The Economics of a Transition to Agroecological Farm Businesses

Report for

Soil Association

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Cumulus

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1 Executive Summary

The report provides definition and analysis of UK agroecological farm businesses. This is based on in-depth literature review, case study development, and economic modelling. This research is drawn together to provide farm level recommendations and business strategies for transitioning to agroecology, and policy level recommendations for encouraging and supporting this transition.

The findings show that the continued profitability of most UK farm types is at risk and vulnerable to changes in policy support and markets. However, if policy and market support can be enhanced to effectively reward land managers for the ecosystem services they provide, agroecology holds huge potential for the future of UK agriculture. Public health, carbon storage, biodiversity, flood regulation, food security and rural economies can all benefit from a transition to agroecological farming.

1.1 Agroecological farm type definitions

The report suggests how each of the main UK farm types could plausibly be restructured to effectively integrate agroecological approaches.

Generally this involves increasing the diversity of what is farmed across all scales of agriculture. Livestock are increasingly integrated into crop rotations to improve soil health and fertility. More permanent soil cover and greater crop diversity is established across farms, such as by planting mixed cover crops or maintaining species rich swards. Interconnected corridors of floristic margins are integrated around and within fields to improve species richness and support populations of beneficial organisms. Various forms of agroforestry are established within the agroecological farms to diversify incomes, increase productivity resilience, and sequester carbon.

All these management changes support agroecological farming that is not reliant on synthetic inputs, but instead utilises nature-based systems to enhance fertility and suppress pests and diseases. These are farm types focused less on yield maximisation and more on profit optimisation, cost reduction and improved long-term resilience.

1.2 The case studies

The impressive work being undertaken by the agroecological farmers who kindly provided the data and insights for this report demonstrate the potential of agroecology and the on-going challenges.

The farmers revealed that agroecology can be an effective strategy for improving economic performance. However, this requires a mindset shift. Farm businesses need to focus on gross margins and input costs rather than on increasing outputs. Agroecology reduces dependence on intensive approaches and expensive inputs, improving business performance. Complete and immediate removal of synthetic input use is not essential for agroecological transition but considered reduction and replacement with nature based solutions such as IPM and fertility building swards is paramount.

Moreover, these approaches can have direct benefits for the wellbeing and job satisfaction of farmers. Reducing the number of hours spent tilling, spraying, processing feed, and reseeding and fertilising pasture can greatly improve the lifestyles of farmers. Similarly, the satisfaction farmers receive as biodiversity returns to their farms, animal welfare improves, disease prevalence reduces, and connection to local supply chains strengthens, should not be undervalued by a purely economic analysis of agroecology.

Beyond the farm level, agroecology plays an important role in the UK food system and rural communities. It draws people onto farms, it creates diverse and meaningful jobs, it provides local sources of nutritious food, and it encourages awareness of food and nature not as a commodity, but as something that is intrinsically connected to the natural world and the services it provides us with.

The diversity of certain farming enterprises, commercial sensitivity of economic data, and limited time available to land mangers meant we were unable to produce a case study for agroecological horticultural production. The difficulty gathering agroecological performance data from farms highlights the need for more reliable, consistent, open, and less commercially sensitive ways for agroecological farmers to share data that can help enhance learning from and application of agroecological approaches. We are very grateful for all those who shared information for the development of case studies.

1.3 The modelling

Current policy and conventional markets provide inadequate support for agroecological farming, and most conventional farm types, to be profitable. Incorporating even conservative projections of future trends in agri-environment support and performance of agroecological farms is enough to change this. These projections mean agroecologically managed cereal, horticulture, dairy, lowland grazing and LFA grazing farms all generate positive net incomes. Cereal, lowland grazing and LFA grazing farms all generate higher net incomes than the conventional analogues.

Although outputs tend to be lower on the modelled agroecological farms, the lower variable costs along with the greater capacity to access agri-environment payments and marginally higher value retained at the farm gate enable the above agroecological farm types to improve profitability.

Based on the modelling in this report, it remains challenging to manage agroecological horticulture, dairy farming, and mixed farming profitably when selling at conventional farm gate pricing. High fixed costs pose a particular barrier. Innovative solutions are necessary to reduce these costs. Continued research is needed to explore these challenges in greater depth and to define solutions for overcoming these barriers.

1.4 Key farm business recommendations

Agroecological approaches can offer direct economic benefits to farmers by decreasing their reliance on costly inputs, enhancing production resilience, and improving access to current and future payments for ecosystem services.

Agroecological farmers need to collaborate to increase the benefits they can provide to each other's enterprises whilst pooling costs and improving access to conventional and environmental markets.

Increased data collection and sharing is needed to inform agroecological management decisions, to communicate and validate the benefits of agroecology, and to improve access to environmental markets.

1.5 Key policy insights

Policy support is often necessary to ensure farm profitability; without Basic Payment Scheme (BPS) many farms would fail to generate adequate income to support farmers. Structuring policy to support a transition to agroecological farming offers a way to produce resilient, nutritious food, whilst simultaneously providing good return on investment through the provision of public goods.

Policy support for agroecology will be better value for money if it provides funding for systemic change. For example, agroforestry will become more widely established if schemes effectively facilitate private investment and if services, advice, and markets for agroforestry are also supported. Increasing systemic support will help increase potential farm profitability, meaning less support will be required to incentivise uptake of agroecological approaches, such as agroforestry. Investment in collaboration, dynamic procurement, landscape level intervention, and supply chain development will all enable a more productive, resilient, and sustainable food system to develop.

1.6 What it means for UK agroecology

Mainstream and large-scale transition to agroecology in the UK will only happen if policy and markets are appropriately structured to support increased farm and landscape level diversity. Plausible policy and market changes are enough to make agroecological management of large percentages of UK farming profitable.

Challenges to agroecological transition remain. To tackle them innovative collaborative agreements between farmers, management and technical innovation, and changes to supply chain structure will be necessary. This will help reduce the impact of fixed costs on certain agroecological farms and narrow the gap between agroecological and conventional outputs.

If this can be achieved, it is possible to imagine a future where agroecological UK farming enables resilient production of diverse nutrient rich food that integrates biodiversity, carbon sequestration, flood regulation, and a wealth of other ecosystem services into the agricultural landscape. Collaboration and data collection will be necessary to enable farmers to access payments for ecosystem services across the landscapes they manage. Improved localised and interconnected supply chains will provide certain agroecological farmers with the higher farm gate prices they need to sustain profitability whilst simultaneously supporting vibrant rural communities and job creation.

This report provides analysis and recommendations for how this future transition to UK agroecological farming can be supported.

1.7 Acknowledgements

The team at Cumulus Consultants would like to thank all those who provided their time and knowledge to this project.

We want to thank all the farmers and crofters who offered their knowledge, time and shared their work with us to enable the case study development. It is the ongoing work, innovation, bold thinking, and voices of land managers like these that is paving the way for others to follow.

We are grateful to all the Soil Association team and experts that participated in the steering group sessions. Their insights and knowledge of UK farming and agroecology provided the foundation for this work and tested and validated the definitions and findings we produced. The time they gave was invaluable to the process.

Finally, we want to thank the Soil Association for commissioning the work. It is an important piece of research and an ongoing discussion that Cumulus Consultants are proud to be part of.

1.8 Suggested citation for this report

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2 Introduction

2.1 Background to the work

Agroecology is a discipline with potential to support productive food systems that simultaneously reduce input use and emissions and enhance food systems equity. There is increasing recognition of the potential agroecology holds for restructuring the UK food system.

The Soil Association has instigated several projects investigating the role agroecology could play in the UK. This has built on the work undertaken by L'Institut du development durable et des relations internationales (IDDRI) exploring the impacts of a ten-year transition to agroecology across Europe and how that would transform the types of food produced and the economics of the food system. Subsequently, the Soil Association has undertaken projects modelling the macro-economic impact of a transition to agroecology across the UK, as well as work investigating the role specific aspects, such as agroforestry, will have upon agroecological transition.

This project is the logical progression of this work and refocuses the lens at the farm level to improve the understanding of how land managers across the UK can profitably shift to agroecological farming approaches and what strategies and policies will be necessary to support this. This more granular and practical assessment draws out a narrative and recommendations that policy makers can review to build a clear understanding of how their decisions can support a profitable, highly integrated, and sustainable shift in the UK's food system.

But why is this work necessary? Unlike more specialised, intensive, or monocultural systems; agroecological farming approaches utilise species, management, spatial and temporal diversity to maintain resilience, productivity, and sustainability. This diversity, amongst other factors, has meant that validation and quantification of the benefits of agroecological approaches has often been complex and, hence, neglected. Whilst there is a growing body of research that validates the multitude of benefits agroecology provides, this is often theoretical or academic. There is a lack of practical farm level examples that illustrate the profitability of agroecological farming, as well as the economic impact of transitioning to agroecological farming. Therefore, practitioners frequently lack the evidence and information to develop clear, reliable, actionable strategies for shifting to agroecological management.

The lack of well validated and communicated examples has often led to the assumption that agroecology can be unproductive and struggle to sustain economic viability. However, studies have shown that agroecological methods such as organic agriculture, especially when diverse, complementary varieties are layered into well-designed systems, can reach yields comparable to or, in certain contexts, greater than conventional production systems and with lower economic, environmental, and social costs (Ponisio et al., 2015; Pretty, 2006).

This means agroecological farming has the potential to enhance the integrated sustainability of agriculture in the UK. Furthermore, the economic sustainability can be enhanced by the suite of private and public payments for ecosystem services that are emerging.

2.2 What we mean by agroecology

Agroecology is a term that means different things to different communities. This has led to broad definitions such as those provided by Francis et al. (2003) who define agroecology as "the integrative study of the ecology of the entire food systems, encompassing ecological, economic and social dimensions". Whilst definitions such as this importantly highlight how society is an inextricable part of agroecosystems, we take a more focused and actionable definition for the purpose of this report.

We use Gliessman's (2007) definition of agroecology: "the science of applying ecological concepts and principles to the design and management of sustainable food systems." This is not to devalue the social or economic aspects of sustainable food systems, which are essential. It merely provides us with a more clearly defined and less subjective definition that we can use to define the agroecological farm businesses that we will analyse in this report.

Our analysis then allows us to consider the economic component of agroecology by modelling the profitability of the agroecological farms. The social element, although not an explicit focus of this report, is highlighted throughout. Particularly within the case studies where the land managers repeatedly evidence the role agroecology plays in supporting rural communities, enhancing farmer wellbeing, and supplying public goods.

Given the sparsity of data and research on agroecology, at times throughout the report we use research and data related to organic farming enterprises and approaches as representative of agroecological approaches. This reflects that the organic sector and research into organic farming provides the greatest amount of data and the most widespread and long term applications of agroecological approaches.

2.3 Project aims

This project intends to tackle the knowledge gap related to the profitability and performance of agroecological farming approaches compared to 'conventional' farming. It provides insights into how agroecological approaches, private and public payments for ecosystem services, and business diversification can be stacked to enhance the economic performance of agroecological farming at the farm level. This is achieved by collating evidence, undertaking economic modelling, and presenting case studies on the application of agroecology to the main UK farm types. This project also provides recommendations for how policy should be structured to effectively support and incentivise agroecology in the UK.

The aims of the work are to:

- Present evidence to national governments and other policy influencers about the potential impacts of agroecology upon the economic performance of UK farms.
- Provide recommendations for how policy can support farmers transition from conventional to agroecological farming systems including stacking public money for public goods alongside other strategies for business viability.
- Provide farmers with well-validated case studies demonstrating the implementation and impacts of agroecological farming practices and how financial strategies can be structured to enable and reward a transition to more agroecological and resilient farming systems.
- Illustrate a range of farm business strategies that would underpin a transition to viable agroecological farm businesses, maximising public goods and minimising negative externalities, while ensuring sufficient production for a healthy, sustainable, and widely affordable diet.
- Model the economic performance of agroecological farming for the different farm types across the UK and contrast these scenarios around agroecological whole farm business transition with a "business as usual" approach, in order to demonstrate the counter-factual risks.

2.4 Approach

The major focus of the project has been constructing the agroecological farm types and modelling and comparing agroecological performance and profitability to average conventional analogous farm types. The construction and modelling of these farm types has been built on four interrelated workstreams:

- **Literature review:** an extensive literature review was undertaken to gather information about agroecological management of the core UK farm types. The focus

"***FarmType***"AND"***ManagementTerm***"AND("agroecolog*"OR"organic")AND("economic" OR"profit"OR"yield"OR"productivity")AND"UnitedKingdom"OR"England"OR"Scotland"OR "Wales"OR"Ireland" was on gathering quantitative information about the impact of agroecological approaches upon farm performance and profitability. A Boolean search methodology was used, and the search was structured as shown in the box below. The bold italicised text was interchanged depending on the farm types and type of management being reviewed. All literature was reviewed. A snowball method was then used to explore additional literature of interested referenced within the initial papers. This ensured a wide proportion of the relevant literature was reviewed for the project. This literature review enabled the definition of the initial agroecological farm types.

- **Steering group discussion and review:** throughout the project an internal panel of experts from the Soil Association were consulted and worked closely with Cumulus to review and refine the agroecological farm type definitions.
- **Case study development:** in parallel to the literature review and with support from the steering group a selection of farmers and crofters implementing agroecological approaches were identified. A selection of these land managers was chosen as case studies representing the agroecological farm types being defined.

The aim of this work was to validate the various data sources and research that supported the modelling with on the ground insights and data from farmers practices agroecological farming. This allowed us to refine and validate the crop rotations, yield estimates and costs that were incorporated in the model. Furthermore, it allowed us to explore the non-economic benefits that agroecology provides to famers, local communities, consumers, and wider society.

Despite efforts to find representative case studies for each of the farm types, management diversity, commercial sensitivity of economic data, and limited time available to land mangers meant we were unable to produce case studies for all farm types within the project timeframe. These issues were particularly relevant to horticulture. This is why we were unable to develop a representative case study for this farm type.

The difficulty gathering agroecological performance data from farms highlights the need for more reliable, consistent, open, and less commercially sensitive ways for agroecological farmers to share data that can help enhance learning from and application of agroecological approaches. We are very grateful for all those who shared information for the development of case studies.

Standardised questionnaires were sent to the chosen farmers and crofters to gather qualitative and quantitative data related to the management, productivity, and profitability of the farms and crofts. Questionnaires were then followed up with a site visit and interview, to gain a more in-depth understanding of the methods implemented and the costs and benefits.

Information from the case studies was used to further refine agroecological farm type definitions; validate the performance modelled; and identify the opportunities and barriers that agroecological farmers face.

- **Economic analysis/modelling:** information gathered from all the work streams was used to refine the definitions of the agroecological farm types, including information on how they are managed, which crops and livestock are produced, how productive the different enterprises are, and the key costs.

  Information from the Organic Farm Management Handbook was then used as the foundation for the performance of each of the enterprises the agroecological farm types were comprised of. Where the defined agroecological farms deviated from standard organic performance the modelled data was adjusted accordingly. The evidence for all these assumptions is included within this report and within the report Annex.

  Each of these agroecological farm types is compared against an analogous conventional farm type. Farm Business Survey (FBS) Data was used to construct these conventional analogues. The conventional farm types were defined based on the standard FBS farm type definitions. The composition of the conventional farm types reflects the proportion of the surveyed farms that is dedicated to different land uses, this includes agricultural land uses, such as cereals, horticulture and pasture; and non-agricultural land uses, such as hedgerows and woodlands. The data corresponding to each of these farm types was used to construct the performance of the average conventional farm types. Budgetary data from ABC and Nix was used to support the economic analysis of the enterprises.

  To explore the performance of agroecological farms and what is required to support a viable agroecological transition, we built certain variables into the model. To analyse the performance of the agroecological farm types we first provide a comparison of how the agroecological farms performs compared to the conventional with all variables set at a baseline level. We define this baseline as agri-environment payment rates set at recently recorded rates (2020); average conventional farm gate pricing for all agricultural outputs (no organic premiums); fixed costs for the agroecological farm based on average organic fixed costs and conventional fixed costs based on FBS data; and nitrogen fertiliser priced at the average level for the last 5 years.

  Our choice to exclude organic premiums is not a critique of organic pricing. Many organic farmers provide excellent examples of agroecological farm management and organic premiums have been necessary for them to operate profitably. Premiums enable organic farmers to cover the additional costs of maintaining farms that often provide higher levels of more diverse ecosystem services than conventional or more intensive farms. We exclude these premiums though to explore how agroecological farms, markets and policies need to be restructured to cover these greater costs without substantially increasing the price of food for the consumer compared to conventionally priced food. This allows us to explore how agroecological food, and therefore much of organic too, can be made more accessible for consumers, and more widely viable for farmers to produce.

For each of the farm types, the average holding area from across the UK was calculated and the economic modelling was based on these average farm areas. Clearly, modelling these average areas will not be representative of all farms and results for significantly smaller or larger farm businesses will differ. Exploration of scale variation and the impact it has on economic performance, however, was beyond the scope of this report. It does warrant future investigation though, particularly in relation to how it affects the relative impact of fixed costs. Policy payments were based on the average environmental payment rates provided to the different farm types. Data from Moakes et al. (2015) was used to estimate the difference in payment rate between the conventional and organic systems.

We then go on to assess how each agroecological farm type performs compared to the conventional counterpart when we vary the performance based on a defined custom scenario. This custom scenario projects how certain variables are likely to change over the next five years, and how this impacts the performance of the farm types.

Within the custom scenarios, the variables farm gate price and fixed costs are set differently for each farm type. They are set depending on the associated performance, management and markets. When varying farm gate price we apply a percentage increase to the farm gate price attained by the agroecological farm and not the conventional. This reflects the increased demand, value, quality, and access to local markets associated with agroecological production.

Work by SYSTEMIQ for the National Food Strategy (2021) suggested that agroecological production increased the retail cost of plant-based products by 1% to 3%; and the cost of animal-based products by 1% to 48%. These cost increases are lower than the reported hidden cost of carbon from conventional production; 2% to 13% for plant-based products and 5% to 145% for animal-based products. In this report, we show that agroecology has the potential to reduce this hidden externality substantially. Hence, the increases to farm gate pricing we include in the custom scenario (ranging from 10% to 30%) can be thought of as a way for farmers and the market to reflect the cost of providing this benefit.

The cost need not be borne by the consumer as it is a societal benefit, though currently it generally is passed on in that way. Offsetting schemes, preferential procurement to meet net zero, more direct routes to market, on farm processing, and a range of other schemes could all provide this increased income to agroecological farmers. These approaches can help to meet and stimulate current and future market demand for food demonstrating reduced environmental footprints or environmental net gain.

For all custom scenarios we set the remaining custom variables at the same level across all farm types. We assume agricultural policy support will increase across the UK to pay farmers to enhance and diversify ecosystem service provision from their farming. The scale of this increased payment across the devolved nations of the UK is uncertain. A reallocation of all BPS payments into agri-environment payments would lead to a considerable increase in the income farmers can generate from agri-environment payments, but without understanding how the payment options will be structured it is difficult to model the costs and incomes associated with accessing this future funding. England has pledged and implemented a 30% increase to agri-environment payment rates (Case, 2022). This is the only defined payment increase provided by a UK government. We view it as the minimum threshold for the increased payments that will be made available to UK farmers and hence take it as a conservative and reasonable estimate of near-term payment increases and apply it to all custom scenarios.

When varying nitrogen fertiliser pricing in the custom scenarios for all farm types, we assume a 50% increase from historic rates. In fact, early in 2022, nitrogen fertiliser pricing increased by 200% due to the Russian invasion of Ukraine (Butler, 2022). In July 2022, AHDB reported nitrogen fertilisers more than 150% higher than the previous year (AHDB, 2022). These prices will not be sustained, but they are emblematic of the vulnerability of input supply chains. Increased geo-political stress, some of it climate induced; increasingly stringent environmental policy; and carbon taxation will likely increase fertiliser costs in the coming years. Hence, to represent this, we model a 50% increase to nitrogen fertiliser pricing across all the custom scenarios.

Carbon sequestration rates were included in the model to estimate the payment for carbon sequestration that could be accessible to the farms in the future. Rates of carbon sequestration for the different land uses was based on several research papers referenced within the model.

The approach outlined above provided the foundation for the modelling that generated the results outlined in this report. The full model and findings are available upon request from the Soil Association.

2.5 Report structure

The main body of this report is divided into **Sections 3 to 8**. These sections cover the main UK farm types. Each section focuses on one farm type and is structured as follows:

- Each section starts with an infographic summary. This covers how the agroecological version of the farm type is structured, including a description of the rotations, yields, and key management practices. It also provides an overview of how the agroecological farm performs economically compared to the average conventional version of that farm type in the UK.

- Next each section describes in greater detail the components of the agroecological farm type, how they are managed and their impacts. This description is backed up by evidence from peer-reviewed literature, FBS data, and case studies developed for this report. We also provide the evidence behind the performance figures we have selected for the agroecological farm type including costs, yields and stocking rates.
- Each section then presents a more in-depth analysis of the modelled performance of each farm type. Here we analyse the performance of the agroecological farm compared to the conventional under the baseline scenario and then go on to show and discuss the results when the custom scenario is applied.
- Each section finishes with a set of recommendations for how a farmer considering undertaking or increasing their uptake of agroecological management practices can do so in a way that is likely to increase their economic performance.
- In **Section 9** we present the discussion of the findings and explore what they could mean for agroecological transition in the UK. **Section 10** of the report provides a set of recommendations for how policy should adapt agri-environment payments, facilitate private investment, provide improved supply chain support, and increase knowledge generation to support and accelerate a sustainable transition to agroecological farming in the UK. The report finishes with **Section 11** which summarises the key barriers and opportunities for agroecological farm business transitions and the key findings from the work.

3 Cereals

3.1 Summary

Conventional cereal production is largely reliant on imported, usually synthetic, fertiliser to increase yields. Livestock are rarely integrated into the rotation and legumes and diverse grasses are seldom grown. In contrast, below we define two typical agroecological cereal farms.

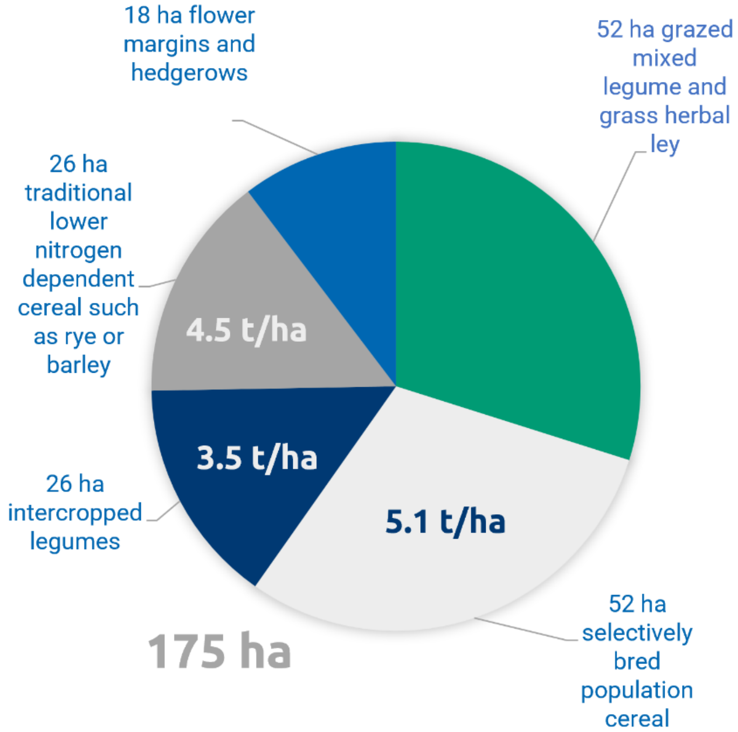
Cereals with grazier

Fertility management

- The herbal sward is grazed under grazier licence
- This provides 80-100 kg N/ha
- Cover crops between rotations provide 25-132 kg N/ha.

Pest management

- 8% of the area as flower margins.
- All crops within 50m of flower margin.
- Can increase avg. yields by 303 kg/ha



Biodiversity

- Organic style management increases species richness by 40% compared to conventional.

C footprint

- Organic systems average 20% lower emissions than conventional.
- Herbal ley sequester, on average, 0.18 t C/ha.

N runoff

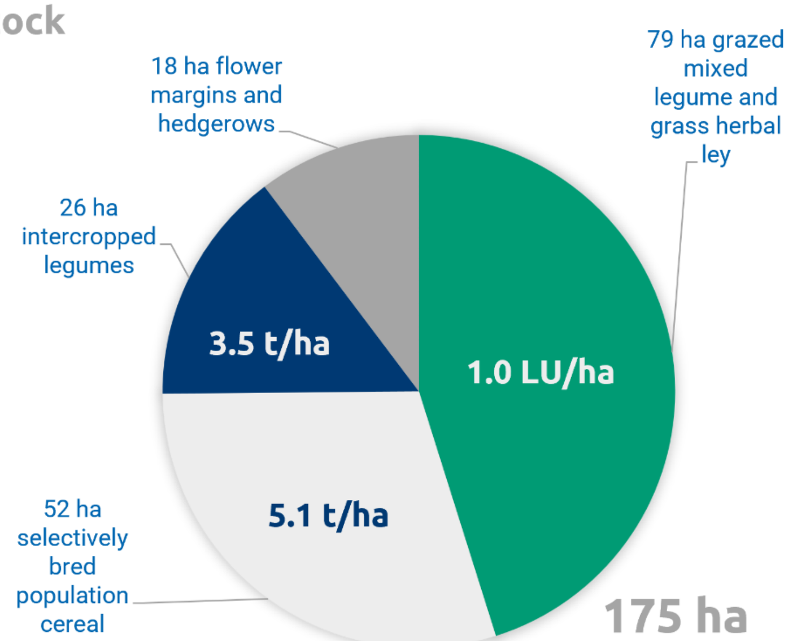
- Cover crops reduce nitrogen leakage by 56%.

Cereals with integrated livestock

On the second cereal farm type the livestock is managed in-hand rather than by grazier. These livestock are used to graze the herbal ley and the cover crops to enhance the fertility.

This means the farmer can generate income from the herbal ley and, hence, can dedicate a larger proportion of the rotation to this land use.

This supports slightly increased outut, but higher costs as the farmer incurs additional expenditure on items such as fencing, water infrastructure, and handling facilities.



Performance of the cereal farms

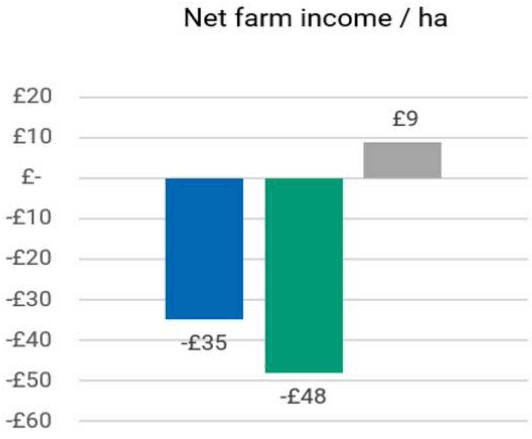
Custom scenario

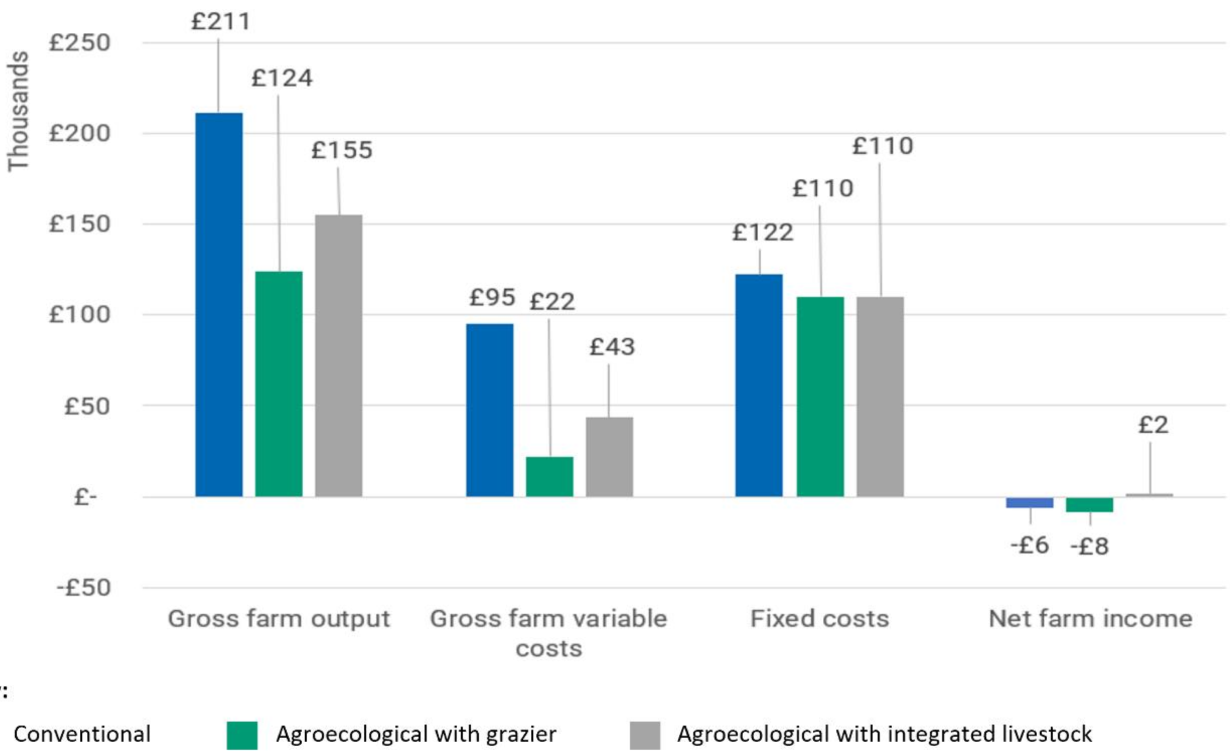
For the custom scenario the following assumptions are modelled:

- Agri-environment payments rise by 30% of current rates.
- A 20% increase to farm gate price.
- Fixed costs 10% below conventional.
- Nitrogen pricing at 150% of historic rates.

Applying these assumptions means agroecological cereal farming can outperform conventional production when livestock is integrated into the farm. The modelled results of this custom scenario modelling are shown in the following two bar charts.

The graphs demonstrate the low profitability and risks associated with future cereal farming. Additional payments for ecosystem services will be necessary to support sustainable cereal production.





Environmental impacts

- Sequesters up to 402 t CO2e per annum
- Prevents 3.9 tonnes of nitrogen runoff
- Increases species richness by at least 40%

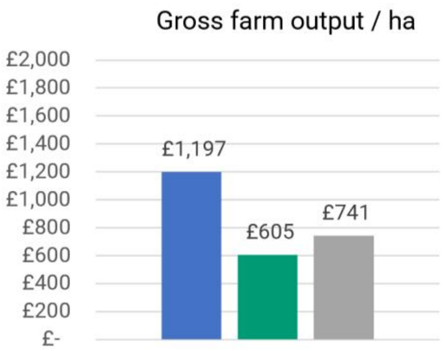
Applying a carbon payment of £15 per tonne CO_2e to the carbon sequestered by all habitats, including above and below ground sequestration, increases the income received by the agroecological farms to up to £6,030 per annum.

This gives one example of the potential for payment for ecosystem service schemes to increase the profitability of agroecological cereal farms.

Baseline performance

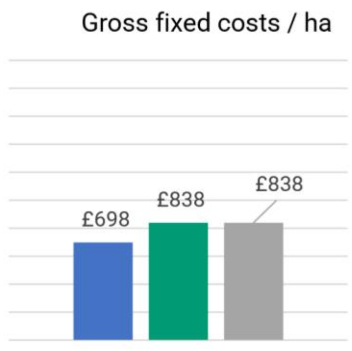
The following graphs show the performance of the cereal farms without the custom scenario applied. This is essentially how the farm types we have defined would have performed on average in 2021 based on the data available.

The lower net incomes for both agroecological farms are due to the combination of lower average yields, less years dedicated to cash crops, and higher fixed costs. The lower variable costs, without increased farm gate price, are not able to compensate for these elements.



- Output was reduced from the areas dedicated to herbal ley.
- Yields reduced on the cropped land.
- Without increased farm gate prices or payment for public goods, we found that the economic output from agroecological cereal farms is lower than conventional.

- Variable costs decline, predominantly due to the reduction in input use.
- The marginally higher variable costs associated with livestock integration are compensated for by the increase in income they generate.



- Higher fixed costs are based on the average fixed costs for organic cereal farms.
- Mechanisation and labour costs are higher.
- Findings from the case studies contradicted this data, farmers claimed reduced spraying and tilling lowered the need for machinery and labour.

Key farm level recommendations and business strategy

- Mob grazing the herbal sward with livestock can generate income from the fertility building years of the rotation. This increases the likelihood of profitability.
- Small amounts of synthetic inputs, selectively, and precisely used, can support high productivity and balance trade offs within agroecological cereal farms.
- Agroecological farmers need a reliable way to increase incomes from these fertility enhancing crops. Identifying local markets for specific legumes could help compensate for the lower gross margin per ha.
- Enhancing the efficiency of cultivation using fewer passes can reduce fixed costs, increase net income, and reduce fuel consumption.
- Processing on farm can enhance the amount of value that can be retained. Milling, butchery, and dehulling all provide options to increas
- There is potential to increase carbon storage on farms by undertaking agroecological methods. Agroecological farms should work to record and promote the carbon stored in their soil and support and work with those looking to develop schemes to pay for soil carbon sequestration.e farm gate pricing.

3.2 Overview – cereal with grazier

These agroecological cereal farms rely on crop rotations, minimum soil disturbance, and continuous crop cover to maintain good soil health and productivity (Ponisio et al., 2015). Costs are reduced by minimising input dependence.

To maintain fertility, leguminous crops and herbal leys are integrated into the rotation to fix nitrogen, to build fertility back into the soil, and to cycle soil nutrients (Iannetta et al., 2016). These legumes are under sown into the previous cereal crop to create a low growing cover that helps suppress weeds and build soil fertility, without interfering with the cereal crop. Cover crops also reduce the risk of nutrient loss and maintain habitat for beneficial organisms.

Grazing the herbal leys and cover crops by a grazier helps to enhance soil fertility and structure, build organic matter, and increase biological activity (Riley et al., 2015). Grass-clover leys in arable rotations enhance resilience to drought and flooding and benefit wheat yields (Berdeni et al., 2021).

Grazing can be managed under license by a local grazier or livestock farmer who would graze the herbal leys under contract. This provides some additional income to the cereal farmer and nutrition to the grazier’s livestock (costs and benefits covered in lowland grazing systems). Grazing is managed as mob grazing with short periods of high density grazing on a land parcel to rapidly graze the preceding crop and cycle nutrients into the soil.

Break crops add, conserve and cycle nutrients, help control pests, disease and weeds, and control and improve soil physical characteristics (Robson et al., 2002). Conservation tillage provides financial and environmental benefits as it reduces erosion risk and enhances soil quality (Hazarika et al., 2009).

North-south orientation tree strips (shelterbelts) provide microclimate regulation to the cereal crops enhancing productivity without overshading. The purchase and establishment of additional fencing and water infrastructure are key costs for this farm type.

3.3 Overview – cereal with integrated livestock

This agroecological farm type operates in much the same way as the cereal with grazier farm type, however, the livestock are raised entirely on the farm. This means greater care must be taken to ensure the rotation provides a complete and adequate diet for the livestock on site. The use of forage legumes provides a nutritious animal feed source and reduces or dispenses the need for mineral N without loss of total output (Iannetta et al., 2016).

Furthermore, areas of trees and hedges provide fodder for livestock. Fodder that is rich in nutritional and medicinal compounds such as tannins. These areas also provide animals with shelter during extreme weather which helps to reduce stress, mortality and enhance growth rate.

Additional costs are predominantly associated with housing, vet and med, water infrastructure, stock care, and fencing. Livestock are mob grazed, with short periods of high density grazing on a land parcel to rapidly graze the preceding crop and cycle nutrients into the soil.

3.4 Changes in environmental impact

3.4.1 Carbon storage and emissions

A study by Smith et al. (2019) found that on average organic crop production has 20% lower greenhouse gas (GHG) emissions than conventional production. Removal of fertiliser use is likely to have the greatest effect on this GHG emission reduction. Lower yields, however, mean that each kg of agricultural production accounts for a larger percentage of the total farm GHG emissions than in a conventional system.

Livestock grazing increases the methane emissions from enteric fermentation in the stomachs of the ruminants. These are emissions that are directly attributable to the system when livestock are managed in hand. Carbon storage in the soil helps to compensate for the increased relative emissions and emissions from livestock.

Smith et al. (2019) predict increased soil sequestration rates of 0.18 Mg carbon per ha per year when rotational grasses are incorporated into an arable rotation in England and Wales. We use this second figure as the rate of carbon sequestration in the agroecological cereal system given its greater relevance to UK agriculture.

Extrapolating this increased soil carbon sequestration across the 158 ha in arable production gives increased annual carbon sequestration of 28.4 tonnes. This will be greater for the longer periods of herbal leys incorporated into the livestock integrated system.

In a meta-analysis of 30 covering 37 study sites across the world, Poeplau & Don (2015) found that cover cropping between harvests, instead of leaving land fallow, increases soil carbon annually by an average of 0.32 tonnes carbon per ha or 1.2 tonnes CO_2e per ha. Applied across all the arable cropped area this sequesters an additional 25 tonnes of CO_2e.

Hence, we estimate that the arable land in the agroecological farm stores 53.4 tonnes CO_2e per year.

3.4.2 N runoff and eutrophication risk

Removal of synthetic nitrogen use in the agroecological farm types reduces the risk of runoff. There is some risk of nitrogen runoff from livestock manure, especially during heavy rainfall. Enhanced soil structure from the cover crops and herbal swards reduces this risk, whilst strategic use of non-provisioning habitats can help to reduce any runoff into local water bodies.

In a global meta-analysis, Thapa et al., (2018) found cover crops, on average, reduce nitrate leakage by 56% compared to non-cover cropped systems. Research by Martin et al., (2016) supports this. A study in Northern America found that when 204.4 kg N per ha was applied to maize, 23 kg of this was lost to N leaching (Tamagno et al., 2022).

Across the 170 ha of agricultural land within the modelled conventional cereal farm, this scale of runoff means 3.9 t of N are leached into water ways annually. Lowering this runoff risk is necessary to reduce N pollution and eutrophication in water bodies.

3.4.3 Biodiversity

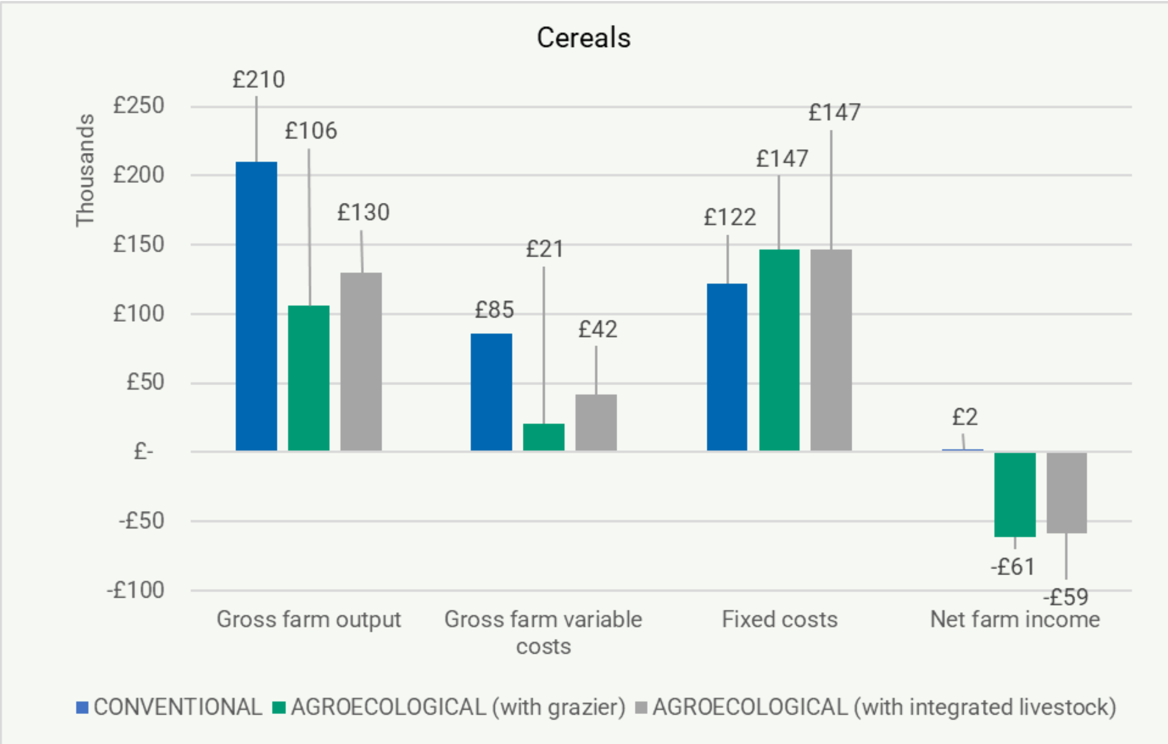
Organic conversion has been shown to have a greater impact upon biodiversity on farming systems with a high percentage of arable fields. Whilst on average organic management increase species richness by 30%, on cereal farms this is just over 40% (Tuck et al., 2014).

Furthermore, maintenance of grass and flower rich margins has been shown to significantly increase the presence of pollinator species and other invertebrates (Meek et al., 2002). Maintenance of these areas will therefore also benefit predators of these invertebrates, including birds, small mammals, amphibians, and reptiles.

3.5 Findings from modelling the farm type

3.5.1 Baseline performance

Figure 1: Baseline economic performance of the cereal farms



3.5.1.1 Net income

The baseline scenario shows the agroecological cereal farms both deriving approximately £60,000 lower net incomes than the conventional cereal farm. The agroecological farm with integrated livestock performs marginally better than the grazier system as the farm can generate income from the years of the rotation that are in mixed herbal sward.

3.5.1.2 Output

Change in gross farm output has the greatest impact on profitability. Despite the agroecological wheat production generating similar gross margins to the conventional farm, the lower percentage of the rotation dedicated to cereal production combined with the lower incomes from the leguminous and grass rotations restrict the attainable output. This leads to the output decline of between £100,000 and £80,000.

The additional £50,000 generated by integrating livestock into the agroecological farm does narrow the gap in output.

3.5.1.3 Costs

Reduction in agroecological variable costs go some of the way towards compensating for the loss in gross farm output, but still leave a gap of approximately £30,000. This gap is exacerbated by the increase in fixed costs that have been modelled which culminate in the loss in net income.

3.5.1.4 Sensitivity analysis

The difference in net income between the agroecological and conventional farms is most sensitive to variation in the fixed costs. Reducing the agroecological fixed costs by 10% narrows the income gap by £15,000. Income also has a high sensitivity to changes in the agroecological farm gate price. Sensitivity is higher in the livestock integrated system again demonstrating the benefit of being able to integrate livestock into the system and how small increases to the farm gate price impact the net income.

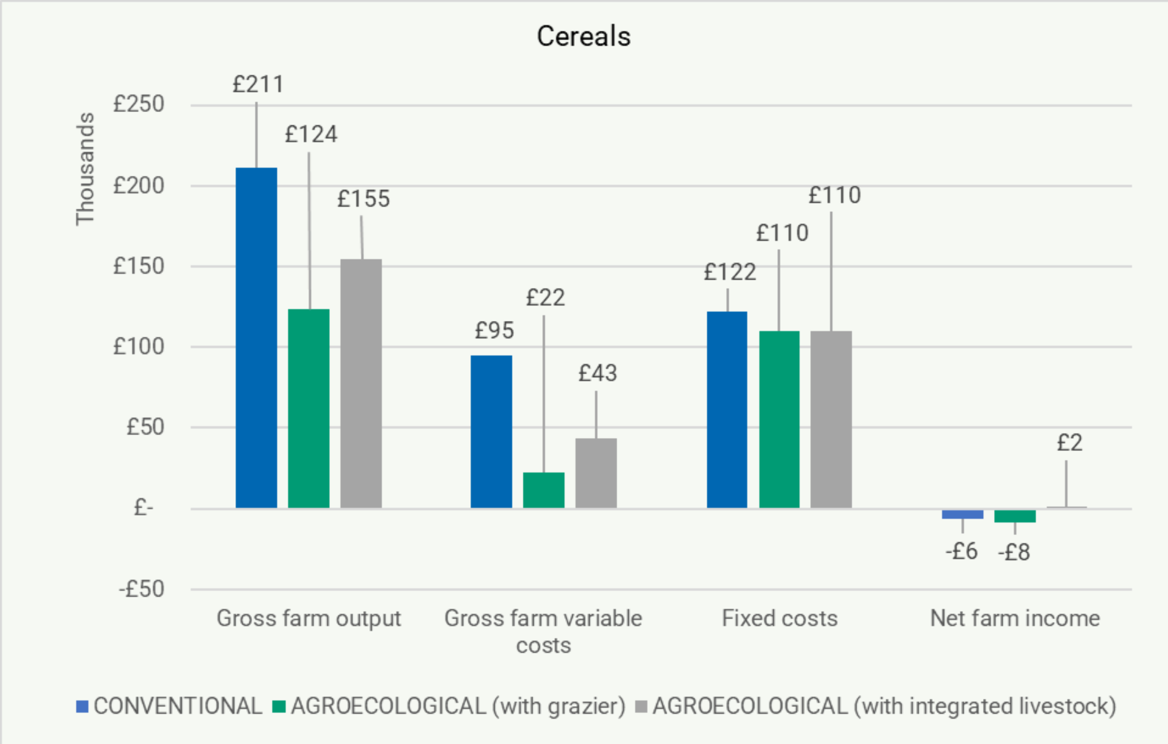
3.5.2 Custom scenario

The custom scenario we have modelled includes the following assumptions:

- **Agri-environment payments rise by 30% of current rates**. Modelled as a conservative estimate of how future funding will pay farmers to provide a range of ecosystem services.
- **A 20% increase to farm gate price.** It is assumed the farmer can generate this increase through improved more direct sales or post-harvest processing.
- **Fixed costs 10% below conventional.** Based on the cereal case studies it is reasonable to assume fixed costs could be even lower.
- **Nitrogen pricing at 150% of historic rates.** This is less than the price spikes caused by conflict in Ukraine and illustrates the increasing issues of nitrogen fertiliser use.

We consider these reasonable and conservative estimates of how these variables are likely to impact future cereal farming.

Figure 2: Custom scenario economic performance of the cereal farms



The income gap between the agroecological and conventional cereal farms transforms when the custom scenario is modelled. When livestock are integrated into the farm, the agroecological farm becomes profitable.

3.5.3 Carbon payment

Applying a carbon payment for the woodland on the farms provides a negligible £150 in additional income to the conventional and agroecological. This is because tree planting is likely to be lower on the agroecological cereal farm types than on other farm types. Tree cover is, therefore, likely to remain consistent across the different forms of cereal farms. That said, the benefits of mixed alley cropped systems of cereals, livestock, and strips of fast growing timber or orchard trees warrant further investigation.

When a carbon payment is applied to the carbon sequestration for all habitats, including above and below ground sequestration, the agroecological payment increases. The conventional cereal farm sequesters negligible carbon and only receives payment of £297. The agroecological farms, however, sequester an estimated 350 to 402 tonnes CO_2e. This generates additional income between £3,000 and £3,500. This makes both agroecological farms more profitable than the conventional and increases net income for the integrated livestock system to £5,000.

Increasing the payment rate to £15 per tonne CO_2e sequestered increases the additional income received by the agroecological farms to up to £6,000 per annum.

3.5.4 Discussion

In the current context, with conventional farm gate pricing, agroecological cereal farms would not be profitable and conventional production is more economically viable. Therefore, direct sales and price premiums are so often relied on by agroecological farmers. However, the custom scenario shown above demonstrates how this could feasibly change with greater understanding of agroecology and continuation of certain political and socio-economic trends.

Agri-environment payments are predicted to increase by a minimum of 30% in order to provide farmers with additional payment for the ecosystem services they support. This does not consider private payments for ecosystem services which could further increase the support for agroecological farms. As awareness and quantification of the value sustainable land management provides to society increases, public and private payments for ecosystem services are likely to rise beyond the 30% we model. Biodiversity Net Gain (BNG) and nutrient neutrality offsetting are just two examples of burgeoning markets for ecosystem services.

Certain customers will be willing to pay a premium for food, but this should not be what agroecological food production depends on. This report aims to explore the capacity of agroecology, which also represents many organic farming enterprises, to produce food for a mass market and highlight the changes necessary to enable this. Hence, organic premiums (averaging an 80% farm gate price increase) have been ignored. However, it is unlikely that agroecological farms would entirely sell the higher quality produce to conventional procurers and processors. Some food will be sold direct, for example to millers and bakers. Furthermore, Case Study 1 demonstrates how on-farm processes such as milling can substantially increase farm gate price. We project a 20% increase to farm gate pricing to account for the additional value that more direct sales and additional processing can provide.

There is sparse and varied evidence about the fixed costs of organic production and negligible economic data related to agroecology specifically. The fixed costs reported for organic cereal production are roughly 10% higher than conventional, but these likely include industrial style organic systems reliant on more intensive cultivation. These systems have little in common with the agroecological cereal farms described within this paper. It is likely that fixed costs in agroecological cereal farms are in fact lower than for conventional. Machinery to spray crops and apply fertiliser will no longer be used, tilling will be less frequent and depreciation cost will, therefore, be lower. Further research on the impacts of agroecological transition upon labour costs is necessary though to verify this assumption.

Continued geo-political unrest and pressures on carbon intensive sectors could have continued impacts on the price of synthetic fertilisers. Rates as high as 300% of historic rates have been reported (Butler, 2022), so a 50% increase in price is tenable and, shifts the average conventional cereal farm into negative net income. Applying a nitrogen price 300% of historic rates to the custom scenario means the conventional cereal farm generates an income of -£36,000. The agroecological farms are barely affected. In reality, this lost income would be counterbalanced by increased farm gate price. Hence, the increased cost of production increases the price of food for the consumer impacting food security and the cost of living. We are already seeing this impact in the UK due to the Russian invasion of Ukraine. An agroecological food system is less exposed to this risk and any price differential is reduced.

3.6 Farm level recommendations and business strategy

- If zero inputs are to be used, it is necessary to generate income from the herbal sward and cover crops within the rotation. Mob grazing livestock can maintain moderate productivity across these fertility building rotations. Furthermore, selling meat more directly offers an effective way to increase the economic output from these areas of the farm. Farmers should make the most of any capital grants available to fund fencing and infrastructure for livestock, which makes it much easier to integrate them into the arable rotation.
- Legumes within the rotation currently generate only a fraction of the income of cereals. Agroecological farmers need a reliable way to increase incomes from these fertility enhancing crops. Identifying local markets for specific legumes could help compensate for the difference in gross margin per ha.
- IPM and diversified rotations support ecological processes than can reduce farmer reliance on costly inputs, this is primarily how agroecological arable farmers maintain productivity. Small amounts of synthetic inputs, selectively, and precisely used, can be sustained alongside a transition to agroecological approaches, an approach clearly not consistent with organic systems. Evidenced by interviews, undertaken for this report, with a farmer who judiciously applied inputs to, for example, balance the needs of certain nesting birds against the desire to treat crops mechanically rather than chemically. For certain farmers, a data driven approach that applies targeted synthetic inputs to maximise yields across a farm containing high proportions of high quality, connected habitat, can provide a way to maintain high food production and net income. This also provides a way for conventional farmers to incrementally reduce input dependence.
- Fixed costs are highly impactful upon the viability of agroecological farms. When developing the case studies for the report farmers reported reduced fixed costs and particularly mechanisation, to be a driver for agroecology. Case Study 6 provides an example of this where reduced machinery costs helped to support cereal profitability. Enhancing the efficiency of cultivation using fewer passes and less tillage will impact net income. This has the dual benefit of reducing fuel use, prices for which are increasingly volatile.
- Processing on farm can enhance the amount of value that can be retained. This is not generally viable for commodity operations but is relevant to more diverse, high quality agroecological farming. Milling, butchery, and dehulling all provide options to increase farm gate pricing. This is also a good way to improve employment and engagement between the farm, the local community, and supply chains. The benefits of processing, however, need to be carefully weighed up against the increased overheads.

- There is potential to increase carbon storage on farms by undertaking agroecological methods. This will only be proven and eventually funded if it is measured. Agroecological farms should work to record and promote the carbon stored in their soil and support.

Case Study 1: George Young – Fobbing Farm

Title: A cereal farm with integrated, diversified enterprises and income streams.

Background / brief description of farm:

George Young farms 485 ha in the *southeast* of England integrates arable and livestock farming. Heritage wheat and legumes are grown along with dual purpose cattle. The system incorporates cover crops, direct drilling, minimum tillage; and is moving to an organic system.

50% of the area is planted with herbal leys grazed by a 50 head herd of dual-purpose red poll cattle. Out wintering is key to this management as far as ground conditions will permit. Hence, almost all shed costs are avoided. In winter hay is provided as supplementary feed.

A wild 'seam' of floristic habitat for birds and beneficial insects has been established through the middle of the farm to continuous and connected habitat. Species supported by this habitat help to increase the resilience of production and the amenity value of the farm.

Grains and pulses produced have been sold to Hodmedod's since 2018. They have also invested in on farm processing, including a mill and a decorticator (to remove the rinds and skin of grains and nuts) to add value to the crops. They have just started direct selling to London bakeries. There is also a plan to slaughter and butcher on farm, aiming to sell wholesale to local butchers. Proximity to London helps support this sales approach which enables the farmer to maintain greater control over farm gate pricing.

They are also trialling an agroforestry system on 50 acres with 7,000 trees. This includes a large proportion of fruit and nut trees as well as some more exotic varieties and some willow for tree mulch and some timber trees.

Image shows the mill George Young has set up at Fobbing Farm.

Aim: To maximise the production of nutritional diversity from the farm. To farm with nature, utilising natural systems such as beneficial insects and livestock integration to support resilient production of diverse, nutritional foods.

Key management features of the agroecological system

Key management features	Description of the management approach and reason for implementing
Heritage seed varieties	Growing of heritage crop varieties For bread flour: Old Kent red, Old Kent Hoary, Orange Devon Blue rough chaff, April Bearded, Emmer
Arable cropping with rotational livestock grazing	Integration of livestock into the rotation through grazing of an herbal ley on 50% of the farm. Diverse crop rotations, including cover cropping. They have a 7-year crop rotation with 4-years as grazed herbal ley before 3-years arable production: • Year 1 - wheat (for bread flour) • Year 2 & 3 - novel crop (peas, lentils, buckwheat) or wheat for plain flour (lower protein) • Year 4 to 7 – grazed herbal ley
Tillage	Direct drill, minimum tillage. The farmer considers tillage to be fine if the subsoil is not disturbed. Active topsoil will rebuild hyphal growth rapidly after shallow tillage.
IPM	Diverse swards, intercropping, good soil health, integrated livestock grazing, wildflower margins will all help to reduce pest and disease risk. There is no silver bullet but, instead, a suite of agroecological methods that enhance systemic resilience. Zero insecticide is key to going agroecological. A major change required is to stop searching for signs of insect damage and feeling the need to respond to these issues with chemicals.
Rotational grazing	The livestock are rotationally grazed and are moved every 3 days. This maintains good fertility and productivity, reduces animal stress and allows pasture time to rest and recover. Cows are grazed at a stocking density of a cow every 2 to 3 acres.
Agroforestry	50 acres of trees have been planted for fruit, nut, mulch and timber production to help to decrease the systems exposure to risk, balancing performance fluctuations across the farm. Aiming to maximise tree species diversity whilst also enabling efficient harvesting. Trees planted in two lines side by side separated by agricultural land. 2 to 3 m between trees (varies). Willow on the farm should help produce mulch on site.

Impacts of the agroecological system

- **Farm resilience** - Improved farm resilience due to low input costs and diversified sales channels.
- **Climate impact** - No use of carbon intensive fertiliser. Climate change adaptation – agroforestry and selection of species adapted to a warming climate.
- **Nutrient runoff** - No nutrient run off. Cover crops, low stocking rates, and trees protect the soil from erosion.
- **Ecological impact** - Positive impact on soil, creation of ecological networks (hedges, flower margins), working closely with local Wildlife Trust, conservation grazing their marshes adjacent to the farm.
- **Societal impact** - Highly nutritious food, high animal health and welfare, carbon and biodiversity benefits, improved water quality, flood protection, enhanced landscape.

Performance

Yield & Profitability	
Yield, revenues, profit margins	
Total business income	£550,000 revenue (including £110,000 business units; £140,000 agri-environment; £100,000 BPS)
Yield wheat	3 to 3.5 tonnes per year. Milled on site. 10% is lost during cleaning. 80% extracted during milling.
Revenue per tonne	• Flour sold at £1.60 per kg • 1 tonne of wheat produces £1,152 worth of flour • Buckwheat flour is sold at £2.10 per kg • Lentils sold at £850 per tonne
Output livestock	500 – 550 kg slaughter weight. Aims to get £2,500 out of the butchery per animal.
Agroforestry	Funding from the woodland trust for trees, guards, and stakes. Works out roughly £1,000 per acre. 20% to 30% loss of trees.
Agri-environment scheme	Mid-tier Countryside Stewardship. Herbal leys, legume fallows and winter bird food.
Variable costs	
Inputs (seeds)	All seed is saved on the farm.

Inputs (feed)	All feed produced on farm
Inputs (fertiliser, pesticides/ herbicides)	• £37,000 fertiliser • £22,000 chemical (will stop)
Livestock replacement	None. Aiming for a closed herd.
Vet/Med	Approximately £1,000 per 50 animals
Fixed costs	
Total business costs	£57,000 (including variable costs)
Machinery & equipment	• Chelli Tiger rotavator – enables wheat to be planted in 3 passes. 1st and 2nd to terminate (by rolling) and 3rd to plant the crop. • Sintech drill – no till drill cost £12,000. • Fencing and water. Permanent ring fencing and portable electric fencing for livestock. A good network of water pipes. Water mains / piping in combination with the temporary piping. • £28,000 for the flour mill. • £30,000 for the bagging machine. • Building out the room cost £18,000. • Machinery for processing (cleaner / dehuller) cost approximately £25,000 Totalling £101,000
Water / electricity / general costs	Similar to conventional farming
Labour	1 Full Time Employee (tractor driver). Farmer does all livestock work, office work, and everything else. Similar to a conventional farm of this size but would not be this varied. It is predicted that mechanical harvesting will be used for the agroforestry due to labour issues.

Key challenges for transitioning to agroecological farming

- **Lack of advice** - Very little advice for arable farmers wanting to learn how to integrate livestock into their production.
- **Lack of support -** Need grants to support investment in farm infrastructure such as permanent fencing and water piping. This can enable more flexible livestock rotations.

4 Horticulture

4.1 Summary

Conventional horticultural production is highly specialise and commoditised. It is highly reliant on imported, usually synthetic, fertilisers and sprays both negatively impacting spoil health and biodiveristy. Tillage and high mechanisation degrade soils. Livestock are rarely integrated into the rotation and legumes and diverse grasses are seldom grown. In contrast, below we have defined two typical agroecological horticultural farms.

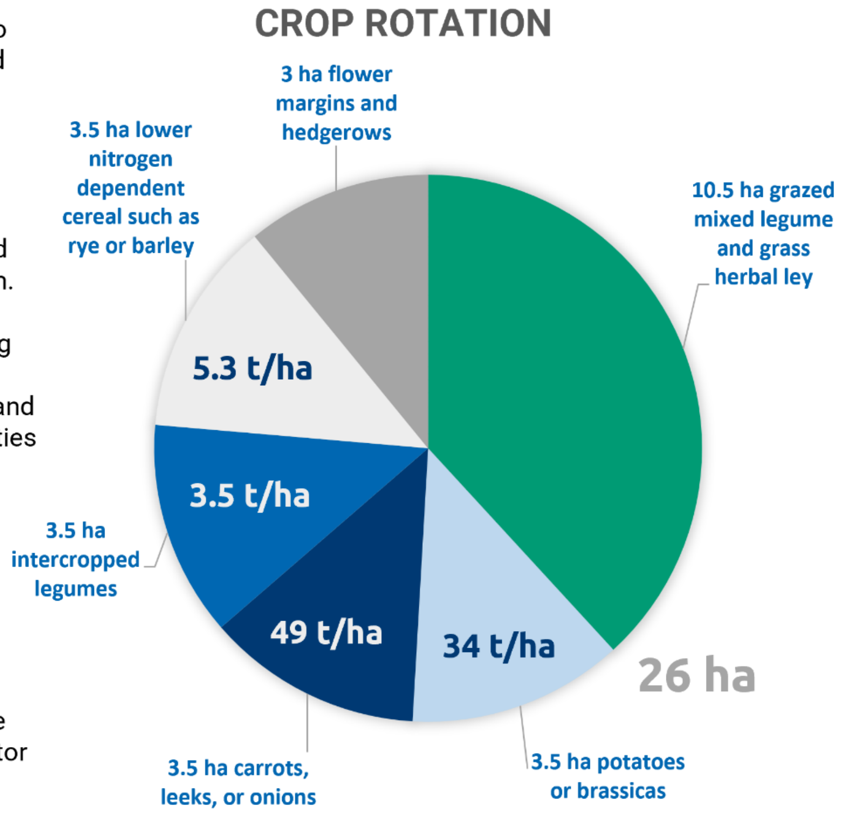
Careful crop selection shapes production to local soils, climatic conditions, markets and supply chains.

Crop rotations ensure crops of the same family are not grown for more than one adjacent season on any field. This reduces disease and pest damage susceptibility and enhances resource recycling and soil health.

Horticulture rotations include nitrogen fixing legumes, grazed herbal swards, and less nitrogen dependent crops such as diverse and hardy cereal varieties. Mixed heritage varieties are used to enhance resilience.

Crops are intercropped with suitable companion species to reduce pest and disease pressure, increase resource use efficiency, and enhance beneficial species populations.

Floristic margins are maintained around the fields to enhance pollinator and pest predator populations.



Fertility management
- The mixes legume and grass herbal ley is grazed under grazier license.
- Fixes an estimate 350 kg of nitrogen into the soil.
- Varied root strcuture help to enhance soil health and biological activity.

Pest management
- Healthy soils helped reduce exposure to pests and disease.
- Varied crop rotations limit the spread of pests and dieases across the farm.
- Pest-predator habitat, diverse swards, hedgerows, margins, and negligible pesticide use also helps to retain rich communities of species that can control pest outbreaks.

Biodiversity
- Hedgerows, floristic margins and herbal swards provide continuous strips of good quality habitat through the farm.

C footprint
- Cover cropping and integration of the herbal leys increase carbon sequestration by 0.5 tonnes per ha.

N runoff
- Synthetic nitrogen application is negligible.
- More continuouse soil cover, varied root structures and non provisioning habitats reduce the risk of runoff from livestock manure.

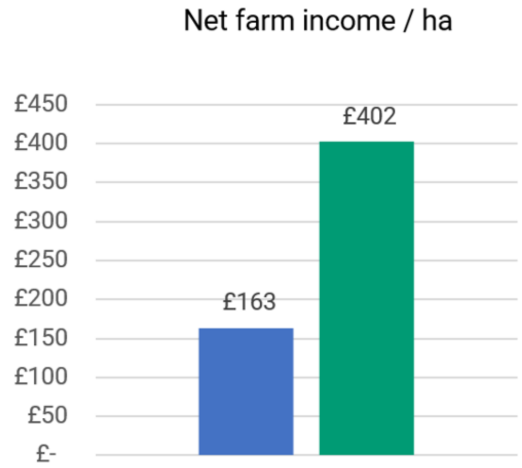
Performance of the horticulture farms

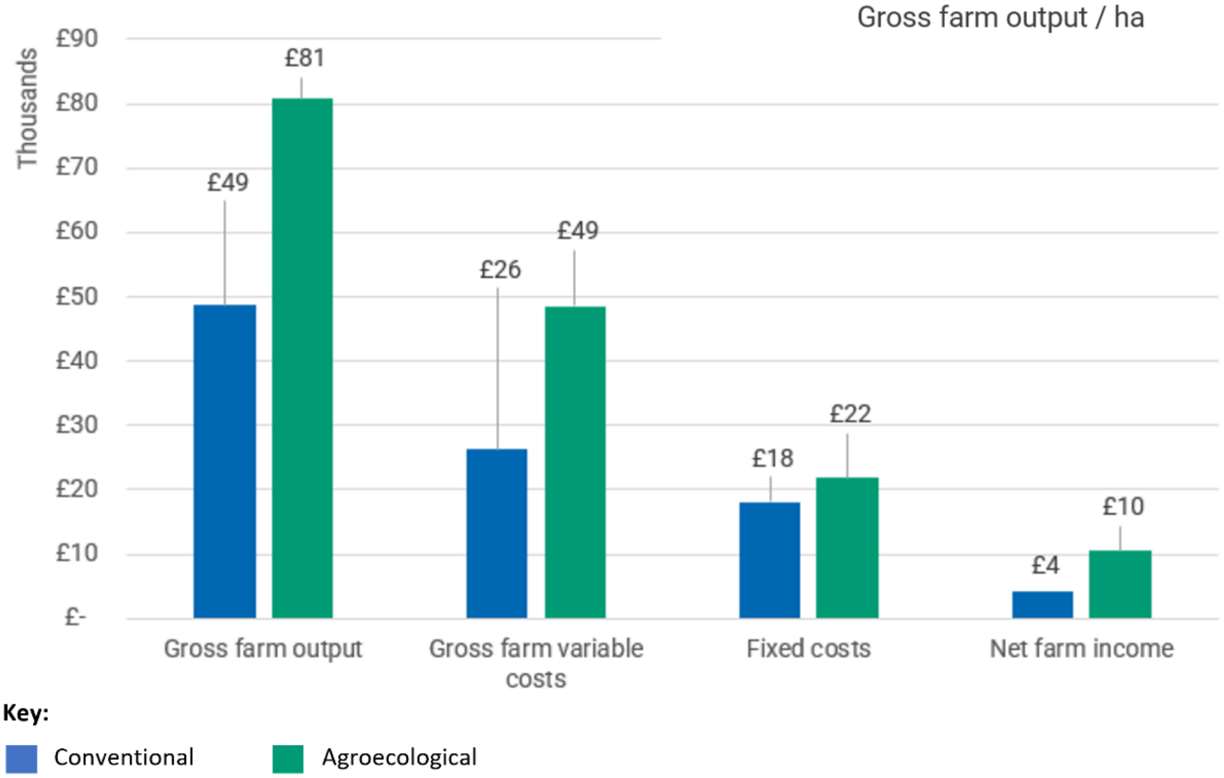
Custom scenario

For the custom scenario the following assumptions are modelled:

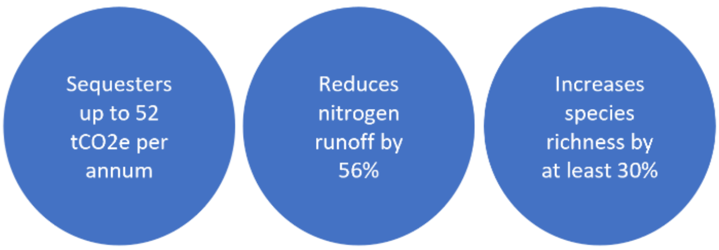
- Agri-environment payments rise by 30% of current rates.
- A 30% increase to farm gate price.
- Fixed costs equal to organic.
- Nitrogen pricing at 150% of historic rates.

Applying the following assumptions to the model means agroecological horticultural farming can outperform conventional production but only when higher farm gate prices are projected. This is a barrier to production of affordable UK-wide agroecological vegetables.





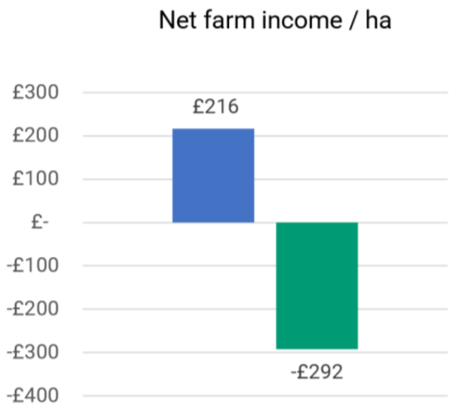
Environmental impacts



Applying a carbon payment of £15 per tCO_2e to the carbon sequestered by all habitats, including above and below ground sequestration, increases annual income received by the agroecological farm by £781.

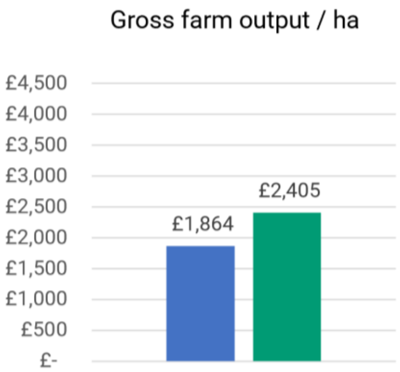
This shows that payment for ecosystem services, like carbon sequestration, may have relatively smaller impact upon high value farm types like horticulture.

Baseline performance



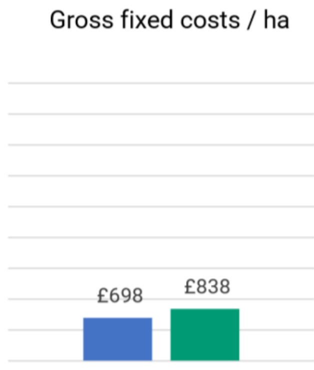
The following graphs show the performance of the hortciultural farms without the custom scenario applied. This is essentially how the farm types we have defined would have performed on average in 2021 based on the data available.

The lower net incomes for the agroecological farm is due, predominantly, to the high variable costs associated with managing the more complex rotations. The higher output, without increased farm gate price, is not able to compensate



- Output marginally increases for the agroecological farm.
- This is because the conventional farm is an average rotation and the agroecological is an optimal rotation.
- In reality, output will be lower due to the need to dedicate more area to fertility building and low nitrogen dependent crops.

- Variable costs are considerably higher for the agroecological farm.
- This is partly because of the increased cost of contracting the cultivation of the root veg.
- Seed costs for non conventional veg cultivation are also high.



- We model similar fixed costs as those modelled for the cereal farms.
- This is because we assume similar machinery if required to manage the majority of the rotation and root vegetable cultivation is outsourced.

Key farm level recommendations and business strategy

- In the short-term, agroecological horticultural production and farmers will need to access higher farm gate pricing through, for example, certification, direct sales, and on farm processing.
- Collaboration and grants should be accessed to explore the potential of dynamic procurement to increase market access.
- Nutritional content, carbon footprint, biodiversity impact and nutrient neutrality all offer ways to differentiate agroecological produce a consistent way to communicate this is needed.
- Ways to reduce the high variable costs of agroecological horticultural farming need to be explored. Technologies such as automation will have a role to play on certain farms.
- Collaborative agreements that contract different farmers to agroecologically manage certain years of a rotation across multiple farms could enable agroecological horticultural farmers to specialise, access economies of scale and justify purchase of more specialised equipment, thereby reducing contracting fees.
- Seed saving and sharing schemes, seed banks and breeding programmes should be established and supported to provide agroecological growers with access to varieties adapted to agroecological farming conditions at lower cost.

4.2 Overview – horticulture with cereals and livestock grazing

Careful crop selection shapes production to local soil and climate conditions as well as local markets and supply chains. This makes horticultural farms more varied and context specific than other farm types.

Crop rotations ensure that no crops of the same family are grown for more than one adjacent season on any single field. This helps to reduce disease and pest damage susceptibility and enhances resource recycling and soil health (Olabiyi et al., 2010). Varied species and varieties are integrated to make effective use of resources, accessing different soil layers through varied root depths and structures (Olabiyi et al., 2010; Soil Association, 2015; ORC, 2017; Teagasc, 2020).

Horticulture rotations include legumes (to fix nitrogen), herbal swards (grazed by livestock), and less nitrogen dependent crops such as population cereal varieties. Diverse varieties are used to enhance resilience. It is also worth noting that stockless horticultural farms have also been shown to be viable forms of production (Preston, 2008). However, we choose to focus on animal integration as this is this emulates the ecological cycling of nutrients within a system and therefore aligns best with the principles of agroecology.

Crops are intercropped with suitable companion species that help to reduce pest and disease pressure, increase resource use efficiency, and enhance beneficial species populations (Teagasc, 2020). Habitat margins are maintained around the fields to again enhance pollinator and pest predator populations.

Fertility is enhanced by grazing livestock which is managed under license by a local grazier or nearby livestock farmer. This provides some additional income to the horticulture farm and provides nutrition to the grazier's livestock. Grazing is managed as mob grazing with short periods of high density grazing on a land parcel to rapidly graze the preceding crop and cycle nutrients into the soil.

4.3 Changes in environmental impact

4.3.1 Carbon storage and emissions

Average GHG emissions from organic crop production are 20% lower than conventional. As with cereal systems, reduced use of fertilisers is likely to have the biggest impact on this.

Annually, cover cropping stores an estimated 0.32 tonnes carbon per ha and the incorporation of herbal swards in the rotation stores an estimate 0.18 tonnes per ha (Smith et al., 2019; Poeplau & Don, 2015). Converting this to tonnes CO_2e, gives an average carbon storage of 1.88 tonnes CO_2e per ha (IPCC, 2014). Total storage across the agricultural area of the farm is, therefore, 45.1 tonnes CO_2e. However, given the greater level of soil disturbance and management intensity of horticultural cultivation, the permanence of this sequestration is uncertain. This will vary across the different crop types.

4.3.2 N runoff and eutrophication risk

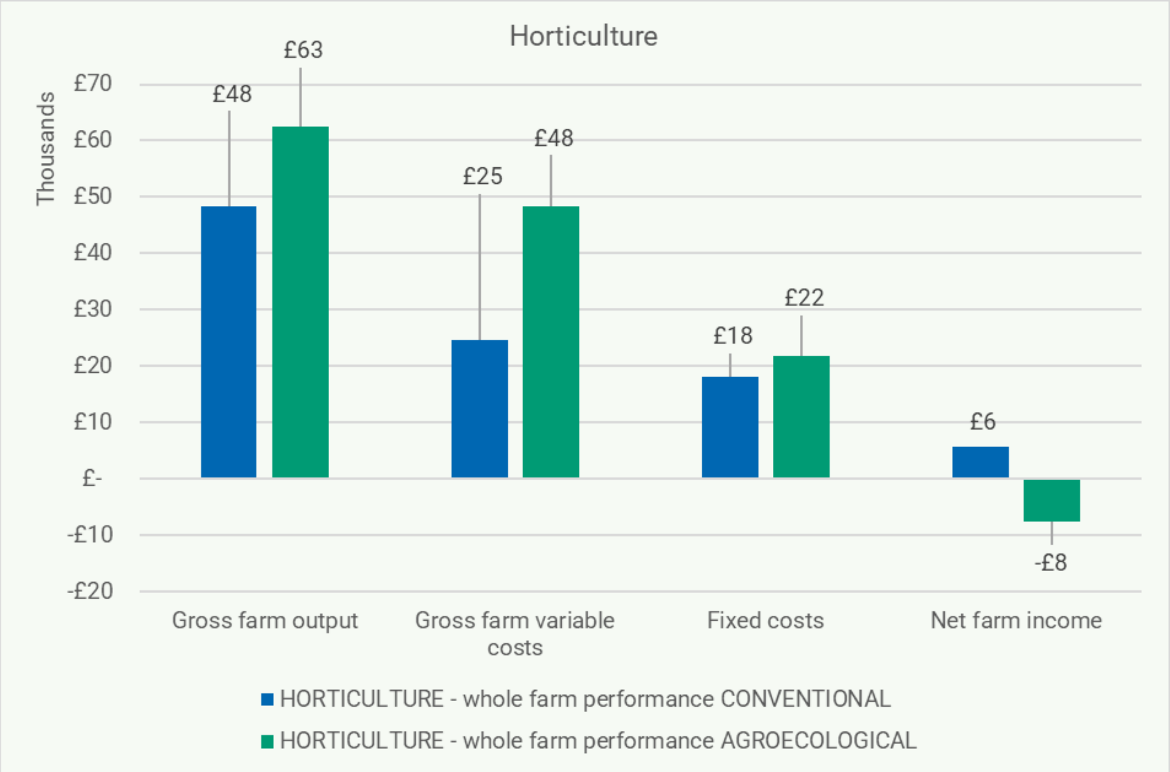
The removal of nitrogen fertiliser drastically reduces the risk of runoff which can be severe given the high fertiliser application rates associated with horticultural production. Like on the agroecological cereal farms, any potential runoff from livestock manure is reduced by at least 56% due to more continuous soil cover. Application of straw to cover the soil around horticultural crops can further help to reduce nitrogen leaching (Finckh et al., 2006).

4.3.3 Biodiversity

Reduced application of fertilisers and sprays has been shown to have a positive impact on species richness. Increase of 30% have been shown for vegetable farms. In parallel the mosaic of habitats provided by floristic margins, diverse swards, and cover crops will help to increase the presence of pollinator species and other invertebrates (Meek et al., 2002).

4.4 Findings from modelling the farm type

Figure 3: Baseline economic performance of the horticultural farms



Comparability of the agroecological horticulture farm against the conventional is problematic. There is a huge diversity of horticultural farms in the UK, with many only growing horticultural produce on a small percentage of the total area. Furthermore, many farmers grow on rented land away from their farms, making the data complicated to compare. The FBS data for horticultural farms aggregates and averages this data across this range of farms. This will mean that the data will likely show lower average per hectare costs, outputs, and incomes than would be realised on a more specialised horticultural farm.

In contrast, the agroecological farm we define presents an optimised system with the horticultural rotation grown across all the agricultural area. This means per hectare values are likely higher than they would be on an average farm, where the management of different areas would be more varied.

We consider the approach to be the most effective way of comparing the horticultural performance against real data. Given the difficulties, however, in this section we focus less on comparison between the agroecological and conventional and more on the exploration of the challenges for the profitability of the agroecological farm.

4.4.1.1 Net income

The baseline scenario shows the agroecological horticultural farm operating at an £8,000 net loss, £12,000 lower profit that the conventional farm.

4.4.1.2 Output

The agroecological horticulture farm has much higher relative output than the other farm types generating £2,500 per hectare. This is because of the high output attainable from the root vegetables in the rotation.

4.4.1.3 Costs

The variable costs have the greatest impact upon the farm's income. At £48,000 the costs are double the average across horticultural farms. Per hectare the variable costs are 3.5 times as high as those incurred by the agroecological dairy farm. This is due to the more intensive nature of horticulture and the need to mechanically control weeds and to contract the cultivation and harvesting of the root crops.

The per hectare fixed costs we model are equal to those of the agroecological cereal farm. This is because we assume cultivation of the non-root crop rotation is similar to the management of the cereal rotation. The fixed costs have a smaller impact upon net income than the variable costs.

4.4.1.4 Sensitivity analysis

The difference in net income between the agroecological and conventional horticulture farms is most sensitive to variation in the farm gate pricing. Increasing the farm gate price by 10% increases narrows the income gap by £6,000. This high sensitivity is due to the higher net output generated from the horticulture farm than the other farm types. In contrast, a 10% reduction to the fixed cost only narrows the net income gap by £2,000. Similar changes to agri-environment payment and nitrogen prices have much lower impacts on the net income.

4.4.2 Custom scenario

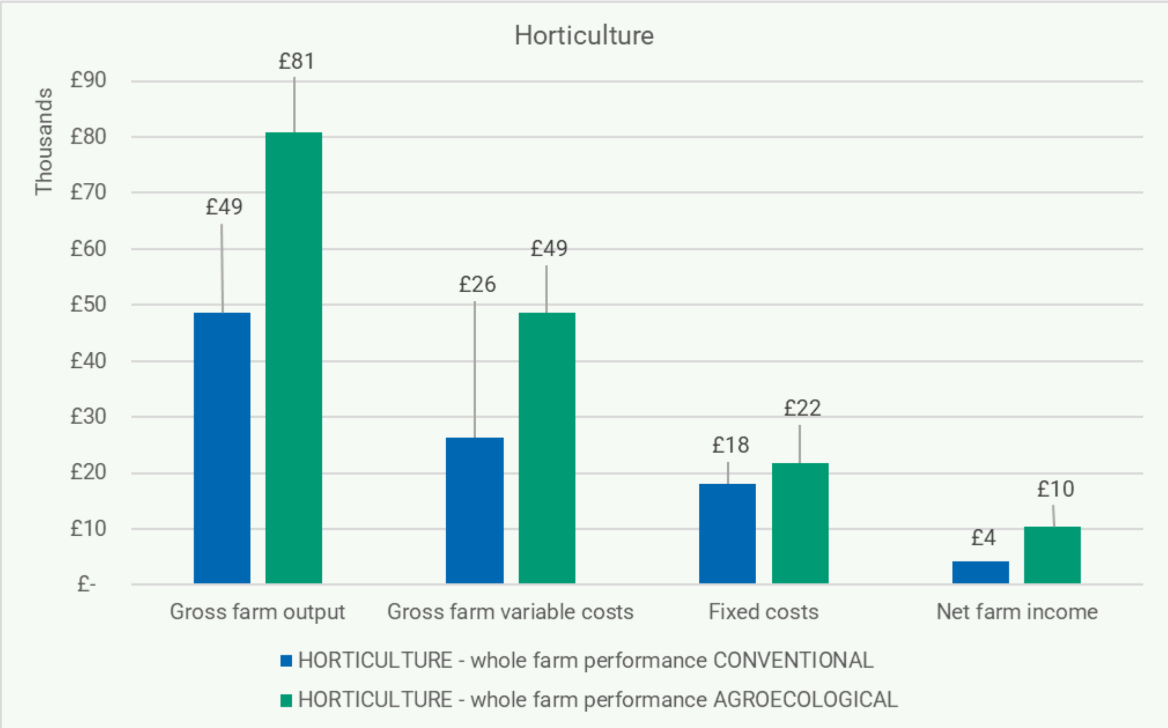
The custom scenario we have modelled includes the following assumptions:

- **Agri-environment payments rise by 30% of current rates**. Modelled as a conservative estimate of how future funding will pay farmers to provide a range of ecosystem services.
- **A 30% increase to farm gate price.** It is assumed the farmer can generate this increase through improved more direct sales or post-harvest processing.

- **Fixed costs equal to organic.** We have modelled the fixed costs based on the fixed costs of a cereal farm with contractor fees for the horticultural crops incorporated into the variable costs. It is uncertain whether fixed costs reduction is a likely scenario.
- **Nitrogen pricing at 150% of historic rates.** This is less than the price spikes caused by conflict in Ukraine and illustrates the increasing issues of nitrogen fertiliser use.

We consider these reasonable and conservative estimates of how these variables are likely to impact future cereal farming.

Figure 4: Custom scenario economic performance of the horticulture farms



The income gap between the agroecological and conventional horticulture farms shifts when the custom scenario is modelled. It is the increase in farm gate price that makes the greatest contribution to the performance change, leading to a positive net income for the agroecological farm that is £6,000 greater than the conventional. Agri-environmental payments are low compared to other farm types and compared the per hectare income of the horticulture farm. This demonstrates the drive for small scale agroecological horticultural farms to seek more direct and higher value markets.

4.4.3 Carbon payment

Applying a £9 per tonne CO_2e payment for the woodland on the farms provides £38 in additional income to the conventional and agroecological. This is because tree planting is unlikely to be a focus on horticultural farms. This is because of the small size and high per hectare value of horticultural production. The revenue from tree planting is unlikely to compensate for the lost horticultural revenue. This may change however as climate change induced temperature rise and droughts make tree shade a key way to retain production through the summer months.

When the carbon payment is applied to the carbon sequestration for all habitats, including above and below ground sequestration, the agroecological payment increases to £469 and stays practically stable for the conventional farm. Given these relatively low rates of carbon sequestration and the associated payment, carbon markets are unlikely to be a substantial driver for agroecological horticulture farming.

4.4.4 Discussion

The baseline net income for the agroecological horticulture farm is negative; approximately £14,000 lower than the conventional farm. The increased complexity of managing agroecological rotations, in combination with the lower yields is currently unprofitable at small scale and with conventional farm gate pricing.

The custom scenario does change this picture, leading the agroecological horticulture farm to generate £10,000 profit. However, this is dependent on a 30% increase to farm gate pricing and, whilst this is feasible for small scale farmers with good market access, it does reveal challenges to the production of affordable UK-wide agroecological vegetables. Some of this farm gate price difference could be reduced by incorporating the cost of environmental externalities into the supply chain, including the hidden cost of carbon (National Food Strategy, 2021), and the costs of pesticide and fertiliser runoff. Furthermore, dynamic procurement, local markets, on farm processing, and product differentiation and clear labelling can enable agroecological horticultural farmers to retain a greater proportion of the market value of their crops. These approaches and innovations will help reduce or remove any of the 30% farm gate price increase paid by the end consumer.

It is the high production cost that provides the greatest challenge for UK-wide agroecological horticulture. Innovative approaches will be needed to reduce this. Novel collaborative agreements that give horticultural farmers access to land within rotations away from their farms could help increase profit margins. This is an approach already taken by large scale organic horticulture farmers in the UK. Access to cheaper horticulture seeds could also lower costs and technology could help to reduce labour costs and enhance yields. Overall, there is a clear need for support and investment in horticultural innovation that is suited to small scale agroecological production.

There is a drive for increased farm gate pricing on agroecological horticultural farms. Direct sales, processing, and certification can all help farmers get higher value for their crops. These are all approaches currently taken by farmers. Dynamic procurement could also help expand the market for locally produced small scale agroecological horticulture and could potentially provide increased value to the farmers without substantially increasing the price paid by the consumer.

Agri-environment and payment for ecosystem service (PES) schemes appear to be less supportive of the horticulture farms. The high-quality land means it is preferable to maintain agricultural production across much of the land and land uses such as woodland planted, which are currently favoured by agri-environment and PES schemes, are rarely advisable on good Agricultural Land Classification (ALC) land. Nutrient neutrality mitigation schemes could be a potential source of additional funding for agroecological horticultural farms, although this needs additional exploration and markets need to be established.

4.5 Farm level recommendations and business strategy

- In the short-term, conventional farm gate pricing is unlikely to support agroecological horticultural production and farmers will need to access higher farm gate pricing. Certification, direct sales, or on farm processing can all increase farm gate value.
- Dynamic procurement can provide small scale growers with efficiently direct routes to large markets. Collaboration and grants should be accessed to explore the potential of dynamic procurement to increase market access. Promoting dynamic procurement of agroecological food as a way for large organisations to meet Environmental, Social, and Governance (ESG) goals could help expand market access.
- Agroecological horticultural farmers need a consistent way to differentiate their produce from more conventionally produced products. Nutritional content, carbon footprint, biodiversity impact and nutrient neutrality all offer ways to differentiate agroecological produce. Labelling and dynamic procurement both hold potential for improving communication of these benefits.
- Ways to reduce the high variable costs of agroecological horticultural farming need to be explored. Technologies such as automation will have a role to play on certain farms. Small scale agroecological farmers need to work with technology developers and researchers to find solutions to the challenges of small to medium size agroecological horticulture.
- Collaborative agreements that contract different farmers to agroecologically manage certain years of a rotation across several farms could enable agroecological horticultural farmers to specialise, access economies of scale and justify purchase of more specialised equipment, thereby reducing contracting fees. This is already undertaken by certain farmers in the sector. The approach needs further exploration and communication. Frameworks and support for collaboration are needed, including support producing contracts that guarantee that certain approaches will be taken to maintain or enhance the quality of the land.
- Seed costs have a significant impact on the profitability of agroecological horticultural farms. Seed saving and sharing schemes, seed banks and breeding programmes should be established and supported to provide agroecological growers with access to varieties adapted to agroecological farming conditions at lower cost.
- PES schemes are unlikely to provide substantial support for agroecological horticulture in the near term. Collaborative schemes to support development of and access to nutrient neutrality offsetting schemes could provide a potential way to increase the economic viability of agroecological horticulture. This requires research and development to validate potential impacts and establish markets.

5 Dairy

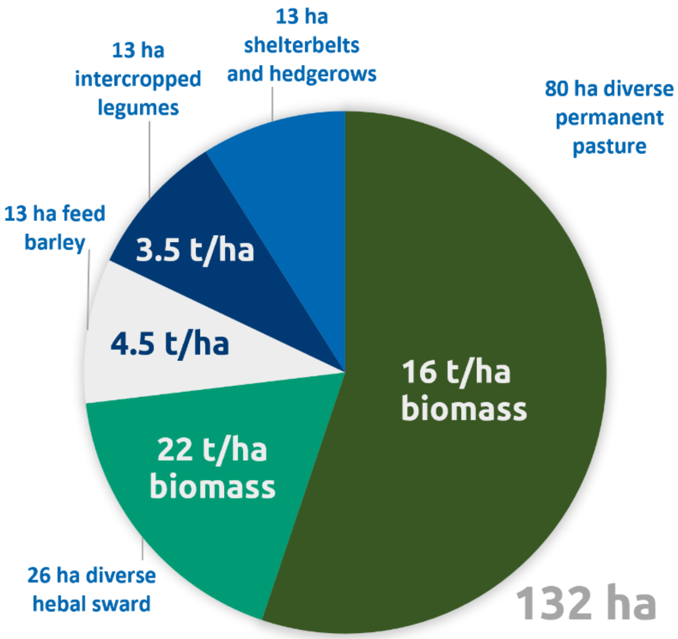
5.1 Summary

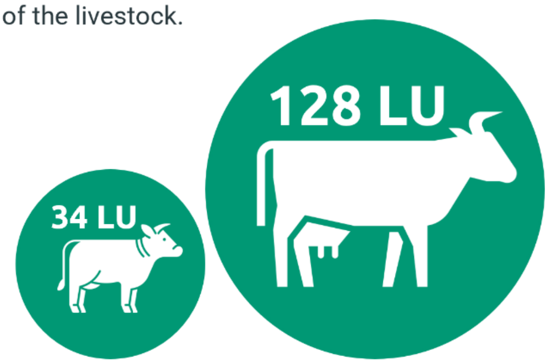
Conventional dairy production is intensive and commoditised, this has pressured dairy farmers to maximise yields through high stocking rates, increased feed sumplementation and high fertilser use. The cows are kept inside for most, if not all, of the time limiting their ability to undertake natural and beneficial behaviours. When pasture fed, conventional systems often rely on heavily fertilised rye grass monocultures. In contrast, below we have defined a typical agroecological dairy farm.

Agroecological dairy farms are largely grass-based systems, with livestock continuously at pasture when conditions allow. Stocking rates are lower than conventional.

Pasture management is a major focus, alongside close integration with the arable rotation. Livestock are rotated to new pasture every 2 to 4 days to give the grass time to regrow and to reduce risk of poaching, compaction, and runoff.

Pastures incorporate diverse grass and leguminous plants. The pasture is partly planted with trees and shelterbelts to provide shade and enhance animal welfare. A small amount of arable production is undertaken on the farm to supplement the dietary needs of the livestock.





Fertility management

- Plant species, such as chicory, help to vary root structure and depth in the pasture which helps to increase soil structure and make efficient use of space and resources.
- Legumes like white clover enhance nitrogen fixation and availability, reducing the need for imported fertilisers.
- Mob grazing helps to efficiently cycle nutrients and allow grass to rest and soil health to improve after grazing.

Pest and disease management

- Diverse sward and browse from trees provide a varied and healthful diet to the livestock, helping to lower disease and mortality risks and vet and med costs.

Health and welfare

- Shelterbelts are strategically planted across the farm to provide shelter and shade to the livestock helping to increase growth rate and reduce mortality.
- Keeping animals at pasture has been demonstrated to benefit animal welfare.

Biodiversity

- Semi natural and diverse swards provide habitat for a range of species.
- Shelterbelts across the farm provide habitat corridors for spiecies dependent on woodlands.

C footprint

- Mob grazing livestock has been found to sequester carbon at rates as high as 3.38 tCO_2e per ha.
- Species rich in tannins, such as birdsfoot trefoil, can help to reduce enteric fermentation.
- Shelterbelts store additional carbon in woody biomass and soil.

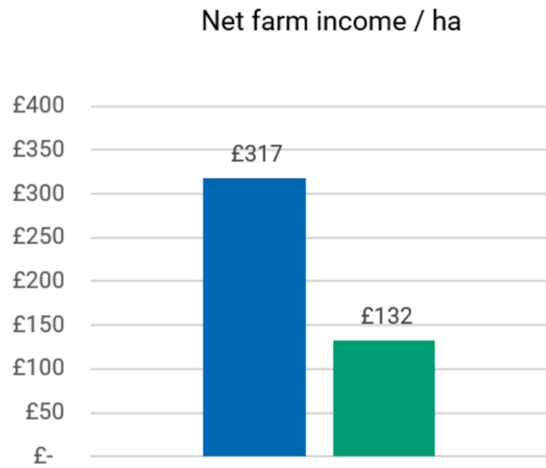
Performance of the dairy farms

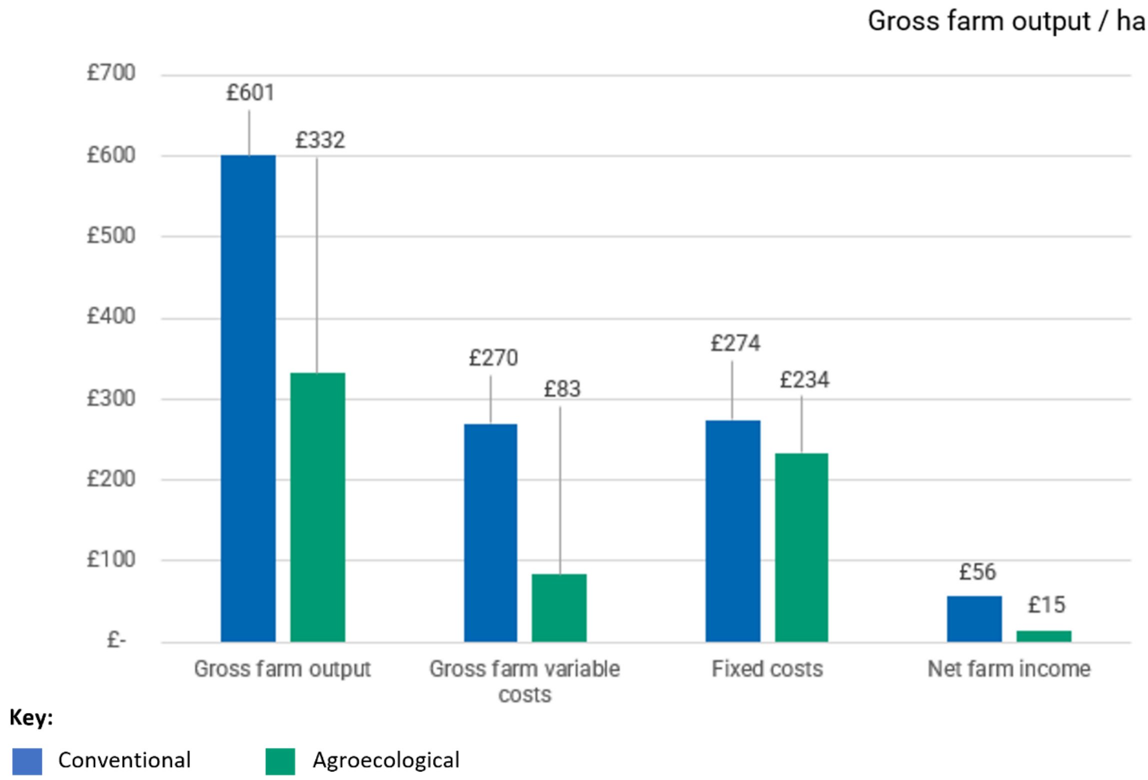
Custom scenario

For the custom scenario the following assumptions are modelled:

- Agri-environment payments rise by 30% of current rates.
- A 25% increase to farm gate price.
- Fixed costs at the same level as reported for organic.
- Nitrogen pricing at 150% of historic rates.

Applying the following assumptions to the model demonstrates the continued challenges for agroecological dairy farming to compete with conventional production. It is clear that market changes or further innovation and adaption of agroecological dairy farming are needed to support wdiespread agroecological production.





Environmental impacts

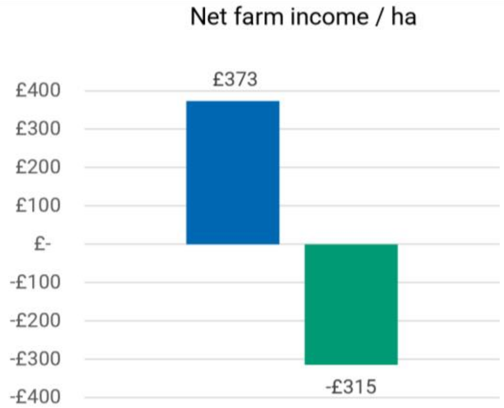
Applying a carbon payment of £15 per tonne CO_2e to the carbon sequestered by all habitats, including above and below ground sequestration, increases the income received by the agroecological farms to up to £8,184 per annum.

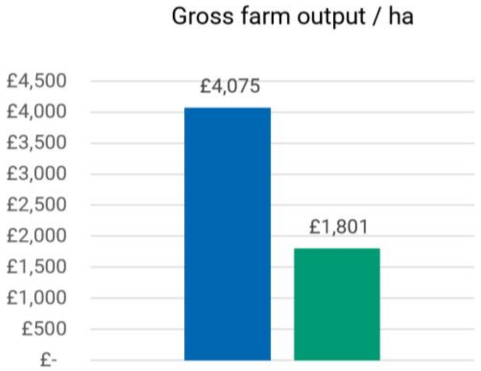
This shows the potential for payment for ecosystem service schemes to substantially increase agroecological dairy farm profitabilty. This is assuming a high soil sequestration rate for mob grazed pasture. This need further validation and the market for soil carbon needs development.

Baseline performance

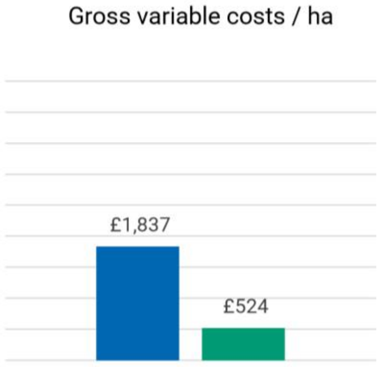
The following graphs show the performance of the dairy farms without the custom scenario applied. This is essentially how the farm types we have defined would have performed on average in 2021 based on the data available.

The lower net incomes for the agroecological farm are due to the combination of reduced stocking rate, lower productivity per cow, and continued high fixed costs.

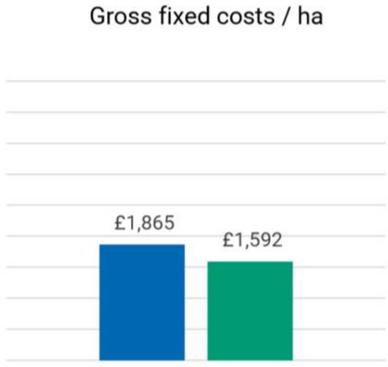




- Output was drastically reduced due to lower stocking rates, lower yield per head, and areas of pasture dedicated to beef finshing.



- Variable costs decline due, largely, to the reduced dependence on imported feed.
- Reduced N fertiliser use, fuel consumption, and lower vet and med costs also contribute.



- Fixed costs are lower for the agroelcogical dairy farm, but not by enough to offset the output reduction.
- Lower milking and land management intensity reduce machinary depreciation.
- Fixed costs for the milking parlour, machinary and labour remain high and difficult to reduce.

Key farm level recommendations and business strategy

- In the short term, alternative routes to market will be necessary for agroecological farms to generate comparable net income to conventional dairy farms. On farm processing of dairy, into products such as yoghurt and cheese, is another method to increase the output from agroecological dairy farms.
- There is a need for improved application of and understanding of the stocking rates attainable with mob grazing approaches to dairy farming and how this can improve profitability.
- Dairy farms rearing dual purpose breeds can reduce their variable costs; however, the profitability of a beef enterprise is low on a per hectare basis when compared to dairy. Selling meat direct or selling beef cattle as stores could help reduce the output lost to the beef enterprise.
- Technology and approaches need to be developed, supported, and invested in to lower the overheads of dairy farming. Reducing milking frequency could be one way to reduce costs and should be researched further.
- Historic milk prices have been kept low and exclude many of the hidden costs of conventional dairy. Agroecological dairy farmers need to prove that they can produce milk that enhances rather than degrades ecosystem services, such as carbon sequestration. This is the first step to incorporating the hidden costs into the milk supply chain.

5.2 Overview – dairy

Agroecological lowland grazing dairy farms are largely grass-based systems, with livestock continuously at pasture when conditions allow. Pasture management (including rotational grazing, mob grazing and holistic grazing) is a major focus, alongside close integration with the arable rotation, and incorporating shelterbelts and silvopasture where possible.

Livestock are rotated to new pasture every 2 to 4 days to give the grass time to regrow and to reduce risk of poaching, compaction, and runoff. Rotations are longer in the winter and shorter in the summer. Daily moves are unlikely to be feasible due to the complexity of managing this frequency of rotation alongside milking.

Pastures incorporate diverse grass and leguminous plants. Species rich in tannins such as birdsfoot trefoil can help to reduce enteric fermentation. Others, such as chicory, help to vary root structure and depth which helps to increase soil structure and make efficient use of space and resources. Legumes like white clover enhance nitrogen fixation and availability, reducing the need for imported fertilisers.

The pasture farm is partly planted with trees to provide shade, enhance animal wellbeing, reduce stress and mortality, and increase milk productivity. Research has shown that during high temperature dairy cows in shade yielded 10% more milk (Collier et al., 2006). Shelterbelts are strategically planted across the farm to maximise access to shelter and shade.

Diverse sward and browse from trees provide a varied and healthful diet to the livestock, helping to lower disease and mortality risks and vet and med costs. A small amount of arable production is undertaken on the farm to supplement the dietary needs of the livestock. Youngstock may be grazed offsite to provide fertility to neighbouring arable systems and to supplement the diet of the livestock.

Stocking rates are lower, but input costs are reduced. Costs associated with herd management and transport to grazing areas away from the farm may be higher but fixed costs more broadly are predicted to be lower due, mainly, to a reduced need for mechanisation on agroecological dairy farms, a shorter housing period and less wear and tear on buildings and fixed equipment.

5.3 Changes in environmental impact

5.3.1 Carbon storage and emissions

Increasingly, studies are showing that agroecological dairy production can reduce GHG emissions. Diversified semi-natural grasslands can also reduce enteric methane and nitrogen losses in urine, helping to lower GHG emissions (Dumont et al., 2020).

Research exploring a shift towards increased grass grazing in dairy production found that, when carbon sequestration in grassland and hedgerows was incorporated, greenhouse gas emissions from the grass grazed system were 14% lower compared with conventional dairy farms of the same area (Duru and Therond, Reference Duru and Therond 2015; Dumont et al., 2018). Other research on 66 cattle France has shown that farms producing their own feed crops had the lowest GHG emissions and non-renewable energy consumption per hectare (Veysset et al., 2014).

The above show how localised diversified feed production can reduce GHG emissions. However, when a mob grazing approach is taken sequestration rates may be greater. A study by Michigan State University found that mob grazing cattle could store 3.38 tonnes CO_2e in the soil per ha per year (Stanley et al., 2019). Whilst this work focuses on beef cows in Northern America, it does reflect the potential of mob grazed dairy systems for carbon sequestration, research projects in England and Wales are underway to validate the impact of mob grazing in the UK (Meat Promotion Wales, 2022).

5.3.2 N runoff and eutrophication risk

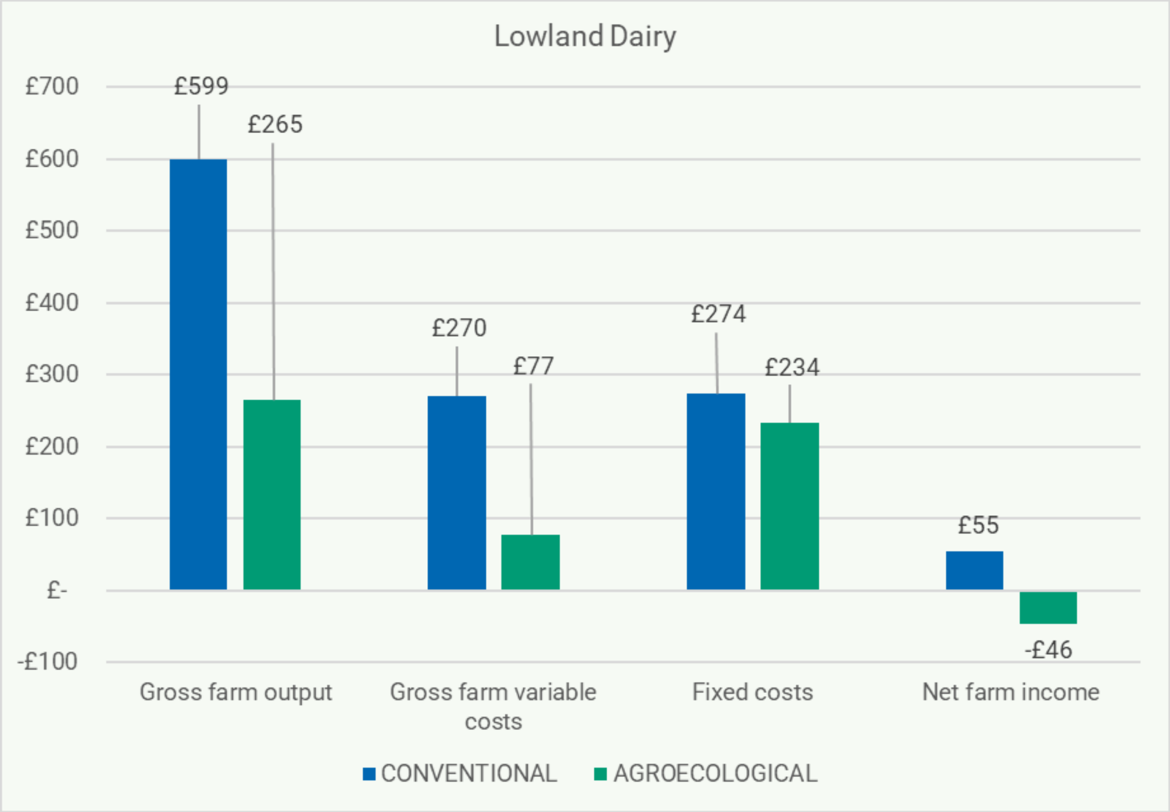
Annual average N losses from grazed pasture of 23 kg N per ha have been reported (Ledgard, 2001). Pasture diversification can help to reduce this by lowering dietary N in the urine of cows by 33% compared to cows fed on rye grass monocultures (Woodward et al., 2012; Dumont et al., 2020). The varied rooting structures of diversified pasture can also help to increase retention of nutrients within the soil.

5.3.3 Biodiversity

Diversification of the farm landscape through incorporation of diverse grass species, and features such as shelterbelts will provide more diverse and continuous habitat across the agroecological dairy farms. There is evidence that for these reasons, as well as the cessation of input application, species richness is higher on organic farms than conventional. However, it has also been shown that between 20% and 50% more land is required to produce 1 kg of organic milk than conventional (Scollan et al., 2017). This shows that to meet current levels of demand additional land use change would be required for a shift to organic dairy production. Hence, either or both milk demand and agroecological production efficiency will need to change to reduce the risk of potential negative impacts from land use change.

5.4 Findings from modelling the farm type

Figure 5: Baseline economic performance of the dairy farms



5.4.1.1 Net income

The agroecological dairy farm we have modelled, generates £100,000 less net income than the conventional counterpart.

5.4.1.2 Output

It the change in gross output that has, perhaps, the greatest impact on dairy farms. Conventional dairy farms house the cows inside for most or all the year. Hence stocking rates can be much higher, unlike on the agroecological farms where stocking rate is linked to the carrying capacity of the grassland. This decrease in the total size of the dairy herd, coupled with a 25% decrease in milk production leads to a 56% reduction in gross farm output.

5.4.1.3 Costs

Reduced variable costs lead to the biggest saving for the agroecological dairy farm, close to £200,000. These savings are largely due to a 75% reduction in feed costs as the agroecological dairy cows are predominantly pasture fed. Fixed costs are slightly lower for the agroecological farm, saving the farm £40,000, but these fixed costs are still far higher than any of the other farm types. This means that the reduced output cannot compensate for these high overheads.

5.4.1.4 Sensitivity analysis

The agroecological dairy farms performance is most sensitive to changes in fixed cost and farm gate price. A 10% change to either narrows the gap in net income between the conventional and agroecological dairy farms by £23,000.

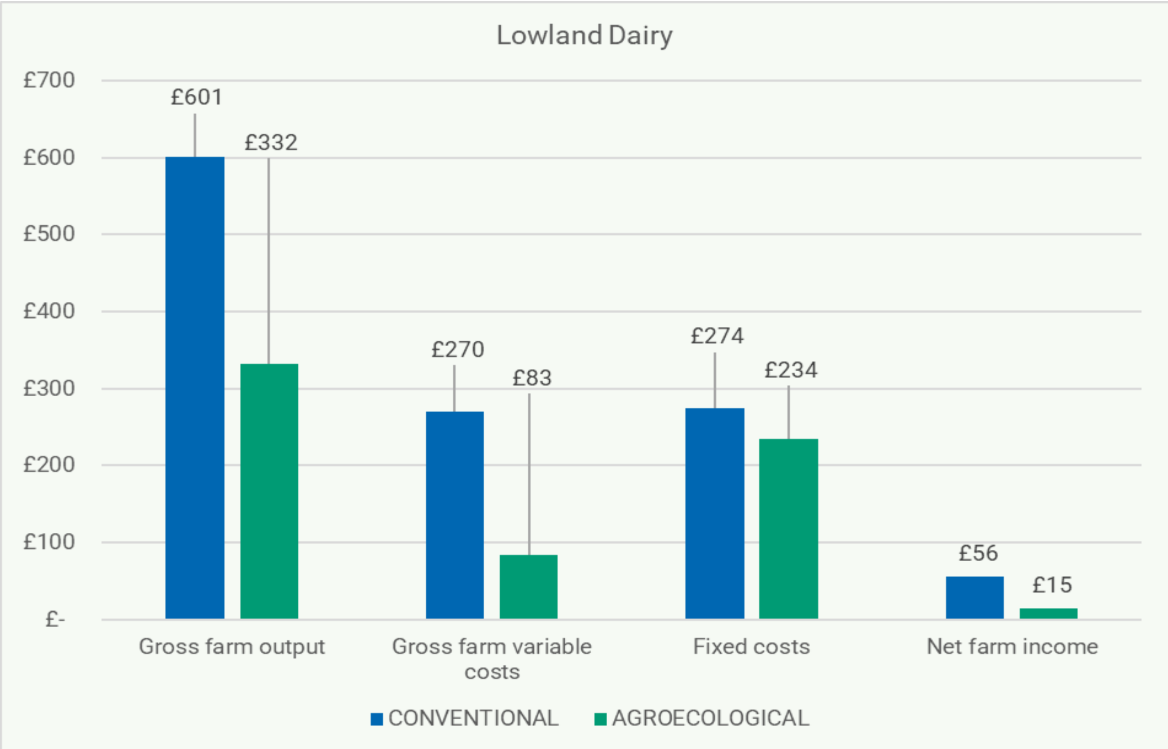
5.4.1.5 Custom scenario

The custom scenario we have modelled includes the following assumptions:

- **Agri-environment payments rise by 30% of current rates**. Modelled as a conservative estimate of how future funding will pay farmers to provide a range of ecosystem services.
- **A 25% increase to farm gate price.** Accounts for the externalities not costed into the price of milk and enables farmers to compensate for higher production costs. This is attainable through more direct routes to market and product differentiation.
- **Fixed costs at the same level as reported for organic.**
- **Nitrogen pricing at 150% of historic rates.** This is less than the price spikes caused by conflict in Ukraine and illustrates the increasing issues of nitrogen fertiliser use.

We consider these reasonable and conservative estimates of how these variables are likely to impact future dairy farming.

Figure 6: Custom scenario economic performance of the dairy farms



Modelling the custom scenario narrows the income gap between the agroecological and conventional dairy farms considerably. The agroecological farm generates over £70,000 more net income when applying these variables.

5.4.2 Carbon payment

Applying a £9 per tonne CO_2e payment to the woodland on the farm provides £346 in additional income to the conventional dairy farm and £1,365 to the agroecological. This marginally narrows the income gap between agroecological and conventional. This additional income recognises some of the value provided by carbon stored in the 7 ha of shelterbelts on the agroecological dairy farm.

However, when £9 per tonne CO_2e payment is applied to the carbon sequestration for all habitats, including above and below ground sequestration, the agroecological payment increases. The conventional dairy farm sequesters some carbon and receives payment of £851. The agroecological farms, however, sequester an estimated 546 tonnes CO_2e. This generates £4,911 in additional income.

Increasing the payment rate to £15 per tonne CO_2e sequestered increases the additional income received by the agroecological farms to up to £8,184 per annum. This narrows the income gap, but the agroecological dairy farm still fails to generate incomes comparable to the conventional system. It would take carbon payments of £61 per hectare for agroecological dairy farming incomes to becomes higher than the conventional. Whilst carbon prices as high as these have been reported, it is unlikely they could be sustained or relied upon.

5.4.3 Discussion

Dairy is one of the more challenging farm types to transition to agroecology. The high fixed costs mean it is more difficult to run profitable lower yielding dairy farms. The reductions to variable costs due to reductions in synthetic inputs and feed, that help to increase the net incomes of other farm types, do not influence the fixed costs which, to are less variable across dairy farms.

The 30% increased agri-environment payment provides some additional funding to dairy farms but compared to the scale of the outputs and costs, these payments are relatively small. It is likely, however, that the model underrepresents these payments, and the defined agroecological may actually receive higher payment compared to the conventional systems due to the establishment and maintenance of semi-natural swards, shelterbelts, and other non-provisioning habitat. More in-depth estimation and validation of the possible payment rates for agroecological dairy could improve understanding of how agri-environment payment may improve the future profitability of these farms.

For the National Food Strategy (2021), SYSTEMIQ undertook research estimating the high externalities associated with conventional food production including the 27% hidden cost of carbon in milk. Agroecology is one approach to reduce these externalities. We assume that rewarding agroecological dairy farmers for the positive externalities they provide can support higher farm gate pricing. Milk is one of the agricultural products that is most commoditised, with the greatest pressure on farmers to intensify production. There is a need to provide sustainable dairy farmers with additional payment in order to alleviate this pressure and the environmental damage that is so often associated with it. The 25% increased farm gate value modelled in the custom scenario is likely to be an underestimation of the externalities that need costing into modern milk production. It also remains lower than the 39% price premium for organic milk.

Again, we model an increase to nitrogen price here. The impact on the profitability of a conventional dairy farm will be an underestimation. This is because it acknowledges the increase cost of forage production but does not factor in the impact increased fertiliser cost would have on concentrate production. Feed costs will be highly influenced by the impact of geo-political events and the impact this has on nitrogen prices but also trade.

Increasing nitrogen pricing to 300% of historic rates and applying this to the custom scenario drastically changes performance, leading the agroecological dairy farm to generate £2,000 more profit that the conventional system. This increased nitrogen price demonstrates the exposure of dairy farms to global markets. Actual fertiliser price increases would correspond to higher milk pricing, as is being witnessed at the time of reporting.

Whilst all the assumptions we explore above will not come to fruition, policy is undeniably moving in the direction of tighter environmental regulation and PES scheme facilitation. Payment for carbon storage, nutrient neutrality offsetting, BNG, funding from utilities companies to improve water quality and forms of environmental taxation are all likely to impact the profitability of dairy production in ways that favour agroecological farming methods. This means that, despite the challenges with high fixed costs, there is a strong long term business case for adoption of agroecological dairy farming. Policy needs to effectively and reliably support the types of financial mechanisms that can support profitable, sustainable agroecological dairy farming.

5.5 Farm level recommendations and business strategy

- Stocking rate is a major factor in the profitability of dairy systems. There is a need for improved application of and understanding of the stocking rates attainable with mob grazing approaches. Exploring methods to maintain high stocking rates with beneficial impacts on pasture and soil will help improve agroecological dairy profitability.
- Dairy farms rearing dual purpose breeds can reduce their variable costs; however, the profitability of a beef enterprise is low on a per hectare basis when compared to dairy. Agroecological dairy farms will need to develop relationships with local butchers, restaurants, or meat boxes to generate higher farm gate prices for the beef and compensate for the loss in milk income. Selling beef cattle as stores rather than finishing them on the farm is another option that could reduce the amount of time and area used to graze beef cattle. This could improve the area of the farm dedicated to grazing of dairy cows and hence the average output per ha.
- Fixed costs are a major barrier for transition to agroecological dairy farming. Technology and approaches need to be developed, supported, and invested in to lower the overheads of dairy farming. Reducing milking frequency could be one way to reduce costs.

Historic milk prices have been kept low and exclude many of the hidden costs of conventional dairy. Agroecological dairy farmers need to prove that they can produce milk that enhances rather than degrades ecosystem services, such as carbon sequestration. This is the first step to incorporating the hidden costs into the milk supply chain.

- In the short term, alternative routes to market will be necessary for agroecological farms to generate comparable net income to conventional dairy farms. On farm processing of dairy, into products such as yoghurt and cheese, is another method to increase the output from agroecological dairy farms.

Case Study 2: Dairy

Title: Agroecological dairy made viable through collective access to a premium supply chain.

Background / brief description of farm: This 97-ha organic farm supplies a local dairy which produces premium organic dairy products. The family owns 34 ha of land, consisting of permanent grassland. The herd is comprised of traditional breeds including 110 cows and 70 followers. The young stock are reared at the home farm. The milking herd is managed on the tenanted land, where the soil is being enhanced using agroecological principles. Much of the animal feed is produced on the farm in rotation.

"When we transitioned, the advice was not there. There is no point having an advisor who does not understand agroecological side."

They have been farming organically for many years and learned some painful lessons. Understanding soil pH and nutrients is important. Whole cropping of wheat and peas did not work for their farm due to differences in harvest times and the cost of drying grain. They therefore moved to arable silage. Fodder beet did not work for them either.

Aim: The farmer's aim is to produce a high-quality nutritious product that customers are willing to pay a premium for. The focus is on enhancing soil health to increase the resilience and performance of the business.

Key management features of the agroecological system

Description of the key management features	Description of the management approach and reason for implementing
Soil health & fertility	The tenanted land has been put to grass and rested to let fertility rebuild after historic intensive management. The land is in rotation with red and white clover for nitrogen fixing.
Rotation	Principally arable sileage wheat/barley, five-year grass ley with whole top red and white clover. The permanent grassland is not in rotation as ground is too wet to cultivate.

Varieties/breeds	Traditional breeds – British Friesians, Dairy Shorthorns and Ayrshires. These breeds balance reduced milk yields with improved hardiness, longevity and efficient conversion of pasture and home-grown forage into milk.
Disease & pest management	Vet carries out routine visits for health to prevent issues early on.
Other	The farm buys in 0.5-0.75 tonnes of feed per cow per year, but this is expected to diminish over time.

Impacts of the agroecological system

- **Farm resilience** - Arable rotation reduces the requirement for bought-in fertiliser and feed, leaving the enterprise less exposed to commodity input prices. Collective price negotiation results in increased revenues
- **Climate impact** - No use of artificial fertiliser which is carbon intensive. The bought-in feed does not contain soya.
- **Nutrient run off** - No nutrient runoff. Permanent grassland protects soil from erosion and absorbs excess rainfall
- **Ecological impact** - Wildlife has returned to the farm: birds, butterflies, heron, kites, and an otter. There is a pond which attracts lots of wildlife and they manage their hedgerows sensitively.
- **Societal impact** - High animal health and welfare. The farm produces a high-quality nutritious product for which their customers are willing to pay a premium price. Carbon and biodiversity benefits, water quality, flood protection, landscape

Performance

Yield & Profitability	
Yield, revenues, profit margins	
Yield per cow	6000 litres per year (620,000 litres total). This is approximately 25% lower than in a conventional system. A conventional Holstein can yield 8,000 to 10,000 litres per year, but this does not work organically as the systems are dependent on high input use. Annually, 15% of cows are sold due to non-productivity.
Revenue per ton (main product)	Revenue based on lower yields but with premium price (confidential). Involvement and negotiation in milk procurement has helped the farmer, along with others, to access excellent

	organic milk prices. This price is key to supporting the agroecological approach.
Yield of arable sileage	Currently 6 tonnes per ha dry matter. Farmer predicts this could be higher - there are organic farms that can do 12t/ha or more. They think they can achieve this in future, as fertility of most fields (used for silage) is good. 16% grass protein content.
Agri-environment support	£7,000 agri-environment + £15,000 Single Farm Payment (SFP)
Variable costs	
Inputs (seeds)	£3,000 per year
Inputs (concentrates)	£80,000 per year (in non-soy based, 0.5-.75 ton per cow/year) This will be reduced over time as productivity of arable sileage increases.
Inputs (fertiliser)	None. Lime: £3,000 per year
Inputs (pesticides/ herbicides)	None. Does not use any pesticides or herbicides / no problems with weeds.
Vet/Med	£13,000 (£1,000 per month for routine vet visits)
Other	Annual soil testing. More use of overseeding and harrowing compared to conventional
Variable costs per cow	£1,000 per year per cow.
Fixed costs	
Housing	Similar to conventional farming. High housing costs and investment in improved slurry management.
Machinery	Similar to conventional farming
Water / electricity / general costs	Similar to conventional farming. Keen to shift to renewables, but lacking capital after investing in infrastructure to be NVZ compliant

Labour (move this to fixed costs)	Father and son. One part-time milk relief worker *"At the end of the financial year, there is about £40,000 to pay ourselves"*
Net margin/profit	£22,000

Key challenges for transitioning to agroecological farming

- **Access to water** - The son would like to do mob grazing but says he cannot do this because of access to water. He does realise that mob grazing would provide him with more forage. He produces 6t/ha of organic dry matter, but 12t/ha should be possible (some other organic farmers do even more, like 14t/ha – but this also depends on soil, location, weather, etc).
- **Advice** - There is a need to improve access to advice which was not there when the farm was transitioning and exploring different forms of agroecological production. There is no point having an advisor who does not understand agroecological side, which can often be the case.
- **Improved grass management** - They would like to shift to better grass management to reduce the cost of buying in feed. The farm is working with a research group from the university to test different fertiliser applications of slurry, farm yard manure, lime applications. They will test pH, macro and micronutrients, and impact on grass productivity.
- **Lack of capital to invest** - Becoming Nitrate Vulnerable Zone (NVZ) compliant required high capital investment in slurry lagoon. The government grant is paid retrospectively, based on costs two years ago. There is no money left to invest in renewables and the business is therefore highly vulnerable to electricity price rises.

6 Lowland grazing

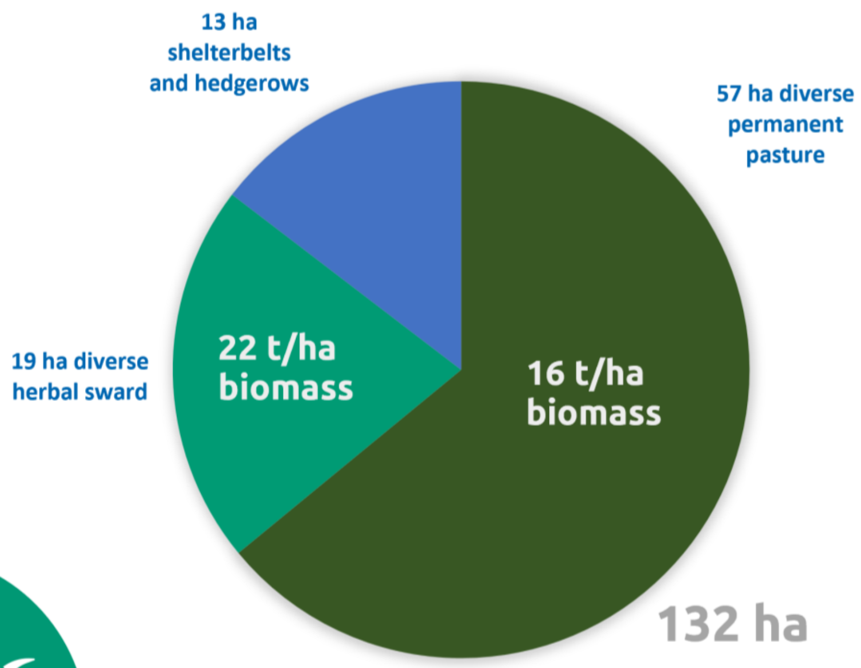
6.1 Summary

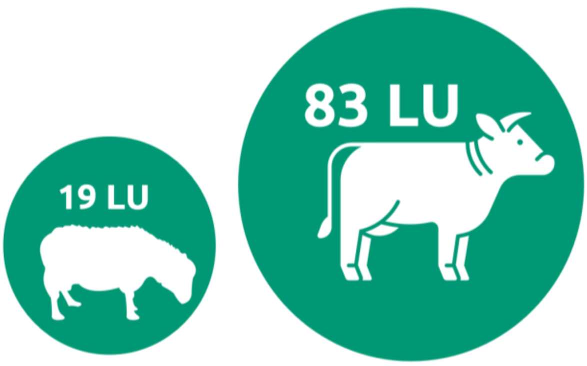
Conventional lowland grazing farms focus on maximising stocking and growth rate. Breeds are selected based on fast growth rate; behavioural traits and hardiness have often been bred out. Pasture is usually modified through nitrogen application and reseeding and is composed of few species. Animals are rarely outwintered and housing and supplementary feed is necessary during these months. In contrast, below we have defined two typical agroecological horticultural farms.

Mob grazing is used to maintain moderate productivity and stocking rates, with low levels of pasture and soil degradation.

Hardy, and often native breeds are selected due to their propensity for grazing diverse forage and suitability for outwintering.

Cattle and sheep are entirely pasture fed with no supplementary feed. Non-provisioning habitat focuses on providing microclimate regulation for the animals as well as refuge for





Fertility management

- Similar to the dairy farm.
- Additionally, mixed livestock graze pastures more evenly supporting species diversity.

Pest and disease management

- Grazing multi-species grasslands can improve livestock health, such as by reducing the need for anthelmintic treatments.

Health and welfare

- Shelterbelts reduce stress and mortality during lambing.

Biodiversity

- Semi-natural, diverse swards and shelterbelts provide connected habitat for a range of species.

C footprint

- Mob grazing livestock has been found to sequester carbon at rates as high as 3.38 tCO_2e per ha.
- Species rich in tannins, such as birdsfoot trefoil, can help to reduce enteric fermentation.
- Shelterbelts store additional carbon in woody biomass and soil.

N runoff

- Synthetic nitrogen application is negligible.
- More continuouse soil cover, varied root structures and non provisioning habitats reduce the risk of runoff from livestock manure.

Performance of the lowland grazing farms

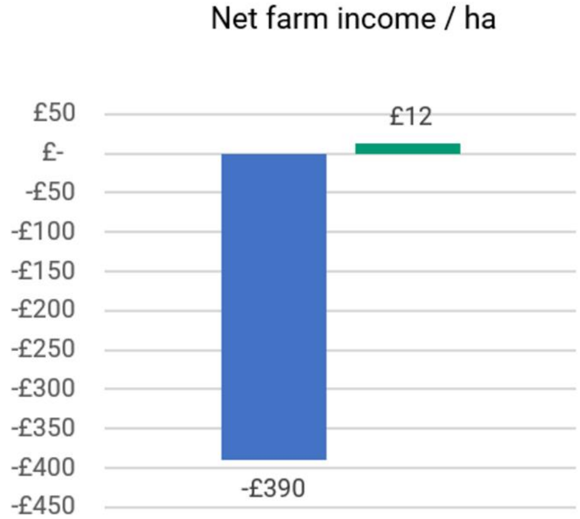
Custom scenario

For the custom scenario the following assumptions are modelled:

- Agri-environment payments rise by 30% of current rates.
- A 10% increase to farm gate price.
- Fixed costs 30% below conventional.
- Nitrogen pricing at 150% of historic rates.

Applying these assumptions means agroecological lowland grazing farming can outperform conventional production. The modelled results of this custom scenario modelling are shown in the following two bar charts.

The graphs show the challenges that confront lowland grazing farms; conventional production is particularly exposed as BPS is reduced. However, the agroecological farm is also only weakly profitable and needs additional support.



Environmental impacts

- Sequesters up to 359 tCO_2e per annum
- Diverse pasture can lower N in excreta by 33%
- Increased habitat diversity and connectivty

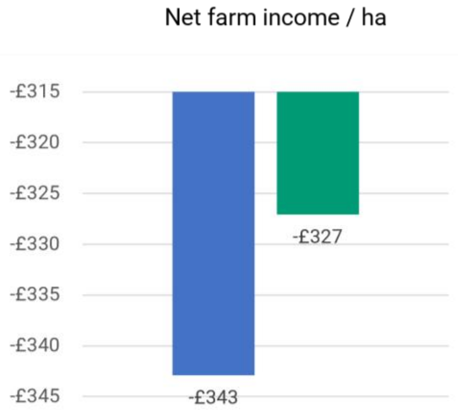
Applying a carbon payment of £15 per tonne CO_2e to the carbon sequestered by all habitats, including above and below ground sequestration increases the income received by the agroecological farms to up to £6,402 per annum.

This gives one example of the potential for payment for ecosystem service schemes to increase the profitability of agroecological lowland grazing farms.

Baseline performance

The following graphs show the performance of the lowland grazing farms without the custom scenario applied. This is essentially how the farm types we have defined would have performed on average in 2021 based on the data available.

Both farms generate negative net incomes; especially so for the conventional system. It appears that the high costs of intensively rearing livestock for meat are, on average, not offset by the output and current meat prices.



- Output is reduced due to the lower stocking rate on the agroeclogcial farm.
- The farm also produces less crops for human or animal consumption.

- The main saving from agroecological production is due to reduced variable costs.
- Pasture is no longer modified and supplementary feed crops are not produced.
- No nitrogen or sprays are applied to the farm.
- Livestock are entirely pasture fed removing the need to buy in feed.

- Average lowland grazing organic data showed that fixed costs are slightly lower than conventional.
- In reality, costs are likely to be lower than these averages.
- Housing, mechanisation and labour are all reduced by taking an agroecological approach to lowland grazing.

Key farm level recommendations and business strategy

- Farmers should focus on gross margins and cost reduction and less on yield maximisation. Reduced exposure to variable cost can be a profitable and resilient strategy.
- Farmers should consider a mob grazing approach as a way to lower their variable costs whilst maintaining moderately high outputs. This can lower exposure to input price fluctuations.
- Peer-to-peer knowledge sharing between farmers practicing and considering mob grazing and pasture fed lowland grazing needs to take place and be incentivised.
- Farmers currently undertaking mob grazing need to work with researchers and diverse organisation to validate and communicate mob grazing stocking rate limits, fixed costs, and carbon storage. It is important that information is also made available about how this varies in different contexts.
- Shelterbelts can combine additional carbon storage, with performance benefiting shelter, and supplementary forage.
- PES schemes such as carbon markets offer a potential way for lowland grazing farms to supplement low average net incomes.

6.2 Overview – lowland grazing

Lowland grazing is managed in a similar way to the dairy system described in section 5. Mob grazing is used to maintain moderate productivity and stocking rates, with low levels of pasture and soil degradation. Livestock are rotated more frequently than on agroecological dairy farms, with moves every 1 to 4 days. Rotations are longer in the winter and often shortening to daily moves in the summer. Hardy, and often native breeds are selected due to their propensity for grazing diverse forage and suitability for outwintering.

Unlike dairy, cattle and sheep in the lowland grazing system are entirely pasture fed with no supplementary feed. Non-provisioning habitat focuses on providing microclimate regulation for the animals as well as refuge for biodiversity. Mixed shelterbelts, sparse trees and areas of woodland provide these beneficial services.

It is assumed that the lowland grazing farms consist of good quality semi-improved grassland. Other priority grassland habitats require more context specific management and are beyond the scope of this modelling work.

6.3 Changes in environmental impact

6.3.1 Carbon storage and emissions

Research in Northern America has shown that although the emissions from mob grazed cattle, at 9.62 kg CO_2e per kg carcass weight, were higher than for concentrate fed cattle, the carbon sequestration in the soil reduced this to −6.65 kg CO2e per kg carcass weight (Stanley et al., 2018). Soil carbon sequestration was 0.9 tonnes C per ha per year, the equivalent of 3.38 tonnes CO_2e per ha. This sequestration was achieved at stocking rates of 2.7 steers per ha, considerably higher than is modelled for this project. This work shows that mob grazing of cattle can, in certain contexts, be a net carbon sink. This is promising research, and ongoing work seeks to validate this across wider areas and across the UK (Meat Promotion Wales, 2021).

Other work has shown investigating the GH emissions of 66 cattle farms in the Charolais region of France found that farms producing their own feed crops had the lowest GHG emissions and non-renewable energy consumption per hectare (Veysset et al., 2014)

There is growing evidence that localised and efficient production of livestock feed at the farm level using agroecological methods can be an effective way to increase levels of soil carbon.

6.3.2 N runoff and eutrophication risk

As with the dairy farm, the species diversity, nutrient content and root structure of mixed pasture can reduce the nitrogen emissions from livestock and reduce risk of runoff and water pollution (Ledgard, 2001; Woodward et al., 20012; Dumont et al., 2020)

6.3.3 Biodiversity

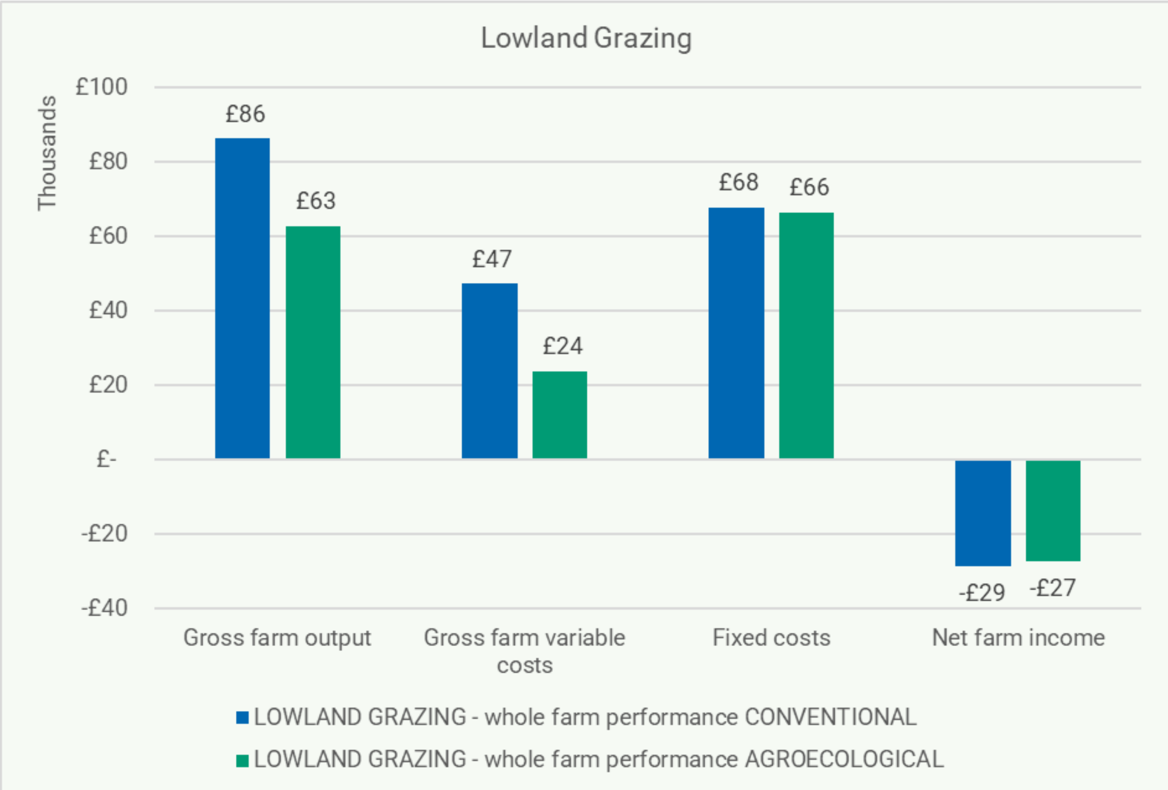
The impact upon biodiversity is complex. Whilst well managed mixed species pasture can provide good quality habitat for floristic species and the associated fauna, grazed livestock do require greater grazing areas than concentrate fed livestock. Research has shown the area needed to produce grass fed beef to be 50% greater than for internally housed animals (Stanley et al., 2018).

At scale, and without a change in national consumption of animal products, a compete shift to grass fed could increase conversion of certain habitats to grassland, with negative impacts on certain species. However, the habitat provided by the mixed swards, shelterbelts, hedgerows, and margins that comprise the agroecological farm would help to compensate for any impacts on habitats. This is especially true if large areas of conventionally managed modified grassland were shifted to mob grazed, no input, species rich grasslands.

6.4 Findings from modelling the farm type

6.4.1 Baseline performance

Figure 7: Baseline economic performance of the lowland grazing farms



6.4.1.1 Net income

Agroecological lowland grazing is the farm type the model shows to outperform the conventional system. £1,327 additional profit can be gained by the farmer by undertaking an agroecological mob grazing approach. Despite the performance benefits of agroecological lowland grazing, neither farm generated a positive net income. This aligns with FBS data. Current lowland grazing farms struggle to attain adequate outputs to offset the fixed and variable costs. Variable costs which, in the case of the conventional system make up over 50% of the output alone.

6.4.1.2 Output

Gross output is reduced by about £24,000. This is just over a 25% reduction. Which is considerably smaller than the 50% and higher reductions that have been estimated across other farm types. The mob grazing approach balances an innovative form of performance enhancement with the ecological needs of the grasslands and enables moderate output to be retain when transitioning to agroecological farming.

6.4.1.3 Costs

Variable cost reduction is the major benefit from agroecological lowland grazing. This alone reduces costs by £24,000, more than compensating for the reduced agroecological output.

Forage production is the area where approximately half of the variable costs are saved. Savings are due to removing the need to fertilise and intensively manage the pasture.

Based on reported organic data, fixed costs are also slightly reduced, further widening the performance gap between agroecological and conventional. Reduced fixed costs range from lower machinery needs, reduced housing and potentially even reduced labour costs.

6.4.1.4 Sensitivity analysis

Net income gap between the two farm management strategies is most sensitive to changes in the agroecological fixed costs and farm gate pricing. However, compared to the cereals and dairy systems lowland grazing is more sensitive to agri-environmental and nitrogen pricing change. The lower outputs and costs per hectare of this farming type mean that changes to input costs and support payments can have a larger impact upon performance than on more intensively manged farms.

Furthermore, average per ha agri-environment payments are amongst the highest for this farm type, with the average organic lowland grazing farm earning closer to twice as much from agri-environment payments than cereal, horticultural or dairy farms. This means that changes to payment rates have a proportionally greater impact upon lowland farms.

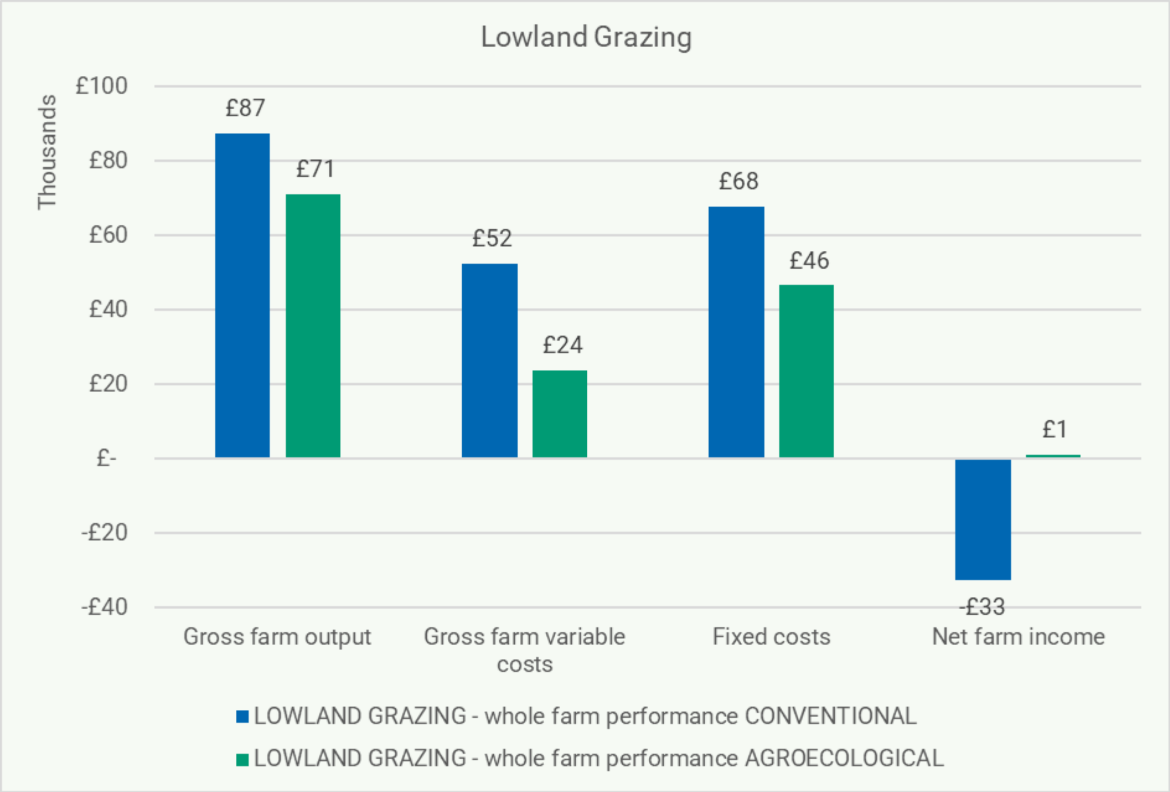
6.4.2 Custom scenario

The custom scenario we have modelled includes the following assumptions:

- **Agri-environment payments rise by 30% of current rates**. Modelled as a conservative estimate of how future funding will pay farmers to provide a range of ecosystem services.
- **A 10% increase to farm gate price.** It is assumed the farmer can generate this marginal increase through some more direct sales and certification.
- **Fixed costs 30% below conventional.** Based on the case studies it is reasonable to assume fixed costs could be even lower.
- **Nitrogen pricing at 150% of historic rates.** This is less than the price spikes caused by conflict in Ukraine and illustrates the increasing issues of nitrogen fertiliser use.

We consider these reasonable and conservative estimates of how these variables are likely to impact future cereal farming.

Figure 8: Custom scenario economic performance of the lowland grazing farms



The income gap between the agroecological and conventional lowland grazing farms widens when the custom scenario is modelled, and the agroecological farm becomes profitable.

6.4.3 Carbon payment

Much of the non-provisioning habitat on the agroecological lowland farm is dedicated to shelterbelt planting. Hence, a £9 per tonne CO_2e payment for the woodland on the farms provides £896 in additional income to the agroecological farm. In comparison the conventional farm only receives £66.

Applying a carbon payment to all carbon sequestered further increases this payment rate as the agroecological farmer can be rewarded for the carbon stored as organic matter across the managed grassland. The conventional cereal farm sequesters little carbon and only receives payment of £309; the modified grassland and high stocking rates limit the carbon sequestration. The agroecological farm, however, sequesters an estimated 360 tonnes CO_2e with the mob grazed pasture being the large source of sequestration. This generates additional income between £3,231.

Increasing the payment rate to £15 per tonne CO_2e sequestered increases the additional income received by the agroecological farms to up to £6,402 per annum.

6.4.4 Discussion

It is telling that, when BPS is removed, average conventional lowland grazing farms perform at a loss in the model and the FBS. Low per hectare income means this farm type faces significant challenges as income price fluctuates and BPS funding reduces. Our modelling shows how exposed to increased nitrogen pricing the conventional farm is, with pricing set at 150% of historic rates triggering a £4,000 reduction in net income and a 300% nitrogen price increasing leading to a £21,000 reduction. Similar impacts could be projected for fuel and feed costs all of which are impacted by geo-political events like those currently occurring in Ukraine.

Predicted increases to agri-environment payments also favour a transition to agroecological lowland grazing. These farms are likely to be able to access payments for maintenance of semi-natural swards and shelterbelts, unlike the conventional systems, where payments will be more limited to agricultural margins and hedgerows. Furthermore, payments for carbon storage have potential to further increase the payments of public goods provided. If mob grazed lowland farms can validate carbon stored, this will further incentivise the transition to agroecological production.

In the custom scenario, we project a modest 10% increase to farm gate pricing for the agroecological farm. There are numerous ways the farmer could access this additional income. Certifications such as organic or pasture for life offer income benefits, butchering on farm can increase value per carcass, and incorporating some more direct sales to restaurants or consumers can help provide a greater margin for a proportion of the meat produced.

In the baseline scenario, we model agroecological fixed costs that are marginally lower than conventional. For the custom scenario we assume fixed costs that are 30% lower than conventional. In reality, fixed costs for a mob grazed system could be even lower. A conventional farm often needs to apply fertiliser and sprays, grow crops, reseed pastures, manage slurry, process silage, feed livestock housed inside, and clean animal housing. In contrast management of an agroecological lowland grazing farm focuses on well managed rotational grazing. Whilst labour to rotate grazing with electric fencing and provide access to water in new grazing areas increases, Case Study 3 showed how this can be managed extremely efficiently and with minimal machinery.

Perhaps the most uncertain aspect of our model is the stocking densities we have selected for the mob grazed system. We predict mob grazing can increase stocking rates by 60%. There is limited peer reviewed, or widely verified information on UK mob grazing to compare this against. Trials currently underway will help to clarify. This will also help to understand the impact mob grazing at certain stocking rates can have upon soil organic matter and carbon storage.

6.5 Farm level recommendations and business strategy

- Key to a transition to agroecological lowland grazing is a mindset shift. Farmers need to stop focusing on yield maximisation and give higher importance to gross margins and cost reduction. Reduced exposure to variable cost can be a more profitable and resilient strategy. Recent high nitrogen fertiliser prices are testament to the benefits of a low intensity approach. Livestock breeds need to be selected to align with this cost minimisation, rather than simply focusing on high productivity.

- The continued and consistent profitability of conventional lowland grazing is at risk. Farmers should consider a mob grazing approach as a way to lower their variable costs whilst maintaining moderately high outputs. This can lower exposure to input price fluctuations. Farmers taking on this approach should ensure their grazing management aligns with current agri-environment options.
- Peer-to-peer knowledge sharing between farmers practicing and considering mob grazing and pasture fed lowland grazing needs to take place and be incentivised. Lowland grazing farmers considering a transition should visit other farmers managing agroecological mob grazing in their area. This will help with carefully planning rotations. It is also important to understand how to efficiently manage rotating livestock with electric fencing, how to connect fencing to power sources, and how to provide the frequently moved livestock with water.
- Farmers currently undertaking mob grazing need to work with researchers and diverse organisation to validate and communicate mob grazing stocking rate limits, fixed costs, carbon storage, and impact upon biodiversity. It is important that information is also made available about how this varies in different contexts.
- Shelterbelts can combine additional carbon storage, with performance benefiting shelter, and supplementary forage. Support schemes for on farm tree planting are also available and can completely cover establishment and maintenance costs.
- PES schemes such as carbon markets offer a potential way for lowland grazing farms to supplement low average net incomes. Carbon stored in shelterbelts could potentially be supported by carbon reduction schemes. Schemes for carbon payments for agroforestry and soil carbon sequestration could further support agroecological approaches.

Case Study 3: Matt and Laura Elliott – The Sandy Hill Mob

Title: Pasture for Life, mob-grazed beef farm.

Background / brief description of farm:

This 110-acre farm in the Cotswolds primarily manages a Pedigree Hereford Cattle herd (15-18 breeding cows plus followers) and has recently integrated Shropshire Sheep (a flock of 14 ewes, growing to 30 in future). They practice mob grazing, moving the cattle around the farm using electric fencing. During the growing season, cattle are moved daily. Cattle are outwintered during which time the rotation is slowed so the cows remain in larger paddocks for 3-4 days. Round hay bales are rolled out during the winter as supplementary feed.

The farm was previously managed intensively and was in poor condition. The arable land (60 acres, sandy, free draining soil) had little topsoil left, and the Parkland (50 acres of permanent pasture) showed low diversity and signs of compaction.

Five years ago, the current tenants took over management. They planted the arable land with a diverse herbal ley, including grass species, sainfoin, chicory, salad burnet, clovers, vetches, and plantain. They are Pasture for Life certified and produce 100% grass and pasture fed beef, which they sell direct (meat boxes are collected or delivered).

"Pasture for life – the network has helped share knowledge about grazing practices, gain access to mentors, and supported with access to farm tenancy."

The agroecological approach is positively impacting biodiversity, with a variety of birds and other wildlife sighted on the farm. Most of the farm is under Higher Level Stewardship options which include floristically enhanced margins around all the herbal leys and limits to hedge cutting providing valuable resources for redwings and fieldfares come the winter.

They have planted half an acre with different varieties of cider apple trees for future cider production. Once the trees are established, the orchard will be grazed by sheep. In future, they plan to incorporate poultry into the grazing rotation. Eggs can help diversification and help draw customers to the farm. They are also looking to further diversify by providing a wider range of seasonal produce through the meat boxes (they are constructing a polytunnel to enable this).

Aim: The main aim is to create multiple income streams for the farm, providing high value products to customers.

Key management features of the agroecological system

Key management features	Description of the management approach and reason for implementing
Diverse herbal swards	The herbal swards are restoring the health of the soils. They appear to be increasing the resilience of the land against drought and enable retained productivity through the year. The mix of species seem to be supporting a wealth of biodiversity including floristic species such as orchids and high levels of insect activity.
Mob grazing	Promotes grass re-growth, making it more productive whilst minimising poaching and compaction
Outwintering	Herefords are suited to this kind of management due to their ability to thrive under adverse conditions. Saves costs of housing and feed.
Multiple organic enterprises	Organic management is part of the marketing. Multiple enterprises are part of a holistic system. Diversification creates multiple income streams and resilience.
Other	Flower margins, reduced hedge trimming. The agroecological approach has brought wildlife back on the farm.

Impacts of the agroecological system

- **Farm resilience** - Arable rotation reduces the requirement for bought-in fertiliser and feed, leaving the enterprise less exposed to commodity input prices.
- **Climate impact** - No bought-in feed, no use of artificial fertiliser which is carbon intensive. Permanent grassland sequesters carbon.
- **Nutrient run off** - No nutrient runoff. Permanent grassland protects soil from erosion.
- **Ecological impact** - the agroecological approach is having a positive impact on biodiversity. Snipe, kestrels, barn owls, and short-eared owl are all presented/have been sighted on the farm. Insect life is increasing and therefore small mammals, foxes, badgers, fallow and roe deer, hares, birds, bats and even a common lizard are observed.

- **Societal impact** - High animal health and welfare. the farm produces a high-quality sustainably produced meat. Carbon and biodiversity benefits, water quality, flood protection, landscape.

Performance

Yield & Profitability	
Yield, revenues, profit margins	
Revenues meat box scheme	Beef: Average of £2,500 per animal. 12 animals finished annually at 300 to 380 kg dead weight. Lamb: £11/kg targeting a finish weight of 20kg.
Mortality rate	1 of 16 calves lost yearly. Approximately 3% calf mortality rate. 12-year life expectancy.
Net margin/profit enterprise	£42,000 profit per annum (£20,000 agricultural net income, £12,500 BPS)
Agri-environment payments	£9,500 higher level stewardship payments.
Variable costs	
Inputs (seeds)	None
Inputs (hay)	£3,500 on hay purchase – should reduce as soil health regenerates, & productivity increases
Inputs (fertiliser, pesticides/ herbicides)	None
Vet/Med	£200 per year. Low worm burden for cattle and sheep
Fixed costs	
Business costs	£26,500 total annual costs (Key costs are: £11,000 rent, £6,500 direct sales costs, £1,500 on fuel, and £1,500 contracting.)
Machinery & equipment	Negligible. Old vintage tractor and a stock trailer. Hay harvesting is contracted. The main cost is the electric

	fencing. Total expenditure was about £3,500 and has lasted for 4 years with no issues.
Water / electricity / general costs	Similar to conventional farming
Labour	Matt and Laura both work part-time

Key challenges for transitioning to agroecological farming

Not having their own bull has meant they have, at times, been restricted by biosecurity issues away from the farm, this impacts the control of their breeding. Hence, the farm is planning to purchase their own bull to gain better control of their system and increase the biosecurity of the herd.

Building up a customer base and keeping those customers is proving challenging. Customers have many competing demands for their interest and money, keeping people engaged with the farm and motivated to purchase through the alternative supply chain is necessary to support their approach.

7 Extensive upland grazing

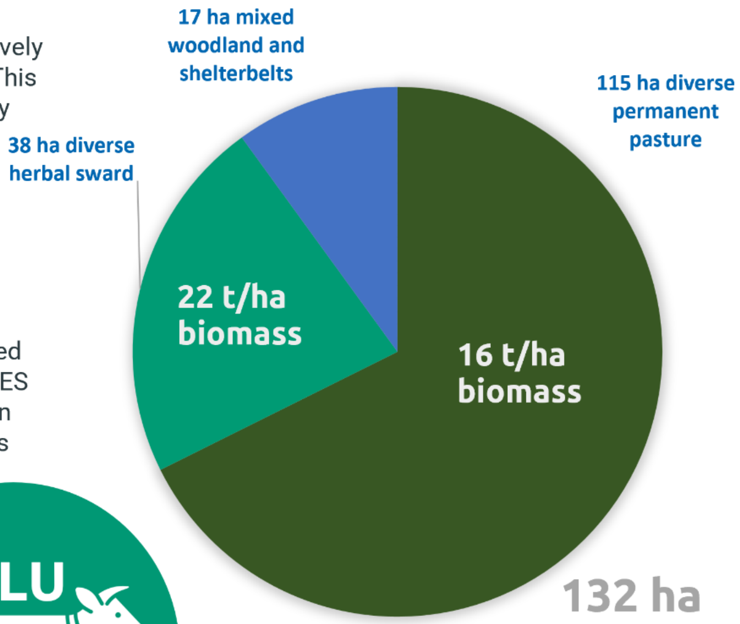
7.1 Summary

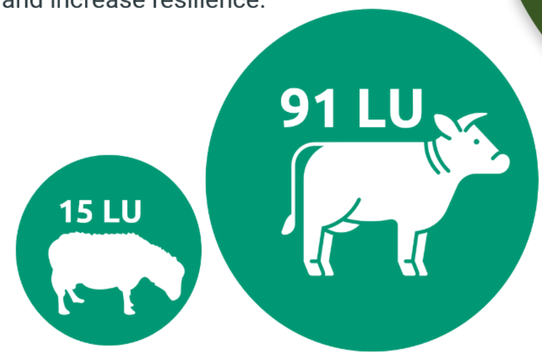
Conventional upland grazing provides important support to rural communities and economies. However, high stocking rates, low tree cover, and pasture modification mean that the land use has contributed to increased flood risk, soil erosioin, water pollution, and habitat loss. Furthermore, BPS reduction is exposing upland farmers to increasing economic risk. In contrast to conventional upland farming and the associated risks, below we have defined two typical agroecological upland grazing farms.

Agroecology in the uplands is characterised by a mosaic of upland heath and wood pasture extensively grazed by mixed livestock at low stocking rates. This approach reduces management and input intensity and, therefore, costs.

Hardy varieties are carefully selected to enable all year-round grazing and to benefit local habitats. Livestock are free to roam and express natural behaviours.

The extensive upland areas are strategically planted with dense areas of trees, supported by blended PES schemes seeking to enhance carbon sequestration and improve landscape hydrology. These elements diversify incomes and increase resilience.





Fertility management
- Soil health benefits from low stocking rates.
- More naturalistic grazing helps to spread excreta more widely, reduces risk of poaching and overgrazing, and enhances soil biology.

Pest and disease management
- Species rich grasses reduce disease prevelance in livestock.
- Reduced stocking rate and stress can lower exposure to the spread of disease.
- This helps to lower labour and vet and med costs.

Health and welfare
- Shelterbelts reduce stress and mortality especially during lambing and calving.
- Trees reduce exposure to more extreme weather, enabling animals to be outwintered, hence, reducing costs.

Biodiversity
- Mixed, low stocking density grazing of upland grasslands, with a higher proportion of cattle, has been shown to benefit insect and bird species richness.

C footprint
- A mix of coniferous and broadleaved woodland can provide substantial carbon sequestration.
- Conifers (Sitka Spruce) in shelterbelts store an annual average of 24 tCO_2e per ha.

Flood regulation
- Strategic tree planting in the uplands can reduce flood risk across catchments.
- Native woodland establishment in upland areas has been shown to increase water infiltration by 80%.

Performance of the upland grazing farms

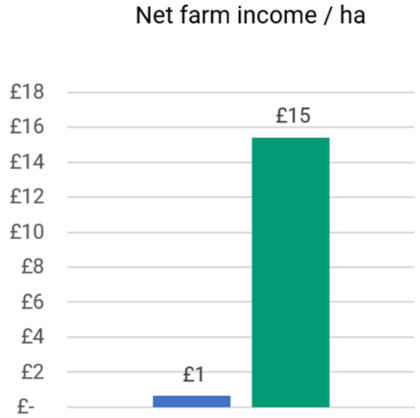
Custom scenario

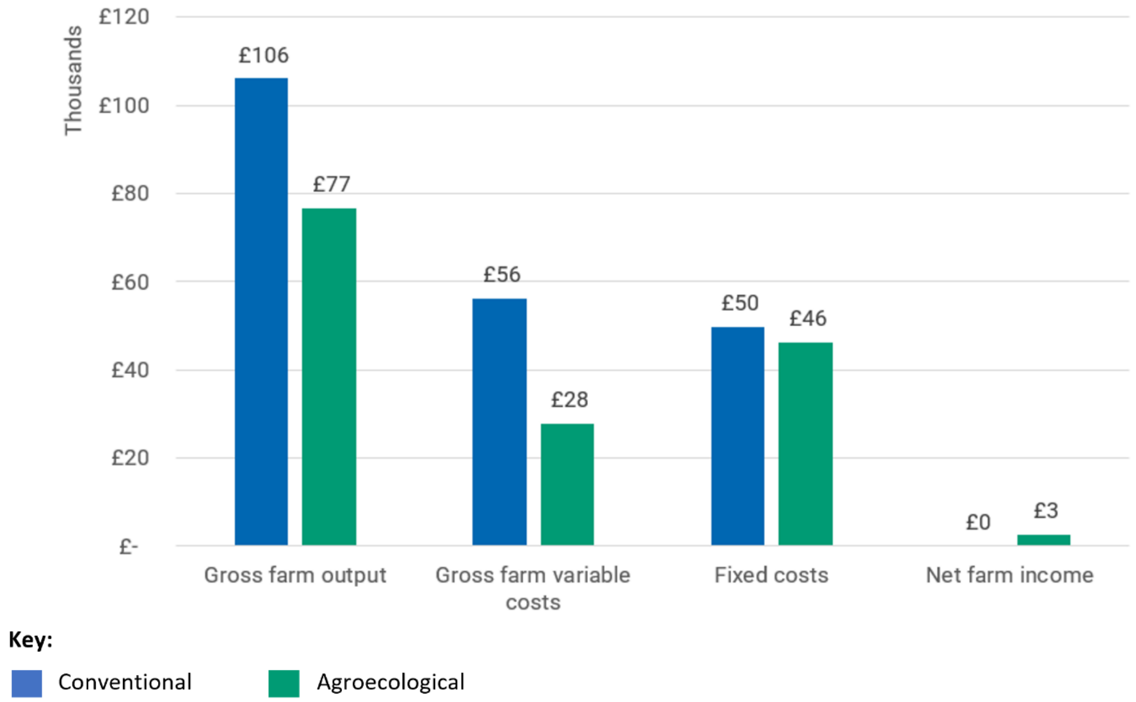
For the custom scenario the following assumptions are modelled:

- Agri-environment payments rise by 30% of current rates.
- A 10% increase to farm gate price.
- Average fixed costs for an organic farm.
- Nitrogen pricing at 150% of historic rates.

Applying these assumptions means agroecological upland grazing farming can outperform conventional production. The modelled results of this custom scenario modelling are shown in the following two bar charts.

The graphs demonstrate the low profitability and risks associated with future upland farming. Farmers need a clear way to monetise the carbon sequestration and flood regulation provided by their land





Environmental impacts

Applying a carbon payment of £15 per tonne CO_2e to the carbon sequestered by all habitats, including above and below ground sequestration increases the income received by the agroecological farms by up to £6,234 per annum.

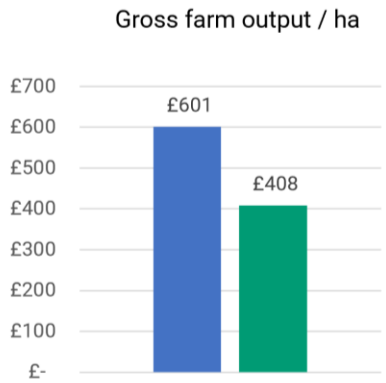
Annual payments for woodland sequestration can provide £3,158. The value provided to society, through sequestration, flood regulation and more is far greater.

Providing conveniently accessible and reliable payment for these services is necessary if sustainable upland farming is to be incentivised and sustained.

Baseline performance

The following graphs show the performance of the upland grazing farms without the custom scenario applied. This is essentially how the farm types we have defined would have performed on average in 2021 based on the data available.

Both farms generate negative net incomes; revealing the risks upland farmers face. However, income on the agroecological farm is considerable lower. Only rewarding upland farmers for their agricultural output is not adequate to make sustainable and resilient



- Reduced output is due to lower areas in productive management and reduced stocking rates.
- Growth rate will also be slower when extensively grazing hardy breeds.
- This does not include potential revenue from any timber sales.

- Variable cost reduction is the main driver for agroecological upland management.
- Vet and med, feed costs, and input consumtion all reduce with agroecological management.

- We model avergae fixed costs similar to those reported on average organic LFA farms. Which are slightly lower than conventional.
- Agroecolgigical fixed costs are uncertain, costs for housing and mechanisations will decrease but fencing and labour costs may increase.

Key farm level recommendations and business strategy

- Shelterbelts, and silvopastoral extensive rotation grazing offer ways to improve animal welfare and productivity, and lower variable costs.
- Timber sales can support increased tree planting and the co-benefits it provides. This can diversify and stabilise incomes.
- To retain profitability, upland farmers need to maximise uptake of agri-environment support options and PES schemes. These forms of support, applied to the form of agroecological upland grazing described above, can help upland farms generate positive net incomes.
- Agroecological fixed costs remain uncertain and a potential barrier to increasing the profitability of agroecological upland grazing. More advice and evidence is needed for how upland farmers can reduce fixed costs.
- Payments for carbon sequestration, flood regulation, and biodiversity net gain will all provide opportunities to maintain and increase the output from upland farms.
- Upland farming can be an essential part of rural communities and economies. Upland farmers are uniquely knowledgeable of their land and are in an ideal position to support the provision of ecosystem services across large areas.

7.2 Overview – extensive upland grazing

Agroecology in the uplands is characterised by a 'wilder' landscape of upland heath and wood pasture extensively grazed by mixed livestock at low stocking rates. This is more of a 'ranching' style of farming incorporating light touch management and low input use to reduce unit costs of production.

Hardy varieties are selected to enable all year-round grazing and livestock have a high level of freedom to roam and express natural behaviours. Species are carefully selected to benefit the quality and structure of the habitat upon which they graze.

Agri-environmental schemes and relationships with conservation organisations support this land management. The extensive upland areas are strategically planted with dense areas of trees, supported by blended PES schemes seeking to enhance carbon sequestration and improve landscape hydrology. These elements diversify the farmers income and increase the resilience of the system.

Several studies with diverse stakeholders have found this type of mixed upland management to be the most popular scenario for the future of upland management (Reed et al., 2008). It enables upland farmers to continue agricultural management whilst also being paid to steward the public goods that their land provides. Public goods, such as flood management, will become increasingly necessary for reducing environmental risks, such as flood damage to downstream conurbation.

7.3 Changes in environmental impact

7.3.1 Carbon storage and emissions

There is mixed evidence about the carbon storage potential of different grazing regimes on upland grassland (Medina-Roldán, Paz-Ferreiro & Bardgett, 2012). Despite the disagreement in the literature, stocking rate clearly leads to variations in above and below ground carbon storage in upland areas, with no or low intensity grazing being preferable. However, upland grass carbon storage is small compared to storage from forestry management (smith et al., 2013).

In the upland agroecological farm, carbon is predominantly stored in the woodland. The 17 ha of woodland are presumed to be an even mix of coniferous and broadleaved woodlands. The faster growing coniferous woodland stores an annual average of 24 t Co2e per ha (Sitka Spruce yield class 14-16) whilst the broadleaved woodland stores an estimated 7 t Co2e per ha (Natural England, 2021). This gives an annual net total storage of 264 t CO2 e across the farm.

7.3.2 Biodiversity

A ten year study investigating the relationship between ruminant livestock and biodiversity in upland areas of the UK found that mixed, low intensity grazing (0.61 ewes per hectare with cows) was a good option for balancing the ecological needs of species across trophic levels (Evans et al., 2015). Work by Fraser et al. (2014) showed mixed grazing of cattle with sheep can enhance populations of birds and butterflies and reduce methane emissions.

Greater inclusion of cattle in rotations has been shown to benefit arthropod and bird species richness (Pakeman et al., 2019).

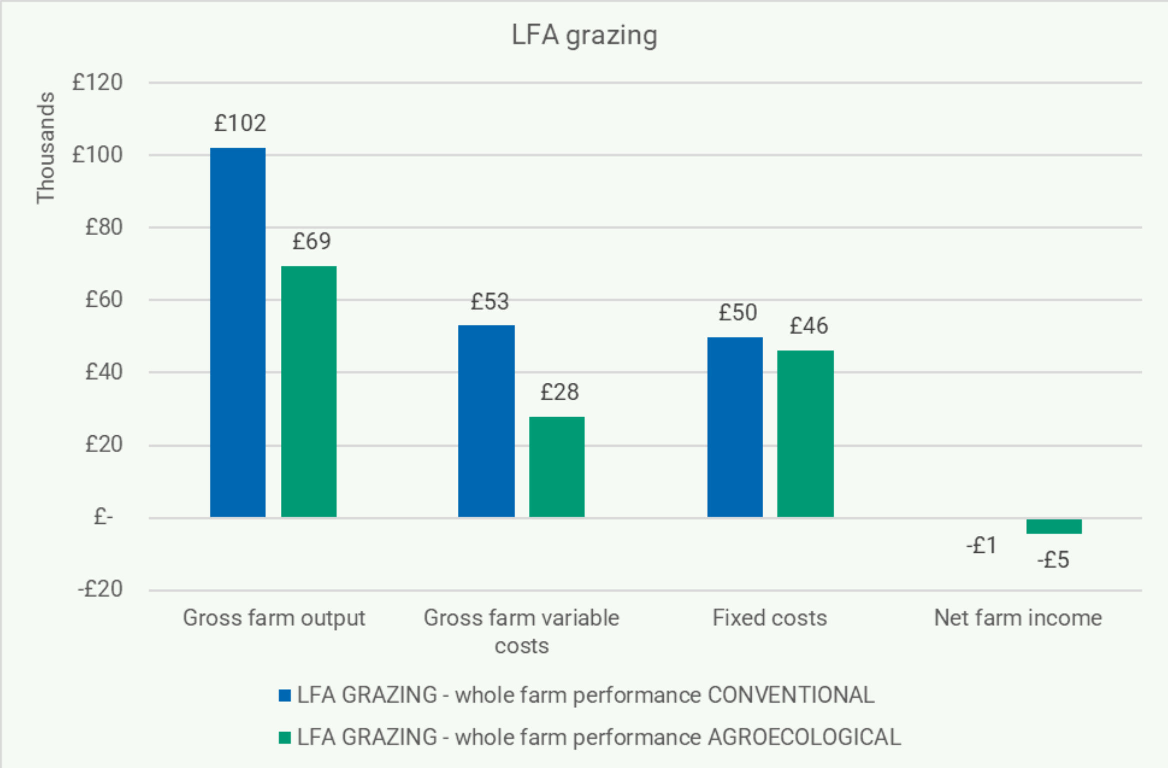
7.3.3 Flood regulation

Native woodland establishment in upland areas across multiple sites has been shown to enhance macropore structure in soils and increase water infiltration rates by, on average, 80% (Murphy et al., 2020; Marshall et al., 2013). Numerous projects, including the work done at Pontbren, have shown the benefits that upland tree planting can have for enhanced water retention on farmland. This ecosystem service is highly contextual as it depends on the hydrology of the area and the proximity to conurbations. Hence, it is not useful to quantify for a completely hypothetical agroecological farm. However, flood regulation will be a key driver for land use change in certain upland areas; payments for increasing the service will impact the profitability of agroecological upland farming.

7.4 Findings from modelling the farm type

7.4.1 Baseline performance

Figure 9: Baseline economic performance of the extensive upland grazing farms



7.4.1.1 Net income

For the upland or LFA grazing farms the model predicts slightly lower net income for the agroecological farm than the conventional when baseline variables are applied. Neither system performs profitably, with high variable costs impeding the profitability of the conventional system, and high fixed costs and reduced output impacts the agroecological.

7.4.1.2 Output

The reduced gross farm output has the greatest impact on agroecological profitability. Unlike on agroecological lowland grazing farms, a mob grazing approach is unfeasible due to the extent and low productivity of the upland grassland. Lower stocking rates across the agroecological farm are therefore necessary. This, coupled with, larger areas dedicated to non-provisioning habitat reduce the agroecological output.

7.4.1.3 Costs

Variable cost reduction does not fully offset the reduced- agroecological output. On conventional upland farms per hectare variable costs are relatively low. Partially due to low use of inputs such as nitrogen fertiliser. Hence, the scope for agroecological practices to enhance profitability by reducing upland variable costs is more limited than on other more intensively managed farm types.

The slight reduction in fixed costs modelled for the agroecological farm helps to narrow the income gap further. It is unclear how much scope there is to further reduce fixed cost.

7.4.1.4 Sensitivity analysis

Difference in profitability between the agroecological and conventional upland grazing farms Is most sensitive to varying agroecological fixed costs. A 10% reduction is enough to make the agroecological farm more profitable. The low output per ha of upland farms means that net income is less sensitive to change in farm gate pricing. Varying the agri-environment payment rates has only a minor impact on the net income gap. This is because both the conventional and agroecological farms receive relatively high agri-environment payments.

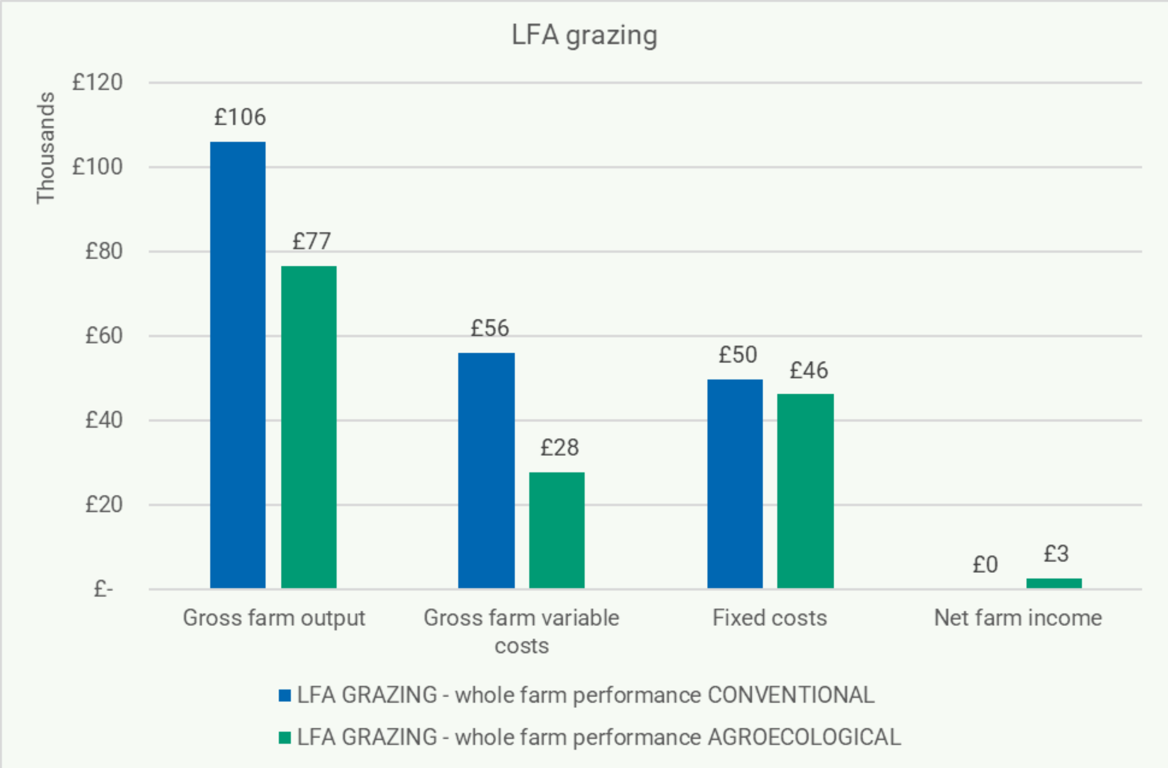
7.4.2 Custom scenario

The custom scenario we have modelled includes the following assumptions:

- **Agri-environment payments rise by 30% of current rates**. Modelled as a conservative estimate of how future funding will pay farmers to provide a range of ecosystem services.
- **A 10% increase to farm gate price.** It is assumed the farmer can generate this marginal increase through some more direct sales and certification.
- **Average fixed costs for an organic farm.** It is unclear how much scope there is for agroecology to reduce the fixed costs of upland farms, hence we base our estimates on average organic fixed costs.
- **Nitrogen pricing at 150% of historic rates.** This is less than the price spikes caused by conflict in Ukraine and illustrates the increasing issues of nitrogen fertiliser use.

We consider these reasonable and conservative estimates of how these variables are likely to impact future cereal farming.

Figure 10: Custom scenario economic performance of the extensive upland grazing farms



The custom scenario is enough to shift the performance of the agroecological and conventional upland grazing farms.

7.4.3 Carbon payment

Given the large areas of woodlands planted across the agroecological upland grazing farm applying a £9 per tonne CO_2e payment for the woodland increases net income by £1,895. The increase for the conventional system is only £161. This demonstrates the important role of agroforestry on upland farms. Trees on farms will provide substantial value through climate regulation as well as supplying performance benefits to livestock and other regulating services.

Providing this payment across all habitats, including above and below ground sequestration, increases the income gained to £3,741 for the agroecological farm and to £1,123 for the conventional. Given the lower potential of upland grassland for carbon storage, woodland carbon sequestration makes up a much larger percentage of the carbon stored than on other farm types. In total the agroecological upland grazing farm sequesters an estimated 416 tonne CO_2e per annum.

Increasing the payment rate to £15 per tonne CO_2e sequestered increases the additional income received by the agroecological farms to £6,234 per annum. Leading to a net income of £9,000.

7.4.4 Discussion

The key component that is missing from our modelling of the extensive upland farms is any payment for additional tree planting and ecosystem services provided by the farms. Flood regulation and carbon storage are two services that are especially likely to provide additional sources of funding to upland farms. These will be higher for the agroecological farm.

In 2017 the Forestry Commission published a report assessing the investment returns of carbon in woodland (Forestry Commission, 2017). Payment rates ranged from £3 to £15 per tonne CO_2e. Taking the average of this range carbon payment for the 17 ha of mixed woodland would provide farmers with an additional £2,400 annual income. This does not include payments from future schemes looking to store carbon in hedges, reduce flood risk, or enhance biodiversity.

A second limitation is the lack of consideration of the performance benefits from silvopastoral grazing and shelterbelts in the model. Reports have evidenced livestock productivity increases as high as 10%. This is currently not factored into the model due to complexity and uncertainty around the performance benefits that would be attainable. However, even a small increase provided by output would make agroecological upland grazing a more persuasive land use option.

Finally, there is uncertainty around the degree to which fixed costs can be reduced using agroecological approaches. Case Studies 4 and 5 evidence approaches that uses minimal machinery and housing. However, changing livestock rotations and management of non-provisioning habitats will all impact fixed costs, especially labour. There is currently inadequate data to estimate how effective agroecology could be for reducing fixed costs. More research is needed but, if fixed costs could be lowered then a transition to agroecological upland grazing would become more persuasive.

7.5 Farm level recommendations and business strategy

- Shelterbelts, and silvopastoral extensive rotation grazing offer ways to improve animal welfare and productivity, and lower variable costs.
- Timber sales can support increased tree planting and the co-benefits it provides. This can diversify and stabilise incomes.
- To retain profitability, upland farmers need to maximise uptake of agri-environment support options and PES schemes. These forms of support, applied to the form of agroecological upland grazing described above, can help upland farms generate positive net incomes.
- Fixed costs remain an uncertainty and a potential barrier to increasing the profitability of agroecological upland grazing. More advice and evidence are needed for how upland farmers can reduce fixed costs. Upland farmers considering a transition to agroecological farmers should visit and speak with other agroecological farmers to understand where fixed costs can be reduced.
- Some more direct sales and marketing to increase the farm gate price of some of the output from agroecological upland grazing farms can support positive net incomes.

- Payments for carbon sequestration, flood regulation, and biodiversity net gain will all provide opportunities to maintain and increase the output from upland farms.
- Upland farming can be an essential part of rural communities and economies. Upland farmers are uniquely knowledgeable of their land and are in an ideal position to support the provision of ecosystem services across large areas. Upland farmers must take advantage of the payments for ecosystem services being developed in a strategic and collaborative manner. This will help to maintain upland farming in a sustainable way and, therefore, the rural communities that it sustains.

Case Study 4: Upland grazing

Title: Extensive silvopastoral upland livestock grazing - enhancing profits rather than revenues.

Background / brief description of farm:

"The management shift was driven by a desire to improve the health of the livestock. It revealed a synergy between improving health of animals and improving the health of environment. Furthermore, the approach led to increased outputs with fewer animals."

This 540-ha hill farm near the Scottish Borders was taken back in hand after years of intensive management. A whole system change was required to reduce exposure to disease that was reducing productivity, and environmental damage. The most significant change was to move from set stocking rates of 1,000 ewes and 100 cows to rotational grazing system of 400 sheep and 55 suckler cows. Other changes included a transition to organic production and tree planting.

The sheep (Texel X) graze the in-bye land through the summer and rough grazing is used by sheep in late summer/autumn and again after tupping through to lambing. They try to finish all lambs on the farm, as fat lambs can be produced on the good quality soil. The suckler cows are Highlanders crossed with Whitebred Shorthorn and are bred with a Limousin. The animals are rotationally grazed and are on rough grazing through the summer months. The animals are sold as stores; very few are finished on the farm.

Most of the animals are grass fed, although they buy in some feed for wintering calves and for multiple lambing ewes. Sheep are outwintered and cows have a mixed system where they have access to a big cubicle shed and to outdoors "We believe it is a good thing for welfare to give animals a choice." Almost all the cows calve outside.

They thought about direct sales but considered it too labour intensive, especially given their location. Instead, the organic livestock is sold through various supply chains including store cattle to a finisher with a Waitrose contract; fat lamb to Tesco; to a local livestock market; and store lambs go to an organic lamb finishing business.

A silvopastoral system for timber and shelter was established including shelterbelts to support improved animal welfare and performance. This approach revealed a synergy between improving the health of animals and improving the environmental health. Tree shelter was needed to enable the farming of Texel X sheep. 10% of the farm (c.54 ha) is devoted to woodland. The shelterbelts on the farm are made up of pine and larch and commercial plantations are largely Douglas Fir, Sitka spruce, and Scots pine (roughly 30% of area). This was grant funded, which was essential as tree planting is a costly undertaking.

Aim: To enhance the health, resilience, and productivity of the farm through extensive silvopastoral grazing and timber production.

Key management features of the agroecological system

Key management features	Description of the management approach and reason for implementing
Hardy livestock outwintering	Hardy livestock can overwinter, therefore reducing housing and feed costs. The agroforestry provides livestock with shelter during more extreme weather.
Reduced stocking rate	The estimated stocking density is 0.3-0.4 livestock units/ha. This reduces pressure on the habitat and gives time for the flower rich grasslands to rest. This reduces environmental damage (water pollution, loss of biodiversity)
Rotational grazing	The livestock are rotationally grazed. Rotational grazing prevents the build-up of diseases (Coccidiosis and worm burden). It enhances animal welfare, health and, therefore, increases productivity.
Agroforestry and farm woodland	Silvopastoral tree planting provides welfare and productivity enhancing shelter, shade, carbon sequestration, improved water infiltration, and timber.

Impacts of the agroecological system

- **Farm resilience** - Improved farm resilience due to low input and feed costs and diversified sales channels.
- **Climate impact** - Carbon neutral farming. no use of carbon intensive fertiliser, permanent grassland sequesters carbon. Value is to hold onto the carbon in the business and not to sell to a very immature market.
- **Nutrient runoff** - Negligible nutrient run off. Low stocking rates, trees and permanent grassland protect the soil from erosion.
- **Ecological impact** - Positive impact, reversing ecological damage bringing biodiversity back to the farm by providing a mosaic of habitats including woodland, wood pasture, and permanent, diverse grassland.
- **Societal impact** - High animal health and welfare, carbon and biodiversity benefits, improved water quality, flood protection, and enhanced landscape.

Performance

Yield & Profitability	
Yield, revenues, profit margins	
Total business income	£125,000 per year
Gross margin cattle	Gross margin of about £550 per head. High fertility rates, greater than 95%. Weaning weights 320kg; as good as more intensive rye grass systems. The mixed traditional breed leads to a relatively small cow, 500 to 600 kg.
Gross margin sheep	Gross margin of about £60/£70 per head for sheep.
Annual return/ha	Sheep and tree enterprises generate similar annual returns of around £129 per hectare.
Variable costs	
Inputs (seeds)	£600 per year
Inputs (feed)	£8,900 per year
Inputs (fertiliser, pesticides/ herbicides)	Lime £5,000 per year (but some years more when P+K added), straw £4,000, silage/hay wrap/netting £3,000. Tractor fuel and quad bike fuel £4,000. Tractor fuel use is approximately 6 tonnes per year.
Livestock replacement	£2,000
Vet/Med	£1,800 per year. Seen a decrease in vet and med costs by quite a margin since shifting to an agroecological/rotational grazing approach. However, the gain is mostly from an increase to productivity due to improved livestock health. A big labour saving as no longer needing to administer medication as frequently.
Fixed costs	
Business costs	£90,000 (Fencing is one of the most significant costs)

Machinery & equipment	Direct seed drill has a key place within any agroecological system. Trying to avoid losing carbon. The drill allows them to stitch in additional clover. Piece of kit is essential, and they contract it out to neighbours. This is a New Zealand grassland farming tool.
Water / electricity / general costs	Similar to conventional farming
Labour	1 full-time and three part-time – similar to conventional farming

Key challenges for transitioning to agroecological farming

- **Lack of support** - There is a huge lack of support for new entrants looking to develop a system and build the knowledge to do this sustainably. A support network is not developed enough to provide information on how to implement agroecology. A way to share this information is needed. Grant aid is essential if agroforestry is to be enabled as it is a costly undertaking. However, policy support needs to be developed that supports agroforestry planting at appropriately low densities.
- **Tenanted sector** - There is a challenge for tenant farmers, who need to pay high rents. This creates pressure to maximise turnover – conflation of turnover and profit – issue will be difficult to shake off – *"it almost needs a crisis or generational change to get this to shift."*
- **Mindset change** - Farmers need to accept that agroecological farming will have a lower yield, but this is compensated for by lower costs. Furthermore, yields improve as the system becomes more resilient (i.e. through improved soil health) however, this takes time.

  Further barriers to change – High fixed costs and the desire to maximise employment from a system can be barriers to change.

Case Study 5: Helen O’Keefe – Middleton Croft

Title: Diversified croft in the Scottish Highlands managing regenerative, upland grazing and strengthening the local community.

Background / brief description of farm: Helen O’Keefe runs an agroecological croft in the Scottish Highlands incorporating extensive sheep grazing, market gardening, agroforestry, and community development. 2 ha of land are owned, another 1ha tenanted as a croft, and a further 1,500 ha of common hill grazing. The grazing is on extensive, High Nature Value, but low-productivity land that is exposed to the harsh climate. Lamb is the main agricultural product alongside produce sold from the market garden and chickens. This income is supplemented with income from a tearoom and farm shop.

Middleton croft supports a local food hub, works with a local part-time butcher (who is also a crofter), and manages diverse enterprises to enhance the capacity of the area to generate fair, meaningful, and independent employment for the community and a supply of diverse and healthy food.

Aim: Helen aims to strengthen the local community and engagement with the landscape and food system. This is to be achieved whilst enhancing the ecological value of the area through low intensity, conservation grazing. Crofting brings people into the landscape creating skilled jobs, knowledge, local high-quality food supply chains, and a community that is inextricably entwined with the landscape.

The aim is to manage diverse enterprises and habitats in a way that fosters resilient employment and environmental sustainability. Policy and burgeoning environmental markets need to be developed to enable small-scale land managers to enhance the habitats they steward. These new policies need to consider the social value provided by crofters and similar communities as well as the purely economic and larger scale habitat changes.

Key management features of the agroecological system

Key management features	Description of the management approach and reason for implementing
Soil health & fertility	Extensive grazing of hardy varieties enhances soil health. Grazing diverse calcareous grasslands helps to retain a healthy sward structure and nutrient cycling. Fertility in this habitat is low but it is a valuable habitat for rare species. The permanent pasture on the inbye land is rotationally grazed. It is put to more intensive use during tupping, lambing and weaning, and rested in between, especially in summer when it is used for hay production. This promotes good soil health.
Rotation	Grazing rotation is low intensity and sheep are allowed to maintain naturalistic grazing patterns. Low stocking densities of hardy stock allow species rich grassland and wading birds to survive. Cutting hay on inbye fields reduces the need for brought in fodder and provides diverse habitat by encouraging a higher proportion of tall herbs in sward. Gathering and management is more time consuming due to large grazing areas. The same is true for feeding.
Varieties / breeds	Shetland sheep are smaller, slow growing, hardy sheep suited to extensive, conservation grazing and harsher climates. They have good temperaments and are valued for high quality wool production and meat quality. Importantly, given the slower growth rates attainable in the uplands, the meat retains its quality at older ages and the older mutton is still a valuable product. Scots Grey Hens are a hardier dual purpose chicken variety. They are slower growing but are suitable for eggs and meat. Slower growth rate leads to a trade off in annual yields.
Disease & pest management	Most disease and pests are managed through low intensity farming. It is hoped that in field trees and shelterbelts will reduce stress, lambing mortality and reduce water logging, which could reduce fluke numbers. When grazing small areas of inbye land and larger common areas it is impossible to manage things like fluke risk by isolating high risk areas. Garden pests are managed by maintaining healthy functioning ecosystems with beneficial insects and predators.

Market gardening	A small outdoor veg garden and polytunnel are managed on the inbye land. This produces fresh produce sold into the local food hub. Potatoes, kale, broad beans, carrots, salad leaves are being grown outside and the polytunnel is intended to extend both the range of produce (e.g. tomatoes, courgettes, French beans) and the length of the growing season (e.g. salad in winter and broad beans in early spring).
Agroforestry	Early-stage agroforestry establishment is underway, including the planting of 4 shelterbelts and about 50 individually guarded in-field trees, to reduce livestock exposure to harsh weather and to enhance grass growth; and the planting of a small orchard to diversify income. Trees and tree guards are costly, whilst growth is slow and risk of damage from deer and sheep is quite high.
Other	Butchering at a neighbouring croft helps the croft and those in the surrounding community retain more value from the meat produced. This is further supported by the food hub. Working together with other producers in the immediate area provides economies of scale to make direct sales of local food more attractive, encouraging more growers to get involved.

Impacts of the agroecological system

- **Resilience** - Agroforestry reduces livestock stress, mortality, predation risk and enhances productivity. Permanent diverse pasture, and agroforestry will be helping to reduce water logging. Extensive naturalistic grazing with sheep grazed outside on a diet of diverse herb-rich sward all year round helps to maintain high animal welfare and reduce diseases that spread when animals are housed inside and at greater stocking densities. Diversification of production through agroforestry, market gardening, the tearoom, and farm shop will help to stabilise and enhance performance. Selling direct provides resilience against global market changes.
- **Climate impact** - The croft management is low intensity and extensive. Shepherding is managed with bucket feeding and dogs in a low stress, traditional style which can be managed on foot, therefore reducing fuel consumption.
- **Nutrient runoff** - The absence of any fertilisers and the maintenance of diverse permanent pasture means nutrient runoff from the croft will be negligible.
- **Ecological impact** - Calcareous grassland is a rare habitat in Scotland, the extensive grazing helps to maintain this valuable habitat in a structure that supports diverse grass, flowering species, and wading birds. The habitat is made even more valuable by having elements of arctic-alpine flora prominent within it.
- **Societal impact** - Supporting rural community development is key to what the croft provides. Establishment of local and direct supply chains help to improve sales and income generation for local crofters. This kind of collective action is core to the intentions of the croft and helps retain and grow rural populations who value and steward the landscape, strengthening communities' ties with the landscape and their responsibility for its management. This kind of productive relationship with the

landscape helps to maintain or improve social cohesion, drawing people together with a shared purpose as opposed to seasonal work such as tourism that does less to unite communities throughout the year.

Performance

Yield & Profitability	
Yield, revenues, profit margins	
Shetland Sheep	15 Beltex X lambs sold as store lambs at the Mart (£50/head) 6-8 carcases as direct sales half sheep boxes (£120/sheep) Aiming to sell 50 to 60 sheep per annum. Approximately 30 carcases as direct sales, individual cuts (£150/sheep).
Scots Grey hens	180 dozen eggs/year (£3.40/dozen)
Revenue	Approx. £4,152 generated from livestock
Net margin/profit enterprise	£12,665 (including £5,000 subsidy)
Agri-environment support	No agri-environment support is provided. Application for support needs collective agreement with multiple crofters which makes applying for grant funding complex. The Agri-Environment Climate Scheme (AECS) is also not designed for small units.
Variable costs	
Total costs	£4,620
Inputs (seeds)	£50
Inputs (fertiliser, pesticides/ herbicides)	None
Vet/Med	£375

Loss (mortality / crop loss)	3% herd mortality (not including pre-weaning lambs) 15% chicken mortality. This includes old birds as they do not cull at a set age.
Fixed costs	
Housing / Buildings	A small stable for emergency shelter of sick livestock. Chicken houses. One grant funded polytunnel for horticultural production.
Machinery	-
Water / electricity / general costs	Fuel and electricity use are very low as herding is managed on foot and horticulture is managed by hand. Delivery of produce to the food hub and animals to the abattoir is the main source of fuel consumption.
Labour	No full-time employment. The croft is managed part time and cannot, currently, support full time work.

Challenges for transitioning to agroecological farming

A key challenge is stabilising a grazing rotation that provides enough nutrition for ewes during lambing, without negative impacts on pasture health or biodiversity. Gathering a decent hay crop has proved challenging too due to a lack of local knowledge on how to undertake this. Improved hay production is targeted to enhance productivity, efficiency, and encourage tall herbs to set seed. The crofter is also aiming to enhance and increase horticultural production.

Fencing off certain areas of the common hill area could improve grazing control and grassland regeneration. However, this would require collective agreement from the crofters which is challenging to facilitate. Helen aims to work with neighbouring crofters to convince them of the benefits of controlled grassland rest periods, and improvement of the mosaics of habitats. No-Fence collars are another approach that is being considered to help tackle this challenge without full shareholder buy-in.

General environmental constraints affect economic viability. Poor ground, harsh climate, low population density, and high transport costs all impose challenges for the croft. High attrition rate and vulnerability of trees due to damage from deer, sheep, and severe weather is an issue. Fencing has been needed to reduce damage. Agroforestry is complicated by a lack of accessible knowledge, advice and funding.

Funding schemes often do not suit small scale, diversified approaches, although this is improving. Regulations and bureaucratic systems need to cater for small producers in rural areas and need to be adjusted to support circular economies. Regulation often restricts or fail to consider small scale local supply chains and waste recycling.

The development of the croft has been supported through advice and knowledge from online and practical courses through the Scottish Agricultural College (SAC), Scotland's Rural College (SRUC), Soil Association and networking. Financially support has come from agricultural subsidies such as Basic Payment, Less Favoured Area Support Scheme (LFASS), Scottish Upland Sheep Support Scheme (SUSSS) and Crofting Agricultural Grant Scheme (CAGS).

8 Mixed farming

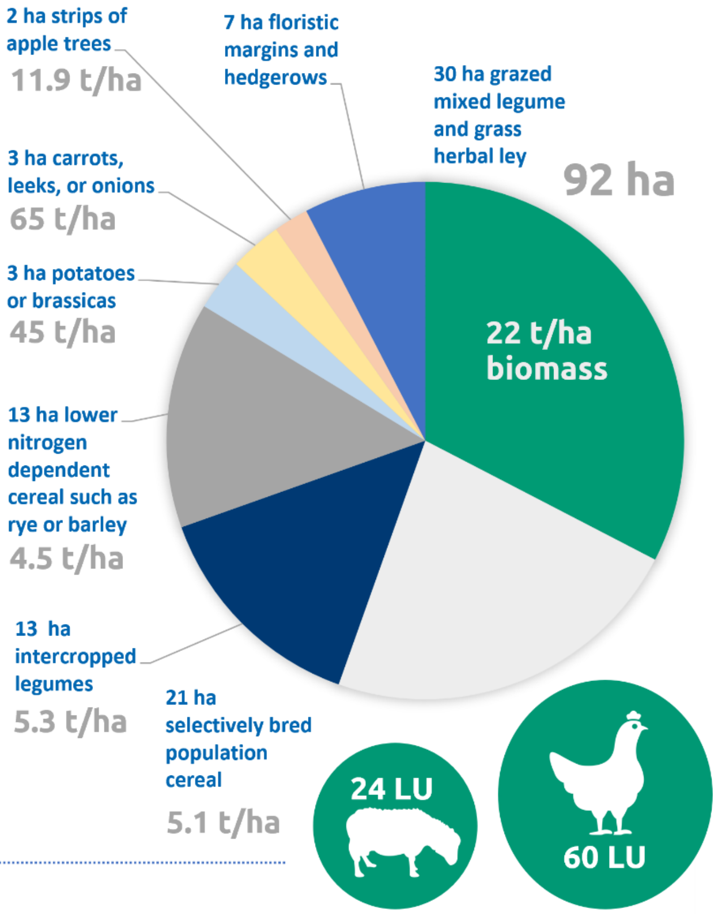
8.1 Summary

Mixed farms are defined as farms where no single farm type provides 2/3 of the standard output. Hence, there is huge variation across this farm type making comparison difficult. Below we have defined one iteration of a agroecological farm whilst acknowledging that there are many forms that this type of farming could take. We intend for the example to provide insights into some common challenges that mixed agrecological farms are likely to face, rather than drawing any definitive conclusions about the economic performance and challanges.

The farm utilises the ecological functions species and habitats to optimise space and resource use. Vegetables, cereals, and herbal swards are grown alongside orchard trees. The trees provide additional income from fruits, nuts, timber and other resources.

Complimentary varieties are carefully selected. Cereal integration diversifies production and lowers nitrogen demand. Legumes enhance fertility and provide additional livestock feed. Specifically selected sheep breeds are grazed between the strips of orchard trees to manage the sward and cycle fertility into the soil.

The chickens natural behaviours help enhance system performance. They can be ranged within the orchard strips feeding upon potential pests. Although not modelled here, pigs can be put out to root within fields at high stocking densities. Insects, roots, diverse swards, and legumes provide local diets to the pigs. Through natural rooting behaviours the pigs build and disperse fertility. Rotating the ranging areas of poultry and pigs continuously provides them with access to fresh resources reducing the need for supplementary feed.



Fertility management
- Grazing mixed livestock maintains healthy swards, rotates nutrients back into the soil and increases nitrogen and phosphorous availability. This improves subsequent yields.

Pest and disease management
- Diversified systems increase abundance of beneficial species and reduce pest abundance.
- Ranging poultry in orchards can reduce weed and pest burden.
- Rotated mixed livestock grazing can reduce parasite burden.

Health and welfare
- Ranging poultry amongst trees enables natural behaviours decreasing stress and aggressive interactions.

Biodiversity
- Increasing diversity within a farming system has been shown to increase biodiversity compared to more simplified systems.

C footprint
- Estimating the carbon footprint is complex. Emissions per unit production, for certain enterprises, will be higher, but, this will be offset by carbon sequestration, particular by mult-species grasslands and trees.

N runoff
- Synthetic N application is negligible.
- Roaming poultry or pigs outside can increase N loss and runoff, however, good soil and root structure will reduce this risk.

Performance of the mixed farms

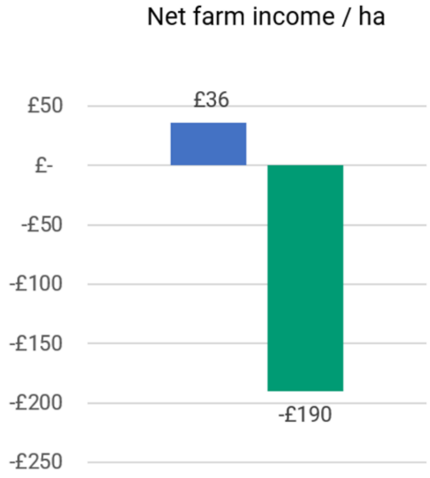
Custom scenario

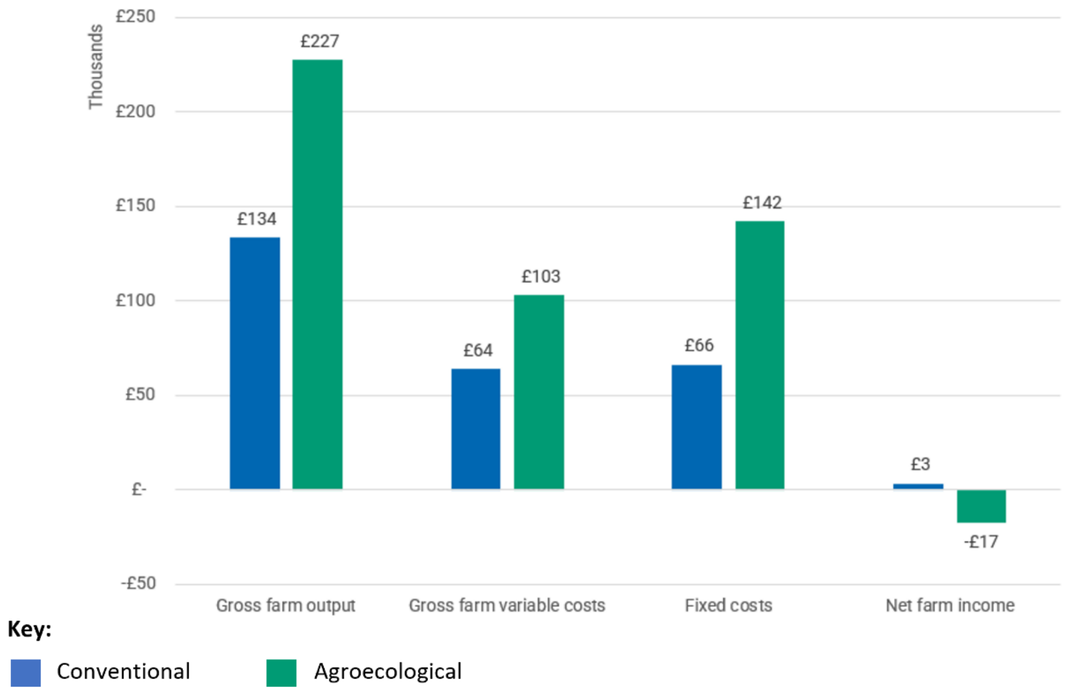
For the custom scenario the following assumptions are modelled:

- Agri-environment payments rise by 30% of current rates.
- A 30% increase to farm gate price.
- Fixed costs at the same level as incorporated in the baseline.
- Nitrogen pricing at 150% of historic rates.

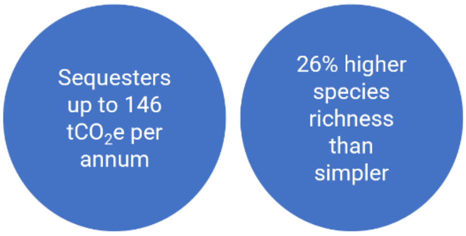
Applying these assumptions means the income for agroecological mixed farming increases but not by enough to generate a net profit. The modelled results of this custom scenario modelling are shown in the following two bar charts.

The graphs demonstrate the difficulty of running numerous complex enterprises profitably without access to market premiums. This is why most highly diversified farms sell direct or integrate their farming with other non-agricultural enterprises.





Environmental impacts



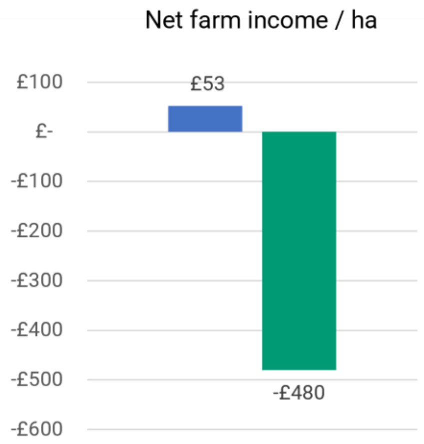
Applying a carbon payment of £15 per tonne CO_2e to the carbon sequestered by all habitats, including above and below ground sequestration increases the income received by the agroecological farms to up to £2,189 per annum.

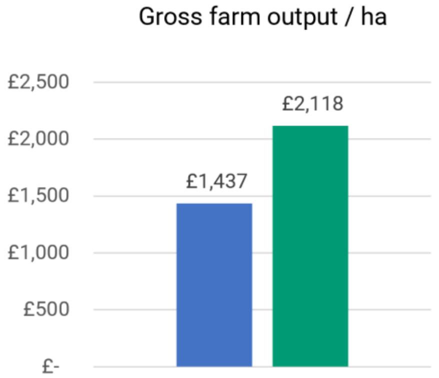
Providing PES to highly diverse farms will be complex given the small area of each land use and the variation in ecosystem services provided across the farm. Farmers are more likely to receive benefits for the services by communicating and demonstrating the impacts directly to customers rather than through PES schemes.

Baseline performance

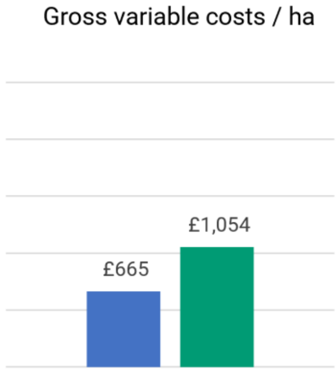
The following graphs show the performance of the mixed farms without the custom scenario applied. This is essentially how the farm types we have defined would have performed on average in 2021 based on the data available.

Both farms generate negative net incomes; revealing the challenges of managing diverse enterprises sold at conventional farm gate pricing. However, income on the agroecological farm is considerably lower. Based on the data, highly diversified farming systems depend on higher farm gate pricing to be profitable.

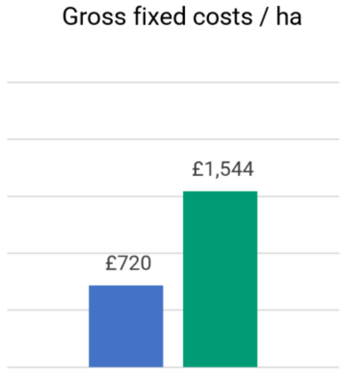




- Combining numerous enterprises increases total output as the various enterprises make efficient use of the resources within the farm.
- This aligns with research that has shown diversity increases the total production attainable per unit area.



- The small area dedicated to each enterprise makes purchase of specialist machinary unviable. Instead orchard and root vegetable cultivation will be contracted out adding to the variable costs.



- Fixed costs are high for the agroecological mixed farm due to the increased complexity of managing numerous enterprises.
- Fencing, housing, labour, feed, marketing, processing, packing and transport costs will all increase with the diversity.

Key farm level recommendations and business strategy

- Methods to reduce the costs of managing diverse agroecological farming systems need to be communicated, researched, or developed. Innovation and technology may have an important role to play here.
- Mixed farmers should aim to produce select high value products for local markets and the remaining products should be complimentary to these enterprises.
- Apple orchards are low profitability. There is a need to establish higher value markets for orchard and timber products from farms.
- Dynamic procurement offers a potential way to increase market access for mixed agroecological farmers. This should be explored by farmer groups and supported by public procurers.
- More data is needed on mixed farms. Farmers should work to collect and share data on the benefits of a mixed agroecological approach. Establishing a solid database for performance of these kinds of farms will help farmers validate the public goods provided and, potentially, access future PES schemes.

This final agroecological farm type is an integrated farm system combining elements of each of the farm types that have been explored so far including rotation ruminant grazing, and cereal and horticultural production. In addition, orchard agroforestry and poultry are integrated. This is just one iteration of a type of farming that is highly varied; other systems could incorporate timber production, pigs, and a range of other enterprises. Here, we use one possible form of mixed agroecological farming to illustrate the performance and challenges of such a system.

8.2 Overview – mixed farming

These mixed enterprise and land use systems utilise the ecological function of each species and enterprise to maximise use of space and resources. Various crops including vegetables, cereals, and herbal swards are grown alongside orchard trees. The trees provide additional incomes from fruits and nuts including apples, pears, cherries, walnuts, and hazelnuts, as well as resources such as bedding, biofuel, and timber.

As with the agroecological horticulture farm type, varieties are carefully selected to provide symbiotic relationships and reduce risks. Cereals are incorporated to diversify production and lower the nitrogen demand of the rotation. Legumes are integrated at a higher rate to enhance fertility and provide feed for the livestock.

Specifically selected sheep breeds are grazed between the strips of orchard trees to manage the sward, provide feed to the sheep, and cycle fertility into the soil.

Poultry are integrated into the system in a variety of ways, utilising natural behaviours to enhance system performance. Poultry can be ranged within the orchard strips. Chickens feed upon larvae and other insects that are potential pests. Geese can be used to reduce the weed burden through grazing.

Although not modelled here, pigs can be put out to root within fields at high stocking densities. Insects, roots, diverse swards, and legumes provide local diets to the pigs. Through natural rooting behaviours the pigs build and disperse fertility within the soil.

Rotating the range areas of the poultry and pigs continuously provides them with access to fresh resources reducing the need for supplementary feed. Legumes grown on the farm produce the remainder of the diets.

Agroecological mixed farms are complex and location specific businesses requiring diverse skills and high fixed costs, such as labour. Although when modelling we compare the agroecological mixed farm to a conventional farm and use conventional farm gate pricing, this is unlikely to be how mixed agroecological farms operate. They are more likely than other farm types to sell to local markets and maintain diversified enterprises such as farm shops and on farm processing. This will allow them to generate higher farm gate pricing supporting the diverse ecosystem services they provide.

Mixed agroecological farms often support cultural services in the form of recreation and education and provide rural employment, which in turn can strengthen rural communities. Both Helen O'Keefe's work at Middleton Croft (Case Study 5) and Fred Price's work at Gothelney Farm (Case Study 6) are excellent examples of the role mixed farming enterprises can play in strengthening local food systems and communities.

8.3 Changes in environmental impact

8.3.1 Carbon storage and emissions

Estimating the carbon footprint of the mixed system is complex. For many of the individual enterprises emissions per unit produced could be higher, however, producing more of the resources within the farm prevent carbon leakage and grazing on good quality species rich grassland between rows of trees will offset emissions.

For poultry, feed production, processing, and transport is responsible for 50% to 70% of the global warming potential (Leinonen et al., 2012; Blonk et al., 2022). The global warming potential for organic layers is 17% higher than for conventional systems and the eutrophication potential is 104% to 140% higher (Leinonen et al., 2012). This is predominantly due to the longer production cycles in organic and free-range systems causing higher feed consumption and manure production (Leinonen et al., 2012). Similar results have been found for pigs (Blonk et al., 2022; Halberg et al., 2010). However, integration of multi species swards into the organic crop rotation may offset this increase in emissions and even lead to net sequestration.

8.3.2 N runoff and eutrophication risk

Rearing pigs and poultry outdoors rather than indoors can increase nitrogen leaching and ammonia volatilization (Hermansen et al., 2004). The need to over feed protein to organic pigs to provide adequate nutrition exacerbates the risk of N loss and runoff (Röös et al., 2018). Eutrophication from nitrogen has been found to be 21-65% higher for organic pig production than conventional (Halberg et al., 2010).

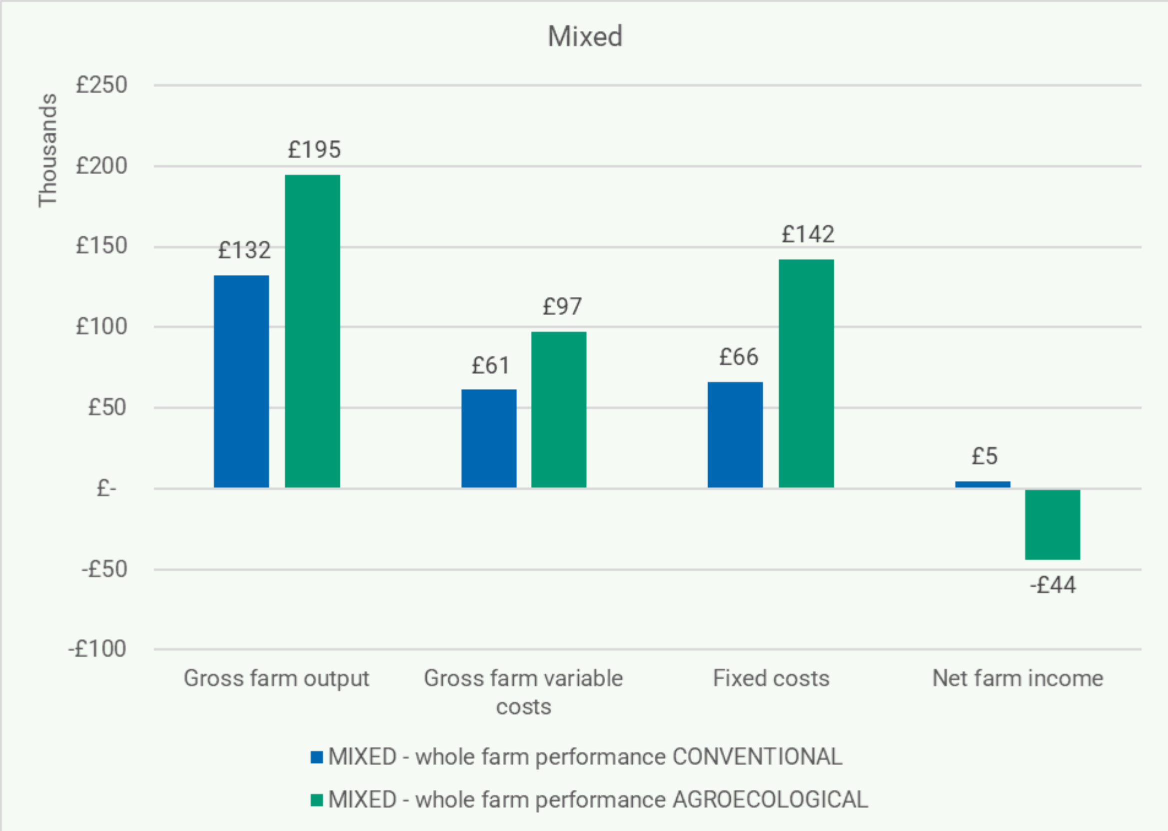
8.3.3 Biodiversity

There is a growing body of evidence that shows that more diversified farming systems support increased biodiversity (Rosa-Schleich et al., 2019; Jones et al., 2021). The largest global meta-analysis to date found that on average diversified farming systems have 26% higher species richness than simplified systems.

8.4 Findings from modelling the farm type

8.4.1 Baseline performance

Figure 11: Baseline economic performance of the mixed farms



Comparing the agroecological mixed farm against a conventional mixed farm is problematic. Data of conventional mixed farms covers a wide range of different farming enterprises and performances. Mixed farms are defined as holdings for which neither cereals, horticulture, dairy, lowland grazing, LFA grazing, pigs, nor poultry account for more than 2/3 of the total standard output. This means that a farm where LFA grazing, dairy, and cereals each make up a third of the standard output would be defined as mixed; as would a farm where poultry, horticulture, and cereal also each account for a third. In the FBS data, information on both these farms could be included. This makes it difficult to compare the agroecological mixed farm we define in this report against the FBS data for the mixed farm type.

Despite the comparability issues, the FBS on the mixed farm is the best comparison we have, however, in the write up where appropriate we also compare against other farm types to show how the agroecological farm compares against all UK farm types.

8.4.1.1 Net income

The baseline scenario shows the agroecological mixed farm derives approximately £49,000 lower net income than the conventional mixed farm. On a per hectare basis this is the greatest loss in net income of any of the agroecological farm types.

8.4.1.2 Output

Output from the agroecological mixed farm is about 48% higher than the conventional mixed farm. Per ha it is only the agroecological horticulture farm and the conventional dairy farm that have higher outputs. This is logical, given that we assume a greater proportion of the rotation on the agroecological horticultural farm can be dedicated to high value field vegetable production. Conventional dairy production is also a high production, high-cost form of agriculture and logically should produce greater outputs than a mixed system.

The poultry production is the highest performing enterprise on the mixed farm, generating £1,302 per ha across the 30 ha of herbal ley. In contrast, the apple orchards, at conventional farm gate pricing, perform at a loss of -£1,624.

8.4.1.3 Costs

The variable costs and fixed costs are both higher for the agroecological mixed farm than the conventional. This is due to the increased complexity of managing diverse enterprises across a single holding. Fixed costs are especially high – more than double the conventional mixed farm – this is because the farm has similar fixed costs to a cereal farm and a livestock farm. Furthermore, the variable costs include contractor fees to manage the cultivation of the root veg and the apple orchards.

It is only the dairy farms that have higher variable and fixed costs than the agroecological mixed farm; likely because of the need to invest in infrastructure such as milking parlours and housing and machinery. The agroecological horticultural farm has higher variable costs than the agroecological mixed farm due to the high costs on contracting the cultivation of part of the horticultural rotation.

8.4.1.4 Sensitivity analysis

The difference in net income between the agroecological and conventional farms is most sensitive to variation in the fixed costs. Reducing the agroecological fixed costs by 10% narrows the income gap by £14,000. Income also has a high sensitivity to changes in the agroecological farm gate price. Adjusting this variable by 10% changes the income gap by £8,000.

8.4.2 Custom scenario

The custom scenario we have modelled includes the following assumptions:

- **Agri-environment payments rise by 30% of current rates**. Modelled as a conservative estimate of how future funding will pay farmers to provide a range of ecosystem services.
- **A 30% increase to farm gate price.** It is assumed the farmer can generate this increase through improved more direct sales or post-harvest processing.
- **Fixed costs at the same level as incorporated in the baseline.** Fixed costs could, in fact, be substantially higher than this. Fixed costs in the model are those attributed to more specialised farms. Given that the agroecological mixed farm incorporates

the same costs over smaller areas, the proportional costs will likely be greater. This warrants further exploration.

- **Nitrogen pricing at 150% of historic rates.** This is less than the price spikes caused by conflict in Ukraine and illustrates the increasing issues of nitrogen fertiliser use.

Figure 12: Custom scenario economic performance of the mixed farms

The income gap between the agroecological and conventional mixed farms narrows when the custom scenario is modelled, but not by enough to make the agroecological farm profitable. A 30% increase to farm gate price is not adequate to counterbalance the high costs of the diverse enterprises.

8.4.3 Carbon payment

Providing a £9 per tonne CO_2e payment across all habitats, including above and below ground sequestration, increases the income gained to £1,313 for the agroecological farm. Given the uncertainty around the conventional mixed rotation, we do not project any additional sequestration for the farm. In total, the agroecological mixed farm sequesters an estimated 146 tonne CO_2e per annum, 28 tonnes of which is due to woodland and orchards. This is low compared to all other farm types, this is likely due to the lower sequestration rates we project for the grazed pasture. This is because we assume it is too complex to manage the grazing through a mob grazing approach, so sequestration rates will be lower.

8.4.4 Discussion

The lack of data on how diverse agroecological farms perform is the greatest limitation to our findings. Much of the data related to the farm type is extrapolated and aggregated from information related to more specialised farm types and enterprises. Performance and costs will change when enterprises are combined, something that we are not able to accurately reflect at this stage. However, the results still provide important insights into the opportunities and challenges faced when integrating multiple enterprises.

Fixed costs are the greatest challenge to mixed farm profitability. As fixed costs are less scale dependent, they will usually be relatively higher for smaller enterprises. Hence, a farm integrating numerous small areas of different enterprises will have relatively higher fixed costs than more specialised farms. For example, a mixed silvopastoral and silvoarable orchard will require fencing to protect saplings and to contain livestock, machinery to cultivate arable and horticultural crops, labour to herd and harvest, and greater complexity to pack, process and sell products to a wider variety of markets.

High output is required to offset the additional costs. Certain enterprises are better suited to this than others. It is possible to generate high incomes from poultry and certain horticultural crops, whilst crops such as beans are less profitable and apple orchards generate a loss without increased farm gate pricing. Mixed farms, in order to be profitable, need to be developed to meet local needs and markets, enabling them to exploit high value crops that larger, more specialised, farms may be less suited to producing. This kind of specificity is not something we are able to draw out in our modelling.

An additional challenge for more heterogeneous farms is that accessing PES schemes will be more complex than for larger more specialised farms. Certifying sequestration or BNG for simple land uses or single habitats is much easier than for mixed land uses that change each year. Collaboration between mixed farmers at larger scales may help to reduce this challenge and new schemes like nutrient neutrality may provide more accessible options for farmers to receive payments. But, at least in the near-term, PES schemes are likely to be more challenging to access for mixed agroecological farmers.

To exploit market niches mixed farms will likely sell more directly to consumer, through dynamic procurement, via on-farm enterprises such as farm shops and cafes, and with further processing. This is the most likely way for highly mixed agroecological farms to be economically viable; it is very unlikely that these farms would sell to conventional markets.

In many ways these mixed farms are likely to exist outside of conventional supply chains. These mixed agroecological farms are not often going to be producing conventionally priced staple foods for cities but they provide numerous other services. They help to support local food systems, employment, rural engagement, community; they can help to retain rare and valuable crop and livestock varieties and provide high-value, highly nutritious food. This is not something that is quantified when making a direct economic comparison between agroecological and conventional farms and should not be undervalued.

8.5 Farm level recommendations and business strategy

- Methods to reduce the costs of managing diverse agroecological farming systems need to be communicated, researched, or developed. Innovation and technology may have an important role to play here. Technology has often been developed for large scale farming and has, in directly, incentivised scaling and specialisation. Companies are now developing smaller scale technologies that can be integrated into heterogeneous farms. This kind of innovation could help reduce the fixed costs of mixed farming.

- Mixed farmers should aim to produce select high value products for local markets and the remaining products should be complimentary to these products. Orchard eggs and heritage carrots could be an example of high value products that a farmer might build a business around with the remaining rotation being sold directly or on the farm.
- Apple orchards are low profitability. There is a need to establish higher value markets for orchard and timber products from farms. By working collaboratively farmers may be able to develop better domestic supply chains for products including hazel nuts, walnuts, and timber. Collaborative action could also reduce the cost of maintaining, harvesting and processing the products, increasing the gross margin available to farmers practicing agroforestry.
- Dynamic procurement offers a potential way to increase market access for mixed agroecological farmers. This should be explored by farmer groups and supported by public procurers.
- More data is needed on mixed farms. Farmers should work to collect and share data on the benefits of a mixed agroecological approach. Establishing a solid database for performance of these kinds of farms will help farmers validate the public goods provided and, potentially, access future PES schemes. This data could range from management costs and yields to species richness and soil carbon.

Case Study 6: Fred Price – Gothelney Farm

Title: Agroecological arable farm system incorporating pigs supplied to local supply chains.

Background / brief description of farm:

Gothelney Farm is a 150-ha arable farm (101 ha family-owned) managed by Fred Price. They grow population and traditional wheat, malting barley and rye varieties (heritage grains). These are varieties suited to low input farming. Wherever possible the cereals are intercropped and under sown.

The farm system incorporates pigs in the rotation at low stocking rates to increase fertility and diversify income. 24 cross-bred Tamworth, Saddleback, Duroc and Large Black sows produce 350 hybrid finished animals annually. Hybrid vigour helps to make effective use of the soya free home-grown feed. The pigs are pasture grazed and fed on home-grown crops (peas, barley and oats). A roundhouse is used as part of the finishing system, where the pigs are moved to at 8 months old. Fred intends to move to 8 month finishing 100% outdoors.

From April to October the pigs are fed on herbal leys with a rich mixture of legumes, grasses and forbs. During the winter, the pigs are fed on multispecies cover crops. The pigs' diet is almost totally grown on the farm. Pig stocking density is higher during the grazing period and pigs are moved to a different area about every 3 weeks ensuring grass has an adequate rest period.

The farm supplies direct to small, local millers, bakers, butchers, meat boxes, and restaurants. The farm also contains a bakery, and a butchery is being constructed. All this helps to increase sovereignty and communicate the benefits of their products. The farm was conventionally farmed until 2015.

Aim: Being independent of inputs to reduce financial risk and improve the ecological health of the farm. To support human scale food systems through localised supply chains and businesses linked within the community.

Key management features of the agroecological system

Key management features	Description of the management approach and reason for implementing
Soil health & fertility	Aiming to enhance organic matter, soil health and biological activity. Zero synthetic inputs. Pig grazed diverse herbal leys and cover crops enhance fertility and remove reliance on synthetic fertilisers. Cover cropping, reduced tillage, and under sowing provide continuous soil cover and help to retain root and soil structure. These approaches build organic matter and enable good biological activity to thrive.
Rotation	• Year 1 & 2 – herbal sward grazed by pigs • Year 3 – cereal production followed by naturally reseeded herbal sward cover crop (maintained from seed bank in soil removing establishment cost) – ploughed, drilled and harvested in 5 passes. Perennial cover crop reduces conflict with the wheat crop. • Year 4 – pea, barley, oat intercrop under sown with an herbal ley. (~5 passes) This rotation, in time, will likely shift to a 7-year rotation with 4 years of ley and 2 to 3 years of arable cropping. Works with a neighbouring sheep farm to graze covers or crops over winter where required.
Heterogenous / population grains	Population varieties are excellent to grow but difficult to bake with and often only make up a small percentage of baker's flour. The aim is to select for strains that not only grow well but also bake well. Agroecological farming with the full food system in mind. **Population / lower harvest index** grains. **Trial plots / Breeding programme -** Trialling and breeding 8,000 varieties of wheat in order to find productive and resilient varieties that work well within an agroecological system. The aim is to select 20 varieties that perform excellently and then combining these into a population wheat to create a heterogenous variety well adapted to the farming system and the conditions.
Traditional breeds	Tamworth, Large Black, Duroc, Saddleback. Heterosis & traditional breeding techniques.
Disease & pest management	Minimal vet/med costs. Beneficial insect habitat.
Other	On site feed production

Impacts of the agroecological system

- **Farm resilience** - Profitable enterprises which are independent of volatile input prices and commodity supply chains. This independence means the Ukrainian crisis has only increased Fred's cost of production £10 per tonne.
- **Climate impact** - No use of artificial fertiliser which is carbon intensive. It is estimated that soil carbon has increased by as much as 4% in 5 years. At 8.9t Carbon per 0.1% per ha that's 365t/ha or 36,000 tonnes of carbon across the farm. Organic matter has increased from 2% to 7% due to agroecological approach.
- **Nutrient runoff** - No nutrient run off. Low stocking rates, cover crops and herbal leys protect the soil from erosion
- **Ecological impact** - Soil, crops and hedges support biodiversity and ecological processes. 8% of the farm is dedicated to managing habitat for beneficial insects – these are mainly field margins.
- **Societal impact** - The farm produces high-quality food for the local community. This is quality that the customers are willing to pay a premium for. Carbon & Biodiversity benefits, water quality improvement, flood protection, and landscape enhancement.

Performance

Yield & Profitability	
Yield, revenues, profit margins	
Yield wheat	2.5-3 t/ha but believes 5 tonnes is feasible once system is further established and soil health is rejuvenated.
Revenue per ton wheat	£650 per tonne. As yield increases (as predicted) this will decrease to maintain a consistent margin per hectare.
Yield arable sileage	4-5 t/ha peas, barley, and oats used for pig feed (40-50 ha).
Revenues and profit pigs	350 pigs. £3.2/kg (increased from £2/kg) wholesale carcass and £10kg retail. £500/ha profit from pig enterprise
Net margin/profit enterprise	£29,000 per year
Agri-environment support	£35,000 agri-environment stewardship payments.

Variable costs	
Inputs (seeds)	Cereal seeds are saved on the farm, so no cost. Seeding rate wheat:175 kg/ha. Seed costs silage crop is £10,000 per year. Seeding rate: 200-250 kg/ha.
Inputs (concentrates)	Minimal. £5,000 per year (1t creep feed)
Inputs (fertiliser, pesticides/ herbicides)	None
Vet/Med	£1,500 per year
Fixed costs	
Housing	Water infrastructure, electric fencing, stock fencing, breeding stock, handling equipment. Roundhouse for the pigs (was expensive investment; in retrospect not essential)
Machinery	Lower cost due to removed need for sprayer and fertiliser spreader. Fundamentally, Fred takes a reflective, systems approach adapting the system to tackle the root of an issue, rather than defaulting to a technological solution. This means machinery costs and unintended impacts are kept low.
Water / electricity / general costs	Similar to conventional farming
Labour	Farmer + 1 full time employee (+ others who run separate enterprises on the farm). General approach is to 'fill the farm with people'.

Key challenges for transitioning to agroecological farming

It is hard to manage an agroecological system profitably when selling into conventional commodity markets. Pressure to meet minimum standards and lack of control over pricing necessitates yield maximisation, farm simplification and, in turn, land consolidation.

"It requires re-imagining an entirely different kind of food system, one that is non-commodity, human scale and decentralised. Farmers need to create this system, where growers know what food is being produced and who it is for. That relationship and understanding can support diverse and resilient agroecological farming."

The shift to entirely home-grown diets away from bought-in soyabeans initially led to a 40% decrease in productivity but breeding to enhance hybrid vigour and balance hardy, traditional, and productive traits is reducing this loss. Most of this 40% productivity loss will be due to a reduction in the availability of essential amino acids. Antinutritional properties in certain seeds and legumes limits the amounts of amino acids that can be provided by these sources a challenge that is still being tackled.

9 Discussion

The research, case studies and modelling in the above report is a step towards better understanding the impact of agroecology on UK farms. There are many ways to interpret this data and it is hoped that this work will stimulate further analysis, research, discussion and data collection. Below we provide some high-level discussion around the results and what they show for the future of agroecology in the UK.

9.1 Agroecology and scale

A key insight from the work is that it is often cost that most impacts agroecological performance and the drive towards transition. Variable cost reduction is a key incentive for agroecological production. For cereal farms, dairy farms, and lowland grazing farms; variable costs tend to be around a third of the fixed costs. In contrast, for the same conventional iterations of these farms variable costs are between 70% and (for dairy) 99% of the fixed costs. It is worth considering how this might influence the scale of agroecological farming. The relatively low agroecological variable costs incentivise increasing scale because greater farmed area will reduce the per hectare fixed costs leading to greater gross margins. This is true for all farm types, but particularly when, as is the case here, variable costs are small compared to the fixed costs. This driver for increasing scale is increased by the low net incomes of the farms.

Without changes to agri-environment payment rates; PESs, such as carbon storage; or methods to access higher farm gate prices; increased scale will be a requirement for producing conventionally priced agroecological food. Novel collaborative tenancy and contracting agreements may be one way of achieving this scale increase whilst simultaneously reducing the fixed costs necessary for single farmers managing diverse enterprises. Under these agreements, different farmers would be responsible for different parts of the rotations. Cereal farmers, horticultural farmers, graziers, and foresters could work together to efficiently manage the different elements of the agroecological farms across much larger areas of land than they could own individually. Some commercial organic horticulture farms already operate like this, cultivating land on rented land for only part of the larger rotation.

These kinds of collaborative agreements could also support landscape scale regeneration enabling agri-environment options and habitats to be joined up across all the collaboratively managed land, thereby, making more effective use of policy support.

9.2 Increasing the impact of the modelled variables

It is also worth noting here that the custom scenarios we project in the report are conservative estimates of future policy support, costs, farm gate pricing and PES schemes. Below we explore some more dramatic changes in these variables.

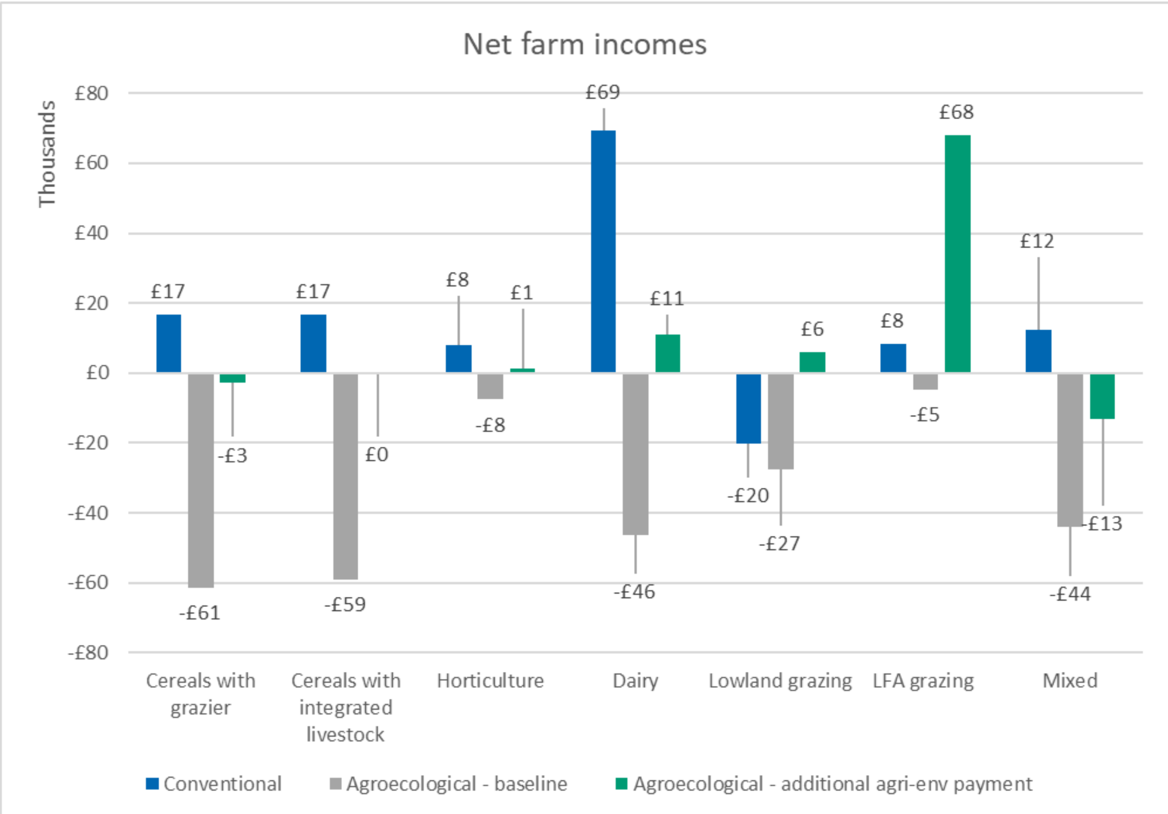
9.2.1 Increased public payment for ecosystem services

As already stated, the 30% increase to agri-environment payments in the custom scenarios is conservative given the additional funding that will be made available as BPS payments reduce. Whilst it is uncertain how these additional funds will be reallocated, it is likely that a proportion will be redistributed into agri-environment payments to pay farmers more effectively for the ecosystem services they support. This will provide a greater incentive for farmers to transition to agroecological farming techniques and provide increased value for money as investments if payments can be aligned with an increase in the societally valuable services.

In order to explore this increase in agri-environment payment, we model a redistribution of 50% of the current BPS payments into agri-environment payments. The redistributed payments are provided proportionally to the average agri-environment rates paid to conventional and organic farms (Moakes et al., 2015). The modelled increased agri-environment payments for the agroecological farm types range from £405 per ha (cereals) to £536 per ha (lowland grazing).

The results of this reallocation are shown in Figure 13 alongside the performance of the conventional farm type when agri-environment payments increase proportional to current payment rates for conventional farms, and alongside the performance of the agroecological farms when no additional variables are applied (the baseline scenario).

Figure 13: Net farm incomes of all farm types with agri-environment payments based on the reallocation of 50% of BPS.



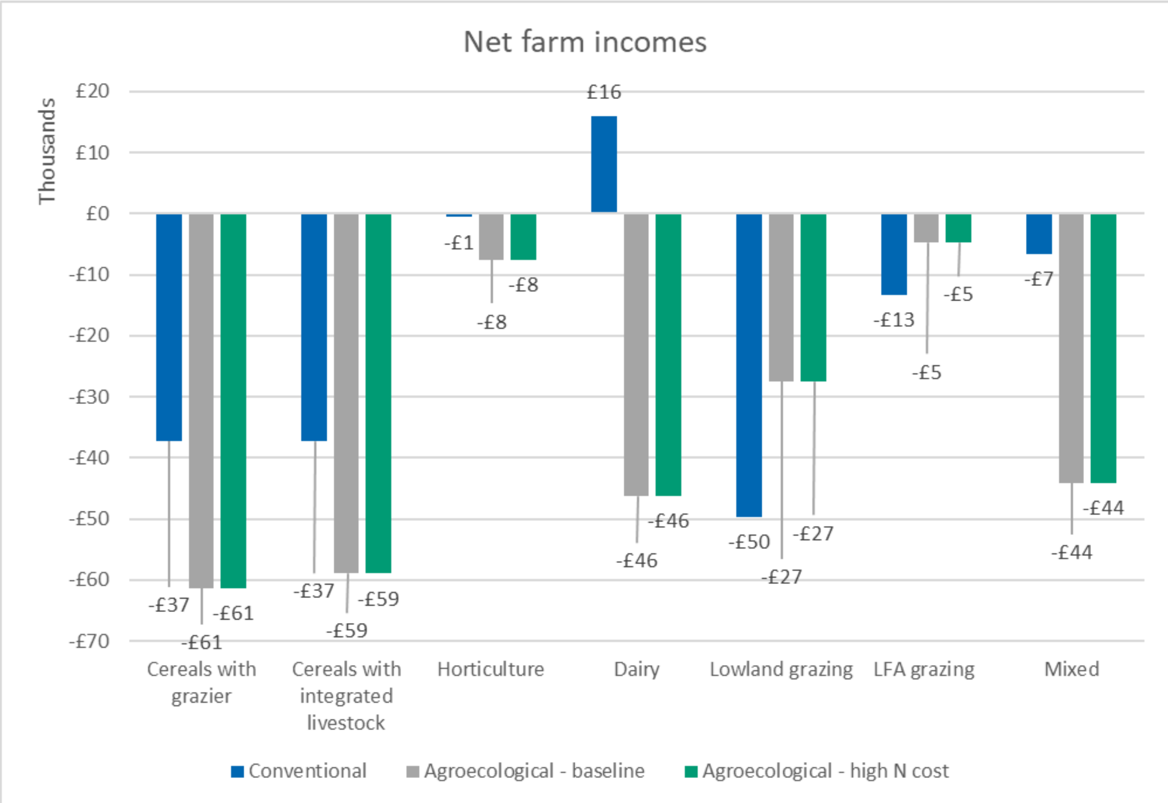
As can be seen in the graph this variation increases net income for all the agroecological farms. In the case of agroecological LFA grazing farms, which, given the larger average farm size, have considerable scope to access increased agri-environment payment. The changed agri-environment payment rates lead the farms to generate attractive profit margins.

Agroecological lowland farms outperform their conventional counterparts but still only generate minimal profit. Likewise agroecological dairy farms shift to a low positive profit margin, but this profit is still low compared to the profit generate from conventional dairy.

9.2.2 Increased nitrogen fertiliser cost

Our custom scenarios are built on N fertiliser costs 150% the historic average. However, recent geopolitical disruption to international supply chains have driven cost up to 300% of historical averages. Modelling this cost increase shows how vulnerable conventional farm incomes are to N cost fluctuation. Figure 14 shows performance at 300% N cost compared to the agroecological farm types.

Figure 14: Net farm incomes of all farm types when N fertiliser cost is 300% the historical average.



With this change in cost applied, all conventional farms, apart from dairy generate negative incomes. Lowland farms perform especially poorly, but conventional cereal farms are also severely impacted but the change in fertiliser cost.

Fertiliser costs as high as this over the long term are not realistic. However, the graph is illustrative of the vulnerability of conventional farming to input costs. Varying oil prices, feed costs, or restrictive legislation or taxes on the use of certain inputs would all have similar impacts upon the profitability of conventional farming.

In reality, this change in cost would not lead to as severe a drop in farm profitability as farm gate prices would increase in response to rising costs. The price increase, however, would lead to a corresponding increase in the price of food for consumers. This is being demonstrated at the time this report is being written (2022) as geopolitical disruption is triggering a rise in food price and exacerbating the cost of living crisis.

In contrast, the agroecological farm types, which are minimally dependent on inputs or important feeds, are practically unaffected by this change in nitrogen fertiliser cost. Agroecology offers an approach to farming that is better shielded from disruptions to global markets and supply chains. Given the prediction that climate change alone will to significant disruption over the next century, a less input dependent food system would be highly advantageous.

9.2.3 High payments for ecosystem services and input cost

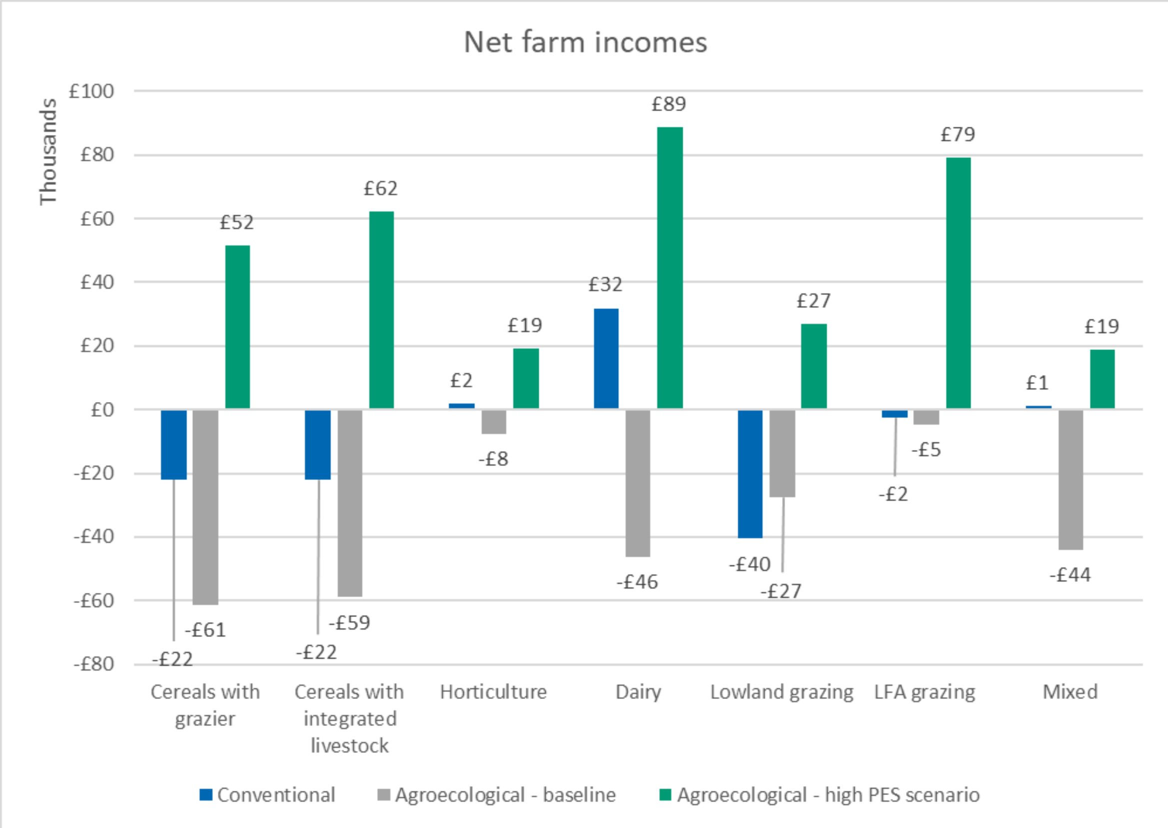
Finally, it is worth exploring the performance of the different farm types when we apply a combination of high PES support and the increased input costs that we discussed in Section 9.2.2. This can be thought of as a combination of assumptions that could be possible and would incentivise agroecological farming.

For this scenario we change the variables in the model to include:

- a payment rate based on the redistribution of 50% of all BPS payments into agri-environment payments;
- 20% increased farm gate pricing;
- agroecological fixed costs 10% lower than conventional farming;
- nitrogen pricing at 300% of historic rates;
- and carbon payment at £15 per tCO_2e (for above and below ground carbon sequestration).

Figure 15 shows the net incomes of the different farm types when the above variables are applied to the model. The above scenario is represented by the high PES scenario and is compared against the performance of the conventional farm types and the agroecological baseline scenario.

Figure 15: Net farm incomes of all farm types with high payments for ecosystem services, high input costs, and low agroecological fixed costs.



When applying these variables, the agroecological farms range from £17,000 (horticulture) to £82,000 (cereals) more profitable than the conventional farm types. All the agroecological farms generate respectable profit margins, whilst most of the conventional farm types are not economically viable.

The assumptions applied in Figure 15 will not all come to fruition. For example, agri-environment payment rates will be restructured in ways that will not directly reflect past payment rates and fertiliser costs will not remain consistently high. We have not built this scenario into the main report as we want to present a more conservative analysis as the main scenarios modelled. However, Figure 15 does represent the likely long term trajectory that public and private payments will take and the increasing risks associated with globalised commodity markets. It demonstrates that progressive and transformational policies, PES schemes, and future input prices could feasibly create a future where agroecology is a far more profitable form of farming than conventional production.

9.3 What might this mean for the future of UK agroecological farming?

Agroecology requires the diversification of agriculture at all scales including genetic diversity, in-field species diversity, varied crop rotations, mixed livestock grazing, multi-species swards, agroforestry, and areas of highly biodiverse non-provisioning habitats. All of these features support low variable cost, resilient productivity. The challenge, and one that is exemplified by the mixed agroecological system, is that the increased diversity increases management complexity and, therefore, fixed costs, such as labour. Today, with the slightly lower agroecological yields per hectare of a single crop, it is difficult for farmers managing all enterprises in-hand and selling at current conventional farm gate prices, to perform profitably. Below we explore two different approaches for alleviating the financial impact of managing complex, diverse farming systems.

To alleviate high management costs, it is possible to envision a future UK food system bifurcated into two types of agroecological farming. The first set of farms are more specialised, managing large areas of diverse agricultural land through diverse, locally adapted crop rotations managed by groups of farmers under collaborative contract. This approach would enable farmers to access economies of scale; invest in and utilise agroecologically aligned technologies; establish collective schemes for landscape restoration though wildlife corridors and woodland planting and receive PESs; and reduce the relative impacts of fixed costs. This is a different type of agroecology to that which is often proposed and understood; it will not align with all conceptualisations. However, it is the kind of innovation that may be necessary to enable agroecology at the scale and efficiency suited to providing to mainstream markets.

The second type of future agroecological food production is closer to how agroecology is currently practiced. More diverse farms will produce high value crops for local markets, helping to provide nutritious food along with a wealth of public services that stimulate greater engagement with the food system and the natural world, increase rural employment and strengthen rural communities. It is important that policy support and PES schemes do not neglect the value these kinds of agroecological farms provide.

Those developing policies for the agricultural and food sectors are at an important point in time. The types of support they provide and the markets they help to establish will set the roadmap for the future of the UK food system. The work undertaken for this report shows that agroecology is not without its challenges. However, it also shows that, compared to conventional farming, this approach to food production has the potential to support more resilient food production that improves the wellbeing of farmers, rural communities and animals whilst providing a wealth of ecosystem services.

10 Policy recommendations

10.1 Key policy insights

Policy support is often necessary to ensure farm profitability; without BPS many farms will fail to generate adequate incomes to support farming as currently practiced. Structuring policy to support a transition to agroecological farming offers a way to produce resilient, nutritious food, whilst simultaneously providing good return on investment through the provision of public goods. Policy support for agroecology will be better value for money if it provides funding for systemic change. Investment in collaboration, dynamic procurement, landscape level intervention, and supply chain development will all enable a more productive, resilient and sustainable food system to develop.

Agroecology offers a route to a food system that is sheltered against global market fluctuations and risks. Reducing reliance on nitrogen fertiliser and other inputs will help to stabilise food supply against the kinds of impacts currently being caused by the Russian invasion in Ukraine and the dangerous effects this is having upon food pricing.

Agri-environment payments providing integrated, systemic support for agroecological farming across the devolved nations will simultaneously improve food production resilience and the supply of ecosystem services. To do so, agri-environment payments need to provide farmers with more than just income foregone and effectively reward land managers for the diverse services they provide. This will help to compensate for lost BPS income whilst incentivising sustainable transition.

Agri-environment support payments need to encourage and enable the integration of diversity into farms. This diversity includes genetic diversity, in-field diversity, integration of livestock with crop production, and bringing agroforestry and trees onto farms. Support payments also need to look beyond the farm, enabling development of supply chains, and innovations that align with diverse agroecological farming.

Current PES schemes are limited. Carbon payments are limited to tree planting and peatland restoration. Providing payments for soil carbon sequestration, such as those already established in Australia, could enhance the profitability of agroecological farms. Payments for more diverse ecosystem services such as nutrient neutrality and flood regulation schemes would provide additional funding streams for agroecological approaches.

What is produced on farms and what is consumed nationally are interrelated and play a role in the obesity crisis. The impact of obesity in the UK is increasing and in 2014/15 cost the NHS £6.1 billion (The King's Fund, 2021). Policy needs to set up schemes that incentivise improved nutritional output from farms and consumption closer to nationally recommended diets (such as the NHS Eatwell Guide). This kind of policy could help to support increasingly diverse agroecological production.

Policy needs to be supportive of innovations that can support small scale efficient agroecological farming approaches. Innovations such as dynamic public procurement and mobile slaughter houses help farmers retain a greater percentage of the value of the food they produce, enabling more sustainable and ethical farming. Policy should support these types of innovations by reviewing regulatory barriers and setting clear and agroecologically supportive procurement targets.

10.2 Payment for environmental and ecosystem services

- Payment rates across the UK must pledge to reallocate funds made available by the reducing BPS payments into agri-environment payment rates. These payment rates should be linked to estimated changes in the provision of integrated ecosystem services and not merely to incomes foregone. This will provide an effective way to incentivise sustainable agroecological farming and validate that public expenditure is leading to a return in investment through an increase in societally beneficial services.

- Evolving agri-environment payment schemes across the devolved nations need to provide integrated support for agroecology that incentivises full farm transition, rather than targeting standalone options. Support schemes for enhancing soil health, transition to low nitrogen and low and no pesticide use could provide this type of more integrated support.
- Given the risk high nitrogen dependence holds for future food security and affordability, payment schemes should be structured to incentivise reduced fertiliser use across all farm types. This could include support for data collection and precision application technologies as well as approaches such as fertility building swards and leguminous rotations.
- Payment needs to be provided for establishment of varied agroforestry systems that can be integrated into UK farm types. This could include grazed orchards, shelterbelts, and sparsely planted silvopastoral grazing areas. Payment rates need to be linked to the integrated ecosystem services that can be provided across farms by increasing agroforestry. This will support increased food system resilience whilst helping governments meet tree planting targets.
- Payment should be provided to farmers wanting to purchase technology that can enable agroecological farming. This should include electric fencing and water infrastructure for mob grazing.
- Funding options should be made available for arable farmers wanting to incorporate livestock grazing into their rotations. This should provide funding for the grazier, and the arable farmers, and provide payments for infrastructure such as fencing.

10.3 Facilitation of private investment

- Policies must be developed to support reliable markets for the environmental services supplied by agroecological farming. This should include markets for carbon stored in the soil and flood regulation from upland farms. Standards need to be developed for evidencing soil carbon storage, either in order to trade the carbon, or just to communicate the carbon footprint of food to consumers.

10.4 Supply chain support

- Public procurement and dynamic public procurement should support local agroecological farmers in order to strengthen the market and supply chains from agroecological food. Governments should set clear and agroecologically supportive procurement targets.
- Policy and regulation need to provide support schemes that align with diverse, local agroecological production. This includes, for example rights to save, breed and cultivate diverse seed varieties; regulatory support for mobile slaughter houses; and support for development of collaborative agreements and supply chains innovations such as digital food hubs.

- Policies need to be developed around ways to effectively communicate agroecological production methods to the consumer. Clear and standardised environmental labelling should be supported by policy to reduce the risk of green washing.
- Agroecological standards and certification schemes also hold potential to increase support for and investment in agroecology across supply chains.

10.5 Knowledge generation

- Government needs to incentivise more nationwide, cross disciplinary research into the potential of agroecological production to increase the economic, environmental, and social sustainability of the UK food system. Potential topics include, exploring the impacts of mob grazing on farm profitability and carbon storage, validating the nutritional composition and health impacts of agroecological products, and investigating the carbon storage from agroforestry.
- Farmer to farmer knowledge building needs to be incentivised and facilitated by the public sector. Forward thinking work by Soil Association Exchange and Innovative Farmers provide useful roadmaps for how to facilitate this kind of knowledge building. Agroecology holds huge potential to meet the environmental aims of the UK governments including transition to net zero, improved biodiversity, improved public health, and increased food security. Agroecological farmers sharing their knowledge provide a public good and should be paid for this service.
- Additional public agri-research funding needs to be more geared to agroecological farming to realise potential to increase productivity. This is summed up effectively in Henry Dimbleby's National Food Strategy (2021); *"It is crucial that Defra sees through this promise to take a farmer-led approach, and backs innovation across the full spectrum of regenerative farming: not just high-tech new ideas (important though these are), but also the agroecological methods that have been starved of investment up to now. It should draw on the experience of successful independent initiatives such as Innovative Farmers…"* A key example is ensuring the plant breeding pipeline is urgently re-focused on low-input varieties and nutrient density rather than assuming ongoing input maximisation for yield maximisation, in spite of the new legal biodiversity target and targets to reduce N pollution.
- Discussion around agroecology can often be siloed. To gain wider support and to foster cross-disciplinary solutions to improve agroecological performance the discussion needs to broaden. Behavioural and social scientists, data analysts, computer scientists, doctors, engineers, biologists, crop and livestock specialists, environmental scientists, marketing experts, and economists are a small selection of the actors that can increase the performance and speed of transition to agroecology. Government can play a key role by encouraging interdisciplinary agroecological research through targeted grants and providing incentives for agroecological research and teaching in academia. Farmers also need greater

access to agronomists and agricultural advisors trained in agroecological management.

- There is also a need to clarify the definition of agroecology and what it means in the UK context. Legislation, certification, and standards can all help to support this.

10.6 Monitoring and data

- The FBS and data on organic farming is currently inadequate for providing insights into how agroecological practices are impacting farm performance and sustainability. There is a need to select an interdisciplinary panel to discuss and select set indicators that should be tracked to gauge the relationship between agroecological methods, and economic performance. Much of this data is likely already collected as part of the FBS and will just need analysing in a different way to yield insights about the role of agroecology in UK agriculture over the coming years.

11 Conclusion

Agroecology holds huge potential for the future of UK agriculture. Public health, carbon storage, biodiversity, flood regulations, food security and rural economies can all benefit from a transition to agroecological farming.

There are clearly challenges, innovative methods are needed to reduce the fixed costs of dairy farms locked into intensification pathways. Collaboration between farms needs to improve to get more livestock onto arable and horticultural farms, to increase knowledge sharing and to enhance access to markets for food and ecosystem services. Understanding around soil carbon storage needs to improve and efficient supply chains suited to diverse agroecological production need to be supported. These are not insurmountable problems.

In this report we set out to explore whether agroecological farming can be a more profitable form of farming than conventional farm management. Crucially we investigated the potential for profitability when all outputs are sold at current conventional farm gate pricing, with no price premium, such as from organic certification. This was undertaken to better understand the potential of agroecology to provide food that is as affordable as food grown on conventional farms.

This work shows that, in the near term, conservative and likely changes to the agricultural sector can make agroecology widely profitable. A 30% increase to agri-environment payment rate; improved understanding of how agroecology can reduce costs; systemic support to enable farmer to retain between 10% and 30% more value from the food they grow through for example, dynamic food procurement; and more effectively paying farmers for the carbon they store makes agroecological production a more profitable farming method than conventional management for the majority of farm types. This is possible without increasing the price of food for the majority of consumers.

In the longer term, agroecology offers a more resilient, more profitable and more societally beneficial food system. Reallocating BPS to pay farmers for the ecosystem services they provide will enable agroecology to become increasingly profitable. Agroecology can reduce dependence on environmentally costly inputs whilst simultaneously creating a food system that is less exposed to volatile commodity markets. It can generate more reliable profits for farmers through more meaningful work, engrained resilience can help to stabilise food costs for consumers and provide a wealth of additional ecosystem services with quantifiable benefits to society.

This report adds to the growing body of literature showing that if policy schemes and markets pay for at least a portion of the environmental externalities existing within our food system, then agroecology will provide an environmentally sustainable, productive and economically viable form of diverse and nutritious food production. One that supports high levels of biodiversity, carbon sequestration, strengthens rural communities and reduces pollution and flood risk. It is in the hands of decision makers to set out a clear road map for how these payments can be facilitated and the necessary transition to agroecological farming enabled.

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Glossary

ABC – The Agricultural Budgeting and Costing Book

AECS – Agri-Environment Climate Scheme

AHDB – Agriculture and Horticulture Development Board

ALC – Agricultural Land Classification

BNG – Biodiversity Net Gain

BPS – Basic Payment Scheme

CAGS – Crofting Agricultural Grant

Defra – Department for Environment, Food and Rural Affairs (England)

ESG – Environmental, Social, and Governance

FBS – Farm Business Survey

GHG – Greenhouse Gas

IDDRI - Institut du développement durable et des relations internationales

IPCC – Intergovernmental Panel on Climate Change

IPM – Integrated Pest Management

LFA – Less Favoured Area

LFASS – Less Favoured Area Support Scheme

NHS – National Health Service

ORC – Organic Research Centre

PES – Payment for Ecosystem Services

SAC – Scottish Agricultural College

SFP – Single Farm Payment

SRUC – Scotland's Rural College

SUSSS – Scotland upland Sheep Support Scheme

Teagasc - Agriculture and Food Development Authority (Ireland)

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