Understanding the financial and climate impacts of regenerative farming practices

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19 December 2023

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Acknowledgements: Kate Winters(SOS-UK) and Sam Smith (FCT) have assisted in the production of this report.

Executive Summary

SOS-UK has commissioned the Farm Carbon Toolkit (FCT), using funding from NEIRF, to conduct financial modelling on the costs or benefits to farm businesses of adopting a range of regenerative farming practices to support discussions about 'carbon insetting'.

FCT approached this task in three ways:

- Evaluation of the most up to date and comprehensive research into the carbon, climate and financial impact of adoption of an agreed suite of farming practices considered to "regenerative"
- Development of farm models for three key farming systems - dairy, arable and lowland beef and sheep farms based on data within the Farm Carbon Calculator database which enabled us to identify the impact on farm greenhouse gas emissions from adopting more regenerative farming practices and systems
- Development of partial budgets for the adoption of key regenerative farming practices using information form key industry sources and innovators in this space.

What is clear from all the areas of activity carried out is that in general there is a challenge to maintain yield and output through the adoption of more regenerative farming systems, especially where land is turned over to fertility building leys and reliance on artificial fertilisers is removed. Many studies in recent years have evidenced this including the National Food Strategy[1]. The extent of the challenge on output is unclear and from the research review carried out, the evidence base for any estimate on this is poor at the moment.

There is also evidence that a transition period is required to allow soil and ecosystem health to improve to be able to function effectively with reduced/ no chemical inputs. Depending upon the starting point this can be up to five years and suggests the need for support to underpin farmers acquiring the new range of skills and knowledge required and to bridge the financial gap until the new farming system is fully established. In England the introduction of the Environmental Land Management Scheme with its range of different elements is providing financial support for the introduction of some key regenerative farming practices such as growing cover crops. However, for more holistic changes to farming systems such as moving to longer and more complex rotations including grass leys, it is less evident that the current financial support will facilitate this transition, unless the farm has a profitable use for the grass and the individual crop gross margins are not compromised significantly.

There is also a cultural and social aspect to the acceptability of a transition to more regenerative farming systems which should not be underestimated. For instance a more regenerative farm is often considered to be less "tidy". Acceptability is increasing, especially where farmer networks exist to reinforce decision making in favour of more regenerative farming practices.

[1] www.nationalfoodstrategy.org

Practices which reduce greenhouse gas emissions

Alongside technical fixes to reduce emissions, such as ensuring all machinery is working as efficiently as possible, many of the recommended ways to reduce farm greenhouse gas emissions are part of the suite of more regenerative farming practices, e.g..

- Reducing the use of cultivations
- Reducing reliance on artificial fertiliser (which can only be achieved when other more regenerative farming practices are in place which support enhanced soil health and fertility)
- Changing feed sources for livestock
- Maximising use of forage for livestock feeding

Impact of regenerative farming practices on greenhouse gas emissions

Adopting regenerative farming practices generally reduces emissions per ha despite lower yields and lower livestock stocking rates.

Typical more regenerative farming practices which are being adopted include replacing fertiliser with legumes within cropping rotations or within grassland management, reducing cultivations for crop establishment, growing herbal leys, challenging received wisdom on the level of artificial fertilisers required by crops and the requirement for use of insecticides. For livestock farmers, typical regenerative farming practices being adopted include reducing the use of supplementary feeds and keeping livestock grazing longer into the autumn, alongside practices to improve soil health and structure.

Financial viability of more regenerative farming practices

Typically the adoption of more regenerative farming practices results in lower yields, lower livestock stocking rates, less risk (as the vulnerability to input costs changes is lower where less inputs are used). However, more farmers are learning how to implement more regenerative farming practices effectively which is reducing the risk of lower yields, but in general new skills are required.

In England, support from the ELM scheme does present a means of underpinning the financial impact of many key regenerative farming practices (over 50% of the practices budgeted show a neutral or positive financial impact, which is largely due to the availability of external financial support).

Recommendations

1. More research is required to provide clearer evidence of the impact of adoption of regenerative farming practices on yield and output as this is seen as a key barrier to adoption by many farmers
2. Increased support for farmers to build the confidence, skills and knowledge required for effective adoption of regenerative farming practices
3. Institutional Landlords provide transition support to tenants undertaking a whole farm approach to the adoption of regenerative farming systems, especially where more complex and longer arable rotations are a central theme of the transition
4. Support the development of Machinery Rings or Syndicates to facilitate access to the type of equipment required to facilitate the transition to more regenerative farming systems

1. Introduction

1.1. Background

The UK market for ecosystem services, including carbon offsetting, has been developing rapidly over recent years in response to the growing urgency of the climate crisis and rapid loss of biodiversity[2]. With 70% of the land mass in the UK under agricultural production[3], there is a focus on both the need for farmland managers to be involved in nature-based solutions and also on the potential revenue streams opening up to agricultural businesses through private finance from organisations looking to meet statutory or voluntary greenhouse gas emissions and nature restoration outcomes[4]. Universities and higher education institutions are setting ambitious goals for reaching net zero and examining how to maximise benefit for nature restoration on their campuses and estates, as well as looking at the impact on nature from their supply chains[5]. Universities are also significant agricultural land owners with estimates in the region of 35,000 to 50,000 Ha owned in total across UK universities and higher education institutions, with some being managed directly as part of teaching and research, whilst the majority is leased out to tenant farmers.[6][7]

1.2. Project rationale

In response to interest within the university sector in climate and nature-positive land management and a need for high integrity, UK-based carbon offset credits, Students Organising for Sustainability UK (SOS-UK) set up a pilot project in 2021 ("Farming for Carbon and Nature") to explore the possibilities for working on these issues with land managers on university and college-owned farmland in the UK. The pilot project has been funded by the Esmee Fairbairn Foundation and by the UK Environment Agency via the Natural Environment Investment Readiness Fund (NEIRF). The overall project aim was to develop a suitable investment mechanism to support farmers on university and college-owned farmland to transition to climate and nature positive farming practices that are encompassed in agroecological and regenerative approaches to farming. Many of these practices may also enhance the environmental and financial resilience of farm businesses in the face of the climate crisis and geopolitical impacts on the costs of farming materials and inputs[8] , which in turn contributes to enhanced national food security[9].

1.3. Project aims

SOS-UK has commissioned the Farm Carbon Toolkit, using funding from NEIRF, to conduct financial modelling on the costs or benefits to farm businesses of adopting a range of regenerative farming practices to support discussions about 'carbon insetting'. We conceptualise carbon insetting as collaboration between actors within a value chain to reduce the total greenhouse gas emissions, which

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[2] IPCC Factsheet on climate and biodiversity
[3] Land Use in the UK
[4] Assessing nature market opportunities
[5] Nottingham Trent University Supplier Tool
[6] FARMING FOR CARBON & NATURE – DEVELOPMENT RESEARCH REPORT. 7th October 2020. SOS-UK. Available as PowerPoint Presentation
[7] Unpublished research from Freedom of Information Requests
[8] AHDB Agricultural input price tracker 2023
[9] Government Food Security Report

may involve interventions in the financial relationship or transactions between those actors. This work will be of value to inform discussions between primary producers supplying food processors and retailers, as well as for land-owners with tenant farmers because under the Greenhouse Gas Protocol, the farm emissions sit under the scope 3 emissions of both the landlords and the downstream buyers in the value chain that sits around a tenant farm. This is covered in chapter 5 of this report. This work builds on previous work exploring the financial implications of shifting to regenerative or agroecological farming[10] in two key ways: (1) it gives granular data on specific regenerative farming practices, whereas previous modelling work was based on farm-level or food-systems level outcomes; (2) it incorporates payment rates for the recently confirmed Sustainable Farming Incentive in England.

Specifically the report will support Universities with land holdings to identify how best to support land managers in moving to more regenerative farming practices. These practices not only promote enhanced biodiversity, but also contribute to a reduction in greenhouse gas emissions and the removal of carbon from the atmosphere. To assist with an understanding of how these practices affect greenhouse gas emissions, we have brought together information on key practices to reduce farm level greenhouse gas emissions.

Within the report, partial budgets have been produced for key regenerative farming practices for the main farming systems practised in the UK. The aim of these budgets is to address the shortage of information on the financial impact of the adoption of more regenerative farming practices. This is an area where a lack of information is sometimes cited as one of the barriers to practise adoption. The reason that there is a shortage of information is linked to the relatively low level of robust research in this area and lack of controls to compare against. However, for a number of practices, there is now more information coming through from practitioners which is helpful, whilst still mainly anecdotal.

It should be noted, (although outside the scope of this report) that customer requirements are already starting to drive some farmers and growers into practice change in favour of more regenerative farming practices, sometimes though with no regard to any additional costs incurred by the farmer in delivering these practices.

Outside the scope of this report is attempting to identify how adoption of key regenerative farming practices might link with payments for other outcomes, e.g. carbon, biodiversity net gain, nutrient neutrality etc, although clearly there is a relationship and the linkages between specific practices and ecosystem service enhancement are shown in Tables 1 and 2 below.

Whilst Agroforestry and increasing the growth of farm hedges are key regenerative farming practices to support carbon sequestration on farm land whilst protecting soils from the effects of flood and drought and supporting enhanced farm animal health and welfare, no attempt has been made within this report to produce partial budgets for their practice due to the lack of robust quantifiable information. Readers are directed to the Agroforestry Handbook .

The overall aim of regenerative farming is often cited as being to improve soil health with secondary benefits in reducing greenhouse gas emissions. For instance when considering minimum tillage the primary benefit reported for this practice relates to a significant reduction in fuel usage followed by reduced soil emissions from cultivations and in some cases increased carbon stocks in the top soil levels. Improved soil biodiversity, better drought and flood resilience and potentially an ability to reduce reliance on chemical fertilisers also flows from improving soil health.

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[10] Economics of a transition to agroecological farming

1.4. Five key principles of Regenerative Agriculture

1. **Minimise disturbance of the soil, both physically and chemically.** The micro-flora and fauna that form the soil ecosystem are harmed by cultivations, especially ploughing, which inverts the top 6-10 inches. There is often a nutrient boost from cultivating; resulting in short-term release of nutrients during a long term decline as many underground 'workers' are killed or rendered homeless and get eaten by predators or scavenging arthropods. Similarly heavy fertiliser or pesticide use will upset the delicate balance where healthy soil is created, for instance too much nitrogen will upset the carbon-nitrogen ratio and encourage microbes to eat organic matter and thus set any improvement back.
2. **Keep the soil covered,** either with living plants (green cover crop) or a mulch of crop residue, like chopped straw. This protects the soil from rain impact, reducing the damage that high speed raindrops will do to the surface and allowing the water to percolate gently down. A good soil cover will also stop overheating by hot sun or freezing in winter, both of which are antagonistic to healthy soil.
3. **Maintain living roots in the soil for as much of the year as possible.** Living roots are the conduit that feed the soil. In conventional arable systems the soil is often left bare for long periods. By planting cover crops the underground ecosystem can be kept functioning.
4. **Maintain as much plant diversity as possible.** Monocultures are an anathema to nature and restrict the variety of soil creatures that can be supported. A diverse population of plants can be grown in companion cropping systems, where two or more crops are grown simultaneously and are harvested together with the seeds being separated post-harvest. More conventionally, robust crop rotations ensure healthier soil and reduced weed and disease pressure. There is also potential for growing crops through a living mulch of clovers which stay close to the ground and allow the cereal to tower above and be harvested when ripe, leaving the understory to carry on feeding the soil and fixing nitrogen.
5. **Reintroduce livestock into the system.** There are already trillions of living creatures in the soil and incorporating appropriate numbers of grazing livestock (appropriately managed) into the farming system will turbo-charge their numbers and increase the biodiversity to the benefit of the soil, as well as adding to the farm income. A diversity of farm animals (cows, sheep, chickens, pigs and goats) will further boost soil fertility and aid animal health.[11]

Bringing together more reliable information on the practices which underlie these principles, along with an analysis of their impacts and implementation costs, is particularly timely. Many mainstream farmers can be reluctant to adopt regenerative farming practices in the absence of reliable evidence of their net cost / benefit and real-world impact. This hesitancy poses a significant barrier to more widespread adoption[12]. Alongside the lack of robust evidence on the financial impact of many regenerative farming practices, there is also often a knowledge gap which affects the effectiveness of practice adoption, which in turn affects the financial impact. This gap is being addressed as practitioners learn more and share learnings and form more research into how best to implement these practices.

In producing this report we have drawn insights from other recent reports, notably the Green Alliance

[11] From Farm of the Future - Journey to net zero report - RASE

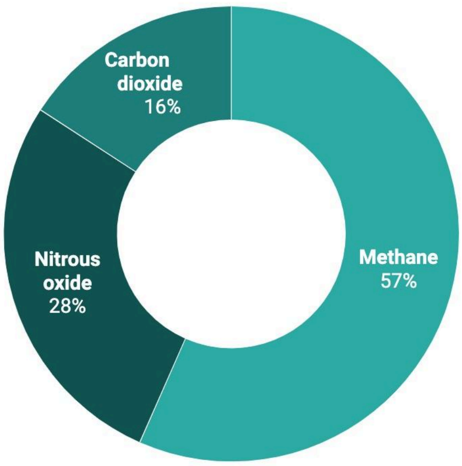
[12] Magistrali, Amelie at el. (2022) Project Report No. PR640-09 Identifying and implementing regenerative agriculture practices in challenging environments: experiences of farmers in the north of England. AHDB.

report produced for the Oxford Farming Conference in 2022 entitled "The opportunities of agri carbon markets - policy and practice"[13] , the suite of TYFA UK reports produced for the Soil Association from 2020/2021[14,] and the FABulous Farmers project report: *Functional Agro-Biodiversity: An evaluation of current approaches and outcomes*[15]*.* These reports examine the impact of adopting regenerative practices at scale across the UK, covering the financial impacts on farm types and impacts on national GHG (Greenhouse Gas) emissions, together with the impact on food production. However they did not go into detail on the impact of adopting more regenerative farming practices on GHG emissions at farm level nor on the financial impact of individual practice adoption. This report aims to go beyond the previous studies, by including information on the estimated impact of regenerative farming practices on emissions from the four main farm types. Furthermore, it estimates the financial impact of individual regenerative farming practice adoption on farm. For the first time, we have been able to bring in real-world data from the Farm Carbon Calculator to demonstrate the impact of practice change on farm GHG emissions.

1.5. Overview of Greenhouse Gas Emissions in Agriculture

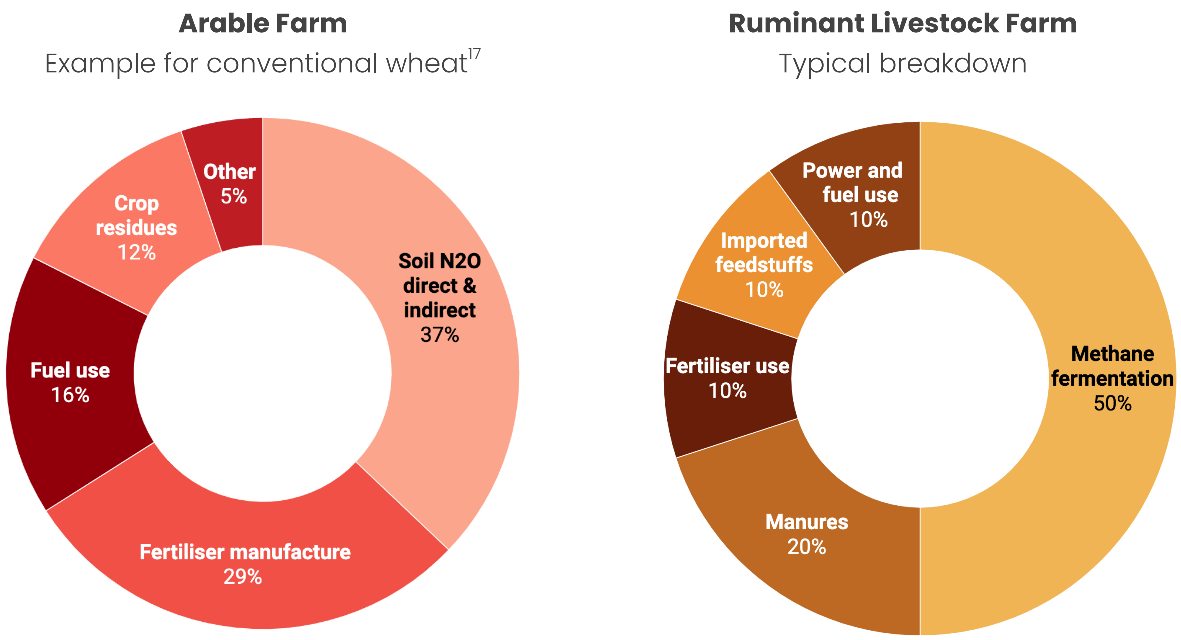
The three greenhouse gases of greatest importance in agriculture are methane, nitrous oxide and carbon dioxide. Outside of agriculture, carbon dioxide is the most important greenhouse gas, much of which arises from our use of fossil fuels. However in agriculture, methane and nitrous oxide are more important. Emissions also vary by farm type as shown in Figure 2.

Figure 1: Breakdown of UK agriculture greenhouse gas emissions[16]



[13] Green Alliance (2022), *The opportunities of agri-carbon markets: policy and practice*. Available at: https://bit.ly/46cEBbU
[14] IDDRI-Asca (2021), Modelling an agroecological UK in 2050 – findings from TYFA. Available at: https://bit.ly/47nNjFm
[15] Maskell, L. C. et al. (2023). Functional Agro-Biodiversity: An evaluation of current approaches and outcomes (submitted for peer review). *Land 2023*.
[16] Department For Energy Security and Net Zero, (2023), *UK territorial greenhouse gas emissions on an end-user basis 1990*-2021. Available at: https://bit.ly/3Gqk2hT

Figure 2: Sources of greenhouse gas emissions for different farm types



Other: Pesticide manufacture = 3%; Seed = 2%

Accounting for Methane: GWP* and GWP100

GWP (Global Warming Potential) is a measure of how much impact a gas will have on warming the atmosphere. The most common method to evaluate the effect of different greenhouse gases (GHGs) is by comparing them over a 100-year lifetime; this is known as GWP100. This is the internationally agreed metric chosen under the Paris Agreement and the primary tool for emission reduction targets globally.

Using GWP, it's possible to compare the impact of different GHGs by converting them to their carbon dioxide equivalent (CO_2e) value. The latest research suggests that using GWP100, biogenic methane emissions are 27 times more powerful than CO_2; and nitrous oxide (N_2O) emissions are 273 times more powerful[18]. However, unlike CO_2 and N_2O gases that last for hundreds of years in the atmosphere, methane only lasts for an average of 12 years after which most of it is broken down. This means that using GWP100, the impacts of methane could be considered overestimated in the long-term, and underestimated in the short term.

In an aim to better account for methane, in 2016, a team of researchers proposed a new metric, known as GWP* that works over a 20 year period[19]. Over a 20 year period, emitting a tonne of methane has 80 times more planet-warming impact than emitting a tonne of carbon dioxide. However, the new metric is also designed to reflect the warming impact of ongoing emissions of methane in relation to the current levels of that gas in the atmosphere. The theory is that, over time, ongoing emissions are not adding warming to the atmosphere, but merely replacing old emissions that have degraded. Essentially, GWP* focuses on changes in emissions rather than absolute emissions. This accounting approach has been gathering support within UK agriculture sector, however it does also face some criticism[20].

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[17] Stoddart, H. and Dimmock, J., (2021). Regional emissions from biofuels cultivation - Revised report: June 2021. *AHDB and E4tech*. Available at: ahdb.org.uk/regional-emissions-from-biofuels-cultivation

[18] IPCC AR6 Synthesis Report: https://www.ipcc.ch/report/sixth-assessment-report-cycle/

[19] For further details about GWP*, see "Climate metrics for ruminant livestock". Available at: www.oxfordmartin.ox.ac.uk/publications/climate-metrics-for-ruminant-livestock

[20] For example: Changing Markets Foundation (2023), Seeing Stars: the new metric that could allow the meat and dairy industry to avoid climate action. Available at: changingmarkets.org/portfolio/growing-the-good

2. Approach

The major focus of the work has been bringing together data from various sources in order to provide evidence to enable farmers and growers to have a better understanding of the financial impact of adopting more regenerative farming practices.

This has included the following workstreams:

(a) **Literature Review:** The Literature Review had several objectives. Firstly, to identify a credible suite of regenerative practices (Appendix 1) which are in line with the principles of regenerative farming; secondly, to identify data on the potential carbon removals impact of implementation of regenerative farming practices; thirdly, to compile data on the financial impact of adopting regenerative farming practices; and finally, to identify the range of Government support available to English farmers for the adoption of regenerative farming practices. Having a credible list of practices to focus on provides a clear focus for all involved. It is acknowledged that there may be additional practices which some feel it is essential to add to this list.

(b) **Farming practices to reduce greenhouse gas emissions:** This list was compiled from information contained within the Farm Carbon Toolkit[21].

(c) **Identification of case studies** from the Farm Carbon Calculator to illustrate the impacts on greenhouse gas emissions possible from the adoption of regenerative farming practices. We selected farms from the four main farm types - dairy, arable, lowland beef and sheep, upland beef and sheep and mixed farms and developed models based on these farms. Farms were selected on the basis of their usage of key inputs - feed, fertiliser and fuels alongside our knowledge of the regenerative farming practices in place on these farms. For all the farm models, we used GWP100 to calculate all GHG emission, although for the dairy farms we also showed how the emissions would have changed had we used GWP* instead (see box).

Within the models developed, it has not proved possible to model the financial impacts of the changes to farming practice accurately for the whole farm as many aspects of farm costs were not available, hence in a succeeding section of this document partial budgets have been constructed to provide an indication of the likely financial impact of adopting key regenerative farming practices.

(d) **Development of partial budgets** for the key regenerative farming practices identified through the literature review.

In developing the partial budgets, information from the 54th edition of the John Nix pocketbook was used to provide average technical performance together with the sale and cost prices included in the gross margin budgets. Where helpful additional information was taken from the Farm Business Survey and other sources such as RB209. Kingshay (www.kingshay.com) dairy costing data was used to inform the partial budget on increased milk production from forage. Practitioner feedback was used to supplement published research and practice data where necessary. In addition to the financial costs/savings from our practitioner data and reference sources used within the partial budgets, we have also included all possible SFI/CS payments to ensure that public support for AgE transitioning is maximised before looking for landlord support. Details of the relevant measures can be found at Appendix 2 (2023 values) to this report and within the individual partial budgets for

[21] The Farm Carbon Toolkit is a freely available resource, available at: farmcarbontoolkit.org.uk/toolkit

which they are relevant. Detailed assumptions and sources used for each practice partial budget are included within the section.

No value for or volume of additional soil carbon has been associated with any individual regenerative farming practice (where this might arise) as the quantitative evidence is often scant and hence not robust.

Where relevant; assumptions have been included and costed within the partial budgets for any change in yield arising from the practice adopted (where this is evidence for such a change occurring in practice). When such changes in yield have been included, they have been calculated from average performance information within the 54th edition of the John Nix pocketbook and with 2023 prices used.

Within some budgets, practice and cost changes may have impacts over more than one year. Where this is the case, this is indicated together with the number of years over which such costs have been spread.

Within the partial budget for holistic grazing it has been assumed that capital investment will be required for fencing materials and water troughs to enable the grazing platform to be split into daily paddocks.

This section does not seek to provide detailed partial budgets, as this would be impossible without specific information about the base farm. Instead, its purpose is to offer insights on the probable elements of cost and income that could be affected by implementation of each practice. It should serve as a starting point for more detailed budgeting for individual farm businesses.

It is clear that the volume of robust evidence on the impact of the majority of these practices is relatively low but growing, as more farmers adopt such practices and are prepared to open their farms up to scrutiny.

3. Literature Review

3.1 Identifying key regenerative practices

The regenerative farming practices listed below have been compiled from the literature review as well as internal project team workshops and represent the practices we have considered when compiling partial budgets to identify the financial impact of their adoption.

- Reduced tillage
- Introduction of Silvopasture
- Enhanced hedge management
- Introduction of herbal leys
- Replacement of monoculture ryegrass swards with grass/ clover swards
- Holistic grazing
- Maximisation of forage in dairy cow diets
- Improved use of manures and composts
- Introduction of cover cropping
- Introduction of longer crop rotations
- Retention and incorporation of crop residues
- Introduction of Agroforestry
- Intercropping/ companion cropping
- Use of living mulches
- Winter grazing of cereals

We assessed the evidence for both practical and financial impacts of a range of key farming practices which together can be considered to make up more regenerative farming systems. The recently published report - Functional Agro Biodiversity- evaluating outcomes and approaches contains the most up to date analysis of the state of the art and contains two key tables which are reproduced below. The first of which assesses the strength of the evidence for the impact of key practices which are considered to support enhanced Functional Agro Biodiversity (FAB). Looking at this list shows that the strongest evidence for the impact of these practices is on soil health (>60% practices have strong evidence for impact). By contrast less than 20% practices have any evidence for impact on crop yield. For water quality, biodiversity and control of pests and weeds more than 50% of the practices listed have strong evidence of impact.

Table 1: Strength of evidence for the impact of practices designed to improve functional agro biodiversity (FAB)

FAB measure	Geographic coverage	Pests & Weeds	Pollination	Biodiversity	Soil quality	Water quality	Yield
1.Conservation tillage techniques	Global	★ (strong)	NE	★ (intermediate)	★ (intermediate)	★ (intermediate)	★ (intermediate)
2a. Mixed crops & crop rotations	EU & US	★ (strong)	★ (intermediate)	★ (intermediate)	★ (strong)	★ (strong)	★ (intermediate)
2b. Sward diversity	EU	★ (intermediate)	★ (strong)	★ (strong)	★ (intermediate)	★ (intermediate)	★ (intermediate)
3. Cover crops inc. legumes	EU	★ (strong)	★ (intermediate)	★ (intermediate)	★ (strong)	★ (strong)	★ (intermediate)
4. Modify Manure	EU	NE	NE	NE	★ (strong)	★ (strong)	★ (strong)
5. Organic matter input	non-EU	NE	NE	★ (intermediate)	★ (strong)	NE	★ (strong)
6. Agroforestry	Global	★ (intermediate)	★ (intermediate)	★ (strong)	★ (strong)	★ (strong)	★ (intermediate)
7. Hedgerow management	UK/FR	★ (intermediate)	★ (intermediate)	★ (strong)	★ (strong)	★ (strong)	★ (weak)
8. Field margin management	EU	★ (strong)	★ (strong)	★ (strong)	★ (weak)	★ (weak)	★ (weak)
9. Reduced use of plant protection products	EU	★ (strong)	★ (strong)	★ (strong)	NE	★ (intermediate)	★ (weak)
10. Semi-natural landscape elements	Global	★ (strong)	★ (strong)	★ (strong)	★ (strong)	★ (strong)	★ (intermediate)

★ (strong) = strong evidence, ★ (intermediate) = intermediate evidence, ★ (weak) = weak evidence, NE = no evidence

Source: Functional Agro-Biodiversity: An evaluation of current approaches and outcomes- Maskell and Radbourne (2023)

The second table brings together findings from a wide range of research in recent years to identify the contributions of these farming practices to ecosystem service provision and farm management. Again what stands out is the low level of reporting of any improvements in crop yield from adopting these practices. In general the reverse has been found more commonly. Similarly conflicting findings on the impact of these practices on GHG emissions are present. However there is a clear consensus for the positive impact of the vast majority of the practices listed on pollination, biodiversity, soil and water quality alongside flood regulation. In fact all the elements of ecosystem service provision are enhanced through adoption of these practices.

Table 2: Selected measures (Designed to improved functional agro biodiversity [FAB]) and their contribution to ecosystem service provision and farm management

FAB measure	Fertiliser use	Pesticide use	Pollination	Biodiversity	Soil quality	Water quality	Flood regulation	Yield	SOC	GHG
Conservation tillage	↑	↑		↑↔	↑	↓	↑	↑↓	↑↓	↑↓
Mixed crops & crop rotations	↓	↓	↑	↑	↑	↑	↑	↑	↑↓	↑↓
Sward diversity	↓	↓	↑	↑	↑	↑	↑	↑↓	↑	↑↓
Cover crops inc. legumes	↓	↓	↑	↑	↑	↑	↑↓	↑↓	↑	↑↓
Modify manure	↓			↑↓	↑	↓	↑	↑	↑	↑↓
Organic matter input	↓			↑↓	↑↓	↓	↑	↑	↑	↑↓
Agro-forestry	↓	↑↓	↑	↑	↑	↑	↑	↑↓	↑↓	↓
Hedgerow management		↑↓	↑	↑	↑	↑	↑	↑↓	↑	↓
Field margin management		↓	↑	↑	↑	↑	↑	↑↓	↑	↓
Reduced use of plant protection products		↓	↑	↑	↑	↑		↓↔		↓
Semi-natural landscape elements	↓	↑↓	↑	↑	↑	↑	↑	↑↓	↑↓	↑↓

Source: Functional Agro-Biodiversity: An evaluation of current approaches and outcomes- Maskell and Radbourne (2023)

Table notes: GHG= GHG emissions, SOC= Soil Organic carbon, ↓=Decrease; ↔= no significant effect, ↑= Increase. The cells have been shaded green (positive effect on ES), red (negative effect on ES), orange (mixed). Presence of multiple arrows indicates good evidence for different effects, often depending on specific context.

3.2 Impacts of regenerative farming practices on soil carbon stocks

Further evidence for the potential of some regenerative farming practices to support carbon storage into soils and non crop biomass is set out in the table overleaf. The authors report on a relative scarcity of robust data for the impacts on soil carbon stocks arising from a shortened range of farming practices. In addition the table reveals the large range in results found from some practices which makes it difficult to assign any specific level of carbon removal or reduction in emissions without measurement.

Table 3: On farm measures and their carbon sequestration land use efficiency

Practice	Land efficiency tCo2e/ha/yr	Source of data	Total UK potential MtCo2e/yr	Assumptions
Paludiculture	19.0 - 39.0*	C Evans et al, 2017	2.0 - 4.1*	25% of lowland peat drained for agriculture becomes paludiculture to meet CCC targets
Halving drainage depths for arable on peat	12.7 - 18.9*	C Evans et al, 2021	5.3 - 7.9*	Drainage depth halved on all drained lowland peat
Agroforestry	4.4 - 10.0 (mainly tropical data so likely a lower range in the UK)	D Kim et al, 2016	1.8 - 4.2	Adoption at 416,700 hectares, A Thomson et al, 2018
Hedgerows	3.1 - 7.3	S Drexler et al, 2021	0.5 - 1.2	Adoption at 168,200 hectares, A Thomson et al, 2018
Organic matter incorporation from residues or amendments	-0.9 - 2.3 depending on clay content in soil	C Poeplau et al, 2015	-1.1 - 2.8	Mid - range rate, adoption at a third of arable area
No till system as part of conservation agriculture	0.3 - 0.6	S Jayarama et al, 2021	0.4 - 0.7	Mid - range rate, adoption at a third of arable area

Source - The opportunities of Agri carbon markets full report, Green Alliance 2022

Agroforestry and hedgerows are the best on-farm measures for carbon sequestration but will need management of woody biomass to sustain sequestration as the trees and hedges reach maturity. While soil carbon measures have low potential per hectare, and are limited in terms of the length of sequestration possible, they have perhaps the highest potential for adoption whilst also keeping land in food production.

3.3 Financial impact of adoption of more regenerative farming practices

Previous work to identify the financial impact of a transition to more regenerative farming systems did not have information on the range of support which is now available to farmers in England for adopting some of the regenerative farming practices identified and analysed within this report. Nor did these reports look at individual practice level, but rather focussed on a range of farming types, providing worked examples on the impact of changing farming practice across a farm . In their report Cumulus calculated that farm gate prices would need to rise by 10 -30% together with higher agri environment payments (+30%) if net farm income from more regenerative farming systems were to stay comparable with their conventional counterparts. This was due to lower average yields and stocking rates, less years in cash crops (arable farmers) and higher fixed costs.

For cereal farms without higher prices and higher agri environment payments, net farm income /ha was predicted to be around £350/ha lower than for conventional arable farming systems. For dairy farms the difference was even greater at £688/ha. For both farm types the mre regenerative farming systems show negative net farm income of around £315- £350/ha.

An interrogation of the support now available from Countryside Stewardship and Sustainable Farming

Incentive schemes in England reveals a range of support payments which have been included in the partial budgets section of this report and which are significant enough to bridge the gap identified by the Cumulus report for many of the regenerative farming practices analysed, although the majority of the higher value support now available is targeted at arable farming systems or arable reversion to grassland with ,as yet little or no support for farmers to maintain carbon already stored in soils as part of less intensive pasture based systems. Appendix 2 contains details of the relevant support measures available as of January 2024.

4. Farming practices to reduce greenhouse gas emissions

In this section, farming practice changes which are able to support reductions in the emission of greenhouse gases from farming are described. Many of these practices can also be considered as regenerative farming practices. More information can be found at the Farm Carbon Toolkit website.

Reduction in mechanical cultivations *(Regenerative farming practice)*:

- Reduces fuel usage
- Can reduce machinery required for crop production
- Can improve soil carbon storage

Reduce usage of chemical nitrogen fertilisers *(Regenerative farming practices enable reduction in reliance on chemical fertilisers):*[22]

- Utilise precision fertiliser technologies to optimise fertiliser application and timing
- Optimise nitrogen use efficiency through nutrient management planning linking application to crop requirements along with regular soil testing and suitably timed Soil Mineral Nitrogen testing
- Use fertilisers with inhibitors (urease or nitrification inhibitors) incorporated to reduce losses through slowing down the rate of ammonium nitrate conversion, reducing urea lost to the atmosphere
- Calibrate your fertiliser spreader to minimise waste through correct application rates
- Incorporate legumes and pulses into arable rotations and grassland
- Improved management of livestock manures; composting of manures/ slurries
- Incorporate cover or companion crops into crop rotations
- Grow living mulches as an understory for arable crops

Ensure machinery and equipment using power are as efficient as possible:

- Minimise idle times for all machinery
- Use technology to track performance/fuel use
- minimise cultivation depth
- Conduct regular maintenance and repairs to keep machinery operating at optimum levels
- Change equipment to the most efficient possible. If electric using green tariff electricity or home produced electric will minimise emissions
- Ensure machinery tyre pressures are optimum
- Use energy efficient lighting

[22] https://farmcarbontoolkit.org.uk/toolkit-page/taking-action/

Minimise harvest and post harvest losses:

Although it is difficult to disaggregate food loss and waste from agriculture from other parts of the production and distribution process, the Waste, Resources and Action Programme (WRAP) estimates 3.6 million tonnes of surplus and waste food from primary production per annum, representing 7.2% of all food harvested in the UK. Reducing farm level waste can improve profitability for farm businesses while decreasing negative impacts on the environment.

Choice of fuel source and machinery using these sources
https://vm-01-crm02.altido.com/clients/rase-c3c5ffc2133a3eed/uploads/documents/website-report/Decarbonising%20Farm%20Vehicles%20and%20Future%20Fuels.pdf

Reduce/ minimise soil compaction such as avoiding field work in adverse weather and adopting controlled traffic farming

- Where soil compaction occurs, remedial action increases emissions and without such action sol structure is damaged increasing emissions from soils

Changing feed sources on livestock farms *(Regenerative farming practices)*:

- [23]Growing herbal leys or grass clover leys instead of grass monocultures allows for a reduction in chemical fertiliser use.
- Reducing reliance on imported concentrate feeds such as soya bean meal and substituting with locally grown alternatives such as peas and beans.
- Improving forage quality with evidence from Scottish Agricultural Colleges (SAC) that Increasing the energy content of ensiled grass by 1 MJ/kg DM will improve feed quality and DM intakes resulting in a reduction of GHGs by approximately 6% per kg of carcass weight

Managing manures and slurries effectively:

- Keep manure stores covered
- Apply manures and slurries at the best time for nutrient uptake and crop growth. Improved equipment for slurry spreading such as trailing shoe or slurry injectors.
- Improved storage and spreading infrastructure enable application of manures/ slurries to maximise nutrient uptake by growing crops and minimise nutrient losses. There are grants available for improving slurry infrastructure, covering manure stores and to purchase equipment for spreading slurry more effectively.
- For every 10% nutrients retained in FYM and available to future crops the financial value is from £1.75 - £2.10/cow per year. This is just in the value of the nutrients compared to their cost in chemical fertilisers and takes no account of the additional benefits inherent in the manures themselves which is known from the long term Rothamsted experiment to be greater than the nutrient value of the manures alone,nor the reduced overall emissions.
- Calculate manure use against crop requirements and density of nutrients in manures/ slurries

Optimising animal health:

Keeping animals healthy reduces emissions per unit of output[24]. For example, SAC has evidence that reducing calf mortality rates by 5% will reduce GHG emissions by 10% per kg carcass weight.

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[23] https://farmcarbontoolkit.org.uk/toolkit-page/dairy-production/
[24] https://farmcarbontoolkit.org.uk/toolkit-page/beef-sheep-production/

Furthermore, optimising productivity, for example, lambs weaned per ewe, and lactations per cow, all reduce emissions per animal. Typical practices include:

- Ensuring a balanced and nutritionally appropriate diet.
- Vaccinations to prevent diseases, routine health monitoring and record keeping.
- Biosecurity measures such as maintaining proper hygiene practices and quarantining new animals.
- Comfortable housing and facilities e.g. space, ventilation, lighting, shelter.
- Following frameworks such as Five Freedoms and Integrated Pest Management (IPM).

Investment in new buildings:

The embedded carbon and energy in new buildings is significant. There are many opportunities to reduce emissions by considering the reuse of materials, the selection of sustainable materials. Energy efficient buildings (if they require heating) and incorporating renewable energy can support reduced emissions over the buildings life. Various frameworks exist to help, such as LEED for Agriculture. Where a new building is contemplated to replace a building less than 10 years old, there needs to be significant benefits in terms of reduced emissions associated with ongoing use from a new building to make such an investment worthwhile in terms of emissions.[25]

On farm energy generation:

After reducing usage and increasing efficiency, the next consideration is on farm generation to reduce reliance on fossil fuels and electricity providers.[26]

5. Impact of adopting more regenerative farming practices on GHG emissions

By drawing on the Farm Carbon Calculator database[27], we have developed models to illustrate the impacts on greenhouse gas emissions and carbon storage from the adoption of more regenerative farming practices.

Three farm types have been considered: dairy, arable and lowland livestock. For upland livestock and mixed farming systems the Farm Carbon Calculator back dataset was considered insufficient to be able to provide credible case study models. The case studies are designed to reflect industry averages in terms of input usage (e.g. feed and chemical fertiliser) and where we had information on their actual farm practices in terms of cultivations, types of grassland leys in use and crops grown, as well as presence of livestock on predominantly arable farms. To select regenerative farms to develop a case study model, we chose ones which incorporated regenerative farming practices.

The practices adopted for each farm type have been listed. The information is not a definitive illustration of these impacts, but serves as a guide for the emission reductions possible.

[25] For further information, visit: farmcarbontoolkit.org.uk/toolkit-page/new-buildings-vs-retrofit
[26] For further information, visit: farmcarbontoolkit.org.uk/toolkit-page/energy-generation
[27] The Farm Carbon Calculator database includes data from all the over 8,000 reports which have been produced using the Farm Carbon Calculator

5.1. Dairy farm model

Three dairy case studies were selected from the Farm Carbon Calculator database in order to develop models for:

- *A sustainable intensification farm*
- *A more regenerative dairy farm*
- *An organic dairy farm*

The more intensive dairy farm model has 100 dairy cows on 70ha producing 10,000 litres per cow from 3.5 tonnes concentrates and using 200 kg N /ha and producing only 2,500 litres from forage. The more regenerative dairy model has 143 cows on 100 ha producing 7,000 litres per cow from 2.24 tonnes of concentrates and using only 80 kg N/ha and producing 4,000 litres from forage. The organic dairy farm model farm is larger at 362 ha with 355 dairy cows producing 6,000 litres per cow from 1.09 tonnes concentrates and using no chemical N fertilisers and producing 4,200 litres from forage. Full details can be found at Appendix 3.

The practices adopted by the more regenerative dairy farm model and the organic model include the use of diverse swards for 50% farm area; producing more milk from forage; reduced chemical fertiliser usage; shorter housing period (-2 months) and leaving hedges to grow longer, with a similar mix of regenerative farming practices on place on the organic farm with higher volume of milk from forage and no chemical N fertilisers used. These practices are fairly typical of those being adopted by more regenerative dairy farms. These models demonstrate clearly the need for greater land area where milk from forage is to be increased with less reliance on chemical fertilisers.

Within the results table below the emissions per kilogram of fat and protein corrected milk are presented. This is the way to make milk from different farms comparable for calculations like this.

The table below shows the greenhouse gas emissions and carbon removals for each farm. It should be noted that the carbon removals do not include any data from soil analysis, only carbon removals from above ground carbon storage and any Natural England estimates for likely carbon removals into soils from Countryside Stewardship grassland prescriptions.

Table 4. GHG Balance (all three gases) using GWP100

Model system	Total farm carbon balance, t CO2e	Carbon balance per ha	Carbon balance per kg FPCM	Total Emissions/ ha t CO2e	Total Sequestration t CO2e
Sustainable intensification dairy farm	848	12	1	12.6	32
Regenerative dairy farm	821	8	1	9.92	171
Organic Dairy Farm	1,690	5	1	6.18	550

If the same calculations had been carried out using GWP* metric instead of GWP 100 and including the assumption of a steady state dairy herd size for all three models the emissions per kg of FPCM, emissions per kg milk would be around 44-60% lower.

For the first two case studies the volume of milk produced is the same (1,000,000 litres), but for the organic farm 2,111,000 litres of milk were produced. However it is interesting that the carbon balance per kg milk is practically identical for the organic and more regenerative dairy farm model and 1.2% better than for the mainstream dairy farm model despite the higher yield per cow, which is considered to reduce emissions per litre. Emissions per ha are highest for the sustainable intensification farm, due to the higher levels of feed and fertiliser used and lowest for the organic dairy farm, due to lower stocking rates, no use of artificial fertilisers and lower levels of supplementary feeding.

5.2. Arable Farm Model

For arable farms two case studies were identified from the Farm Carbon Calculator database to illustrate the impact on emissions of adoption of more regenerative farming practices.

- *Mainstream arable farm model*
- *More regenerative arable farm model*

The mainstream arable farm totals 471 ha with 418 ha in arable cropping whilst the more regenerative model has 600ha of which 400 ha is devoted to cropping with the remainder in grassland and woodland. Both farms have woodland but the more regenerative farm has a greater area of woodland which enhances carbon removals. Both farms grow barley, oilseed rape and wheat, but the more regenerative farm also grows beans and oats in addition to 150ha grassland, 100ha of which is in temporary grass and 50 ha in habitat grassland prescriptions. The grassland is occupied by 140 rearing cattle at any one time. Full farm details for each model can be found in Appendix 3 Including average yields for crops on both model farms as well as sources of carbon removals on the farm.

Overall N fertiliser usage on the more regenerative farm is around 40% lower than on the more mainstream farm. This is partly down to the inclusion of beans and temporary grass (herbal leys) in the rotation. Red diesel use on both farms is similar on a per ha basis.

The practices adopted and brought into the more regenerative arable farm model include reduced use of fossil fuel based fertilisers, Introduction of legume rich swards, introduction of livestock and reduced cultivations.

Table 5. Comparative analysis of GHG emissions, sequestration and carbon balance for arable farm models

Model system	Total farm carbon balance t CO_2e	Carbon balance per ha	Total Emissions t CO_2e per ha	Total Sequestration t CO_2e
Mainstream arable farm model	799	1.70	2.24	253
Regenerative arable farm model	752	1.25	1.70	273

The table illustrates that both farms have similar levels of total emissions despite the more regenerative farm having 140 cattle on the farm and 27% larger farm area .. The more regenerative farm model has significantly lower levels of emissions per ha (-24%). The main reason for this is that the methane generated by the cattle has been compensated for by the reduced use of fossil fuel based fertilisers on the more regenerative arable farm. Both farms have similar arable areas and relatively similar arable crop yields. In line with the lower level of emissions per ha, the more regenerative farm has a 26% lower carbon balance per ha than the more mainstream farm model.

5.3. Lowland beef and sheep farm

For lowland beef and sheep farms two case studies were identified from the Farm Carbon Calculator database to illustrate the impact on emissions of adoption of more regenerative farming practices.

- *Mainstream lowland beef and sheep farm*
- *More regenerative lowland beef and sheep farm*

For this farm type there is a significant difference in the scale of the two models developed from case studies derived from the Farm Carbon Calculator database and the more mainstream beef and sheep farm also has a significant arable enterprise too. Although not typical for all lowland beef and sheep farms, it is becoming more common, as where arable cropping is possible, this represents a more profitable enterprise for many farmers.

The more mainstream farm totals 593 ha of which 348 ha are in arable rotation with the remainder (228ha in grassland). By comparison the more regenerative lowland beef and sheep farm is all grass and totals 90 ha. Both models include beef cattle and sheep, however the stocking rate of livestock on the more mainstream model is significantly higher at around 1.9LU/ha compared to around 1 ha per LU for the more regenerative farm model. The more regenerative farm has very low use of all the main inputs, feed, fertiliser and fuel whilst the more mainstream farm has high usage, especially of red diesel.

The more regenerative farm model has adopted the following regenerative farming practices - reduced use of fertiliser, diverse legume rich swards and holistic grazing which has enabled cattle to stay out longer in the winter.

Table 6. Comparative analysis of GHG emissions, sequestration and carbon balance for lowland beef and sheep farm models

Model system	Total farm carbon balance	Carbon balance	Total Emissions	Total Sequestration	Methane as a proportion of total emissions
	t CO_2e	per ha	t CO_2e/ha	t CO_2e/ha	%
Mainstream lowland beef and sheep	1,941	3.27	3.53	0.26	51
Regenerative lowland beef and sheep	247	2.74	2.88	0.14	68

The significant difference in emissions and sequestration figures for these two models is primarily linked to the difference in farm size and production activity, with the more mainstream farm being more than five times larger than the more regenerative farm model. The emissions per ha figure for the more regenerative farm is some 18% lower than for its mainstream counterpart. This is due primarily to the very low level of inputs used on the more regenerative farm and no arable cropping and is despite the fact that stocking rates on the grazing areas are similar. The more mainstream farm includes 15ha of permanent wetlands which sequester 22.5 tonnes CO2e per year which has boosted the sequestration figure for the more mainstream farm model.

6. Partial budgets for key regenerative farming practices

6.1. Summary

Partial budgets for a range of practices have been assessed within a range of typical farm types: dairy, arable, mixed (non dairy livestock and arable), lowland livestock and upland livestock.

In all budgets, costs are calculated on an annual basis. Input and sale values reflect prices in 2023 and are drawn from reliable industry sources. For future years the actual impact will be affected by changing prices and costs.

Whilst we are finding out more every year about the impact of many regenerative farming practices which is helping to fill the information void, machinery manufacturers are also coming to market with improved equipment to enable some of the machinery linked regenerative farming practices such as reduced cultivation and intercropping/ companion cropping. These innovations are both reducing the cost (in some cases) for practice implementation and also improving the effectiveness of the practice itself.

In completing this section a number of key issues surfaced which have a significant bearing on the introduction of these practices:

1. **Capital investment required:** This is particularly the case where specialist machinery and / or equipment is required for instance for adopting minimum cultivations, intercropping and holistic grazing. For reduced cultivations the need for more specialist drills is sometimes balanced by the ability to reduce the overall machinery inventory. In addition Defra has made capital grant available for some innovative items of machinery and equipment through the Countryside Productivity Scheme, which reduces the initial capital required to adopt these practices. Other mechanisms to support access to appropriate machinery and equipment might be through machinery rings or syndicates or through third parties such as landlords underwriting the capital costs for these investments.
2. **New technical skills required:** It is clear that some practitioners have acquired the necessary skills to adopt regenerative farming practices with little or no yield penalty which increases the financial viability of their adoption. As these skills become more common the adoption of these practices should increase. However supporting wider understanding of the skills and techniques required will accelerate adoption alongside an inherently better understanding of their financial viability.
3. **Linkage of the value of regenerative farming practices to the price of farm resources and inputs:** Many of the regenerative farming practices described through this report involve a reduction in farming intensity. However this can be difficult to implement when the cost of the key resources required (especially land) is high. There is no easy answer for this challenge, but many farmers will cite their need to finance their ongoing business to their adoption of more intensive farming practices.

In the table overleaf the financial viability of each practice as derived from the partial budgets has been summarised.

Table 7. Regenerative farming practices and their financial viability, including external support where available[28]

Regenerative farming practice	Dairy	Arable	Mixed	Lowland Beef and Sheep	Upland beef and Sheep
Reduced cultivations	🟢	🟢	🟢	N/A	N/A
Introduction of herbal leys	🟢		🟢	🟢	
Introduction of clover/ grass leys for grazing or cutting	🟢		🟢	🟢	
Holistic grazing combined with extended grazing	🟢		🟢	🟢	🟢
Increased milk production from forage	🟢🟠				
Introduction of cover crops		🟠	🟠		
Enhanced hedge management	N/A	N/A	N/A	N/A	N/A
More complex and longer rotations		🟣	🟣		
Intercropping		🟢	🟢		
Retaining crop residues as soil improvers		🟣	🟣		
Use of living mulches		🟢	🟢		
Winter grazing of cereals		🟢	🟢		

Key: 🟢 positive impact on profit, 🟠 neutral impact on profit, 🟣 negative impact on profit

6.2. Reduced cultivations

The key reason to adopt minimal tillage is to improve soil health (and hence, carbon stocks) and reduce production costs. There are very limited long term studies exploring the impact of this practice on soil health, carbon removal and overall farm economics. Hence no value for permanent carbon removal has been included within the partial budget.[29] Soil type and weather have to be taken into account with the potential to potentially reduce fuel usage more on clay soils through adopting min till.

Assumptions and discussion points for the partial budget

Cultivations: Ploughing and seedbed preparation is replaced by a single pass with a combination drill type equipment. In line with common practice as described by practitioners consulted. All costs have been taken from the John Nix Pocketbook 54th Edition.

Fuel: Reductions in fuel costs are generally reported by practitioners adopting this practice, but the level of savings reported can be highly variable (15-50 litres/ha). Hence, farmer contract costs have been used as these combine fuel, machinery and labour .

Machinery requirements: In general practitioners report a reduction in machinery required when moving to reduced cultivations – for example, a reduction in the number of tractors

[28] Organic maintenance payments not included

[29] The Integrity Council for Voluntary Carbon Markets cites the need for permanence in additional soil carbon storage and the need for additional practices (outside normal farming practice) before carbon offsets can be created and monetised.

required. However this change, nor its impact, have been included within the partial budget due to the high level of variability across farms, depending on the starting point (reliance on owned versus contracted machinery). Where the required machinery inventory is reduced, this could lead to greater financial benefits than stated within the partial budget and reinforces the need for all businesses to carry out their own partial budgets based on their own unique circumstances .

Impact on crop yield: This is variable, with a range of yield changes reported. Improved technical efficiency and a better practical understanding of the practice by growers is improving crop yields where minimum tillage is practised. Many practitioners report an initial yield dip, but with yields returning to close to more normal averages within five years on transition. Within the partial budget below, a reduction of crop yield of 5% has been incorporated with a cereal price of £200/tonne[30]. Where minimum tillage is used to establish forage crops, the information on any likely yield reductions is scarce and will depend very largely upon the previous ground cover. As for cereals, a yield reduction of 5% has been incorporated into the partial budget and the use of a strip seeder in place of traditional cultivations for reseeding forage leys has been assumed. The value of forage has been assumed at £60/tonne Dry Matter.

Fertiliser use changes: No impact on fertiliser requirement has been included for this practice, although separately some arable farmers are reporting the ability to reduce usage, but based mainly on challenging past usage and improving soil health in complementary ways, such as growing cover crops. It is not clear whether it is possible to assume any level of reductions in fertiliser requirement as a direct result of moving to minimum tillage alone, although where improvements in soil organic matter levels are found, this could contribute to reductions in the requirements for chemical fertiliser.

Herbicide us changes: Typically the additional herbicide, often required to support reduced cultivation adoption is cited as a significant drawback. Combining cover crops with min till can assist in minimising the need for additional herbicides. In the partial budget below an additional pass with a herbicide is included as an additional cost.

Introduction of an SFI payment in January 2024 underpins the viability of this practice as shown in the partial budget below.

[30] https://ahdb.org.uk/Cereals-and-Oilseeds-markets-at-a-glance

Table 8. Partial budget for reduction in cultivations

	Dairy farm	Arable farm / Mixed farm
	£/ha/year	£/ha/year
Change in income		
5% reduction in yield for feed wheat and grass	(60)	(86)
SFI Payment for No till	73	73
Reduced costs		
Reduced contractor costs (this will include fuel and machinery costs) (£/ha)	110	110
Additional costs		
Herbicide (£/ha)	(28)	(28)
Herbicide spray application (farmer's cost) (£/ha)	(12)	(12)
Impact on farm profit per ha - increase(reduction)	**83**	**57**

Conclusion

Reduced cultivation is becoming a relatively low risk practice to adopt, although for some farmers the barrier has traditionally been the need for investment in new drills and the concern over the impact on crop yields. Grant aid from Defra (Farm Equipment Technology Fund - FETF) has been available for equipment to support reduced cultivation (typically around 30%) which is helpful. The concern over the capital cost is obviously affected by farm size and technology improvements are reducing any yield penalty.

6.3. Introduction of herbal leys

Assumptions and discussion points

Seed cost changes: It is assumed that the herbal ley will have a 4 year life which is the same as for the grass ley it replaces. Herbal ley seed costs are generally higher than for traditional leys. The difference in price has been depreciated over four years.

Fertiliser requirement changes: Practitioners report a significant reduction in fertiliser usage once herbal leys are established due to the presence of a higher proportion of legumes within the sward. For many, adopting herbal leys removes the need for chemical fertiliser completely.

Impact on crop yield: There is restricted information on annual forage production from herbal leys when compared with typical grass based leys. Hence I have not included any impact arising from any change in crop yield nor from a reduction in supplementary livestock feed required, although the anecdotal information for a benefit arising from the introduction of herbal leys is fairly consistent.

Changes in animal performance: There is mounting anecdotal evidence for improved liveweight gain and reduced requirement for anthelmintics. The strongest area of evidence is for the reduced requirement for intestinal parasite treatments, hence a cost reduction equivalent to one anthelmintic dose per lamb has been included in the budget.

Table 9. Partial budget for the introduction of herbal leys

	Dairy farm	**Mixed farm**	**Lowland beef and sheep farm**
	£/ha/year	**£/ha/year**	**£/ha/year**
Increased revenue			
CSS payment for growing herbal leys	382	382	382
Reduced costs			
Fertiliser (£/ha)	100	92	88
Anthelmintics (1 less treatment for lambs) (£/ha)		15	15
Increased costs			
Seed costs (£/ha)	(30)	(30)	(30)
Impact on farm profit per ha increase (reduction)	**452**	**459**	**455**

Conclusion

Growing herbal leys is becoming mainstream due to its many benefits together with support from Defra from SFI and CSS.

6.4. Introduction of clover grass leys for cutting or grazing

Assumptions and discussion points

The main difference of this practice compared to growing monocultures of perennial or Italian ryegrasses is the potential for reducing chemical fertiliser usage and the inability to use cheaper herbicides where broadleaved weed control is required. In addition, the forage produced will generally have a higher protein content and facilitate a reduction in the requirement of bought in protein feeds.

The evidence indicates that including 30% canopy cover of white clover in a ley results in similar overall production to a fertilised ryegrass ley. Any reduction in production can be compensated for by better drought resilience. Hence no reduction in production has been included in the partial budget.

Table 10. Partial budget for the introduction of clover/ grass leys

	Dairy farm	Mixed farm	Lowland beef and sheep farm
	£/ha/year	£/ha/year	£/ha/year
Increased revenue			
SFI Payment	102	102	102
Reduced costs			
Fertiliser (£/ha)	60	60	58
Increased costs			
Herbicide (£/ha)	(15)	(15)	(8)
Impact on farm profit per ha - increase(reduction)	**147**	**147**	**152**

6.5. Holistic grazing and extended grazing season

Assumptions and discussion points

The benefits for soil, biodiversity and animal health and welfare are becoming better understood.

Stocking rate: Practitioners also report that an increase in stocking rate becomes possible as a result of greater grass growth stemming from improved soil health. However no value for this has been included within the partial budget as the current evidence is restricted.

Soil health and grazing: Where soil health improves it may also be possible to reduce the housed period with cattle grazing for longer. Within the partial budget it has been assumed that cattle can graze for an additional 60 days per year. In practice weather conditions and soil type will have a significant impact on whether this is possible or not.

Table 11. Partial budget for holistic grazing combined with extended grazing

	Dairy farm	Mixed farm	Lowland beef and sheep farm	Upland Beef and sheep farm
Assumed stocking rate	**2 cows/ha**	**1.5 cows/ha**	**1.5 cows/ha**	**1 cow/ha**
	£/ha/year	**£/ha/year**	**£/ha/year**	**£/ha/year**
Reduced costs				
Anthelmintics (1 less treatment for lambs) (£/ha)		15	15	10
Reduced bedding costs	60	30	30	20
Reduced fuel costs	10	8	8	5
Labour (for bedding, feeding and cleaning out)	54	37	37	28
Increased costs				
Capital investment in fencing, water etc. (£/ha)[31]	(30)	(30)	(30)	(30)
Additional labour costs to move fences	(20)	(20)	(20)	(20)
Impact on farm profit per ha - increase (reduction)	**74**	**40**	**40**	**13**

Conclusion

For this practice to be financially rewarding without additional incentives there is a need to graze livestock for more days per year or to include a measure of improved livestock performance/ reduced feed costs.

6.6. Increasing milk production from forage

Assumptions and discussion points

Targeting increases in milk from forage is a key regenerative practice within dairying as it reduces reliance on buying-in feed grown on cropland that could be growing food for humans. There can also be benefits for animal health.

It is all but impossible to define one path and one partial budget for the financial impact of increasing milk from forage as dairy cow milk yield ranges so widely in the UK, hence we have shared data derived from dairy farm costings from the past 12 months to illustrate the impact and key features of this practice. In general, it makes financial sense to maximise milk from forage, especially when compound feed prices are high and milk price is falling. UK average milk from forage sits at around 3,000 litres, although where dairy cow diets are forage-only, milk yields of up to 5,500 litres have been seen, but only where forage quality is high enough to maximise intake and nutrient availability. The data below has been taken from Kinshgay dairy costings[32] to provide an indication of what is being achieved in the UK.

[31] Assumption of £10,000 to provide fencing and water for a 30 ha grazing platform

[32] Available at Kingshay.com

Table 12. Kingshay annual results (ranked by milk from forage)

	Top 10%	Average	Bottom 10%
Stocking rate (cows /ha)	2.06	2.35	2.51
Milk yield per cow (litres)	8,785	8,456	8,568
Milk price (p/litre)	46.45	46.18	45.59
Milk from forage per cow	4,366	2,801	1,487
Concentrate use per cow (t)	2.213	2.667	3.145
Margin over purchased feed (£/cow)	3,216	2,865	2,673

Table 11 indicates that it is possible to increase margin over purchased feed per cow where milk from forage is maximised (the table above indicates a 12% increase on average performance). It also demonstrates the link between stocking rate and milk yield from forage, with top performers having close to 22% slacker stocking rate. Conversely top performers for milk from forage are feeding nearly 30% less compound feed and achieving higher milk yields. This table also points to a possible relationship between land prices (to buy or to rent) and increasing concentrate usage for livestock.

6.7. Introduction of cover crops

Assumptions and discussion points

Available financial support: The benefits of growing cover crops can take a few years to emerge, and so it is very helpful that this practice is being supported within SFI, CSS (£129/ha) and by private sector organisations such as water companies. In general the support provided covers the cost of implementing the practice.

Cultivation: Cover crops established in the autumn by traditional means, destroyed in the spring with glyphosate or traditional cultivations and followed by normal cash crop establishment with power harrow and drill. Where reduced cultivations are employed and equipment capable of disestablishing the cover crop and drilling the next crop in one pass are used, machinery and fuel costs are reduced.

Applied Nitrogen: Practitioners report that reductions in applied chemical Nitrogen of up to 30 kg N /ha can safely be made without compromising yield. No value for this has been included within the partial budget below. Had this been included this practice would have shown a small positive impact on farm profit per ha at current N fertiliser prices.

Table 13. Partial budget for the introduction of cover crops

	Arable farm	Mixed farm
	£/ha/year	**£/ha/year**
Increased revenue		
SFI support	129	129
Increased costs		
Cover crop seeds (£/ha)	(40)	(40)
Cover crop establishment (contractor cost) (£/ha)	(64)	(64)
Cover crop destruction (£/ha)	(23)	(23)
Impact on farm profit per ha **-**increase (reduction)	**2**	**2**

Conclusion

Where support is obtained from SFI or CSS or similar, the adoption of this practice should become standard on all arable farms from a financial standpoint, with other benefits for soil health and soil carbon storage as additional benefits. Cover crop establishment and destruction costs vary depending on individual farm circumstances. For instance, crop destruction by sheep might provide an income.

6.8. Enhanced hedge management

This practice consists of supporting hedges to become taller and wider. In doing this, hedges provide a better habitat for wildlife as well as providing more food for wildlife through the year. A further benefit of enhanced management is additional carbon sequestration within the hedge. Enhanced hedges also provide better shelter for grazing livestock. Support is available within CSS to cover such activities as gapping up and hedge laying which makes this practice a sensible option to adopt. Hedge payments within CSS mean that for the first time hedges are no longer a cost. ie hedge cutting finally covered by hedge payments (even under reduced trimming regime).

6.9. Hedgerow creation

All the benefits of enhanced hedges will flow from newly created hedges once they have become properly established. Within CSS Mid Tier, a payment of £22.97/ metre is available (2023) to create new hedges.

6.10. More complex and longer rotations

Assumptions and discussion points

To accurately calculate the total impact of moving from an arable rotation of, for instance, wheat → wheat → oil seed rape, to change to wheat → oil seed rape → wheat → beans→oats → fallow (supported by SFI), it is necessary to look across the whole rotation. In this scenario an SFI funded fallow has been included rather than two years of grass/clover which would have been the alternative.

Available financial support: The SFI payment for no insecticide (£45/ha) has been included within relevant crops within the more regenerative rotation. In addition the SFI payment for an arable fallow (£593/ha) has been included for 1 year within the proposed 6 year rotation.

Changes to Cultivations: Within the more regenerative rotation it is assumed that minimum tillage has been adopted reducing crop establishment costs by around £65/ha

Changes to input costs:.Within the more regenerative rotation it is assumed that it is possible to reduce reliance on sprays and fertilisers by 10%

Benefits: The benefits of longer rotations including grass or fallow / clover and pulses/ legumes are reported by practitioners to include improved soil health, increased soil carbon sequestration, increased beneficial insect presence reducing the requirement for pesticides and reduced requirement for chemical fertilisers over the rotation. The support for a two year fallow also has benefits for blackgrass control

Where it is difficult to justify the introduction of grass into the rotation it is still possible to derive many of the benefits of more complex rotations especially where a range of rooting depths can be achieved, but the impacts on soil health and carbon sequestration are likely to be less marked without grazing livestock.

Table 14. Partial budget for more complex rotations

	Typical arable rotation	**Regenerative arable rotation**
Crops Gross Margins	GM/ha /year	GM/ha/ year (£)
1st Wheat	1,116	1,177
2nd wheat	1,038	
Oilseed rape	944	994
1st Wheat		1177
Beans		589
Oats		800
Legume fallow with SFI payment less seed costs		533
SFI payment for no insecticide		225
Total Gross margins	**3098**	**5495**
Labour, machinery and fuel costs		
Wheat	440	380
Wheat	440	380
Oilseed rape	447	447
Oats		380
Beans		330
Legume fallow		184
Total labour, machinery and fuel costs	**1,327**	**2,101**
Gross margin / ha/year	**590**	**566**

Conclusion

Without factoring reductions in cultivation and input costs(around £120/ha/year) this practice change is financially very unrewarding . Hence, it is often difficult to justify and therefore some form of external support or incentive would be beneficial, especially where no profitable use can be found for the grass/ clover fertility phase of the regenerative arable rotation. The result of adopting more complex rotations is also very dependent on the price of cereals achieved, although risk is reduced through growing a greater variety of crops. Crop storage is more complicated unless crops are sold off the combine..

6.11. Intercropping/ companion cropping

Assumptions and discussion points

Current adoption and benefits: It is estimated that currently no more than 2% EU agricultural land is used for cereal and beans or peas intercropping. However, adopting this option has a number of benefits, including increased biodiversity, improved soil health, weed suppression and a reduced requirement for chemical fertilisers and pesticides. This has been identified by practitioners and increasingly by researchers through projects such as Leguminose[33].

Fertiliser requirement: The reduced requirement for chemical fertilisers is cited up to 50% by some practitioners, however only 10% has been included in the partial budget below due to the low level of robust research evidence to date.

Pesticide reduction: There is little value in applying pesticides within an intercropping setting typically a reduction in the requirement for pesticide due to weed suppression and greater beneficial insect presence. In addition there are currently no chemicals approved for use across typical bicrops grown in the same field which currently limits uptake of this practice, unless no pesticides are used.

Yield: Up to a 20% increase in combined crop yield have been found by some studies (generally within organic settings), however an increase in overall crop yield of 5% has been included here.

Cultivation and harvesting: Increasingly as drills and harvesters become more sophisticated the issues surrounding drilling different seeds and harvest segregation are being solved making this option much more possible.

Financial support: Through the SFI there is support for intercropping/ companion cropping (£55/ha) as well as additional support for additional IPM measures aimed at reducing the reliance on chemical pest control.

[33] See www.leguminose.eu

Table 15. Partial budget for companion / intercropping

	Arable farm £/ha/year	Mixed farm £/ha/year
Increased revenue		
SFI support	55	55
Yield change	65	65
Reduced costs		
Chemical fertilisers	20	20
Pesticides	22	22
Increased costs		
Increased harvesting costs	(50)	(50)
Additional seed costs	(30)	(30)
Impact on farm profit per ha - increase (reduction)	**82**	**82**

Conclusion

This option requires support to increase growers' understanding on effective implementation as the major considerations are practical and technical concerning machinery effectiveness and knowledge on how best to implement this practice.

6.12. Retaining crop residues as soil improvers

Assumptions and discussion points

The main reason that farmers are increasingly adopting this practice is to return additional organic matter to soil, which can be especially effective where soil organic matter levels are below 5% although modest improvements take 8-10 years to become visible. AHDB estimates that the nutrient value of returning straw residues is about £45/ha (P, K, Mg). However this has to be set against the potential value of straw in the swath sales at around £136/ha.

Removing straw can result in increased compaction under adverse weather conditions leading to a requirement for remedial soil management activity. This cost saving is included within the partial budget below.

Table 16. Partial budget for retaining crop residues as soil improvers

	Arable farm	Mixed farm
	£/ha/year	£/ha/year
Increased costs		
Additional pesticides (slug control) (£/ha)	10	10
Straw chopping (£/ha)	23	23
Reduced costs		
Fertiliser reductions (£/ha)	45	45
Reduced soil remediation (resulting from straw removal) (£/ha)	25	25
Reduced sales		
Straw in swath (£/ha)	(136)	(136)
Impact on farm profit per ha - increase (reduction)	**(99)**	**(99)**

Conclusion

The main reason for straw incorporation into soil is to improve soil physical properties, including a reduction in bulk soil density and an improvement in soil health, despite the financial disincentive. The value of straw has a huge bearing on the decision to chop straw or not.

6.13. Use of living mulches

Assumptions and discussion points

Living Mulches are (semi) permanent clover understories with cereal crops established in autumn or spring. Post harvest, the living mulches can be grazed with sheep to provide an entry for the next crop.

Typically living mulches are made up of a 70:30 mix of wild white (AberAce) and medium leaf (AberHerald) white clover. The challenge with living mulches is to restrict their competitiveness of the mulch against the cash crop planted, to minimise any yield reduction, which on farm research to date estimates at up to 30%[34].

The benefit is the ability of the living mulch to fix nitrogen from the air and hence reduce the requirement for chemical nitrogen fertiliser. In addition to the benefit of nitrogen requirement reduction (estimated at around 30 kg/ha additional available N), living mulches also keep soil covered and support improved soil health[35].

[34] Innovative Farmers Field Lab information

[35] https://www.organicresearchcentre.com/wp-content/uploads/2023/01/IF_-LM_Final-report_2022.pdf

It should be possible to include the SFI payment for growing cover crops when this option is chosen.

Table 17. Partial budget for the introduction of living mulches

	Arable farm	Mixed farm
	£/ha/year	**£/ha/year**
Increased output		
Grass keep at £0.3/ewe/week for 12 weeks and 5 ewes /ha (£/ha)	18	18
Cover crop SFI payment	129	129
Reduced costs		
Fertiliser reductions (£/ha)	30	30
Reduced cultivations to establish cereal crops	110	110
Reduced sales		
Reduced cereal sales (-20%) £/ha)	(280)	(280)
Impact on farm profit per ha - increase (reduction)	**7**	**7**

Conclusion
For non-organic farmers this practice looks financially unattractive unless it is possible to include the SFI payment for growing cover crops. However research continues to find different clover varieties capable of maintaining the living mulch but providing less competition with cereal crops.

6.14. Winter grazing of cereal crops

This practice was common in the second half of the 20th century and is making a comeback as it can support greater cereal tillering[36] and reduce winter/ spring disease in cereals[37] as well as providing clean grazing for sheep in winter when grass is less available. There are no costs for this practice as in general, the sheep keeper will both manage the sheep and pay a weekly grazing fee which could be as much as £4/ha where 10 ewes / ha are applied for one week. The challenge in adopting this practice is around timing and sheep management.

No partial budget has been included as the only variables are the price achieved for the sheep keep and any reduction in fungicides which might result but is far from guaranteed.

7. Conclusions and recommendations

Practices which reduce greenhouse gas emissions

[36] Tillering is a physiological process of continuous underground branching of compact node joints of the primary shoot. Grazing of the primary cereal shoot encourages further branching to occur in cereal plants
[37] Farm Advisory Service (2023), *Sheep Grazing Winter Crop*: *What You Need To Know*. Online article. Available at: www.fas.scot/article/sheep-grazing-winter-crop-what-you-need-to-know

Alongside technical fixes to reduce emissions, such as ensuring all machinery is working as efficiently as possible, many of the recommended ways to reduce farm greenhouse gas emissions are part of the suite of more regenerative farming practices, e.g..

- Reducing the use of cultivations
- Reducing reliance on artificial fertiliser (which can only be achieved when other more regenerative farming practices are in place which support enhanced soil health and fertility)
- Changing feed sources for livestock
- Maximising use of forage for livestock feeding

Impact of regenerative farming practices on greenhouse gas emissions

Adopting regenerative farming practices generally reduces emissions per ha despite lower yields and lower livestock stocking rates.

Typical more regenerative farming practices which are being adopted include replacing fertiliser with legumes within cropping rotations or within grassland management, reducing cultivations for crop establishment, growing herbal leys, challenging received wisdom on the level of artificial fertilisers required by crops and the requirement for use of insecticides. For livestock farmers, typical regenerative farming practices being adopted include reducing the use of supplementary feeds and keeping livestock grazing longer into the autumn, alongside practices to improve soil health and structure.

Financial viability of more regenerative farming practices

Typically the adoption of more regenerative farming practices results in lower yields, lower livestock stocking rates, less risk (as the vulnerability to input costs changes is lower where less inputs are used). However, more farmers are learning how to implement more regenerative farming practices effectively which is reducing the risk of lower yields, but in general new skills are required.

The introduction of the Sustainable Farming Incentives (part of the Environmental Land Management Scheme) is providing payments which support the adoption of many of the more regenerative farming practices analysed in this report, removing the need for further financial incentives. There are however some areas where the support now available to farmers in England is still considered inadequate to incentivise adoption of more regenerative farming practices.

A good example of this is the adoption of more complex arable rotations. Adoption of this practice would result in a reduction in income of at least £24/ha/ year even with the benefit of reducing cultivations to min till levels, reducing fertiliser and pesticides used by 10% and with no loss in yield. Within the partial budget calculated, only one year in six is devoted to fertility building leys (supported by NUM3). Ideally a grass ley should be introduced for two years to provide significant benefit for soil health.

A second example is incorporating straw residues on arable land. Where straw is worth more than £46/ha this practice does not stack up financially, despite it benefitting soil health.

This suggests that there are areas where additional financial support for land managers is required to ensure that some key regenerative farming practices are adopted at scale.

Recommendations

1. More research is required to provide clearer evidence of the impact of adoption of regenerative farming practices on yield and output as this is seen as a key barrier to adoption by many farmers
2. Increased support for farmers to build the confidence, skills and knowledge required for effective adoption of regenerative farming practices
3. Institutional Landlords provide transition support to tenants undertaking a whole farm approach to the adoption of regenerative farming systems, especially where more complex and longer arable rotations are a central theme of the transition
4. Support the development of Machinery Rings or Syndicates to facilitate access to the type of equipment required to facilitate the transition to more regenerative farming systems

Appendix 1. Regenerative agricultural practices and their typical benefits

Practice	Detail	Typical benefits arising from practice (impact potential)				
		Ecosystem services	GHG emissions	Soil health	Carbon storage	Financial
Reduced tillage for grassland	Reduction in inversion cultivation in favour of reduced cultivations through e.g. strip/ slot till seeding	Maintained or improved	Reduction in fuel usage for seedbed creation	Generally improved	Increased potential for soil carbon sequestration	Neutral to minor negative impact
Agroforestry	Establishing silvopastoral or agroforestry activity on farm. This could include trees for shade/ shelter as well as the establishment of new tree based enterprises. Agroforestry can deliver considerable co-benefits if managed sustainably	(for example, enhanced biodiversity, soil fertility, water filtration and income) where a suitable additional agroforestry enterprise is chosen.	Net reduction due to the carbon sequestered into woody biomass	Evidence of improvement	Carbon storage in trees as well some potential for additional carbon storage in soils	Dependent on type of Agroforestry enterprise chosen
Enhanced hedge management	Typically this includes allowing hedges to expand both skywards and outwards, alongside improving the contiguity of hedgerows	Hedgerows can have additional benefits such as reducing soil erosion and flood risk, providing forage and shelter for livestock and wildlife, and linking habitats allowing wildlife to move across the landscape, especially if the hedge contains mature trees.	Definite reduction arising from carbon sequestration into the biomass of the hedge with values ranging between 1 -2.9 tonnes per km hedge (depending on details of hedge management)	It is often cited that soil health is at its optimum within hedge boundaries as soil has not been disturbed and can develop the optimum micro fauna	Soils under hedgerows store a significant amount of carbon (average of 31% more than in adjacent grass fields and up to 57% more for hedges more than 37 years old). Maintaining existing hedgerows is key to maintaining existing carbon stores.	Reduced cropped area plus field operations more difficult where fields are small. Benefits can include shade and shelter for livestock, increasingly financially valuable and for cropping their value in reducing the movement of soil and in preventing erosion have an increasing financial value.
Hedgerow planting	Creating new hedgerows to support grater landscape connectivity	Over time this will provide the same benefits as for hedgerow management above and contribute to IPCC targets of an increase of	As above	As above	As above	As above

Practice	Detail	Typical benefits arising from practice (impact potential)				
		Ecosystem services	GHG emissions	Soil health	Carbon storage	Financial
		40% in UK hedgerow length				
Introduction of herbal leys	Replacement of more mono cultural grass swards with herbal leys which typically include a range of herbs, grasses and legumes	Improved soil and above ground biodiversity; improved flood and drought resilience	No evidence in either direction and will vary depending on the overall system the herbal ley is operated within	Improved soil structure and ability to reduce reliance on artificial fertilisers brings soil health benefits	Increased carbon storage in soils at depths below 10cm	Generally positive and certainly positive where Government support for this practice is taken up
Replacement of monoculture ryegrass swards with grass/ clover swards	Replacement of more mono cultural grass swards with white/ red clover grass swards with greater grass species diversity	Enhanced drought tolerance compared to ryegrass swards	No evidence in either direction and will vary depending on the overall system the herbal ley is operated within	Reduced requirement for chemical fertilisers leads to soil health benefits	Increased carbon storage in soils at depths below 10cm	Neutral to positive, when Government support is taken up. More profitable when fertiliser prices are high
Holistic grazing	Animals move from paddock to paddock mirroring natural herding behaviour. Longer rest periods (30-42 days plus) between grazing, allowing pastures to become much higher with deeper roots followed by intensive grazing at high stocking rates for short periods.	Enhanced below and above ground biodiversity alongside enhanced soil and water quality	Reduced reliance on artificial fertilisers reduces overall emissions from grassland managed in this way compared to more mainstream practices	Can lead to improved soil structure due to promotion of deeper rooting of sward plants	Some evidence for increased carbon sequestration into soils compared to intensive grazing practices	There is a financial benefit where holistic grazing practices are coupled with shorter housed periods for cattle
Maximisation of forage in dairy cow diets	Targetting 4,500 - 5,000 litres from forage rather than the average current UK position of around 3,200 litres	Benefits for ecosystem services on farm will depend upon the detail of the farming system supported	Reductions from the reduced reliance on supplementary feeds, but increases from the generally larger area of land required per cow within UK systems	Any soil health improvements will depend upon how the grassland area is managed. However through reducing the area of cereals required per cow this could have positive impacts on soil health where soil organic matter losses from cultivation are	The benefit could be in reducing carbon losses from previously arable land	There is no one answer regarding the financial impact of maximising forage fed to dairy cows as the financial impact will depend on technical performance and relative prices of inputs and outputs

Practice	Detail	Typical benefits arising from practice (impact potential)				
		Ecosystem services	GHG emissions	Soil health	Carbon storage	Financial
				minimised.		
Introduction of cover cropping	Overwinter cover crops or catch crops before autumn planting can be grown The aim is to keep soils covered for as much of the year as possible. Crops can be destroyed by chemical or mechanical means often followed by direct drilling of the following cash crop	Enhanced above and below ground biodiversity, improved soil and water quality and supporting drought and flood regulation	Reduces emissions from soil as a result of keeping soil covered	Soil health is improved though keeping soil covered for more months during the year and from the presence of living roots in the soil supporting soil microfauna and soil structure	Increases carbon sequestration	When this practice is supported with Government or private sector funding it can be financially positive
Reduced tillage	Minimum tillage, non-inversion tillage, and reduced tillage are all terms which refer to cultivation techniques that do not include deep inversion ploughing.	Improved soil structure and water retention capacity which prevents soil erosion and promotes soil biological activity.	Reduced emissions associated with the reduction in fuel required for this practice	Soil microbiota are less disturbed which leads to enhanced below the surface soil life and improved soil health	Increases carbon sequestration in soil (especially in the upper volumes of soil)	Neutral to positive financial impact depending upon effect on crop yield
Introducing longer crop rotations	Introduce greater diversity within the crop rotation, including pulses/ legumes and fertility building grass leys. Move away from rotations such as wheat/ wheat/ oilseed rape	Enhanced soil health and generally improvements in above and below ground biodiversity plus improvements in water quality and flood mitigation.	Reduced requirement for artificial fertilisers leads to reductions in emissions.	Improvements stemming from the reduction in reliance on artificial fertilisers and the greater diversity of plants at any one time supporting more insect life.	Mixed evidence for any impact on carbon storage, which will depend primarily on how the crops themselves are grown.	No evidence for any positive financial impact from this practice
Retention of crop residues	This is essentially leaving crop residues on land after the main crop has been harvested	Reduces soil erosion; contributes nutrients to the soil and enhances water retention capacity	Small reduction due to no fuel being required to bale and cart straw from the field	Improves soil structure and reduces the potential for soil compaction on straw removal	Enhances carbon storage	Generally financially negative unless the straw has no sale value
Intercropping/ companion cropping	Popular UK intercropping might consist of peas/beans and cereals, often oats. Companion cropping involves growing another crop alongside the main cash crop.	Enhanced presence of pollinators increases above ground biodiversity. Below ground soil quality improved from	Reduced emissions where this practice enables a reduction in artificial fertiliser usage and greater pest and disease resilience allows	Improved soil health resulting from the range of rooting depths and reduced reliance on artificial fertilisers and pesticides resulting from	Potential to increase soil carbon storage through presence of a range of rooting depths	Intercropping can increase the overall yield from a given area due to the ability of the legume to fix nitrogen and for the cereal to provide a

Practice	Detail	Typical benefits arising from practice (impact potential)				
		Ecosystem services	GHG emissions	Soil health	Carbon storage	Financial
		presence of different rooting depths	for a reduction in pesticide usage.	this practice		structure for the pulse to grow up. Given the Government support currently available, this practice can be financially rewarding
Use of living mulches	Growing a permanent understory of white clover (generally) under arable crops. After harvest the clover can be grazed prior to drilling the next year's crop	Enhanced soil quality with greater below ground diversity and potential to improve water quality and flood regulation	Emissions reduced as a result of keeping soils covered and potentially from any reduction in artificial fertilisers achieved from nitrogen fixation	Improved soil health arising from keeping living roots in the soil all year and providing greater diversity and complexity for soil microbiota	Keeping soils covered allows for additional carbon storage	Generally financially unrewarding due to the current level of yield reductions sustained
Winter grazing of cereals	Use of livestock (normally sheep) to intensively graze cereal crops through the winter	Enhanced crop tillering; reduced requirement for fungicides due to reduced crop canopy to be affected by fungal infections; additional clean grazing for livestock	Potential for reduced emissions where artificial fertiliser use is reduced as a result of sheep grazing	Potential for improved soil health arising from sheep grazing and reduced use of artificial fertilisers	No impact	Small financial benefit

Appendix 2: Support available for regenerative farm practices through the Sustainable Farming Incentive Scheme in England

The table below lists SFI options which relate to the regenerative farming practices at section 2 of this report (*Payment rates accurate as of March 2024*)

Option code	Option	Payment rate from 1 Jan 2023 (annual)	Regenerative practice this support links to	Management requirements
HRW2	Management of hedgerows	£13/ 100 Metres	Enhanced hedge management	Cut no more than 1 year in 3 Hedges must be maintained at 2 m high and 1.5 m wide
SAM3	Herbal leys	£382/ha	Introduction of herbal leys	Establish and maintain a mixed grass, legume, herb and wildflower sward Mange the sward by cutting and grazing
GS6	Management of species rich grasslands	£646/ha	Holistic grazing	Land must be mapped as a priority habitat - prerequisite
IPM2	4-6 m buffer strip on cultivated land	£798//ha	Pollinator strips	On the edges of cultivated fields between crop and feature such as a hedge
SAM2	Winter cover crops	£129/ha	Introduction of cover crops	For cultivated land vulnerable to leaching
NUM2	Establish and maintain legumes on improved grassland	£102/ha	Protects soil surface, manage nutrient efficiency, supports soil structure, minimises nutrient leaching and supports IPM	Ensuring that legumes are growing within improved grassland from spring till early autumn
NUM3	Legume fallow	£593/ha	This action's aim is that there's a legume fallow that produces areas of flowering plants from late spring and during the summer months	This action can be applied for annually
IPM3	Companion crops on arable and horticultural land	£55/ha	Reducing use of pesticides	See SFI Guidance
IPM4:	No use of insecticide on arable crops and permanent crops	£45/ha	Reducing use of pesticides	See SFI Guidance
AHL4	4-12 m grass buffer strip on arable/ horticultural land	£515/ha	Reducing the use of pesticides	grass, legume, herb and wildflower sward Mange the sward by cutting and grazing

Appendix 3: Model farm details for GHG comparisons

Dairy Farm models

	Sustainable intensification dairy farm	More regenerative dairy farm	Organic dairy farm
Farm Size (Ha)	100	100	362
Dairy Cows (No)	100	143	355
Weight of cow (Kg)	600	550	550
Milk Yield (litres /cow)	10,000	7,000	6,000
Milk from forage (litres)	2,500	4,000	4,200
Number of grazing days / year	150	215	210
Concentrates per cow (tonnes)	3.5	2.24	1.09
Artificial Nitrogen usage per Ha (Kg)	200	80	0
Carbon sequestration assumptions			
Hedges (Km)	20	20	None recorded
In field trees	30	100	
Habitat grassland (ha)	50	36	
Diverse legume rich swards (ha)		36	
Regenerative practices		Use of diverse swards for 50% area	Use of grass clover leys
		Reduced fertiliser use	No artificial fertiliser use
		Shorter housing period (-2 months)	Shorter housing period (-2 months)
		5 km hedges left to grow longer	

Arable farm models

	Mainstream arable farm	More regenerative arable farm
Farm area (ha)	471	600
Cropped area (ha)	418	400
Grassland area (ha)	43	150
Other land use (ha)	10 (woodland)	50 (woodland)
Cattle (No.)		140
Barley yield (T/ha)	7.3	7
Wheat yield (T/ha)	10	8.6
Oats yield (T/ha)	6.2	
Bean yield (T/ha)		3.9
OIl seed rape yield (T/ha)	3.7	3.5
Artificial N fertilisers used (Tonnes)	325	208
Red diesel used (litres/ha)	71.64	69
Carbon sequestration assumptions		
Hedges (Km)	13	20
In field trees		
Habitat grassland (ha)	43	50
Diverse legume rich swards (ha)		
Broadleaf woodland (ha)	10	50
Uncultivated field margins (km)	13	
Permanent wetland (ha)		5
Regenerative practices		
		Reduced use of fossil fuel based fertilisers
		Introduction of legume rich swards
		Introduction of livestock
		Reduced cultivations

Lowland beef and sheep farm models

	Mainstream lowland beef and sheep farm	More regenerative lowland beef and sheep farm
Farm area (ha)	593	90
Grassland area (ha)	228	89
Cropped area (ha)	348	0
Other land use (ha)	17	0
Beef cattle (No.) - on average through the year	420	62
Breeding ewes (No.)	800	200
Livestock feed purchased (Tonnes)	60	9
Nitrogen fertiliser purchase (Tonnes)	214	7
Red diesel used (litres/ha)	142	37
Carbon sequestration assumptions		
Permanent wetland (ha)	15	
Hedges (Km)	12	7
Broadleaf woodland (ha)	2	1
Grass margins (ha)	10	
Regenerative practices		
		Reduced use of fertiliser
		Diverse legume rich swards
		Holistic grazing