which may be offset through potential long-term yield stability associated with regenerative agriculture. For example, if regenerative agriculture helps to maintain soil fertility compared with 'conventional' practices, this could be seen as a **relative** yield gain. Conversion of natural habitats to agriculture typically results in considerable biodiversity loss and greenhouse gas emissions, as the dominant areas for cropland expansion as extrapolated from current trajectories are highly diverse tropical regions of Africa, South East Asia and, to a more limited extent, South America (Williams et al., 2021).

Although there is documented evidence that practices such as reduced tillage, diversification of crop rotations, and cover crops can improve various soil properties, links between these soil outcomes and socio-economic factors are often less easily evidenced, with examples limited and variable within and between specific interventions. There may be broader socio-economic impacts and trade-offs if there is a large-scale move towards regenerative agriculture in the UK. For example, as farming practices shift, this may begin to change the ratios and diversity of available farmed products from UK farms. This is likely to have very complex outcomes, which may range from very positive for a sustainable food chain (e.g. increased diversity in local product availability) to some which may be less desirable (such as a need for increased imports of specific products, as farmers grow fewer of them). These trends and outcomes are difficult to predict, and as yet are under-researched. Answering these questions is beyond the scope of this report, but recognition of them asserts the need to connect exploration of agricultural transformation across disciplines and methods.

Nevertheless, despite these uncertainties, this chapter has shown that some aspects of regenerative agriculture may offer a pathway towards sustainable food production in the future. However, its implementation involves short-term challenges such as yield reductions and transition risks. Yet, with careful management and long-term commitment, regenerative practices may lead to improved soil health, biodiversity and economic stability, offering potential solutions to address both environmental and socio-economic concerns in agriculture during the coming years, when resilience will be more important than ever. Despite ongoing debates about the effectiveness of a regenerative approach, navigating the complexities may help to achieve sustainability goals, although evidence of trade-offs and of yield impacts is still limited, and more funding and commitment to long-term studies are needed.

References

Abdalla, M. et al. (2019). A critical review of the impacts of cover crops on nitrogen leaching, net greenhouse gas balance and crop productivity. *Global Change Biology*, 25: 2530– 2543.

Achankeng, E. and Cornelis, W. (2023). Conservation tillage effects on European crop yields: A meta-analysis. *Field Crops Research*, 298: 108967.

Al-Kaisi, M. M. and Lal, R. (2020). Aligning science and policy of regenerative agriculture. *Soil Science Society of America Journal*, 84: 1808–1820.

Altieri, M. A. et al. (2017). Technological approaches to sustainable agriculture at a crossroads: An agroecological perspective. *Sustainability*, 9: 349.

Armengot, L. et al. (2015). Long-term feasibility of reduced tillage in organic farming. *Agronomy for Sustainable Development*, 35: 339–346.

Atkin-Willoughby, J. et al. (2022). Microclimate drives shelter-seeking behaviour in lambing ewes. *Forests*, 13, 12: 2133.

Ball, B.C. et al. (1997). Soil structural quality, compaction and land management. *European Journal of Soil Science*, 48: 593-601.

Bastiaans, L. et al. (2008). Focus on ecological weed management: What is hindering adoption? *Weed Research*, 48: 481–491.

Bedini, S. et al. (2013). Mycorrhizal activity and diversity in a long-term organic Mediterranean agroecosystem. *Biology and Fertility of Soils*, 49: 781–90.

Bedini, S. et al. (2009). Changes in soil aggregation and glomalin related soil protein content as affected by the arbuscular mycorrhizal fungal species *Glomus mosseae and Glomus intraradices. Soil Biology and Biochemistry*, 41: 1491–6.

Blanco-Canqui, H. and Lal, R. (2008). No-tillage and soil-profile carbon sequestration: An on-farm assessment. *Soil Science Society of America Journal*, 72:10.

Blanco-Concqui, H. and Wortmann, C.S. (2020) Does occasional tillage undo the ecosystem services gained with no-till? A review. *Soil and Tillage Research*, 198: 104534.

Bonmarco, R. et al. (2013). Ecological intensification: Harnessing ecosystem services for food security. *Trends in Ecology & Evolution*, 28: 230–238.

Boselli, R, et al. (2020). Cover crops during transition to no-till maintain yield and enhance soil fertility in intensive agro-ecosystems. *Field Crops Research*, 255: 107871.

Brierley, J. et al. (2020). *Detection of Rhizoctonia solani AG-2.1 across the CSC rotation (2011–2019)*. Report for the Centre of Sustainable Cropping.

Brooker, R. W. et al. (2015). Improving intercropping: A synthesis of research in agronomy, plant physiology and ecology. *New Phytologist*, 206: 107–117.

Brzozowski, L. and Mazourek, M. (2018). A sustainable agricultural future relies on the transition to organic agroecological pest management. *Sustainability*, 10: 2023.

Büchi, L. et al. (2017). Long and short term changes in crop yield and soil properties induced by the reduction of soil tillage in a long term experiment in Switzerland. *Soil and Tillage Research*, 174: 120–129.

Büchi, L. et al. (2018). Importance of cover crops in alleviating negative effects of reduced soil tillage and promoting soil fertility in a winter wheat cropping system. *Agriculture, Ecosystems & Environment*, 256: 92–104. https://doi.org/10.1016/j.agee.2018.01.005

Büchi, L. et al. (2022). Pedoclimatic factors and management determine soil organic carbon and aggregation in farmer fields at a regional scale. *Geoderma*, 409:115632.

Cardinale, B. J. et al. (2003). Biodiversity and biocontrol: Emergent impacts of a multi-enemy assemblage on pest suppression and crop yield in agroecosystems. *Ecology Letters*, 9: 857–865.

Cavalaris, C. et al. (2023). Rotational tillage practices to deal with soil compaction in carbon farming. *Soil Systems*, 7, 4: 90.

Chen, C. et al. (2019) Meta-analysis shows positive effects of plant diversity on microbial biomass and respiration. *Nature Communications*, 10: 1332.

Chen, L. et al. (2022). The impact of no-till on agricultural land values in the United States Midwest. *American Journal of Agricultural Economics*, 105: 760–783.

Cole, L. J. et al. (2020). A critical analysis of the potential for EU Common Agricultural Policy measures to support wild pollinators on farmland. *Journal of Applied Ecology*, 57(4): 681-694.

Cooper, H. V. et al. (2021). To till or not to till in a temperate ecosystem? Implications for climate change mitigation. *Environmental Research Letters*. https://doi.org/10.1088/1748-9326/abe74e

Coudrain, V. et al. (2016). Temporal differentiation of soil communities in response to arable crop management strategies. *Agriculture, Ecosystems & Environment*, 225: 12–21.

Crittenden, S.J. et al. (2015). Earthworm assemblages as affected by field margin strips and tillage intensity: an on-farm approach. *European Journal of Soil Biology*, 66: 49–56.

Crowder, D. W. and Jabbour, R. (2014). Relationships between biodiversity and biological control in agroecosystems: Current status and future challenges. *Biological Control*, 75: 8–17.

Daryanto, S. et al. (2018). Quantitative synthesis on the ecosystem services of cover crops. *Earth Science Reviews*, 185: 357–73.

De Graaff, M.A. et al. (2015). A meta-analysis of soil biodiversity impacts on the carbon cycle. *Soil*, 1: 257–271.

Eisenhauer, N. (2016). Plant diversity effects on soil microorganisms: Spatial and temporal heterogeneity of plant inputs increase soil biodiversity. *Pedobiologia*, 59: 175-177.

Emerson W.W. (1995). Water-retention organic-c and soil texture. *Australian Journal of Soil Research*, 33: 241–51.

Ewer, T. et al. (2023). *Aligning regenerative agricultural practices with outcomes to deliver for people, nature and climate*. The Food and Land Use Coalition.

FAO (with major processing by Our World in Data). (2023). ‘Share of cereals allocated to animal feed – FAO’ (dataset); ‘Food balances: Food balances (–2013, old methodology and population)’; ‘Food balances: Food balances (2010)’ (original data).

Fargione, J. E. et al. (2010). The ecological impact of biofuels. *Annual Review of Ecology, Evolution, and Systematics*, 41(1): 351-377.

Fisk, J. W. et al. (2001). Weed suppression by annual legume cover crops in no-tillage corn. *Agronomy Journal*, 93: 319–325.

Franke, A.C. (2009). The role of arable weed seeds for agroecosystem functioning. *Weed Research*, 49: 131–41.

Franzluebbers, A. J. et al. (2020). Focusing the future of farming on agroecology. *Agricultural and Environmental Letters*, 5: e20034.

Garibaldi, L. A. et al. (2017). Farming approaches for greater biodiversity, livelihoods and food security. *Trends in Ecology & Evolution*, 32: 1.

George, T. S. et al. (2014). Field phenotyping and long-term platforms to characterise how crop genotypes interact with soil processes and the environment. *Agronomy*, 4: 242–278.

Gerssen- Gondelach, S. J. et al. (2017). GHG emissions and other environmental impacts of indirect land use change mitigation. *Gcb Bioenergy*, 9(4): 725-742.

Ghaley, B.B. et al. (2018). Simulation of soil organic carbon effects on long-term winter wheat (Triticum aestivum) production under varying fertilizer inputs. *Frontiers in Plant Science*, 9: 1158.

Giller, K. E. et al. (2021). Regenerative agriculture: An agronomic perspective. *Outlook on Agriculture*, 50, 1: 13–25. https://doi.org/10.1177/0030727021998063

Gokhale, C. S. and Sharma, N. (2023). Optimizing crop rotations via Parrondo's paradox for sustainable agriculture. *Royal Society Open Science*, 10: 221401.

Graves, A. R., et al. (2007). Development and application of bio-economic modelling to compare silvoarable, arable, and forestry systems in three European countries. *Ecological Engineering*, 29(4): 434-449.

Guenet, B. et al. (2021). Can N2O emissions offset the benefits from soil organic carbon storage? *Global Change Biology*, 27, 2: 237–256.

Habib, H. et al. (2016). Conversion to no-till improves maize nitrogen use efficiency in a continuous cover cropping system. *PLOS One*, 11: e0164234.

Habib, H. et al. (2016). Conversion to no-till improves maize nitrogen use efficiency in a continuous cover cropping system. *PLOS One*, 11: e0164234.

Hawes, C. et al. (2021). Agroecological practices for whole system sustainability. *CAB Reviews*, 16, 5.

Hawes, C., et al. (2019). Whole-systems analysis of environmental and economic sustainability in arable cropping systems: A case study. *Agronomy*, 9: 438. DOI: 10.3390/agronomy9080438

Holland, J.M. (2004). The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. *Agriculture, Ecosystems and Environment*, 103: 1–25.

Holland, J. M. (2004). The environmental consequences of adopting conservation tillage in Europe: Reviewing the evidence. *Agriculture, Ecosystems & Environment*, 103: 1–25.

Hughes, H. M. et al. (2023). Modelling the soil C impacts of cover crops in temperate regions. *Agricultural Systems*, 209: 103663.

Iannetta, P.P. et al. (2016) A comparative nitrogen balance and productivity analysis of legume and non-legume supported cropping systems: the potential role of biological nitrogen fixation. *Frontiers in Plant Science*, 7: 1700.

Iannetta, P. P. et al. (2016). A comparative nitrogen balance and productivity analysis of legume and non-legume supported cropping systems: The potential role of biological nitrogen fixation. *Frontiers in Plant Science*, 7: 1700.

Ingraffia, R. et al. (2022). Early sowing can boost grain production by reducing weed infestation in organic no-till wheat. *Journal of the Science of Food and Agriculture*, 102: 6246–6254.

Isbell, F. et al. (2017). Benefits of increasing plant diversity in sustainable agroecosystems. *Journal of Ecology*. 105: 871–9.

Jensen, E.S. et al. (2020). Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertiliser N: A global-scale analysis. *Agronomy for Sustainable Development*, 40: 5.

Jordon, M. et al. (2021). *Temperate regenerative agriculture; a win-win for soil carbon and crop yield. Environmental Research Letters*. DOI 10.1088/1748-9326/ac8609

Jose, S. (2009). *Agroforestry for ecosystem services and environmental benefits: an overview*. Springer.

Kaye, J. P. and Quemada, M. (2017). Using cover crops to mitigate and adapt to climate change. A review. *Agronomy for Sustainable Development*, 37: 4.

Knapp, S. and van der Heijden, M. G. A. (2018). A global meta-analysis of yield stability in organic and conservation agriculture. *Nature Communications*, 9: 3632.

Korschens, M. (2006). The importance of long-term field experiments for soil science and environmental research—A review. *Plant, Soil and Environment*, 52, 1–8.

Krauss, M. et al. (2020). Enhanced soil quality with reduced tillage and solid manures in organic farming – A synthesis of 15 years. *Scientific Reports*, 10: 4403.

Kremen, C. (2015). Reframing the land- sparing/land- sharing debate for biodiversity conservation. *Annals of the New York Academy of Sciences*, 1355, 1: 52–76.

Kremen, C. and Miles, A. (2012). Ecosystem services in biologically diversified versus conventional farming systems: Benefits, externalities, and trade-offs. *Ecology and Society*, 17, 4.

Kumar, A. and Verma, J.P. (2019). The Role of Microbes to Improve Crop Productivity and Soil Health. In: Achal, V. and Mukherjee, A. (eds) *Ecological Wisdom Inspired Restoration Engineering*. Springer.

Lange, M. et al. (2015). Plant diversity increases soil microbial activity and soil carbon storage. *Nature Communications*, 6: 6707.

Le Mire, G. et al. (2016) Review: implementing plant biostimulants and biocontrol strategies in the agroecological management of cultivated ecosystems. *Biotechnology, Agronomy, Society and Environment*, 20: 1780–4507.

Lehnhoff, E. et al. (2017). Organic agriculture and the quest for the holy grail in water-limited ecosystems: Managing weeds and reducing tillage intensity. *Agriculture*, 7: 33.

Letourneau, D.K. et al. (2011). Does plant diversity benefit agroecosystems? A synthetic review. *Ecological Applications*, 21: 9-21.

Leybourne, D. et al. (2021). Drought has negative consequences on aphid fitness and plant vigour: Insights from a meta-analysis. *Ecology and Evolution*, 2021, 11(17):11915-11929.

Liebman, A.M. et al. (2018). Legume cover crops and tillage impact on nitrogen dynamics in organic corn production. *Agronomy Journal*, 110: 1046–57.

Loreau, M. (1998). Biodiversity and ecosystem functioning: A mechanistic model. *Proceedings of the National Academy of Science*, 95: 5632–5636.

Mann, L.K. (1986). Changes in soil carbon storage after cultivation. *Soil Science*, 142: 279–88.

Marshall, E.J.P. et al. (2003). The role of weeds in supporting biological diversity within crop fields. *Weed Research*, 43: 77–89.

Martinez, I. et al. (2016). Two decades of no-till in the Oberacker long-term field experiment: part I. Crop yield soil organic carbon and nutrient distribution in the soil profile. *Soil and Tillage Research*,163:141–51.

Martinez, I. et al. (2016). Two decades of no-till in the Oberacker long-term field experiment: Part I. Crop yield soil organic carbon and nutrient distribution in the soil profile. *Soil and Tillage Research*, 163: 141–151.

McKenzie BM et al. (2017). Platforms to test and demonstrate sustainable soil management: integration of major UK field experiments. AHDB Final Report RD-2012-3786.

McLauchlan, K. (2006).The nature and longevity of agricultural impacts on soil carbon and nutrients: a review. *Ecosystems*, 9: 1364–82.

Mueller, G. et al. (2013). Evaluation of soil structure in the framework of an overall soil quality rating. *Soil Tillage Res*., 127: 74-84.

Eisenhauer, N. et al. (2010). Plant diversity effects on soil microorganisms support the singular hypothesis. *Ecology*, 91: 485-496.

Newton, A.C. et al. (2020). Identifying spring barley cultivars with differential response to tillage. *Agronomy*, 10(5):686.

Norris, R.F. and Kogan, M. (2000). Interactions between weeds, arthropod pests, and their natural enemies in managed ecosystems. *Weed Science*, 48: 94–158.

Ntatsi, A. et al. (2018). Impact of variety and farming practices on growth, yield, weed flora and symbiotic nitrogen fixation in faba bean cultivated for fresh seed production. *Acta Agriculture Scandinavia Section B - Soil Plant Sciences*, 68: 3619–30.

Nuaima, R.H. et al. (2019). Effects of cover cropping on microbial communities associated with Heterodera schachtii and nematode virulence. *Soil Systems*, 3: 67.

Nunes, M. R. et al. (2019). Corn root and soil health indicator response to no-till production practices. *Agriculture, Ecosystems & Environment*, 285: 106607.

Osipitan, O. A. et al. (2019). Impact of cover crop management on level of weed suppression: A meta- analysis (Erratum: 2022, 62, 2: 964).

Palomo-Campesino et al. (2018). Exploring the connections between agroecological practices and ecosystem services: A systematic literature review. *Sustainability*, 10: 4339.

Pearson, C. J. (2007). Regenerative semiclosed systems: A priority for twenty-first-century agriculture. *Bioscience*, 57: 409–418.

Peixoto et al. (2020). Occasional tillage in no-tillage systems: A global meta-analysis. *Science of The Total Environment*, 745: 140887.

Petersen, J. et al. (2018). Crop response to sustained reductions in annual nitrogen fertilizer rates using long-term experiments as research platform. In *Proceedings of NJF Seminar 407*, Askov Experimental Station and Sandbjerg Estate, Jutland, Denmark, 16–18 June 2008: 36–39.

Ponisio, L. C. M. et al. (2015). Diversification practices reduce organic to conventional yield gap. *Proceedings of the Royal Society B: Biological Sciences*, 282: 20141396.

Pretty, J. (2008). Agricultural sustainability: Concepts, principles and evidence. *Philosophical Transactions of the Royal Society B*, 363: 447–465.

Pritchard, C. et al. (2021). Spatial behaviour of sheep during the neonatal period: Preliminary study on the influence of shelter. *Animal*, 15, 7: 100252.

Raseduzzaman, M.D. and Jensen, E.S. (2017). Does intercropping enhance yield stability in arable crop production? A meta-analysis. *European Journal of Agronomy*, 91: 25-33.

Reimer, M. et al. (2019). Interactive effects of subsidiary crops and weed pressure in the transition period to non-inversion tillage, a case study of six sites across northern and central Europe. *Agronomy*, 9, 9: 495.

Roberts, M. et al. (2023). Environmental management on agricultural land: Cost benefit analysis of an integrated cropping system for provision of environmental public goods. *Journal of Environmental Management*, 331: 117306.

Röös, E. et al. (2018). Risks and opportunities of increasing yields in organic farming. A review. *Agronomy for Sustainable Development*, 38: 14.

Root, R. (1973). Organisation of a plant-arthropod association in simple and diverse habitats: the fauna of collards (Brassica oleracea). *Ecological Monographs*, 43: 95–124.

Roriz, M. et al. (2020). Legume biofortification and the role of plant growth-promoting bacteria in a sustainable agricultural era. *Agronomy*, 10:435.

Sanaullaha, M. et al. (2020). Terrestrial ecosystem functioning affected by agricultural management systems: A review. *Soil and Tillage Research*, 196: 1–11.

Schmitz, A., & Moss, C. B. (2015). Mechanized agriculture: *Machine adoption, farm size, and labor displacement*.

Schoeneberger, M. et al. (2012). Branching out: Agroforestry as a climate change mitigation and adaptation tool for agriculture. *Journal of Soil and Water Conservation*, 67(5): 128A-136A. https://doi.org/10.2489/jswc.67.5.128a

Searchinger, T. et al. (2008). Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science*, 319(5867): 1238-1240.

Smith, B.M. et al. (2020). The potential of arable weeds to reverse invertebrate declines and associated ecosystem services in cereal crops. *Frontiers in Sustainable Food Systems*, 3:118.

Smith, F.A. et al. (2009). More thana carbon economy: nutrient trade and ecological sustainability in facultative arbuscular mycorrhizal symbioses. *New Phytologist*, 182: 347–58.

Smith, L. G. et al. (2019). The greenhouse gas impacts of converting food production in England and Wales to organic methods. *Nature Communications*, 10: 4641.

Snyder, W. E. (2019). Give predators a complement: Conserving natural enemy biodiversity to improve biocontrol. *Biological Control*, 135: 73–82.

Squire, G.R. (2019) Transitions to greater legume inclusion in cropland: defining opportunities and estimating benefits for the nitrogen economy. *Food and Energy Security*, 8: e00175.

Sradnick, A. et al. (2013). Changes in functional diversity of the soil microbial community in a heterogeneous sandy soil after long-term fertilisation with cattle manure and mineral fertiliser. *Applied Soil Ecology*, 63: 23–28.

Stewart, C. et al. (2021). Trends in UK meat consumption: Analysis of data from years 1–11 (2008–09 to 2018–19) of the National Diet and Nutrition Survey rolling programme. *The Lancet Planetary Health*, 5, 10: e699-e708.

Storkey, J. and Neve, P. (2018) What good is weed diversity? Weed Research, 58: 239–43.

Struik, P. C. and Kuyper, T. W. (2017). Sustainable intensification in agriculture: The richer shade of green. A review. *Agronomy for Sustainable Development*, 37: 39.

Sun, B. et al. (2020). Greater fungal and bacterial biomass in soil large macropores under no-tillage than mouldboard ploughing. *European Journal of Soil Biology*, 97: 103155.

Tamburini, G. et al. (2020). Agricultural diversification promotes multiple ecosystem services without compromising yield. *Science Advances*, 6, 45: eaba1715.

Tilman, D. (2001). Functional diversity. *Encyclopedia of Biodiversity*, 3: 109–120.

Torralba, M. et al. (2016). Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. *Agriculture, Ecosystems & Environment*, 230: 150–161.

Tsonkova, P. et al. (2012). Ecological benefits provided by alley cropping systems for production of woody biomass in the temperate region: a review. *Agroforestry systems*, 85: 133-152.

Valentine T.A., et al. (2012). Soil strength and macropore volume limit root elongation rates in many UK agricultural soils. *Annals of Botany*, 110: 259–70.

Van Capelle, C. et al. (2012). Tillage-induced changes in the functional diversity of soil biota – A review with a focus on German data. European Journal of Soil Biology, 50: 165–181.

van Groenigen, J.W. (2014). Earthworms increase plant production: a meta-analysis. *Nature Scientific Reports*, 4:6365.

Van Zeist, W. J. et al. (2020). Are scenario projections overly optimistic about future yield progress?. *Global Environmental Change*, 64:102120.

Vasconcelos, M.W. et al. (2020). The biology of legumes and their agronomic economic and social impact. In: Hasanuzzaman, M., Araújo, S., Gill, S. (eds) *The Plant Family Fabaceae*. Springer, Singapore: 3–25.

Villat, J. and Nicholas, K. A. (2024). Quantifying soil carbon sequestration from regenerative agricultural practices in crops and vineyards. *Frontiers in Sustainable Food Systems*, 7: 234108.

Wang, Z. et al. (2023). Temporal complementarity drives species combinability in strip intercropping in the Netherlands. *Field Crops Research*, 291. https://doi.org/10.1016/j.fcr.2022.108757

Williams, D. R. et al. (2020). Proactive conservation to prevent habitat losses to agricultural expansion. *Nature Sustainability*, 4, 4: 314–322. https://doi.org/10.1038/s41893-020-00656-5

Wittwer, R.A. and van der Heijden, M.G.A. (2020). Cover crops as a tool to reduce reliance on intensive tillage and nitrogen fertilization in conventional arable cropping systems. *Field Crops Research*, 249: 107736.

Wittwer, R. A. et al. (2017). Cover crops support ecological intensification of arable cropping systems. *Nature Scientific Reports*, 7: 41911.

Zaller et al. (2021). Effects of glyphosate-based herbicides and their active ingredients on earthworms, water infiltration and glyphosate leaching are influenced by soil properties. *Environmental Sciences Europe*, 33. https://enveurope.springeropen.com/articles/10.1186/s12302-021-00492-0

Zhao, J. et al. (2022). Global systematic review with meta-analysis reveals yield advantage of legume-based rotations and its drivers. *Nature Communications*, 13: 4926.

Chapter 5: Opportunities and barriers for farmers

Authors: *Philip Donkersley, Alexandra Tomlinson, Alice Midmer, Alastair Leake, Edward Baxter, Charlotte Curtis*

Summary

Previous chapters have focused on the academic literature concerning regenerative agriculture. This chapter complements these perspectives with views from active practitioners of regenerative agriculture across the UK. In doing so, it brings together empirical data from interviews with 11 farmers and one independent agronomist, and existing research regarding the opportunities and challenges associated with a transition towards regenerative farming methods.

Our expert interviewees identified three key opportunities associated with the effective deployment of regenerative agriculture: increased productivity and profitability; heightened resilience against external factors; and improved levels of farmer satisfaction and wellbeing.

Barriers to the uptake of regenerative agriculture were also identified around five themes: technical knowledge and skills; changes in mindset; agricultural policy; finance and business structure; and land ownership and tenancies. Interviewees reflected on how these challenges can be overcome through training, networking, external technical advice and peer-to-peer support. Some barriers may require systemic changes, and this is discussed with regard to the agricultural policy landscape in the UK and farm business structures.

5.1 Introduction

The authors of the other chapters of this report have established that, from an ecological perspective, what is best for a farm is context dependent. As such, efforts to support the adoption of positive aspects of regenerative agriculture identified previously also require recognition of the barriers and opportunities facing individual farmers and land managers who are looking to either start that journey anew or build on positive changes they are already making. The purpose of this chapter is to explore these barriers and opportunities in the context of agriculture in the UK.

To do so, this chapter explores relevant literature regarding farmers' decision-making and capacities to adopt potentially more regenerative farming methods. This approach is supplemented by interviews with a panel of 12 expert practitioners currently working in the sector across all four nations within the UK. Of these experts, 11 are currently farmers and one is an independent agronomist. We recognise that this does not constitute in any way a sample representative of the farming community across the UK. However, it does ensure that farmer voices are integrated into this work as part of efforts to ensure that any transition towards regenerative farming represents the needs and expertise of the farmers who currently manage around 70% of the UK's land area. The chapter addresses both arable and animal agriculture, including the opportunities for integration between the two approaches. Questions around the specific barriers facing tenant farmers wishing to move to more regenerative agricultural practices are also considered.

Farms are an important part of the rural economy in the UK, providing employment and income to farming families and their staff. These economic considerations provide a necessary framework for analysing the opportunities and barriers associated with regenerative agriculture. However, it is also important to acknowledge that these economic questions connect with the policy landscape, historical circumstances and ecological conditions within which farmers operate. This chapter outlines a more holistic view of the economic, social and ecological factors governing the success or failure of regenerative agriculture.

Fundamentally, net financial productivity stands as a crucial economic criterion in evaluating prospective changes to agricultural systems (Charles et al., 2014; Piñeiro et al., 2020; Pretty et al., 2010). In the current food system, achieving greater sustainability on farms involves sustaining or improving profitability while minimising environmental impact. This involves a recognition that agriculture always requires environmental interventions and that this can create both damage and opportunities for restoration.

A recent policy briefing (Donkersley et al., 2021) highlighted the long-term sustainability concerns of current agricultural production models in the UK. This includes the fact that many farms, in particular low productivity upland grazing farms (Defra, 2022; Franks et al., 2020), have come to rely on government subsidies for financial viability.

Significantly, these financial aspects intertwine with the profound relations farmers have with their land (Howley et al., 2015). This sense of stewardship not only influences how external interventions are received but also steers the sustainable long-term use of the land.

This chapter intends to explore these multiple dimensions to shed light on the obstacles and prospects related to the adoption of regenerative agriculture.

As Chapter 2 demonstrates, however, understanding of what constitutes regenerative agriculture varies across disciplines, contexts and organisations. This reality was reflected in our discussions with farmers. Nevertheless, as Figure 5.1 illustrates, several key themes emerged from our interviews, which are reflected throughout the report – specifically a focus on soil, a recognition of the importance of context-specific application of methods, and a desire to improve agricultural conditions for future generations from their current baseline. Both the significance of, and complexities presented by, these tenets are reflected in the discussion below.

Figure 5.1: A selection of interview comments from across the range of experts interviewed for this report

“I like the term 'Regenerative Agriculture' as it is broad and a good conversation starting point — it's all about regenerating the soil and what's above it.”
Jake Freestone

“...with different soils, different environments, you'd apply these tools differently. Regenerative agriculture is based entirely on enhancing life - it's about maximum diversity above and below ground. Maximising life and biodiversity on your farm by managing for your ecosystems processes."
Silas Hedley-Lawrence

“...first heard of regenerative agriculture about a decade ago, and understanding it has a 'lit a lightbulb' and brought everything together... [I] always have the principles in the back of my mind.”
Doug Christie

“"Not sure it' s useful to pin a badge on it. It's an evolution of the agricultural system, and we're being encouraged to farm with nature in mind ... we just have different knowledge and methods of measuring what we're doing now."
Mark Coulman

“It's a rebranding of good practice, with a little bit extra added. Recommended adaptations to farm systems must be supported by specialist knowledge.”
Tom Will

“to end up with more than you started with ... better soil than you started with (soil is the farmer's biggest asset).”
Andrew Court

“the opposite of degeneration. Achieved through widespread change rather with tweaks around the edges.”
Clare Hill

“...allowing the ecosystems that we're managing to fully recover and regenerate. Helping biodiversity to recover and putting carbon back in the ground.”
Sam Beaumont

“I find it useful to explain the five key principles of regenerative agriculture, but [I] don't like the term ... focused on nature, soil condition and profit.”
Johnny Wake

5.2 Regenerative transitions: Opportunities for farmers

5.2.1 Increased productivity and profitability

Previous chapters have suggested that regenerative agriculture can increase farm productivity, which in turn can increase profitability (LaCanne and Lundgren, 2018). While some farmers adopting more regenerative methods may immediately see increased yields, others may suffer a lag while the soil recovers (see Section 5.3).

However, where farmers see marginally decreased productivity, they often still experience a slight increase in profitability due to the reduced input costs regenerative agriculture allows (LaCanne and Lundgren, 2018). This is because farming regeneratively can avoid the costs associated with buying in extra feed, chemical inputs, medicines and fuel (Schulte et al., 2022). On arable farms, for example, significant time, labour and fuel costs can be saved by reducing or eliminating tillage, as discussed in Chapter 3. On pastoral farms, reducing inputs and feeds as a result of lower impact grassland management can have similar economic benefits. As one farm manager interviewed for this chapter put it:

> *"I couldn't figure out why ... everything was inside for half the year and farmers spent fortunes on buying inputs, feeds, etc, which they could get for free by managing grasslands better and using things that are free more efficiently." (Silas Hedley-Lawrence)*

In fact, other farmers we interviewed also cited finances and cost squeezes as the main reason they had transitioned to regenerative farming:

> *"After transitioning to more regenerative practices, productivity did drop initially, but margins throughout remained steady. The reduction in fuel use and synthetic fertiliser was the main driver for reduced costs." (Doug Christie)*
>
> *"The biggest boost for regenerative agriculture here [in Northern Ireland] was the fact that fertiliser prices went up so much that people were forced into doing something different." (Stephen Alexander)*
>
> *"And so I suppose the takeaway from me from that was it certainly hasn't done any damage. In year one we had a significant, I think about a 45% reduction in our establishment costs because we did a lot less, a lot less cultivation." (Mark Coulman)*

Conventional livestock farms can save particularly on housing and fuel costs when transitioning to regenerative agriculture because outwintering livestock, rather than keeping them indoors through the colder months, reduces costs associated with the housing, heating and staff to muck out and manage. Foodstuffs produced using more regenerative methods can also open up new routes to market for farmers due to their enhanced environmental, as well as nutritional, credentials (Daley et al., 2010; McAfee et al., 2011). As one farmer interviewed put it:

> *"People are much more interested these days in the provenance of the product. We charge decent prices for a decent product [pasture-fed beef]." (Stephen Alexander)*

This possibility connects regenerative agriculture with calls from groups like Eating Better and the Sustainable Food Trust for fairer prices for farmers and more localised food supply chains. The increased agricultural diversity that regenerative methods foster would also bolster this prospect through offering an increased variety of local produce. Nevertheless, the extent of contemporary food insecurity across the UK shows that scalability, affordability and access also remain important focal points for visions of a more ecologically sound food system.

5.2.2 Resilience against external factors

Due to the potential long-term improvements in the soil and ecosystem services that regenerative farming can facilitate (see Chapters 3 and 4), the farmers interviewed for this chapter see more regenerative approaches as the key to a sustainable business model and to future adaptation to changes in the environment, including climate change and novel invasive pests. In this regard, more regenerative or environmentally oriented approaches to farming may be seen as benefiting, rather than compromising, farmers' security in the long run (Breier et al., 2023; Eckberg et al., 2020; Gosnell et al., 2019).

Volatility in fertiliser prices, evolving subsidy regimes and environmental legislation, and changing climatic conditions are encouraging food producers to look for alternatives to high-input farming (Wiltshire and Beckage, 2023), with farmers increasingly looking to future-proof their farms through investment in soil fertility. Our expert practitioner interviews also highlighted the fact that regenerative farming may help farmers feel they have more time and capacity to plan for the future, helping enhance resilience. As two interviewees put it:

> *"It has been a very positive experience of stepping off the treadmill of hopefulness that things would get better towards a non-hope-based approach through planning for unhelpful weather patterns and working with seasonality." (Clare Hill)*
>
> *"We're trying to make ourselves more resilient against [changing climate conditions]." (Dafydd Owen)*

In their experience, greater financial stability and less reliance on external inputs has helped bring costs under control and made regenerative farms more resilient:

> *"It's a transition, you have to wean yourself off of some of these inputs [e.g. fertiliser]." (Sam Beaumont)*

On-farm economic diversification (also known as 'enterprise stacking') also creates resilience in fluctuating markets, and regenerative farming may provide more financial opportunities in the future for articulation with carbon trading, biodiversity net gain-style policies, and funding from government agri-environment schemes than business-as-usual approaches (see Chapter 6).

5.2.3 Farmer satisfaction

The appeal of regenerative farming for farmers goes beyond just increasing profits. Our interviewees noted that, regardless of financial incentives, they were seeing a movement towards regenerative farming among farmers who feel that restoring the soil and the biodiversity of the surrounding environment is normatively the right thing to do (Mills et al., 2018):

> *"Regardless of policy, encouragement and private finance, regenerative agriculture seems to be getting bigger every year... Whatever happens with everything else higher up the food chain, there are a lot of people on the ground who are diving into this because they see it and believe in it." (Silas Hedley-Lawrence)*

Each expert practitioner we interviewed cited regenerative agriculture as having given them an increased sense of satisfaction with their work. To explain this, they pointed to an enhanced understanding of how they farm and why, as well as their own anecdotal perception of improvements in biodiversity across their farms, which are supported in research literature (Brown et al., 2022; Fenster et al., 2021; Giller et al., 2021; Kallio and LaFleur, 2023; Morris, 2021). Interviewees noted feeling that reconnecting with nature, and working in tune with it, was very restorative:

> *"I didn't want to be in a closed dairy farm, I wanted to be out in fields with flowers and hedgerows and wildlife ... I realised that the way that I farmed could enhance all those things, and that became a real motivator for me ... Now I see wildlife every day that hasn't been seen in years." (Silas Hedley-Lawrence)*
>
> *"We have seen both financial gain and biodiversity gain for us, and environmental gain to the wider community. We're not poisoning any lakes or watercourses, that's for sure." (Stephen Alexander)*

The farmers interviewed for this chapter also felt a satisfaction from getting off the wheel of constant application of chemical inputs that they knew were having negative impacts on the environment. This links to the long-standing recognition in agricultural social science of a 'treadmill' of synthetic input usage, which it is difficult to move away from (Ward, 1994). As one interviewee put it:

> *"When you know that something's not truly sustainable, but you're doing it because you don't feel like you have any other option, it's not a great place to be. But when you find that there's another way, a way that actually allows you to believe in what you're doing and also doesn't crucify the bottom line; that's quite an exciting development." (Johnny Wake)*

The satisfaction factor can go beyond the farm manager to the whole team, with some farmers interviewed for this chapter noting that staff morale is higher since changing approach. Despite some initial scepticism, their teams are now keen to adopt new practices and help drive the businesses forward:

> *"This has been a positive experience for me and my staff, with improved work rate and more opportunity to share what they are doing through social media and videos." (Jake Freestone)*
>
> *"The work–life balance ... enjoying what you're doing rather than rushing around." (Dafydd Owen)*

In total, these opportunities for farmers connect with the ecological advantages and possibilities established in previous chapters. As our interviews with expert practitioners show, many land managers across the UK are exploring these opportunities practically. What is perhaps more important, however, when engaging with farmers on questions of agricultural transition, is exploring barriers to future uptake and how to overcome them in a way that is both fair and realisable.

Box 5.1: Regenerative agriculture in Scotland

In November 2023, the British Ecological Society organised a workshop to discuss how regenerative agriculture can be implemented in Scotland, in the context of the development of the Agriculture and Rural Communities (Scotland) Bill and Scotland's Strategic Framework for Biodiversity. The workshop brought together key actors in the farming community, academics and policy makers from the Scottish Government and NatureScot. This box summarises the key points made during the workshop, many of which reflect the findings of this chapter.

Definition

Participants discussed how regenerative agriculture can be articulated in Scotland, where upland farming predominates, the time window to plant winter crops is more limited, the growing season is shorter than in other parts of the UK, and therefore the choice of practices is more restricted. Also, livestock integration is not always possible in a Scottish context, because not all farmers have the necessary infrastructure like fences. Minimum tillage is also not always an option, for example in the case of very wet spells or where there is the presence of a substantial weed seedbank. In general, participants agreed with the British Ecological Society' definition based on objectives and principles, but not on a prescriptive set of practices, as the choice of practices will depend on the context and constraints of the agricultural systems in different parts of Scotland. In order to define themselves as regenerative, farmers should have all the principles in mind when choosing their management practices.

In general, the term ‘regenerative agriculture’ is gaining widespread interest in Scotland, and the Government’s ‘Vision for Agriculture’ commits Scotland to be at the forefront of the global transition towards regenerative agriculture. However, there is some suspicion around the term, partly because of its potential risk of greenwashing, and partly because conventional farmers feel that it can be used to argue against intensive farming practices, which have previously been encouraged by agricultural policies. To avoid tensions between farmers who label themselves as regenerative and those who do not, it will be important to adopt a positive narrative, and present regenerative agriculture as a journey, not as a binary choice of regenerative versus non-regenerative.

An increasing number of farmers in Scotland are becoming interested in regenerative agriculture, but a wide uptake will require rewarding farmers for the public goods they provide. A wide range of mechanisms need to be used for that, including agri-environment measures, supply chain initiatives and awareness-raising actions, as well as support for research.

Motivation of regenerative farmers

One of the main reasons why an increasing number of farmers are moving towards regenerative agriculture in Scotland is that many practices, including increasing diversity of crops, breeds and landscape elements, build resilience to climate extremes, as well as to pests, pathogens and forest fires, all of which are anticipated to increase with climate change. Cost reduction is another motivation for farmers – in particular agrochemical costs – as is the intention to improve soil health and the sustainability of farming practices.

Barriers and needs

In general, regenerative agriculture brings benefits to farmers through a reduction in costs related to agrochemicals, and reduced vulnerability to climate-related events. However, there are some risks and often a yield penalty in the transition phase. For this reason, agri-environment schemes will need to play a key role in the transition towards regenerative agriculture, especially in the transition phase. It will be important to provide farmers with clarity on the rewards that will be available to them in the long term, to help them in their management choices.

Information gaps are a considerable barrier towards the adoption of regenerative agriculture practices. Ensuring funding for training, skill sharing and facilitated peer-to-peer knowledge exchange will be essential to give farmers confidence to modify their management practices.

Public rewards will not be enough to encourage a wide uptake of regenerative agriculture principles in Scotland. An appreciative supply chain will be needed, with an endpoint of consumers who understand the benefits and value of regenerative agriculture. Ensuring public recognition of the public goods provided by farmers, and thereby a sustained demand for regenerative agriculture products, will require awareness-raising initiatives and education.

5.3 Barriers and potential solutions

5.3.1 Technical knowledge and skills

Adopting new regenerative farming practices can be highly knowledge-intensive and will in many circumstances require farmers to acquire new equipment, skills and knowledge (Brown et al., 2022; Luján Soto et al., 2021; O'Donoghue et al., 2022). Technical issues and lack of knowledge are therefore barriers to any successful transitions made by farmers towards more regenerative methods (Magistrali et al., 2022). Some farmers reported that, when they started farming using the regenerative principles analysed in this report, they were part of only *'a small group of people doing it ... [with] sketchy information and not much advice' (Jake Freestone)*. However, past research with farmers in England has indicated that many regenerative practices represent 'common sense' in terms of actions which both cut costs and improve environmental outcomes (Beacham et al., 2023).

According to our interviewees, some examples of common technical challenges faced by arable farmers moving towards these approaches include failure to establish crops under new drilling systems and problems with weeds. As well as some farmers lacking experience, some things remain difficult to achieve within a regenerative system at this point in time, in part because of the legacies of previous practices which have favoured persistent and resistant weed species and have failed to consider weed ecology (MacLaren et al., 2020). For example, one farmer interviewed reported that weeds remain a significant issue in their system, and they have not been able to reduce herbicide use much (see also Beacham et al. (2023); Giller et al. (2021); McLennon et al. (2021)).

Many of the interviewees saw engaging an independent agronomist as key to their success in rolling out regenerative practices:

> *"We deliberately chose an independent [agronomist] ... that was really the starting point." (Andrew Court)*

Bringing on board an independent agronomist has helped farmers to have *'honest and open discussion[s]' (Jake Freestone)* on what is best for their farming system. There was a feeling that there was a lack of agronomists willing to help convert farms to a regenerative system – potentially due to a lack of recent research and education. The sheer number of decisions needed to change a farm was noted to be overwhelming by some interviewees – *'it has been difficult to take all aspects in' (Doug Christie)*.

Farmers therefore need to be supported by an improved knowledge exchange system in each nation of the UK, including training, education, advice and research with active farmer engagement (Lampkin et al., 2015). Such improved information and knowledge exchange systems are required to build on tacit farmer knowledge and active producer participation (Lampkin et al., 2015). This has been done in France, where training for farmers was reformed and several training programmes in agricultural colleges and universities were revised to focus more on agroecological principles and practices (Mottershead and Maréchal, 2017). Teachers, lecturers and members of staff at the regional ministry services received specific training on agroecology, with a view to acting as advisors to other teaching staff in colleges and universities (Mottershead and Maréchal, 2017). Many of our interviewees spoke positively about training:

> *"Training has helped overcome challenges. For example the Cranfield Business Growth Programme, where I had to present this business to peers and a councillor and be externally challenged. The IAgrM [Institute of Agricultural Management] leadership course also helped a huge amount." (Johnny Wake)*

Networking with other farmers facing the same challenges has allowed many of our interviewees to gain confidence in the changes they are making, as well as providing opportunities to skill share. Conferences, festivals and mentoring programmes present a chance for farmers to share both the successes and challenges they are facing in moving to more regenerative practices. Farmers we spoke to highlighted how useful networking had been:

> *"Going round other farms, BASE [Biodiversity, Agriculture, Soil & Environment], Conference and talking with other farmers on the same journey helped make change." (Doug Christie)*
>
> *"Attending courses, going on on-farm walks, sharing ideas and getting people onto the farm to pass comment." (Andrew Court)*
>
> *"[We hold an annual conference on the farm] to share regenerative agriculture with others; and the message that if we're feeding the soils, we're feeding ourselves and staying profitable." (Dafydd Owen)*

Established groups such as BASE, LEAF (Linking Environment and Farming) and the Nature Friendly Farming Network, among others, provide peer-to-peer support and advice which can be invaluable to farmers:

> *"We [the Nature Friendly Farming Network in Northern Ireland] connect farmers to give advice to each other. If you go looking for advice, you'll get it. We promote it as best we can." (Stephen Alexander)*
>
> *"What helped me most was joining farmer groups and going to see other farms ... [which] helped to define our unique context. Every farm is different." (Sam Beaumont)*

Others, such as Doug Christie, have also felt they have benefited from collaborating with agricultural research institutes such as the James Hutton Institute in Scotland to enhance their understanding of the ecological systems on their farms and facilitate farm visits. Connecting with ecologists was also highlighted as useful in overcoming knowledge gaps:

> *"We had an ecologist come and do a habitat baseline survey and it really helped [us to decide how] best to manage the habitats we have ... [it was important] having the right expertise at the right time to make the right decisions – because you can't know it all. Farmers know their land better than anyone else, so you have to be fully involved." (Sam Beaumont)*

Farmers such as Jake Freestone also reported using social media to connect with others on their journey with regenerative agriculture.

5.3.2 Mindset and socio-behavioural changes

> *'The more I do this, the more I think the physical barriers aren't actually that difficult. It's the social barriers and mentality shift that are the hardest thing.' (Sam Beaumont)*

Existing worldviews and habits can create barriers to any social change. Changing the culture around farming towards one that values regenerative agriculture could facilitate the generation of 'social capital' on farms that are exemplary practitioners (Burton and Paragahawewa, 2011). A transition to regenerative farming often necessitates a shift in farmers' understanding of both agronomic and marketing processes, with researchers noting that farmers may need to change their outlook in a way that sees them better able to 'accept mess' (Beacham et al., 2023; Gordon et al., 2022; O'Donoghue et al., 2022; White, 2020).

It was put forward by interviewees that regenerative approaches will require changing the cultural norms of farmers, policy makers and wider society about what a healthy agricultural landscape and healthy soil look like (Gordon et al., 2022; Miller-Klugesherz and Sanderson, 2023). Opinion leaders, networks and relationships are crucial pieces of the puzzle to achieve this normative change. Accepting the mess can be difficult when, in recent history, agriculture has been about *'keep[ing] things looking tidy ... nice uniform-looking green field' (Sam Beaumont)*.

Accordingly, mindset change was cited as a key barrier by many of the farmers interviewed. One farmer stated that mindset change and doing something different created doubts, as it is hard to question conventional wisdom both individually and among your peers. On this same point, it was also stated that self-belief can be an issue in changing a farming business, and that shifting practices can have effects on relationships with employees; this can also cause problems and stall progress (Burns, 2021; Cusworth et al., 2022; Gordon et al., 2022). The cognitive shift can be *'hard to get your head around ... being told that what you're doing is wrong, because you've been following the best advice' (Clare Hill)*. As one interviewee said:

> *"The barriers to uptake were the emotional burden of making change and bringing all parties along with you. Although there is a risk of making change, this felt like a less risky path overall. It is difficult to do, though, when some peers are not encouraging and also it involves admitting what you did before was the wrong path." (Johnny Wake)*

Moving towards regenerative farming can be seen as a big risk to take, not just by the farmer but by all the other people involved in the business, as the farmers we interviewed discussed:

> *"You've got to not only convince yourself and your own business partners... you've also got to convince all these other people who've been a trusted influence in your business for a long time." (Clare Hill)*
>
> *"There's the risk element too, it's very easy for people at policy level, and farmers too, to say it would be amazing if all farmers did that, that's what should happen. But all of the risk really sits with the farmer and the land manager because the margins in farming are so tight anyway. There's not a lot of room to take big risks." (Silas Hedley-Lawrence)*

Some interviewees valued coaching through their transition to support them through this required change in mindset:

> *"My transition [to regenerative agriculture] was part of a project that was sponsored, I was able to have access to regenerative coaches and that was solely the reason why I was able to make so much progress in a short time." (Clare Hill)*

Others saw this change in outlook occurring in their customers (see also Burns (2021); Cusworth et al. (2022); Stephens (2021)):

> *"As time has gone on, people have started to respect what we do, and customers now care more about the provenance of their food." (Stephen Alexander).*

All interviewees rated the change in mindset as a key barrier to their own and others' journeys to more sustainable farming systems, but saw that support through the transition could help overcome this:

> *"Once you empower people to do it little by little, they'll see the positive feedback loops of how things improve and they'll then get the confidence to go and do it at a bigger scale." (Silas Hedley-Lawrence)*

Uptake of regenerative agriculture will ultimately be dependent on ensuring community buy-in and co-design of programmes and support. Social science research has identified that treating farmers exclusively as 'economically rational actors' is a key impediment to environmental restoration (Mills et al., 2018; Vanclay, 2004).

Many farms in the UK face long-standing issues with their financial viability. These issues are driven by overlapping historical factors. Nevertheless, many farmers persist with farming despite the stresses, precariousness, long hours and dangerous working conditions that farming involves. It is necessary to consider this commitment to farming when thinking about transitions towards regenerative agriculture and the policies that will support such transformation if desired (Darnhofer et al., 2016; Hansson et al., 2013; Suess-Reyes and Fuetsch, 2016).

Fundamentally, understanding and integrating an appreciation of social factors is key to integrating more regenerative practices into conventional agriculture. Evidence suggests uptake of agri-environmental approaches is encouraged by a perception that it will improve farmers' standing in the community (Gosnell et al., 2019; Page and Witt, 2022). Further evidence from the Pasture for Life movement indicates the importance of being part of a group of farmers, and of mechanisms where farmers can learn from and support each other (Norton et al., 2022).

Other social factors also influence farmers' openness to change. Multiple thought leaders from the sector who we interviewed described a generational divide, with younger farmers being increasingly concerned with the impacts of climate change and rising costs of inputs, such as synthetic fertiliser. However, there are people cautious of a regenerative agriculture approach in all age groups and, conversely, farmers willing to transition across the age groups. In fact, according to one interviewee, many older farmers' in his experience had an 'attitude [which] has been, *"'Let's get on with it!"' (Andrew Court)*.

The position of agriculture and agricultural land in societal considerations of mitigating and adapting to climate change is also significant. In the face of growing pressure on land use multifunctionality, one farmer reported a concern that 'other industries may say *"'let's just dump all of the requirements onto ... farming" because then [they – the other industries] can offset what [they] do and carry on' (Mark Coulman)*.

Openness towards cooperation is another area in which farmer attitudes vary (Emery, 2015). Farming clusters focused on changing practices or landscapes (e.g. England's Farming in Protected Landscapes programme) or catchment-level action have sprung up across the country in recent years (Velten et al., 2021; Warrener, 2017). One participant discussed how being part of a farming cluster, working towards similar outcomes, provides the opportunity to work at a landscape scale:

> *"What you then get is what nature needs, which is these continuous joined-up efforts. I really hope that this pilot of the cluster delivers – I'm sure it will just because of the people involved and the buzz around it. I think those organised groups on a landscape level could break those boundaries down." (Silas Hedley-Lawrence)*

Exacerbating the challenge with knowledge and experience is that regenerative agriculture often requires a system redesign of the farm rather than a straightforward substitution of produce or practice (Girling et al., 2015). This brings complexity, win–wins but also trade-offs. No single practice is likely to deliver all the benefits simultaneously (see Chapter 2) and instead farmers need to financially and personally invest in a mosaic of approaches to deliver better overall results (Girling et al., 2015). The feasibility of this redesign is questioned by many farmers, and more work needs to be done to understand how to help farmers carry this out in practice (Padel et al., 2018).

5.3.3 Agricultural policy and metrics

Each of the UK's four nations have been developing agri-environment schemes following the UK's departure from the European Union. While the current agri-environment schemes promote several measures that fit within a regenerative approach, there is currently a lack of policy incentives to promote change at the whole-farm level (UK Parliament, 2020). Farmers complained that grant criteria do not always fit their specific practices and that they therefore have a disincentive to apply for such funds (Cusworth et al., 2021; Manshanden et al., 2023). Instead, it was suggested that farmers should have access to grant schemes that support public goods through a **whole-farm** transition, rather than by modular practices. Some interviewees cited their involvement with public bodies such as the Agriculture and Horticulture Development Board (a non-departmental public body) as a way to keep informed about policy developments and correspond ing funding opportunities (Magistrali et al., 2022).

Uncertainty over recent years has impacted farmers' ability to make decisions on system-level changes (Allen et al., 2024; Miller-Klugesherz and Sanderson, 2023), with a worry that investments in machinery had to be *'the right ones, [so as] not to be told to do something different in the future' (Andrew Court)*. Interviewees also voiced residual frustration in the sector associated with this transition, the bureaucracy associated with subsidies, and the recognition that policymaking is often as much about regulation as about financial encouragement:

> *"There's a disjointed relationship between people doing it on the ground and policy. I think a lot of the bottlenecks and bureaucracy could be lifted." (Silas Hedley-Lawrence)*
>
> *"There is massive potential [for agri-environment schemes], but only if they are incentivising people rather than forcing their hand." (Dafydd Owen)*

To date, 10,000 applications have been made to England's Sustainable Farming Incentive and Wales's Sustainable Farming Scheme (Defra, 2024), which have both been designed to encourage farmers to farm in a more environmentally sensitive way. In Scotland, the Scottish Government has published its vision for agriculture, which includes 'to become a global leader in sustainable and regenerative agriculture' (Scottish Government, 2022). In Northern Ireland, the development of agri-environment schemes has been delayed due to the suspension of the devolved government – adding increased uncertainty for over 26,000 farmers in the country (Defra, 2023), though this has been resolved in 2024. Unlike the other devolved nations, Northern Ireland's *'farming with nature package isn't going to be running until 2026' (Stephen Alexander)*.

For any policy to be successful for farming and the environment, there need to be suitable metrics against which progress towards environmental or ecological objectives can be evaluated. According to interviewee Tom Will, these metrics should measure the longer-term outcomes and legacy of regenerative activities, and should be used to critically evaluate the implications of regenerative agriculture (approaches to these metrics and their delivery are discussed in Chapter 3). This need for a long-term view was echoed by other interviewees, who feel they are too early on in their regenerative journey to measure the impacts that would be considered as metrics by agri-environment schemes, although there is a hope that widely applicable indicators will soon be developed. As with monitoring all environmental impacts, regular auditing, appropriate oversight and enforcement will be necessary to achieve effective management in the long term.

5.3.4 Finance and business structures

Farmer surveys conducted by researchers at the University of Gloucestershire and by Natural England indicate that, although many factors influence farmer decisions, financial incentive is always one of them (Mills et al., 2018). Access to finance, limited cashflow and rejected grant applications can also cause problems for farmers looking to transition to more regenerative methods (Dipu et al., 2022; Hurley et al., 2023). However, many farmers see regenerative farming as part of a longer-term economic perspective on future-proofing their farms, and are thus willing to accept these risks.

Significant investments by government and the farming industry will be necessary to facilitate the widespread adoption of regenerative farming practices across Europe (Kanter et al., 2018; Manshanden et al., 2023; Tittonell et al., 2022). First, farmers will need to shift to machinery adapted to regenerative farming. Furthermore, activities like soil testing are currently an additional expense for farmers, yet are a crucial step towards better soil management (as the initial modules of England's Sustainable Farming Incentive recognise). As one interviewee said:

> *"I think that [the hesitation] is [about financial] security. If you're borrowing a lot of money, it's easier to say to the bank manager, well, if I do it in this way, I should be getting X amount of returns. So, I should be able to meet your interest payments." (Andrew Court)*

Agricultural practitioners interviewed for this chapter gave the example of the acquisition of a direct drill as typical of the kind of investment regenerative agricultural transition may require. They highlighted that *'regenerative equipment manufacturers tend only to do bigger machines, which are more expensive' (Andrew Court)* and that often there are *'very limited direct drills available' (Jake Freestone)*. However, some of this expense can be avoided through cooperative equipment sharing among neighbouring farms, an emerging paradigm (Borsari, 2020; Day and Cramer, 2022; Schulte et al., 2022) primarily driven through regenerative agriculture's origins as a farmer-led movement:

> *"[One of our neighbours invested in a one-metre drill] so we used them to drill quite a bit of stuff ... and then used [our regular contractor] to drill in other areas... so you can mix and match things really." (Mark Coulman)*

Some of these core expenses, such as a seed drill for direct drilling, can be more justified when implementing more regenerative agriculture practices. For example, according to one farmer interviewed for the chapter, direct drilling can be used for both productive crops and for cover crops, *'spread[ing] the depreciation across twice the acreage' (Andrew Court)*.

An alternative option is to *'manage your farm with contractors'* so you do not need *'to fund lots of expensive bits of equipment' (Mark Coulman)*. It was suggested that taking this approach could also help to minimise the barriers for new entrants to farming, who may not have access to funds for very expensive pieces of equipment. It may also be important to engage with agricultural machinery manufacturers to support the production of machinery for regenerative approaches (e.g. smaller, lighter, less impactful on the soil) or even develop new purpose-built equipment. Working with contractors can also bring challenges, which was noted by some farmers. Outsourcing is a necessary reality in some agricultural economic systems (Bowman and Zilberman, 2013; Nye, 2020; Pugliese, 2021; Zilberman et al., 2023). Getting involved with established farmer networks and groups (as discussed above) can offer guidance on accessing financial support. As one farmer put it:

> *"I like to get involved with external projects, to help me down the road, to steer me in the right direction, because funds are tight and if LEAF are willing to pay then it's a lot cheaper." (Andrew Court)*

While many of the farmers interviewed said their margins were higher due to lower input costs, one expressed frustration that there were no mainstream markets adding value for their regenerative farming actions. It was suggested that even a simple market premium like those facilitated by organic agricultural certification (Reganold and Wachter, 2016) would be a welcome start.

The yield 'dip' (the temporary drop in yields following commencement of regenerative agriculture practices) was also mentioned by interviewees as a barrier. When making changes and *'weaning your farm off inputs' (Jake Freestone)*, some loss of production and inconsistency occurs. Of the many farm businesses already facing tight margins, some cannot afford this even if more positive outcomes further in the future are assured (Franks et al., 2020; Giller et al., 2021; Howley et al., 2015; LaCanne and Lundgren, 2018; Mills et al., 2018; Schulte et al., 2022).

Additionally, a key component of the regenerative agricultural principles discussed in this report is the inclusion of livestock within arable crop production systems. According to Andrew Court, for farms which are currently dominated by arable cropping this can present a barrier to adoption, as substantial investment in infrastructure may be required. Incorporating even low-level livestock cultivation on arable farmland would be accompanied by the need for familiarisation with relevant regulatory requirements, including keeping records of all veterinary medicines used, animal identification tags and movement sheets, manure records and adherence to nitrates regulations. Therefore, farmers may not want to manage livestock due to a lack of knowledge and appropriate infrastructure, or personal preference. However, other options are available. Farmers may opt to let their land to stockmen (who manage all aspects of livestock, including supplying electric fencing and managing records/welfare, etc) to circumvent these complications, and these arrangements can be beneficial for both parties (Farm Animal Welfare Council, 2007). For farms that include a produce crop within the rotation, livestock is restricted in the rotation, due to the perceived risk to food safety as exemplified, for example, by Red Tractor Assurance standards.

5.3.5 Land ownership, management and tenancies

Finally, an additional structural issue impeding farmers' capacity to transition to more regenerative methods in the UK is the confounding structure of land ownership and tenancy.

Land tenancy in agricultural systems is widespread across the UK. Tenancies are highly variable in nature, encompassing grazing agreements, cropping agreements, land swaps, annual tenancies, biannual tenancies, lifetime tenancies and generational tenancies. They are also highly bespoke in nature, with likely no single tenancy being 'typical' or even replicated across farms in England (Brader, 2021). A substantial number of farms in England (45% as a proportion of all holdings) are whole or part tenant holdings (Tenancy Working Group, 2022). The figure for Wales is 30% (NFU Cymru, 2022), and there are approximately 25,000 tenancies across Scotland (Scottish Government, 2024).

Traditional agricultural tenancies were long-term arrangements, often spanning three generations of a farming family. This was a deliberate policy designed to ensure that tenants were incentivised to invest in farm infrastructure (often with support from the landlord), keep the land free from weed infestations, and ensure that the soil was maintained in good structural condition.

The introduction of short-term tenancies, known as farm business tenancies, meant land could be let for a single growing season before being auctioned again to the highest bidder. Growers who specialise in particular crops can rent land on an annual basis and do not then need to get involved in the complexities of crop rotations (Tenancy Reform Industry Group, 2017).

Certain crops need to be grown as part of a longer rotation to perform well, and this allows these specialist growers to seek out land at the optimal point in the rotation for their particular crop and rent it for a single season. Consequently, tenant farmers may become disincentivised to invest in long-term measures (Tenancy Reform Industry Group, 2017), such as those involving increasing soil organic carbon. This contrasts with the understanding that higher quality land commands the highest rental value because of its ability to grow high-value crops (Scottish Government, 2020), although 'high' quality may be artificially achieved through inputs in the short term.

Tenancy influences the connection between the farmer and their land. Those with long-term tenancies have *'opportunities [that] are probably the same as a landowner' (Mark Coulman)*. Fundamentally, when exploring barriers for farmers inclined to move towards more regenerative methods, short-term tenancies remove the incentive for land managers to manage the land for the long term. The system disconnects the farmer and the land that they work on:

"Short-term tenancies are a different kettle of fish... when will you see the benefit? ... farming is a long-term project." (Mark Coulman)

It was proposed that agents and landlords reconsider a view of 'that's not the kind of tenant we want' (Mark Coulman). In reference to the perceived 'short-termism' of tenant farming, there is a need for open communication about the mutual long-term environmental and economic benefits of regenerative management of agricultural land for both the landowner and the tenant.

Long-term tenancies enable greater investment in the land and the implementation of sustainable farming methods, as there is a higher chance of experiencing the benefits of these investments over an extended period. Conversely, farms with short-term tenancies may prioritise immediate high yields and short-term gains due to the lack of long-term ownership or security, resulting in less focus on sustainable practices (Tenancy Reform Industry Group, 2017).

5.4 Conclusions

Across this chapter, through exploring the experiences of regenerative agriculture practitioners across the UK, we have repeatedly found that, although regenerative agriculture faces substantial challenges, those we interviewed reflected the positivity of people who are enthusiastic about it and its prospects:

"Whatever happens with everything else higher up the food chain, there are a lot of people on the ground who are diving into this because they see it and believe in it." (Silas Hedley-Lawrence)

References

Allen, C. et al. (2024). Modelling six sustainable development transformations in Australia and their accelerators, impediments, enablers, and interlinkages. *Nature Communications*, 15, 1. https://doi.org/10.1038/s41467-023-44655-4

Alonso, J. et al. (2015). Improved estimation of bovine weight trajectories using support vector machine classification. *Computers and Electronics in Agriculture*. https://doi.org/10.1016/j.compag.2014.10.001

Beacham, J. D. et al. (2023). Contextualising farmer perspectives on regenerative agriculture: A post-productivist future? *Journal of Rural Studies*, 102: 103100. https://doi.org/10.1016/j.jrurstud.2023.103100

Borsari, B. (2020). Soil quality and regenerative, sustainable farming systems. *In Zero Hunger. Springer*: 823–832. https://doi.org/10.1007/978-3-319-95675-6_72

Bowman, M. S. and Zilberman, D. (2013). Economic factors affecting diversified farming systems. *Ecology and Society*. https://doi.org/10.5751/ES-05574-180133

Brader, C. (2021). *Agricultural tenancy reform*. House of Lords Library. https://lordslibrary.parliament.uk/agricultural-tenancy-reform/

Breier, J. et al. (2023). Regenerative agriculture for food security and ecological resilience: Illustrating global biophysical and social spreading potentials. *Earth4All: Deep-Dive Paper*, 13. https://doi.org/10.48485/pik.2023.001

Brown, K. et al. (2022). Can regenerative agriculture support successful adaptation to climate change and improved landscape health through building farmer self-efficacy and wellbeing? *Current Research in Environmental Sustainability*, 4: 100170. https://doi.org/10.1016/j.crsust.2022.100170

Burns, E. A. (2021). Regenerative agriculture: Farmer motivation, environment and climate improvement. *Policy Quarterly*, 17, 3. https://doi.org/10.26686/pq.v17i3.7133

Burton, R. J. and Paragahawewa, U. H. (2011). Creating culturally sustainable agri-environmental schemes. *Journal of Rural Studies*, 27, 1: 95–104.

Charles, H. et al. (2014). Food security and sustainable intensification. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 369: 1639. doi/10.1098/rstb.2012.0273

Cusworth, G. et al. (2021). Agroecological break out: Legumes, crop diversification and the regenerative futures of UK agriculture. *Journal of Rural Studies*, 88: 126–137. https://doi.org/10.1016/j.jrurstud.2021.10.005

Cusworth, G. et al. (2022). Green rebranding: Regenerative agriculture, future-pasts, and the naturalisation of livestock. *Transactions of the Institute of British Geographers*, 47, 4: 1009–1027. https://doi.org/10.1111/tran.12555

Daley, C. A. et al. (2010). A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. *Nutrition Journal*, 9, 1. https://doi.org/10.1186/1475-2891-9-10

Darnhofer, I. et al. (2016). The resilience of family farms: Towards a relational approach. *Journal of Rural Studies*, 44: 111–122. https://doi.org/10.1016/j.jrurstud.2016.01.013

Day, C. and Cramer, S. (2022). Transforming to a regenerative U.S. agriculture: The role of policy, process, and education. *Sustainability Science*, 17, 2: 585–601. https://doi.org/10.1007/s11625-021-01041-7

Defra. (2022). *Agriculture in the United Kingdom evidence pack: September 2022 update*. https://assets.publishing.service.gov.uk/media/633

Defra (2023). *The Agricultural Census in Northern Ireland. Results for June 2023*. https://www.daera-ni.gov.uk/sites/default/files/publications/daera/Agricultural Census 2023 Publication.pdf

Defra. (2024). Thousands of applications made for Sustainable Farming Incentive. Press release. https://www.gov.uk/government/news/thousands-of-applications-made-for-sustainable-farming-incentive

Dipu, M. A. et al. (2022). Drivers and barriers to uptake of regenerative agriculture in southeast Queensland: A mental model study. *Agroecology and Sustainable Food Systems*, 46, 10: 1502–1526. https://doi.org/10.1080/21683565.2022.2114120

Donkersley, P. et al. (2021). Sustainable land management: Managing land better for environmental benefits. *POSTbrief*, 42. https://post.parliament.uk/research-briefings/post-pb-0042/

Eckberg, J. et al. (2020). Regenerative agriculture: A farmer-led initiative to build resiliency in food systems. *Cereal Foods World*, 65, 6. https://doi.org/10.1094/cfw-65-6-0065

Emery, S. B. (2015). Independence and individualism: Conflated values in farmer cooperation? *Agriculture and Human Values*, 32, 1: 47–61. https://doi.org/10.1007/s10460-014-9520-8

Farm Animal Welfare Council. (2007). FAWC report on stockmanship and farm animal welfare. https://assets.publishing.service.gov.uk/media/5a7eb072e5274a2e8ab47927/FAWC_report_on_stockmanship_and_farm_animal_welfare.pdf

Fenster, T. L. D. et al. (2021). Regenerative almond production systems improve soil health, biodiversity, and profit. *Frontiers in Sustainable Food Systems*, 5: 664359. https://doi.org/10.3389/fsufs.2021.664359

Franks, J. et al. (2020). Barriers to increasing productivity on upland farms. *International Journal of Agricultural Management*, 8, 4: 125–133. https://doi.org/10.5836/ijam/2020-08-125

Giller, K. E. et al. (2021). Regenerative agriculture: An agronomic perspective. *Outlook on Agriculture*, 50, 1: 13–25. https://doi.org/10.1177/0030727021998063

Girling, R. et al. (2015). *The role of agroecology in sustainable intensification*. https://orgprints.org/33067/

Gordon, E. et al. (2022). Transforming landscapes and mindscapes through regenerative agriculture. *Agriculture and Human Values*, 39, 2: 809–826. https://doi.org/10.1007/s10460-021-10276-0

Gosnell, H. et al. (2019). Transformational adaptation on the farm: Processes of change and persistence in transitions to 'climate-smart' regenerative agriculture. *Global Environmental Change*, 59: 101965. https://doi.org/10.1016/j.gloenvcha.2019.101965

Hansson, H. et al. (2013). Farmers' motives for diversifying their farm business – The influence of family. *Journal of Rural Studies*, 32: 240–250. https://doi.org/10.1016/j.jrurstud.2013.07.002

Howley, P. et al. (2015). Explaining the economic 'irrationality' of farmers' land use behaviour: The role of productivist attitudes and non-pecuniary benefits. *Ecological Economics*, 109: 186–193. https://doi.org/10.1016/j.ecolecon.2014.11.015

Hurley, P. D. et al. (2023). Barriers and enablers to uptake of agroecological and regenerative practices, and stakeholder views towards 'living labs'. In *Evaluating the productivity, environmental sustainability and wider impacts of agroecological compared to conventional farming systems*. Defra. https://randd.defra.gov.uk/ProjectDetails?ProjectId=20584

Kallio, G. and LaFleur, W. (2023). Ways of (un)knowing landscapes: Tracing more-than-human relations in regenerative agriculture. *Journal of Rural Studies*, 101: 103059. https://doi.org/10.1016/j.jrurstud.2023.103059

Kanter, D. R. et al. (2018). Evaluating agricultural trade-offs in the age of sustainable development. *Agricultural Systems*. https://doi.org/10.1016/j.agsy.2016.09.010

LaCanne, C. E. and Lundgren, J. G. (2018). Regenerative agriculture: Merging farming and natural resource conservation profitably. *PeerJ*, 2: e4428. https://doi.org/10.7717/peerj.4428

Lampkin, N. et al. (2015). *The role of agroecology in sustainable intensification*.

Luján Soto, R. et al. (2021). Learning from farmers' experiences with participatory monitoring and evaluation of regenerative agriculture based on visual soil assessment. *Journal of Rural Studies*, 88: 192–204. https://doi.org/10.1016/j.jrurstud.2021.10.017

MacLaren, C. et al. (2020). An ecological future for weed science to sustain crop production and the environment. A review. *Agronomy for Sustainable Development*, 40, 24. https://doi.org/10.1007/s13593-020-00631-6.

Magistrali, A. et al. (2022). *Identifying and implementing regenerative agriculture practices in challenging environments: Experiences of farmers in the north of England*. https://ahdb.org.uk/regenerative-agriculture-in-challenging-environments-farmer-experiences-in-the-north-of-england-ahdb-bbsrc-net-zero-initiative

Manshanden, M. et al. (2023). *Regenerative agriculture in Europe: An overview paper on the state of knowledge and innovation in Europe*. Wageningen Economic Research. https://doi.org/10.18174/629483

McAfee, A. J. et al. (2011). Red meat from animals offered a grass diet increases plasma and platelet n-3 PUFA in healthy consumers. *British Journal of Nutrition*, 105, 1: 80–89. https://doi.org/10.1017/S0007114510003090

McLennon, E. et al. (2021). Regenerative agriculture and integrative permaculture for sustainable and technology driven global food production and security. *Agronomy Journal*, 113, 6: 4541–4559. https://doi.org/10.1002/agj2.20814

Miller-Klugesherz, J. A. and Sanderson, M. R. (2023). Good for the soil, but good for the farmer? Addiction and recovery in transitions to regenerative agriculture. *Journal of Rural Studies*, 103. https://doi.org/10.1016/j.jrurstud.2023.103123

Mills, J. et al. (2018). Understanding farmers' motivations for providing unsubsidised environmental benefits. *Land Use Policy*. https://doi.org/10.1016/j.landusepol.2018.02.053

Morris, C. D. (2021). How biodiversity-friendly is regenerative grazing? *Frontiers in Ecology and Evolution*, 9: 816374. https://doi.org/10.3389/FEVO.2021.816374/BIBTEX

Mottershead, D. and Maréchal, A. (2017). *Promotion of agroecological approaches: Lessons from other European countries*. Natural England. https://publications.naturalengland.org.uk/file/5826624064323584

NFU Cymru. (2022). Minister's confirmation of Tenancy Working Group welcomed by NFU Cymru. https://www.nfu-cymru.org.uk/en/news-and-information/confirmation-of-tenancy-working-group-welcomed-by-nfu-cymru/

Norton, L. R. et al. (2022). Learning from innovative practitioners: Evidence for the sustainability and resilience of pasture fed livestock systems. *Frontiers in Sustainable Food Systems*, 6: 1012691. DOI: 10.3389/fsufs.2022.1012691

Nye, C. (2020). Agriculture's 'other' contingent labour source. Agricultural contractors and relationships of interdependence at the farmer-contractor interface. *Journal of Rural Studies*, 78: 223–233. https://doi.org/10.1016/j.jrurstud.2020.06.031

O'Donoghue, T. et al. (2022). Regenerative agriculture and its potential to improve farmscape function. *Sustainability (Switzerland)* 14, 10: 5815. https://doi.org/10.3390/su14105815

Padel, S. et al. (2018). Transitions to agroecological systems: Farmers' experience. *Aspects of Applied Biology*, 136: 27–32. https://www.cabidigitallibrary.org/doi/full/10.5555/20173379794

Page, C. and Witt, B. (2022). A leap of faith: Regenerative agriculture as a contested worldview rather than as a practice change issue. *Sustainability (Switzerland)*, 14, 22. https://doi.org/10.3390/su142214803

Piñeiro, V. et al. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nature Sustainability*, 3, 10: 809–820. https://doi.org/10.1038/s41893-020-00617-y

Pretty, J. et al. (2010). The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 4: 219–236. https://www.tandfonline.com/doi/abs/10.3763/ijas.2010.0534

Pugliese, E. (2021). Agriculture and the new division of labor. In *Towards a New Political Economy of Agriculture*. Routledge: 137–150. https://doi.org/10.4324/9780429269493-8

Reganold, J. P. and Wachter, J. M. (2016). Organic agriculture in the twenty-first century. *Nature Plants*, 2, 2: 1–8. https://doi.org/10.1038/NPLANTS.2015.221

Schulte, L. A. et al. (2022). Meeting global challenges with regenerative agriculture producing food and energy. *Nature Sustainability,* 5, 5: 384–388. https://doi.org/10.1038/s41893-021-00827-y

Scottish Government. (2020). *Agricultural Rents*. http://www.gov.scot/publications/results-2019-december-agricultural-survey/pages/4/

Scottish Government. (2022). *Sustainable and regenerative farming - next steps: statement*. https://www.gov.scot/publications/next-step-delivering-vision-scotland-leader-sustainable-regenerative-farming/

Scottish Government. (2024). *Agricultural holdings including crofting and small landholdings*. http://www.gov.scot/policies/agricultural-holdings-crofting/

Stephens, P. (2021). Social finance investing for a resilient food future. *Sustainability* (Switzerland), 13, 12. https://doi.org/10.3390/su13126512

Suess-Reyes, J. and Fuetsch, E. (2016). The future of family farming: A literature review on innovative, sustainable and succession-oriented strategies. *Journal of Rural Studies*, 47: 117–140. https://doi.org/10.1016/J.JRURSTUD.2016.07.008

Tenancy Reform Industry Group. (2017). *Post Brexit policy RE productivity and the agricultural tenanted sector: Recommendations for changes to the Agricultural Tenancies Act 1995*. https://tfa.org.uk/wp-content/uploads/2017/10/TRIG

Tenancy Working Group. (2022). *The Rock Review: Working together for a thriving agricultural tenanted sector*. https://www.gov.uk/government/publications/the-rock-review-working-together-for-a-thriving-agricultural-tenanted-sector/the-rock-review-summary-and-recommendations

Tittonell, P. et al. (2022). Regenerative agriculture—Agroecology without politics? *Frontiers in Sustainable Food Systems*, 6. https://doi.org/10.3389/FSUFS.2022.844261/FULL

UK Parliament. (2020). Agriculture Act 2020, Chapter 21, 1–95. https://www.legislation.gov.uk/ukpga/2020/21/contents

Vanclay, F. (2004). Social principles for agricultural extension to assist in the promotion of natural resource management. *Australian Journal of Experimental Agriculture*, 44, 3: 213–222. https://doi.org/10.1071/EA02139

Velten, S. et al. (2021). Success of collaboration for sustainable agriculture: A case study meta-analysis. *Environment, Development and Sustainability*, 23, 10: 14619–14641. https://doi.org/10.1007/s10668-021-01261-y

Ward, N. (1994). *Farming on the treadmill: Agricultural change and pesticide pollution*. Doctoral thesis. University of London.

Warrener, S. (2017). *Farmer clusters – Working together to achieve more*. Natural England. https://naturalengland.blog.gov.uk/2017/03/21/farmer-clusters-working-together-to-achieve-more/

White, C. (2020). Why regenerative agriculture? *American Journal of Economics and Sociology*, 79, 3: 799–812. https://doi.org/10.1111/ajes.12334

Wiltshire, S. and Beckage, B. (2023). Integrating climate change into projections of soil carbon sequestration from regenerative agriculture. *PLOS Climate*, 2, 3: e0000130. https://doi.org/10.1371/journal.pclm.0000130

Zilberman, D. et al. (2023). *Sustainable resource development in the 21st century: Essays in memory of Peter Berck*. https://library.oapen.org/handle/20.500.12657/86100

Appendix 1: Interviewees

We interviewed members of the regenerative agriculture community across the UK, to determine the barriers and opportunities that regenerative agriculture presents for them.

Andrew Court

Cotes Lodge Farm, Staffordshire, England

Andrew Court farms in partnership with his mother and brother on a 274-acre farm in Staffordshire. It is a multi-generational family farm on light land growing 205 acres of combinable crops in rotation with grass, alongside 55 acres of permanent pasture supporting 100 Aberdeen Angus suckler cows. Control passed to the partnership in 2020 and they have since had two full years of regenerative agriculture, growing winter oilseed rape, winter wheat, spring peas and winter barley. Grass leys are put down where the land needs a rest and cover crops, supported by Severn Trent Water Authority, are grown most years. The cattle grazing grass are on a four-day shift.

Clare Hill

Planton Farms, Shropshire, England

Clare is an advocate for regenerative agriculture and agroecology. Planton Farms aims to fast-track and demonstrate agroecology in action, combined with running a regenerative accelerator programme for cohorts of farmers. Clare also works with New Foundation Farms https://www.newfoundationfarms.com/.

Nikki Yoxall

Grampian Graziers and Pasture for Life, North East Scotland

Nikki is currently a PhD student and Head of Research for Pasture for Life, and runs a grazing business, Grampian Graziers, with her husband in North East Scotland. Its principal focus is on regenerative, holistic cattle grazing in collaboration with Highland Rewilding. Its collaboration with Highland Rewilding is 'designed to meet the landowner's aims, particular ecological aims and carbon sequestration aims, and undertake lots of ecological monitoring to measure the impact of that and build a beef business around that'.

Sam Beaumont

Gowbarrow Hall Farm, Cumbria, England

Sam and his wife have been manging Gowbarrow for five years. They have taken an ecological approach to their farming system, transitioning from a traditional Swaledale sheep flock to a Pasture for Life-certified pedigree shorthorn beef suckler herd, five pigs and five fell ponies, selling all beef and pork products direct to customers.

Doug Christie

Durie Farms, Fife, Scotland

Doug farms 570 hectares in total. Some is organic (mainly beef cattle-focused) and there are more than 300 hectares on an arable conventional stockless rotation, most of which has not been ploughed since 2000. Initially, a simple mix of mustard and oats was used as overwintered cover crops. Doug is gradually integrating more species diversity within his cropping. He has been adopting regenerative agriculture practices for a while and is an active member of BASE.

Jake Freestone

Overbury Enterprises, Gloucestershire, England

Overbury Enterprises is an arable farm of 1,565 hectares, with sheep and some land let out for vegetable production. All arable land is zero tilled and there are cover crops throughout. In 2012, the farm became a LEAF Demonstration Farm.

Johnny Wake

Courteenhall Farms, South Northamptonshire, England

Courteenhall was a traditional estate with lots of tenant farms. These were taken back in hand and on a wheat–rape rotation for a while, resulting in a heavy blackgrass issue. After running a controlled traffic farming system for a while, Johnny has recently diversified rotation and increased stewardship. Half the farm is now contract farmed in wheat for two years, while the other half is in sown legume fallow.

Mark Coulman

Hall Farm, North Lincolnshire/East Yorkshire border, England

Mark is a long-term tenancy farmer on 235-acre arable farm with a pig fattening unit for 2,000 pigs, growing wheat, seed maize, potatoes, peas and occasionally oilseed rape. He has a small area of grass that is run with a local farmer who has sheep and cattle, but also grazes sheep on the cover crops. A member (and national chairman) of the Tenant Farmers Association, Mark spent some time in agricultural consultancy and optimising agricultural software before returning home to farm.

Stephen Alexander

Ballyboley Dexters Farm, Antrim, Northern Ireland

Ballyboley Dexters is a family-run farm business breeding and rearing pedigree Dexter cattle, whose meat they market and sell direct to a few local businesses and a Northern Ireland-wide customer base. Stephen farmed a little throughout his government career before becoming a full-time farmer later in life, starting in 2009. Some of his small, regenerative livestock farm is on an area of special scientific interest at Strangford Loch.

Tom Will

Vegetable Consultancy Services, Norfolk, England

For 35 years, Tom has been working in agronomy and is now an independent agronomist specialising in root vegetables, managing a company called Vegetable Consultancy Services UK Ltd. His work covers 18,000 hectares and includes the whole of the UK, with projects overseas as well. He has experience of working in about 14 countries.

Silas Hedley-Lawrence

FAI Farms, Oxford, England

Silas is a farm manager at FAI Farms, with a keen interest in how farming can influence global supply chains. He is originally from New Zealand, and so previously spent time on conventional dairy farms and kiwi fruit orchards that were using lots of fertilisers and pesticides. His first farm management role on the Isle of Wight gave him the opportunity to cut unnecessary inputs and put cattle out to graze all year. His key motivation is farming in a way that enhances fields, hedgerows and wildlife.

Dafydd Owen

Coed Coch Farms, Conwy, Wales

Dafydd is a shepherd in North Wales, farming as part of a share farming agreement of 300 hectares. He manages a flock of around 2,000 Romney ewes and has begun grazing heifers from a local dairy farm on the land. Coed Coch Farms organises and hosts a conference on-farm annually about regenerative agriculture, and is keen to share what is working and what isn't to build peer-to-peer knowledge in the local area.

Chapter 6: Policy and recommendations

Authors: *Jennifer Dodsworth, Kathryn Powell, James Robinson, Rob Patchett*

Contributors: *Jenny Rhymes, Ngoc Thuy Nguyen, Cathie Hazra, Benjamin Gregson, Jordon Millward*

6.1 Introduction

In this chapter, we outline the current and potential relationship between the practice of regenerative agriculture and policy in the UK. It is important to consider not only the ways in which policy instruments and initiatives could support farmers to adapt and establish environmentally beneficial regenerative agriculture approaches, but also to emphasise how the principles of regenerative agriculture discussed in the previous chapters can inform wider thinking about agri-environmental policy in the future.

Understanding how regenerative practices align with societal goals is crucial for developing supportive policies and corporate strategies that can enhance the adoption of the right regenerative agricultural principles in the right places across the farmland of the UK's four nations. As this is a chapter oriented towards practical recommendations to deliver positive agricultural change, we recognise the different context across the different constituent countries of the UK, and these differences are reflected where relevant below.

The adoption of regenerative practices could help progress towards achieving UK targets for improving the health of natural resources – particularly soil, as is shown by the potentially positive effects of regenerative agriculture highlighted in previous chapters of this report. Regenerative agriculture principles such as maintaining living roots, keeping plants in the ground and keeping soil covered can contribute to improving soil health. These clear benefits for soil directly address the Scottish Soil Framework's targets for enhancing soil organic matter, reducing soil contamination, maintaining soil structure and reducing erosion (Scottish Government, 2009), and the Northern Ireland Sustainable Agricultural Land Management Strategy's target to increase soil health through improving nutrient balance (DAERA, 2016). Reduced run-off resulting from improved soil structure could also help address targets relating to water quality in the Environment Act 2021 in England, for example, as well as the more localised river basin management plans across all four UK nations, which outline the need for more efficient water usage on farms and a reduction in diffuse pollution (Natural Resources Wales, 2023; Scottish Environmental Protection Agency, 2024).

As also outlined in Chapter 3, regenerative agriculture practices can increase soil health and regeneration through improving the structure of the soil for nutrient and water retention and increasing humus production, both of which allow soil invertebrates to thrive (Jeffery and Gardi, 2010). As well as being a biodiverse community of organisms themselves, soil invertebrates provide vital ecosystem functions that support above-ground biodiversity (Lavelle at al., 2006). This increase in on-farm diversity, and soil health improvement associated with regenerative agriculture, could potentially act as a lever for achieving national biodiversity targets, helping deliver on both emergent national legislation on species recovery and international commitments such as the Convention on Biological Diversity Global Biodiversity Framework.

Finally, with increasing demand for food, it is imperative to transform agricultural practices so that we can increase food security while limiting the environmental footprint of farming. Biodiversity and resilience to climatic instability are essential for food security, and, as outlined in Chapter 3, these aspects of the environment are negatively impacted by unsustainable agricultural practices. As Chapter 4 considered in greater detail, regenerative agriculture could potentially help create a more resilient food system, with initial pressures on yield in certain forms of agriculture balanced out over years alongside greater resilience to shocks and improved ecosystem services. Chapter 5 highlighted that there are also potential complementarities for farmers based on the experiences of the expert practitioners interviewed.

As such, this report argues that the principles of regenerative agriculture discussed could form part of an approach to sustainable food production which could improve the environmental outcomes of farming while remaining sensitive to food security issues. Further exploration of regenerative agriculture could thus play an important role in the bid to build the UK's resilience to crisis and shocks in the food system that is required by, for example, England's Food Strategy (Defra, 2022a) and the national 'Good Food Nation Plan' in Scotland (Scottish Government, 2024).

The complexities associated with defining regenerative agriculture, and the uncertainties and knowledge gaps around the benefits of rolling out principles and practices at scale, mean the question of whether regenerative agriculture is the definitive answer to the problems associated with the agricultural sector is not straightforward to answer. Nevertheless, this report recognises that the openness of the agricultural community to regenerative agriculture as a movement – in combination with the areas where evidence is strongest for its positive environmental contributions – means it can act as a starting point for catalysing change. The rest of this chapter explores policy approaches that support this movement, the shortcomings of such approaches, and recommendations that could generate further progress in the sector. The chapter will examine various mechanisms, such as agri-environment schemes, regulation, certification schemes, private finance and agricultural advice. In the final section, we outline a series of comprehensive recommendations based on the overall report. We illustrate how these recommendations, which take inspiration from the preceding discussion and analysis of regenerative agriculture, can work together to improve the uptake and credibility of more regenerative agricultural practices in British farming.

6.2 Existing approaches to supporting regenerative agriculture

Table 6.1: Overview of policy tools and other instruments which may support regenerative agriculture approaches in the UK

Instrument type	Voluntary	Compulsory
Public: Government	Agri-environment schemes	Regulation
Non-governmental (independent third party)	Certification	
Private	Corporate finance Internal value chain External nature markets	

There are a variety of governmental and non-governmental mechanisms utilised across the UK and around the world to stimulate and incentivise the use of more environmentally friendly agricultural practices that aim to deliver benefits such as improved water quality, better soil health, and the reduced use of agrochemicals.

In this section, we use the term '**policy tools**' to refer to a range of both public and private **instruments**. The majority of these instruments are **voluntary**: there are few examples of **compulsory** regulatory tools in place which are specific to regenerative agriculture approaches. We begin by outlining the most significant voluntary policy tool for promoting regenerative agriculture practices, agri-environment schemes, before outlining elements of compulsory regulation which also facilitate the use of regenerative agriculture practices. Next, we summarise two potential non-governmental policy tools of support for regenerative agriculture: certification schemes and private finance opportunities. Lastly, we highlight some of the other policy tools which policy makers, **non-governmental** organisations and private companies should all consider when attempting to incentivise regenerative agriculture.

6.2.1 Public policy

With the UK's departure from the European Union (EU), each nation has started to develop new agri-environment policies, all with slightly different emphases and different levels of balance between payment for ecosystem services. The agricultural policies in each of the devolved nations include both subsidies, oriented towards catalysing positive environmental change in farming, and regulation, which is designed to exclude practices known to have harmful impacts. Figure 6.2 shows an overview of key policy developments during this transitional period in post-Brexit development in the UK. Below, we look at how the development of these new schemes across the UK might encourage a transition towards regenerative agricultural practices. While each country's scheme may not explicitly use the term 'regenerative agriculture', they all include measures and actions that align with regenerative agriculture principles to varying degrees. These include practices such as minimising soil disturbance, maximising crop diversity, keeping soils covered, maintaining living roots year round, and integrating livestock, all of which contribute to building more resilient and sustainable agricultural systems.

6.2.2 Regulation

As well as incentivisation, regulation is crucial in minimising the environmental impacts of agriculture on water and chemicals, establishing a baseline that farmers must meet. This regulatory baseline is essential for farmers to achieve before regenerative agriculture can become truly impactful. Furthermore, agreements should be locally applicable for each farm in order that farmers who are already doing well and using different regenerative practices are rewarded and not penalised for having a good starting point.

The nations of the UK have, globally speaking, relatively high regulatory agricultural standards. However, applying the principles of regenerative agriculture in this area could encourage the gradual strengthening of certain areas of law as regenerative agricultural practices are adopted and become more widespread.

An approach inspired by regenerative agriculture, however, might highlight that, despite the critical role of soil health, the constituent nations of the UK lack explicit and direct soil protection regulations. Various policies indirectly protect soils, but there is no comprehensive soil framework. The Environment, Food and Rural Affairs Committee's report in December 2023 called for soil health to be prioritised alongside water and air quality, with statutory targets established by 2028. The current aim in England, established via the Environmental Improvement Plan, is for 40% of soils to be under sustainable management by 2028. What this means in practice remains to be seen. In Wales, soil carbon storage is an indicator for the Wellbeing of Future Generations Act 2015. In Scotland, a new soil strategy does not introduce new policies or investment. More action is required in this space across the UK.

Since the abandonment of the EU Soil Framework Directive in 2017, progress has, however, been made in this area by Europe, through the EU's Soil Strategy for 2030, which will be integrated into the EU Soil Health Law (see Box 6.1). The new EU legislation underscores the need for coherent soil protection policies, which the UK may need to consider to maintain environmental standards and trade compatibility.

Box 6.1: The EU Soil Health Law

The EU Soil Health Law, as outlined in the EU Soil Strategy for 2030, is set to impose a combination of binding regulations and advisory guidelines. The law is described as a 'legal instrument', indicating that it will include mandatory requirements for member states. These requirements are aimed at ensuring sustainable soil management and improving soil health across the EU.

Key components of the EU Soil Health Law include:

- Legally binding rules: The law is expected to establish clear, enforceable standards for soil health. This includes regulations that non-EU producers may also need to comply with to trade with the EU, ensuring that agricultural and other practices meet specified soil health criteria.
- Advisory guidelines: In addition to binding regulations, the law will incorporate strong advisory components to guide and support best practices in soil management. These guidelines will help stakeholders implement effective soil conservation strategies.

Existing regulation also focuses on protecting watercourses and reducing or mitigating the impact of the use of agricultural inputs like synthetic fertilisers, which resonates with the principles of regenerative agriculture set out in this report. However, recent controversies over the quality of fresh water across the UK and the licensing of neonicotinoid pesticides banned in the EU raise questions about the clarity and ambition of the outcomes of existing regulatory approaches and their implementation and enforcement. Further consideration of regulation is explored in the recommendations below.

6.2.3 Certification

Certification is another means through which uptake of the agronomic practices and principles of regenerative agriculture could be both enhanced and assured. Certification processes often involve the assessment and verification of approaches to producing food in order to indicate to consumers that it meets certain criteria in terms of, for example, an environmental or animal welfare baseline label. There is no current industry-agreed method for certifying products produced by farms using regenerative agriculture principles. As discussed in Chapter 2, however, the desirability of rigidly defining regenerative agriculture via a certification scheme or schemes may vary across practitioners, and arguably does not necessarily reflect the pragmatic and/or context-dependent approach advocated for by adopters of regenerative agriculture. This reflects the fact that recent efforts to agree a ‘bolt-on’ sustainability module to supplement the existing widely used Red Tractor Assurance scheme were met with criticisms from farming groups, notably the National Farmers’ Union.

Nevertheless, the success and influence of organic certification schemes in the UK and beyond, for example as overseen by the Soil Association or Organic Farmers & Growers, demonstrate the capacity of these methods to raise both expected agricultural or horticultural standards and awareness among the public. Some studies have shown that consumers are willing to pay a premium for products with eco-labels (Bougherara and Combris, 2009). Having an industry-agreed method and introducing tighter regulation on certification could also help prevent ‘regenwashing’ or ‘greenwashing’ of products, avoiding flooding the market with products that are not produced under regenerative principles, but which claim to be (discussed further below). Such standards for certification could follow the standardised definition of the principles of regenerative agriculture laid out in Chapter 2 of this report, and in so doing encourage the adoption of regenerative farming by land managers.

Case study 6.1:

The Peatland Code

Author: Jenny Rhymes, Greenhouse Gas Flux Scientist, Centre for Ecology & Hydrology, UK

Drainage practices on lowland peat have resulted in highly productive yet deeply unsustainable agricultural systems, which produce about half of all UK-grown vegetables yet have the highest carbon emissions per unit area of any type of land use in the UK, inherently caused through peat oxidation from agricultural drainage. The Peatland Code, a voluntary certification standard to market the climate benefits of carbon farming on peat (IUCN, 2023), now includes a procedure for supporting restoration on lowland peat, which in principle can also support wetter farming practices for emission reductions. With emerging funding options like the Peatland Code, there are opportunities for farmers to bring income in from both the commodities being grown and the carbon credits sold.

The Peatland Code, with its focus on restoring degraded peatlands, aligns closely with the principles of regenerative agriculture. By promoting practices that minimise soil disturbance, such as re-wetting drained peatlands, the Peatland Code supports the preservation of carbon storage and reduces emissions from peat oxidation. Peatland restoration efforts increase soil health and biodiversity by minimising bare soil, encouraging the growth of living roots, and creating new habitats for diverse plant and animal species. As organic matter accumulates in the soil through restoration, the need for synthetic fertilisers diminishes, further reducing reliance on chemical inputs. See Case Study 2.1 for more information.

There may, however, be advantages associated with the adoption of certification that could enhance the future prospects of farming driven by regenerative principles. However, there are several limitations with certification schemes which will likely impact the number of farmers that decide to transition. The requirement for third-party verification through audits may create a perception that this takes the power out of farmers' hands (Hatanaka et al., 2005 Wilson et al., 2022). An increasing amount of food with eco-labels tied to agricultural certifications could overwhelm consumers, meaning the benefits of certification are reduced (Moon et al., 2017; Wilson et al., 2022). Certification schemes may favour large-scale over small-scale operations, owing to the benefits of economies of scale. There are upfront costs associated with certification which may limit the capability of small- to medium-sized farms to transition. These include the costs of modifying the production system to meet standards, record keeping, administration, implementing farmer training, audits and using the eco-label.

Case study 6.1 offers an example of a certification scheme relevant to regenerative agriculture. Though the Peatland Code does not explicitly use the term 'regenerative agriculture', the case study shows that the Peatland Code's relevance for this report is evident in how it is aligned with regenerative agriculture's principles, focusing on improving soil health, enhancing biodiversity, and reducing reliance on synthetic inputs.

The British Ecological Society is not in a position to explicitly call for any new certification scheme for regenerative agriculture at this point in time. Nevertheless, it is very likely that further efforts to assure the sustainability of produce will remain in the future. Where these do emerge:

- Certification schemes should **incorporate stringent criteria** aligned with regenerative agriculture principles, with guidance drawn from existing agri-environment schemes. Strong certification programmes with rigorous standards can help differentiate genuinely regenerative practices from those that are not.
- **Utilising credible, third-party verification systems** can help producers, companies and consumers ensure that sustainability claims are backed by empirical data and genuine outcomes. However, it is' essential to acknowledge and proactively attempt to mitigate potential downsides, such as the cost of participation and the risk of overly prescriptive requirements, while still recognising the potential benefits of certification.

A thorough research evaluation of existing certification schemes could offer valuable lessons for improvement. Comparative analysis and research findings may help to make certification processes more comprehensive and outcome-focused to drive meaningful change.

6.2.4 Engaging the private sector

As this report shows, farming according to regenerative principles offers promise for addressing sustainability challenges in the farming sector, providing potential pathways to solutions to decrease the environmental impact of farming. However, the widespread adoption of regenerative practices often requires financing, meaning that, as things stand, private sector investment will be a crucial component of its prospective success.

Yet, simultaneously, regenerative agriculture has become something of a buzzword in recent years. This increased popularity and attention has, excitingly, led to more and more private companies expressing the desire to support and enable regenerative agriculture among their suppliers.

How corporations proceed in the sector is not necessarily a question of public policy, yet how the supply chain is regulated and assured is, as too is the extent to which investment is supported or de-risked by public money. Furthermore, a critical eye must be maintained on the extent to which large-scale corporations' engagement with regenerative agriculture is meaningful and beneficial for farmers and for nature. Critics from within the farming sector point to how greenwashing can distort market dynamics. Companies that invest in genuine regenerative practices may face higher costs. If greenwashed products are sold at similar or lower prices, it creates an unfair market where the true costs and benefits of sustainable practices are not reflected. Falsely marketed sustainable practices may not deliver the environmental benefits they promise, resulting in continued degradation of ecosystems. This can add complexity and cost for all stakeholders involved in regenerative agriculture. It also defeats the purpose of regenerative agriculture, which aims to restore and enhance the natural environment.

Widespread adoption of a term like regenerative agriculture and associated 'greenwashing' or 'greenwishing' can lead to increased scrutiny and the need for more stringent regulations and certification processes to prevent actors that are attempting to restore ecosystems being undercut by competitors making similar claims with less positive environmental outcomes. So, how are private enterprises entering into the space in efforts to catalyse the uptake of potentially regenerative farming? One prominent model for private sector engagement in regenerative agriculture involves direct integration within the value chain of companies operating in the agricultural sector. This approach sees companies incorporating regenerative practices into their supply chains. By sourcing ingredients from farms employing regenerative methods, these companies aim to promote sustainable farming while ensuring the quality and integrity of their products. This model offers several positive aspects, including alignment with corporate social and environmental responsibilities, and the potential for direct impact on supply chains. However, to encourage meaningful private sector investment in this model, it is crucial to empower and respect farmer-led efforts to develop effective regenerative ways of farming and the knowledge these produce, while also incorporating robust ecological metrics to measure outcomes and impact in order to develop a robust evidence base.

While this model presents exciting opportunities, caution is necessary to ensure a genuine commitment to sustainability. The extent to which value chain models are 'voluntary' is also important to consider, to ensure full, effective participation from farmers and buy-in of new standards under these schemes. Where margins are very small, and prices paid to farmers are volatile, the extent to which farmers have a choice in undertaking new standards is not always clear. For instance, in industries where farmers are often 'price takers', such as dairy farmers, annual and seasonal price fluctuations may mean they are more likely to join new initiatives following a sharp drop in their prices. This is because farmers may perceive the 'premium' for goods sold under new initiatives as essential to cover losses from previous price reductions. As this report demonstrates, however, the impetus that has come from farmers in defining and exploring regenerative agriculture independently is important, and participation in schemes should not come as a result of external pressure from within the supply chain.

Another model for private sector engagement involves investing in external initiatives to promote regenerative agriculture. Companies provide funding or resources to initiatives like research projects, educational programmes or community-based agriculture initiatives. This enables scaling of impact and broader adoption of regenerative practices by leveraging expertise and resources. For example, the Sustainable Markets Initiative, launched by His Majesty King Charles III when he was Prince of Wales, demonstrates this model. Through collaboration with businesses, investors and governments, it promotes sustainable practices, including regenerative agriculture. By providing support to businesses which encourage these approaches, the Sustainable Markets Initiative facilitates the adoption of sustainable farming practices, contributing to more resilient food systems. While this model offers advantages like leveraging resources and scaling impact, careful considerations are needed to ensure alignment with company values, assess initiative effectiveness, and address challenges like fragmentation. Clear governance and monitoring mechanisms are essential for successful implementation.

Case study 6.2:

External initiatives: How corporations can help farmers transition to regenerative agriculture

Established by King Charles III, the Sustainable Markets Initiative's mandate, the Terra Carta, is to 'build a coordinated global effort to enable the private sector to accelerate the achievement of global climate, biodiversity and Sustainable Development Goal targets'.

The Sustainable Market Initiative's Action Plan for Scaling Regenerative Farming identified five issues which need to be considered to make regenerative farming 'pay' for the farmer. These are:

1. Agree common metrics for environmental outcomes

2. Build farmers' income from environmental outcomes

3. Create mechanisms to share the cost of farmers' transitions

4. Ensure government policy rewards farmers for transition

5. Source differently to share cost across value chains

The organisation argues that, to overcome these issues, industry must:

- Shift its mindset from focusing on what the farmer needs to do to what organisations can do to make it easier and more attractive to adopt regenerative farming
- Accept ambiguity and make decisions based on the balance of evidence, not precise costs and valuations
- Get better at collaboration within and across sectors and value chains to maximise the potential benefits and cost-sharing opportunities

It is evident that private sector investment is likely to play an important role in advancing regenerative agriculture. Whether through direct integration within value chains or support for external initiatives, companies have the opportunity to drive positive change in the agricultural sector. However, ensuring meaningful engagement and robust sustainability practices is essential to maximise the potential impact of private sector investment in regenerative agriculture. By addressing key considerations and working collaboratively, stakeholders can unlock the full potential of private sector finance to promote a more sustainable and resilient agricultural system.

6.2.5 Advice and support models

The transition to alternative modes of farming is not easy; however, farmers can seek out a wide range of advice and support when making decisions on land management. These typically range from formal, paid-for advisors through to informal shared experiences between family and friends. Each different type of advice and learning could have an important role to play in the transition towards regenerative agriculture.

At the formal end of the scale, farmers might seek advice from their agronomist or land agent regarding how to use regenerative agriculture techniques, including crop rotation, cover crops, decreased tillage and boosting organic matter content. Agronomists may also be consulted to assess elements such as soil quality and to advise on the development of personalised ‘soil management plans’, which (as seen in the Sustainable Farming Initiative (SFI) standards in England) are becoming key components of agri-environment schemes that aim to address soil health and diversity.

However, as discussed in this report, and particularly in Chapter 5, the farmer-led dimension of experimenting with and promoting regenerative agriculture is understood to be at the heart of its potential. Governments are increasingly paying attention to the value of other structures of advice, such as peer-to-peer learning through local farmer networks and consultants, training groups and online toolkits, with the aim of facilitating such forms of knowledge development. One notable example of a successful peer-to-peer learning group is the Pasture for Life Association, which has used Farming in Protected Landscapes funding to provide experienced farmer ‘mentors’ to those keen to learn skills for free (see case study 6.3). This no-fee model encourages a sense of informality, camaraderie and trust between farmers, encouraging an open, approachable advice system which is key to the buy-in of new agri-environment schemes. In another example of a farmer-led learning and support initiative, BASE UK was set up in 2012 to provide a farmer-to-farmer knowledge exchange network. It now has more than 500 members and holds regular farm walks, an annual two-day conference, and field trips abroad. It is an organisation that has a maximum of 20% of non-farmer members. The significant growth of Groundswell, the Oxford Real Farming Conference and other similar gatherings of farmers also reinforces the way that these approaches have captured and enhanced enthusiasm about regenerative agriculture among sections of the farming population.

Case study 6.3:

Pasture and Profit in Protected Landscapes

Pasture and Profit in Protected Landscapes[1] is a non-profit, farmer-led programme established by the Pasture Fed Livestock Association (PFLA). When farmers sign up, they are 'matched' by experienced officers at the PFLA with a willing mentor who has similar experiences or a compatible enterprise to the new mentee. The mentors are paid through Farming in Protected Landscapes funding, and there is no cost to the mentee.

Once farmers are signed up, they attend farm walks, webinars and other events to find out more about the benefits of different grazing strategies. Farmers learn together about the low-input, regenerative agriculture benefits of pasture-fed livestock, such as improved soil health and the reduced financial burden of fertilisers, feed and chemical inputs.

The aim of the mentorship is to provide farmers with support in their transition towards a pasture-based system. The significant success of the scheme across three of Southern England's Protected Areas led to a successful funding bid to expand the project across five National Parks and National Landscapes across the North of England.

1. See: pastureforlife.org/webinars/pastureandprofit/

6.3 Policy recommendations to encourage more regenerative agriculture in the UK

Throughout this report, we have highlighted the capacity of regenerative agriculture to potentially reconcile agricultural and environmental objectives across the UK. In this concluding section, we draw together key findings and a range of policy recommendations to help further the transition towards regenerative agricultural principles and practices across England, Wales, Scotland and Northern Ireland. Some of these recommendations are explicitly rooted in scaling up practices associated with regenerative agriculture as established in Chapter 2. Others are more holistic, taking inspiration from the principles of regenerative agriculture and the farmer-led movement associated with it. The recommendations look to create knowledge exchange and collaboration between farmers, land managers, policy makers and the ecological and scientific community as a whole.

Recommendation 1

Increase support and advice to help farmers make the transition to regenerative agriculture

Both the accessibility and the quality of support and advice available to farmers need to be upgraded for regenerative agriculture's positive principles and practices to become more widespread across the UK. Transforming how we produce food in the UK will be a knowledge-intensive process: the current agricultural landscape is complicated and the evidence and prospects for changing farming practices depend on context and application.

To help farmers navigate through the complexity of the landscape towards regenerative agriculture, it i's essential to establish a robust network of mentors and facilitators who can offer context-specific advice and support. This involves:

> **Increasing and widening support for peer-to-peer knowledge exchange:** This is exemplified by initiatives like Pasture for Life's 'Pasture and Profit' projects. Informal networks should be encouraged to start where they do not already exist, with financial support from public authorities where needed (for example, Scotland's Knowledge Transfer and Innovation Fund). Knowledge exchange programmes and enhanced agronomic and ecological advice should help farmers understand the need to monitor conditions on their farms and facilitate the establishment of baselines, to guide farmers towards the principles and practices that could help move them towards regenerative agriculture.

Establishing a clear educational trajectory and career path for advisors in regenerative agriculture, ensuring they possess the necessary skills and knowledge, including in ecology. This could include establishing training programmes and accreditation standards specifically for regenerative agriculture advisors. Consideration should also be given to how ecology is taught in schools and colleges, particularly to students pursuing agricultural careers.

Sufficient and secure public funding: This is required to establish, maintain and improve these advice streams. Often, innovative advice and support programmes are reliant on ad hoc, short-term project funding sources. This means that valuable time is wasted by organisations securing the next short-term financial support source. A stable, long-term funding mechanism would enable this time and resource to be used more effectively.

Increasing infrastructure that supports this collaborative environment: This includes financial incentives, technical support from arms-length government bodies, and access to resources (e.g. upgraded equipment and access to low-interest financing) to help farmers transition to regenerative practices. Flexible funding options (e.g. capital grants for second hand equipment) would also incentivise and enable soil-friendly farming techniques by making these practices more accessible to farmers who cannot afford new machinery but who could adapt existing equipment with funding support. Funding research into technological solutions for monitoring and measuring the transition towards outcome-based incentives is also recommended.

Recommendation 2

Ensure farmer-led innovation is placed alongside scientific evidence to inform agricultural policy and practice

Success in regenerative agriculture will require recognition of different kinds of expertise and the development of a collaborative environment that builds strong institutions and rewards. This can be achieved in a number of ways:

Increasing agri-environment scheme payment rates to reflect the knowledge and expertise of farmers: Policy should recognise farmer expertise by using farmer knowledge to inform the development of agri-environment schemes, and by recognising their time and expertise in increased payment rates. This ensures that compensation aligns with the effort required to transition to regenerative practices. Farmers possess embedded knowledge of their land, which is crucial for implementing regenerative practices effectively. Their understanding of local conditions – such as soil types, microclimates and existing ecological challenges – enables them to make informed decisions with support from scientific expertise.

Allowing the flexibility to incorporate contextual knowledge into practice and scheme design: Agri-environment policy should be flexible, rather than prescriptive, to allow farmers to apply contextual knowledge when deciding which regenerative practices to use. This personalised approach improves the chance that the practices used will be viable on each farm.

Ecologists need to work with farmers: Farmers need clear, practical advice from ecologists that explains the rationale behind recommended actions. This transparency helps farmers understand why certain practices are beneficial and how they align with the broader goals of soil health and ecosystem sustainability. For example, in England, initiatives like the Sustainable Farming Incentive management plans and soil testing provide valuable insight into soil health and the practical benefits of regenerative practices, increasing farmer buy-in and enthusiasm. Development of agri-environment policy in other devolved nations would benefit from following this approach, and from extending the programmes to learning about the benefits of biodiversity above ground.

Recommendation 3

Use regenerative agriculture principles to co-design impactful and measurable agricultural policy

As discussed above, there are a variety of proposed actions/measures from the evolving new schemes that support regenerative agriculture principles. Integrating regenerative agriculture principles directly into agri-environment policy could further propel the uptake of sustainable practices. This approach should be developed collaboratively with farmers, scientists and other stakeholders. This will mean not just aligning with core principles promoting soil-friendly agricultural practices, but also co-designing schemes with farmers which acknowledge agricultural and ecological specificity through local institutions and investment.

By recognising and leveraging farmers' expertise, providing comprehensive support, and maintaining sustained engagement, policy could effectively drive the transition to a more sustainable agricultural future. This ensures that the policy is rooted in practical, evidence-based strategies that support regenerative farming practices, including:

Options for agri-environment schemes shaped by regenerative practices: Schemes should cover all critical aspects of regenerative agriculture, including soil health, biodiversity and water management. Each element should allow the flexibility for practices to be tailored to local contexts to maximise impact, while aiming to move in the direction of the broad regenerative agriculture principles outlined in Chapter 2.

Co-designing schemes: Retain and embed the commitment to co-design by all devolved governments in agri-environment policy development processes, for example through a 'co-design covenant' commitment from policy makers. The uptake of co-design approaches has been inconsistent, due in part to the absence of farmer input in the initial stages of policy design. Re-prioritising co-design involves sustained dialogue among stakeholders, feedback on policy drafts, and field visits to understand on-ground realities, moving beyond symbolic consultations. Many institutions (governmental and non-governmental) lack the necessary time and resources for effective engagement with stakeholders. Substantial investment of time and financial resource is needed to facilitate meaningful co-design processes. **This would require a major increase in the agriculture budget**. Increasing the national budget by at least 1 billion pounds a year over the current Parliament would mean more time and energy could be spent on aligning schemes with regenerative agriculture principles, as well as providing the resources required for farmers to make the transition and feel supported.

Diverse and flexible long-term funding streams: Farmers should have access to a variety of funding sources, including public funds, private investments and blended finance options. This diversity ensures financial resilience and supports long-term transitions to regenerative practices. This includes initial investments for transition phases using public funding, as we have seen through schemes such as Farming in Protected Landscapes in England, and ongoing support to maintain regenerative practices once established. Without sufficient payment, farmers might opt for short-term solutions like planting herbal leys and then ploughing them up, producing only short-term, temporary improvements to soil health; long-term maintenance is therefore imperative when designing payment schemes.

Hybrid payment approaches: Payment models should blend various methods, such as upfront payments for actions, payments for observed results in line with regenerative agriculture principles, and modelled outcomes. As discussed in Chapter 3, this includes outcome-based rewards, which will require further research and development to get right. This hybrid approach offers flexibility and incentivises both immediate actions and long-term results.

Spatial prioritisation: Statutory local plans like local nature recovery strategies should receive adequate time and delivery funding to become effective following the development phase. There should be much stronger alignment between these approaches and agri-environment policy, to allow the right regenerative agriculture practices to align spatially with local nature recovery strategy plans for the area.

Regulation: To further advance progress towards regenerative agricultural approaches, meaningful and accessible regulation needs to be in place in order to set a strong baseline upon which to improve through regenerative principles. Regulation should not lag behind improvements, however – minimum standards should evolve to reflect a progressive baseline of requirements, and should adapt and evolve to reflect emerging best practices. **Strengthening regulation could involve enacting legislation specifically focused on soil protection**, ensuring that soil health is prioritised and integrated into farming practices. Information about regulations needs to be accessible to farmers. Legislation should provide a simple and pragmatic definition of baseline regulations as well as regenerative agriculture principles, making it clear and understandable for farmers. This accessibility empowers farmers to comply with regulations effectively and integrate regenerative practices into their operations. Overall, strong regulation is essential for initiating progress towards a more desirable outcome under regenerative agriculture, providing a solid foundation for ecological health on farms and long-term viability in farming.

Recommendation 4

Advance innovation in regenerative agriculture

Innovative practices, experimentation and technological advancements are needed to propel the regenerative agriculture movement forward. To ensure continuous progress in regenerative agriculture, it is crucial to develop a comprehensive and forward-looking research agenda. This vision should include:

> **Mobilising long-term funding for experiments:** Sustainable innovation requires consistent and long-term funding. Governments, private investors and institutions should commit to long-term funding for research projects that explore new regenerative techniques and technologies.

> **Co-developing research priorities:** Acting on research gaps that are being identified through further research by different communities of practice, be that agricultural or ecological. For example, Chapter 4 of this report highlights how there are unresolved questions around the capacity of minimum and no-tillage approaches to sequester carbon or better manage pests and diseases.

> **New and accessible co-designed technologies:** Investment in new technologies that support regenerative agriculture via accessible and relatively affordable hardware is also required. Public funding should continue to assist farmers in trialling and investing in novel technologies. This includes initial investments and ongoing support for innovations that enhance sustainability. For instance, a recent moorland SFI pilot conducted with farmers by the Foundation for Common Land worked with the Land App to develop a user-friendly mobile phone application for identifying and mapping environmental public goods for use in the SFI rollout. Farmers can use the app for a price of £0.60 per hectare per year.

However, when promoting technological advancements, it is essential to recognise and mitigate the potential risks some new agricultural technological advancements may pose. For instance, investments in biotechnology and pesticide and fertiliser technologies must avoid undermining regenerative principles.

Recommendation 5

Ensure the credibility, transparency and consistency of regenerative agriculture initiatives across the whole supply chain

While it will be important to effectively engage the private sector in regenerative agriculture, regulators must ensure credibility, transparency and consistency across the supply chain when doing so. In this chapter, we have outlined key models of corporate funding (internal value chain and external investment arrangements) and the use of non-governmental certification schemes as potential mechanisms for financing regenerative agriculture. Despite these not being reliant on public funding, there is an important role for governments to play in ensuring that such approaches remain rigorous, transparent and fair to producers and consumers, including enabling:

> **Meaningful choice for farmers:** Design value chain programmes that allow farmers to opt in rather than being mandated. Programmes should offer flexibility to adapt to the specific contexts and needs of individual farms, reflecting the design of agri-environment schemes to ensure value chain approaches are inclusive and adaptable. Adopt frameworks like the Sustainable Markets Initiative, which emphasise supporting farmers rather than dictating their actions. This approach respects farmers' knowledge and expertise, empowering them to implement regenerative practices tailored to their specific contexts. External initiatives should encourage their corporate members to provide financial incentives, technical assistance and resources to help farmers transition to regenerative agriculture. Support can include grants, low-interest loans, and access to corporations' cutting-edge technology and research.

> **Shorter and more equitable supply chains:** Reduce the number of intermediaries between farmers and consumers to ensure that more of the financial benefits of regenerative practices reach the farmers themselves. Shorter supply chains can also make the entire process more transparent, allowing consumers to see exactly how their products are produced and how the costs are distributed. Develop mechanisms to ensure that profits are shared equitably across stakeholders in the value chain, in particular rewarding farmers who implement regenerative practices.

> **Supply chain transparency:** Introduce educational campaigns and labelling that inform consumers about the distribution of costs, profits and sustainability of their food across the value chain. This could include information on packaging or through digital platforms where consumers can trace the journey of their food from farm to table. Develop marketing strategies that clearly explain the benefits and principles of regenerative agriculture. Use simple,

accessible language to educate consumers about how these practices improve soil health, biodiversity and overall sustainability. Ensure marketing materials and campaigns are transparent about what regenerative agriculture entails and the positive impacts it has on the environment and food systems. Labels should accurately reflect the regenerative practices used in producing the product, and be based on clear, verifiable criteria to avoid consumer confusion and build trust.

The use of blended finance, which could significantly boost investment in regenerative agriculture. This approach would involve combining public and private funding sources to support innovation and scale up successful practices. Private investors, such as those in impact funds, may require more detailed and nuanced monitoring of outcomes. This could lead to more rigorous and reliable measurement practices, enhancing the overall effectiveness of regenerative projects, where there are appropriate regulation and assessment criteria in place to protect both the farmer and the respective company. For instance, a clear easement policy will need to be outlined early on to ensure that farmers who are significantly affected by weather extremes, particularly in the early years of their transition, are not punished for factors outside their reasonable control. Therefore, there are important lessons for private contracts to learn from the more flexible approaches of public policy. Public funding can complement private investments by enabling a diverse range of cost-effective indicators, making it easier for farmers to participate in regenerative practices and access both public and private support.

Collaboration and standards: By working together, corporations can provide the support and infrastructure necessary for farmers to adopt regenerative practices effectively. Corporations should form networks to share best practices for engaging with and supporting farmers. Collaborative efforts among corporations can drive industry-wide standards, allow the sharing of best practices, and create consistent, credible messages for consumers. This collective approach not only empowers farmers but also builds a robust market for regenerative products, ensuring that sustainability becomes a cornerstone of the agricultural supply chain. These networks can develop standardised guidelines for promoting regenerative agriculture, ensuring consistency and effectiveness across different companies and sectors. Facilitate regular industry forums, workshops and conferences where corporations can exchange insights and strategies on regenerative agriculture. This collective knowledge can drive innovation and improve practices industry-wide.

References

Bane, M. S. et al. (2023). An evidence-base for developing ambitious yet realistic national biodiversity targets. *Conservation Science and Practice*, 5, 2: e12862. https://doi.org/10.1111/csp2.12862

Beacham, J. D. et al. (2023). Contextualising farmer perspectives on regenerative agriculture: A post-productivist future? *Journal of Rural Studies*, 102: 103100. DOI: 10.1016/j.jrurstud.2023.103100

Bougherara, D. and Combris, P. (2009). Eco-labelled food products: What are consumers paying for? *European Review of Agricultural Economics*, 36, 3: 321–341. https://doi.org/10.1093/erae/jbp023

Burns, F. (2023). State of nature 2023 – *Report on the UK's current biodiversity* https://stateofnature.org.uk/

Cardinale, B. J. et al. (2012). Biodiversity loss and its impact on humanity. *Nature*, 486, 7401: 59–67. https://doi.org/10.1038/nature11148

DAERA. (2016). *Sustainable agricultural land management strategy*. https://www.daera-ni.gov.uk/articles/sustainable-agricultural-land-management-strategy

DAERA. (2023). *Draft ammonia strategy for Northern Ireland consultation*. https://www.daera-ni.gov.uk/consultations/draft-ammonia-strategy-northern-ireland-consultation

Defra. (2022a). *Government food strategy*. https://www.gov.uk/government/publications/government-food-strategy/government-food-strategy

Defra. (2022b). *New legally binding environment targets set out*. https://www.gov.uk/government/news/new-legally-binding-environment-targets-set-out

Hatanaka, M. et al. (2005). Third-party certification in the global agrifood system. *Food Policy*, 30(3), 354–369.

Hayhow, D. B. et al. (2019). *State of nature 2019*. State of Nature Partnership. https://jncc.gov.uk/news/uk-state-of-nature-2019-report/

Housden, S. (2020). *Putting Scotland on a path to recovery: The case for nature recovery targets*. Scottish Environment LINK. https://www.scotlink.org/publication/putting-scotland-on-a-path-to-recovery-the-case-for-nature-recovery-targets/

IUCN. (2023). *Peatland Code*: Version 2.0. https://www.iucn-uk-peatlandprogramme.org/sites/default/files/2023-03/Peatland%20Code%20V2%20-%20FINAL%20-%20WEB_2.pdf

Jaworski, C. C. et al. (2024). Sustainable soil management in the United Kingdom: A survey of current practices and how they relate to the principles of regenerative agriculture. *Soil Use and Management*, 40, 1: 1–20. DOI: 10.1111/sum.12908

Jeffery, S. and Gardi, C. (2010). Soil biodiversity under threat – A review. *Acta Societatis Zoologicae Bohemicae*, 74: 7–12.

Lavelle, P. et al. (2006). Soil invertebrates and ecosystem services. *European Journal of Soil Biology*, 42, 1.

Moon, S. J. et al. (2017). The impact of consumer confusion from eco-labels on negative WOM, distrust, and dissatisfaction. *International Journal of Advertising*, 36, 2: 246–271.

Natural Resources Wales. (2023). *River basin management plans 2015–2021*. https://naturalresources.wales/evidence-and-data/research-and-reports/water-reports/river-basin-management-plans/river-basin-management-plans-published/?lang=en

Scottish Environmental Protection Agency. (2024). *River basin management planning*. https://www.sepa.org.uk/environment/water/river-basin-management-planning/

Scottish Government. (2009). *The Scottish Soil Framework*. http://www.gov.scot/publications/scottish-soil-framework/

Scottish Government. (2024). *Working towards a good food nation*. http://www.gov.scot/publications/national-good-food-nation-plan/pages/4/

UK Government. (2019). *Clean air strategy 2019*. https://www.gov.uk/government/publications/clean-air-strategy-2019

Welsh Government. (2023). *Clean air plan for Wales: Healthy air, healthy Wales* https://www.gov.wales/clean-air-plan-wales-healthy-air-healthy-wales

WFD. (2000). Directive of the European Parliament and of the Council, 2000/60/EC. Establishing a framework for community action in the field of water policy. *Official Journal of the European Parliament*. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:-2000:327:0001:0072:EN:PDF

Wilson, K. R. et al. (2022). Different stakeholders' conceptualizations and perspectives of regenerative agriculture reveals more consensus than discord. *Sustainability*, 14, 22: 15261.

Appendix 2: Agri-environment scheme development in the four nations of the UK

England's agri-environment scheme development

England's **Environmental Land Management** (ELM) programme is a series of three schemes: the Sustainable Farming Incentive (SFI), Countryside Stewardship (CS) and Landscape Recovery (LR). Under SFI, farmers are paid for the delivery of standards relating to particular environmental outcomes. Each standard is compiled from a list of 'actions' that farmers can complete to get paid. An overview of the standards and actions offered in SFI 2023, and how they relate to regenerative agriculture principles, is outlined in Figure 6.3. Although the SFI standards do not specifically refer to 'regenerative agriculture', several of these actions show acknowledgement of regenerative principles and encourage farmers to adopt practices that support regenerative agriculture objectives.

The second scheme is CS. Previously set to be titled 'Local Nature Recovery', the new CS scheme will continue to provide the familiar mechanisms of the existing CS scheme (introduced in 2014) that farmers are accustomed to. CS will pay for targeted actions from a menu of options, tied to specific locations, farm features and habitats, and will provide an extra incentive through 'CS Plus' for land managers to join up across local areas to have an impact on a wider spatial scale.

England's third environmental land management scheme is LR. LR agreements will be long-term, large-scale, usually collaborative projects which aim to holistically address a specific issue, from the restoration of floodplains and peatlands to the creation of woodlands and wetlands. LR is competitive: land managers put forward a project proposal and compete for funding from a limited pot. The extent to which each agreement includes aspects of regenerative agriculture may vary, and there is no food production required.

While still in development, the programme aims to give farmers the resources and incentives they need to transition to more environmentally friendly and productive farming methods, which could help advance regenerative agriculture across the industry.

Scotland's agri-environment scheme development

The Scottish Government is currently reforming its agricultural policy, stating in the Agriculture and Rural Communities Act (2024) that it aims to 'become a global leader in sustainable and regenerative agriculture'. The Scottish Agricultural Reform Programme includes development of a Future Support Framework to replace the direct and indirect support payments of the EU Common Agricultural Policy (CAP). This framework aims to deliver four main outcomes: high-quality food production; climate mitigation and adaptation; nature restoration; and wider rural development. The protection of peatlands and wetlands is also a priority in the framework.

The proposed Future Support Framework is split into four tiers: Base Level Direct Payment (Tier 1); Enhanced Level Direct Payment (Tier 2); Elective Payment (Tier 3); and Complementary Support (Tier 4). The proposed Base Level Direct Payments are conditional upon farms or crofts meeting minimum essential standards. These essential standards are aimed to align with EU CAP cross-compliance conditions at a minimum. Farmers will also be required to undertake a Whole-Farm Plan, which includes soil testing, an animal health and welfare declaration, carbon audits, biodiversity audits, and supported business planning. The aim of the Whole-Farm Plan is to 'help businesses become more environmentally and economically resilient and sustainable'.'

The list of measures that farmers and crofters can choose to implement under the Enhanced Level Direct Payment is currently under development, but a draft list of measures is available in the Agricultural Reform Route Map and is structured in terms of outcomes, packages and measures. The packages include groups of complementary measures that are targeted towards achieving the respective higher-level outcomes. The list of measures is currently undergoing evaluation to determine which measures will be eligible for future support and at which payment tier.

Although 'regenerative grazing' is the only measure to mention the term 'regenerative' explicitly, there is substantial overlap between regenerative agriculture principles and the measures included in the draft list. Minimising soil disturbance could be directly supported by the 'minimum-/no-tillage' measure. The winter cover measure, including crop stubble retention and/or planting cover crops, aims to minimise bare soil. Increasing plant diversity could be supported through a range of measures relating to arable and grassland habitats, such as crop diversification and integration of trees. While only mentioned explicitly once each, rest periods are included in the 'regenerative grazing' measure and the use of organic inputs in the 'efficient nutrient management' measure. Reduction of synthetic inputs is addressed by a package of dedicated measures, and knowledge of context is key to the Whole-Farm Plan.

Wales's agri-environment scheme development

The Agriculture (Wales) Bill introduces a new framework for agricultural support called 'Sustainable Land Management' (SLM) to allow transition from the CAP. The Bill establishes four objectives for SLM: 1) to produce food and other goods in a sustainable manner; 2) to mitigate and adapt to climate change; 3) to maintain and enhance the resilience of ecosystems and the benefits they provide; and 4) to conserve and enhance the countryside and cultural resources, promoting public access to and engagement with them, alongside sociocultural aims such as to sustain the Welsh language and promote and facilitate its use.

These objectives for SLM then provide the foundations and reporting criteria against which the Sustainable Farming Scheme (SFS) is being developed. The SFS is set to commence in 2026 and is currently described as an 'outline scheme proposal' which was the subject of a co-design process with farmers and stakeholders during 2022 to inform further refinements before a final consultation period in 2023.

In broad terms, the SFS proposals support the principles of regenerative farming, given aligned objectives to ensure that food production through farming can be sustainable, maintaining and enhancing ecosystems and countryside resources. However, the specific term ‘regenerative farming’ is not utilised at any point in the scheme proposal document; the closest reference relates to ‘regenerating’ soils and associated improvements to soil health by:

- Keeping it covered so it is not exposed to the wind and rain (some cover crops also have the benefit of creating habitat for pollinators)
- Lowering the risk of compaction and poaching from machines and livestock
- Improving soil structure and soil organic matter

Soil monitoring (testing) is also included as a key precursor to guide subsequent management decisions.

Co-design feedback has not indicated that further reference to the term ‘regenerative farming’ would be a preference for farmers. While explicit reference to the term ‘regenerative agriculture’ is not made, the SFS in Wales does refer extensively to ‘soil regeneration and health’ being the primary focus of the framework and for further development of the scheme in the future. Nonetheless, the SFS does include a number of proposed actions which can help to deliver a regenerative approach and are not just limited to soil health. These include actions for increased efficiencies, including in the use of artificial inputs; conservation and management of water resources on the farm; and maintenance and restoration of natural ecosystems to support biodiversity as well as mitigating and adapting to climate change. These actions are delivered through a combination of different ‘Universal’, ‘Optional’ and ‘Collaborative’ actions, which constitute the three layers of the scheme; however, to be eligible farmers must sign up to the Universal Action Scheme and do the minimum to be eligible for the other options available.

The SFS is not compulsory, and farmers not engaged with the SFS will be regulated by the ‘National Minimum Standards’ that are set to replace cross compliance and consolidate existing standards. While this regulatory ‘floor’ sets a minimum standard for good farming practice, and hence lays the foundation for regenerative approaches, it is unlikely to provide a substantive mechanism to support regenerative agriculture – which is more likely to be delivered through the SFS.

Northern Ireland’s agri-environment scheme development

The Northern Ireland Government’s Future Agricultural Policy Decisions paper, which sets its policy goals for the farming industry, strongly focuses on fostering environmental practices. The document is a positive step towards encouraging an agricultural industry that is more ecologically responsible and sustainable. The document’s recommendation to encourage regenerative farming methods, which focus on improving soil health, fostering biodiversity and minimising synthetic inputs, is one of its most important recommendations. The study acknowledges the significance of these practices in fostering environmental sustainability and minimising the environmental effect of agriculture. Meanwhile, the study has drawn criticism for needing to be more specific about how the Government intends to assist farmers in implementing these practices.

There is an urgent need for further information on how the Government intends to assist farmers in implementing these practices. Effective implementation of regenerative agricultural practices necessitates significant time and resource commitment. To encourage the adoption of regenerative agriculture practices, more information should be given to justify the policies and more details given surrounding the incentives. The study recommends actions that farmers should take, but many of its recommendations need to be more specific. For example, it mentions active farming approaches to grazing practices. However, it gives no specifics on what defines a more sustainable stock animal, such as the minimum and maximum ages of stock. The more comprehensive and long-term nature of regenerative agricultural practices may also require adapting the report's outcome-based methodology. Given that terminology like 'low intensity' is ambiguous for agricultural practices to follow, regenerative agriculture practices are calling for these parts of the report to be clarified, enlarged and fully stated to specify how long the stock should be grazed and grown. The possibility of further piquing community interest needs to be improved by conveying to stakeholders the broader advantages of these practices. The report's outcome-based methodology could only partially account for the effects of these practices, which might restrict their influence on the environment and the more significant farming industry.

Despite these drawbacks, the report's emphasis on supporting ecologically sound farming methods and regenerative agriculture is a step in the right direction. The Northern Ireland report and Government acknowledge the significance of lessening agriculture's adverse environmental effects and encouraging more sustainable agricultural methods. The significance of biodiversity in fostering environmental sustainability is also acknowledged in the study. In order to enhance biodiversity and aid in the adoption of regenerative agricultural techniques, the paper suggests the establishment of biodiversity corridors. These corridors may offer critical habitats for animals and support biodiversity in the broader agricultural sector. To sum up, the Future Agricultural Policy Decisions study is a step towards encouraging environmentally sound farming methods in Northern Ireland.

BRITISH ECOLOGICAL SOCIETY

britishecologicalsociety.org

British Ecological Society
42 Wharf Road, London N1 7GS
Tel: +44 (0)20 3994 8282
hello@britishecologicalsociety.org

Charity number 281213