



Miller Research (2025) Evidence Review of Proposed SFS Optional & Collaborative Themes

Welsh Government

September 2025

info@miller-research.co.uk

01873 851880

miller-research.co.uk/

Miller Research (2025) Evidence Review of Proposed SFS Optional & Collaborative Themes

Dr Sean Heron, Dr Nick Morgan, Dr Bethan Thompson, Scout Astley Jones, Gabby Hopkins, Thomas Donovan, Nick Miller, Yasmin Pemberton, Angelica Nahalka, Alice Broome, Filippo Compagni and Iestyn Allen / Miller Research (UK) Ltd.

For further information please contact:

Dr Sean Heron

sean@miller-research.co.uk

Pen-y-Wyrlod, Llanvetherine, Abergavenny, Monmouthshire, NP7 8RG, UK

www.miller-research.co.uk | 01873 851880 | Twitter: @miller_research

Table of contents

Executive Summary	1
Introduction	1
Methodology	3
Enhanced Woodland Management	17
Woodland and Agroforestry Creation	41
Enhanced Biosecurity	78
Enhanced Habitat Management	101
Implementation of Designated Site Management Plans	135
Hedgerow Creation or Restoration	146
Advanced Continuous Professional Development (CPD)	159
Improved Soil Health and Multispecies Crop Cover	171
Sustainable Production	179
Organic Farming (Support and Conversion)	196
Creation of Temporary and Permanent Habitats	203
Improved Public Access to the Countryside	222
Improved water quality, water usage and flood mitigation	230
Improved Air Quality and Lowering Ammonia Emissions	247
Collaborative Innovation, Research and Development	254
Collaborative Landscape Scale Activity	284
Collaborative Market and Supply Chain	306
Conclusion	336
References	390
Annex A – Search Strategies	435
Annex B - Additional grey literature sources	448

Glossary

Agri-Environmental Schemes (AES)

Agri-environmental schemes are programmes which provide funding for farmers and land managers to adopt practices which enrich and enhance the environment.

Business Case

A management tool for scoping, planning and evaluating a proposal and repository for the evidence base.

Catchment Sensitive Farming (CSF)

A programme or scheme which provides farmers with advice and support to reduce pollution from their farms, working in the context of a specific drainage basin (catchment).

Collaborative Themes (CTs)

The proposed Sustainable Farming Scheme is structured around 3 layers. The Collaborative layer comprises the Themes where farmers can choose to work together and with others in a coordinated way to collectively deliver outcomes that cannot be delivered on a single farm scale, in exchange for being paid additional scheme payments.

Common Agricultural Policy (CAP)

A European Union Policy which provides agricultural subsidies and programmes covering farming, rural development and environmental measures in European Union member states.

Conservation Tillage (CT)

A farming practice which minimises soil disturbance during planting and harvesting, with the aim of reducing soil erosion.

Continuous Personal Development (CPD)

An ongoing learning and development process to build skills and knowledge.

Critical Success Factors (CSFs)

Key areas of activity that must be done effectively for a scheme or project to achieve its planned objectives. Critical Success Factors (CSFs) are identified in a project's Business Case.

Environment and Rural Affairs Monitoring and Modelling Programme (ERAMMP)

A partnership led by the UK Centre for Ecology and Hydrology that provides Welsh Government with business-critical evidence and expertise through monitoring, modelling and provision of evidence and advice.

Green House Gas (GHG)

A gas in the atmosphere that absorbs and re-emits infrared radiation, trapping heat and contributing to the greenhouse effect.

Internet of Things (IoT)

Refers to a network of physical devices, such as sensors, appliances, and vehicles, connected to the internet, enabling them to collect, exchange, and act on data without direct human input.

Key Performance Indicators (KPIs)

A set of measurable targets (related to business, livestock or management practices) which can be used to make data driven management decisions

Light Detection and Ranging (LIDAR)

A remote sensing method that uses lasers to measure distances to the Earth's surface and is often used to create detailed 3D models of the landscape.

Life Cycle Assessment (LCA)

A method for evaluating the environmental impacts associated with all stages of a product, process or services' life cycle, from raw material extraction to disposal.

Nature-based solutions (NBS)

Actions that protect, sustainably manage, and restore natural or modified ecosystems to address societal challenges while simultaneously benefiting people and nature.

Natural Flood Management (NFM)

A flood risk management approach that focuses on using and enhancing natural processes and features to reduce flood risk, rather than relying solely on engineered solutions.

Nitrate Vulnerable Zone (NVZ)

Areas designated as being at risk from agricultural nitrate pollution.

Optional Themes (OTs)

The proposed Sustainable farming Scheme is structured around 3 layers. The Optional layer is comprised of the Themes which farmers can choose to

undertake above and beyond the Universal Actions depending on what suits their farm business and ambitions the most, in exchange for additional scheme payments.

Payment for ecosystem services (PES)

A term to describe a range of schemes whereby the beneficiaries of nature's services pay or fund the providers or stewards of those services.

Rapid Evidence Assessment (REA)

A review method that applies systematic review principles to locate, appraise, and summarize relevant research on a specific question or topic, suitable for generating structured, timely summaries of the available evidence while maintaining transparency and methodological rigor.

Sustainable Farming Scheme (SFS)

The proposed main support scheme for Welsh farmers from the Welsh Government from 2026 onwards.

Sustainable Land management (SLM)

Sustainable Land Management incorporates the environmental, economic, cultural and social contribution of farmers in Wales. It is based on an internationally recognised concept so that resources, including soils, water and crops, are used for the production of goods to meet changing human needs in such a way that the needs of the current generation are balanced with our obligations to future generations. In Wales, SLM is defined by the 4 SLM objectives in the Agriculture a (Wales) Act 2023.

Universal Action (UA)

This layer of the SFS comprises of the Universal Actions which all farmers participating in the Scheme will need to undertake, in exchange for being paid the Universal Payment, which is comprised of the Universal Baseline Payment and the Social Value Payment.

Value for Money (VfM)

Value for money (VfM) is a balanced judgement about finding the best way to use public resources to deliver policy objectives

Water Quality Trading (WQT)

A market-based mechanism that enables the buying and selling of pollution credits among sources within a defined watershed region, with the aim of achieving water quality standards more efficiently and at lower cost.

Welsh Government (WG)

The Government of Wales.

Willingness to pay (WTP)

Willingness to Pay (WTP) is a technique for the inference of value of a non-marketed good or service from the amount that respondents to an expertly designed survey are willing to pay to acquire a good or service.

Executive Summary

Introduction and Background

The Welsh Government is developing the Sustainable Farming Scheme (SFS) as the successor to agricultural support previously delivered through the European Union's Common Agricultural Policy (CAP). Rooted in the Sustainable Land Management (SLM) framework outlined in the Agriculture (Wales) Act 2023, the SFS aims to enable Welsh farmers to contribute to a range of social, economic, and environmental benefits for them and the people of Wales.

As part of the Scheme's development, the Welsh Government is producing a full Five Case Business Case in line with HM Treasury's Five Case Model which is the required framework for considering the use of public resources [footnote ¹]. This report forms part of that evidence-gathering process, providing a review of available literature to assess how the proposed SFS Optional Themes (OTs) and Collaborative Themes (CTs) may align with a set of Critical Success Factors (CSFs). These CSFs relate to:

- Strategic fit and business needs
- Value for money
- Supply side capacity and capability
- Affordability.

The report reviews evidence related to 17 individual Optional and Collaborative Themes proposed as part of the Scheme, offering insights into their potential environmental, social and economic impacts. The review is reflective of the Optional and Collaborative Themes during a particular period in their development, with the possibility that ongoing policy development may to some extent change the details of farm practices under consideration within Themes. Therefore, the focus of the evidence presented may have lower alignment to the final policy position. Furthermore, this review includes farm practices intended to be available as part of the Optional and Collaborative Themes in 2026. Additional Themes may be available at a later date, and these are not considered in this review.

¹ HM Treasury, [Better business cases: investment decision-making framework](#), 2018

These Themes are grouped as follows:

- Enhanced Woodland Management
- Woodland and Agroforestry Creation
- Enhanced Biosecurity
- Enhanced Habitat Management
 - Including Peatland Management and Restoration
- Implementation of Designated Site Management Plans
- Hedgerow Creation or Restoration
- Advanced Continuous Professional Development (CPD)
- Improved Soil Health and Multispecies Crop Cover
- Sustainable Production
- Organic Farming (Support and Conversion)
- Creation of Temporary and Permanent Habitats
- Improved Public Access to the Countryside
- Improved Water Quality, Water Usage and Flood Mitigation
- Improved Air Quality and Lowering Ammonia Emissions
- Collaborative Innovation, Research and Development
- Collaborative Landscape Scale Activity
- Collaborative Market and Supply Chain.

Methodology

The assessment followed a Rapid Evidence Assessment (REA) approach, suitable for generating structured, timely summaries of the available evidence while maintaining transparency and methodological rigor. 17 REAs were conducted, one for each of the Themes and an additional one for Peatland Management and Restoration which is now included under Enhanced Habitat Management. The REAs were guided by a framework of

research questions relating to intervention design, uptake, impact, barriers and evidence gaps.

The REA process was broken into 5 phases:

- Planning – establishing research goals, scope, and timelines
- Scoping – defining inclusion/exclusion criteria, relevance thresholds, and search strategies
- Evidence review – extracting and analysing relevant literature using an evidence register
- CSF analysis – assessing the alignment of each Theme with the Welsh Government Business Case CSFs
- Reporting – summarising findings by OT/CT and across the Scheme.

The evidence base was primarily drawn from academic sources accessed via Scopus, supplemented by grey literature and government reports. Articles were evaluated for quality (1–5 scale) and relevance (1–4 scale), focusing on the Welsh context and contexts comparable to Wales. After applying inclusion, quality and relevance criteria 938 articles and reports were reviewed for the report.

Limitations

While this approach offers a practical and structured method to support the development of a Business Case, several key limitations must be acknowledged:

- Scope and scale: The wide range of Themes for which REAs were undertaken (17 in total) and the variety of farm practices within each Theme assessed meant this limited review could not explore each practice in depth or evaluate their interactions at the individual farm level
- Time constraints: The short timescale for delivery of this project limited the depth of the analysis and restricted the use of more resource-intensive methods such as systematic reviews or impact modelling

- Definition variability: Some Themes, like Hedgerow Creation or Restoration, were clearly defined, whereas others (for example, Improved Air Quality and Lowering Ammonia Emissions) were framed around broad objectives at the time the REAs were conducted, making it difficult to assess the evidence base uniformly across all Themes
- Variety of on-farm practices: Some Themes such as Sustainable Production focussed on a narrow set of on-farm practices whereas others (particularly those using capital funding) encompassed a much wider range of on-farm practices
- Context-specific evidence: Many interventions rely heavily on site-specific conditions such as soil type, climate, or farm system. Consideration of these context-specific factors was outside the scope of this assessment, however, where context-specific factors may affect the relevance of a study to Wales this has been highlighted
- Not predictive or prescriptive: The assessment does not predict likely outcomes or propose implementation strategies. It explores only the potential for alignment with the SFS Business Case CSFs based on existing identified evidence
- Reflective of policy under development: Due to ongoing development of Optional and Collaborative Themes, the detail of delivery of some Themes will have continued to change since the research was undertaken, meaning that some assessments may lack detail on farm practices added later in the process, or may contain detail on farm processes that have been removed from Themes
- Relevant to farm practices: The assessments relate to Themes which that may be available from 2026, and do not consider Scheme Themes which may be introduced later.

These limitations mean that findings should be treated as indicative rather than definitive. They reflect potential alignment rather than guaranteed delivery of outcomes. The ultimate impact of each Theme will depend significantly on implementation, design, and uptake.

Potential Alignment with Critical Success Factors

The evidence reviewed indicates that many of the SFS Themes have the potential to align well with the Scheme's CSFs, particularly in delivering long-term public value across

environmental, economic and social domains. However, this alignment is conditional on implementation, including appropriate Scheme design, farmer engagement, access to support, and whether the on-farm practice is appropriate for the chosen site.

This report assesses the potential alignment of each proposed SFS Optional and Collaborative Theme with 4 CSFs used in the Five Case Business Case model: Strategic fit and business needs, Value for money, Supply side capacity and capability, and Affordability. These CSFs were defined for this REA as follows:

Strategic fit and business needs (strategic case):

- aligns with the Sustainable Land Management Objectives established in the Agriculture (Wales) Act 2023.
- aligns with the WG's objectives reflected in the Well-being of Future Generations (Wales) Act 2015 and the Environment (Wales) Act 2016, especially in relation to sustainable land management
- is approved of and supported by key stakeholders, in particular those directly impacted by the SFS (such as farmers and rural communities) and wider groups across Wales
- provision of financial support is linked to delivery of measurable economic, environmental, and social outcomes
- farmers see sustainable practices as economically feasible with SFS support.

Value for money (economic case):

- the SFS is accessible to all farms and farmers
- farmers receive clear, accessible information about the direct and wider benefits and requirements of the SFS
- farmers are incentivised to change their behaviour to adopt more sustainable farming practices to the benefit of [disadvantaged] rural or farming communities
- farmers are encouraged to act to adapt to and mitigate the effects of climate change.

Supply side capacity and capability:

- farmers are equipped to undertake a holistic assessment/appraisal of the potential value of adopting [more] sustainable farming practices
- farmers have sufficient access to advisory services and support networks (including peer-to-peer learning and demonstration projects)
- farmers are encouraged to collaborate to improve the efficiency of agricultural (and food) supply chains.

Affordability:

- farmers' costs of participating in the SFS are minimised
- farmers are able to supplement SFS support by attracting additional funding from investors other than the Welsh Government.

It is important to emphasise that this assessment is based solely on a review of existing evidence, drawn from peer-reviewed and grey literature, and is not predictive of likely outcomes under the SFS. The findings reflect how similar interventions have been delivered or studied in other contexts, rather than outcomes from the SFS itself. As such, all alignment ratings should be interpreted as indicative only, and heavily dependent on future policy and implementation design.

Below is a summary of the Optional and Collaborative Themes potential alignment with each CSF.

Potential Alignment with Strategic fit and business needs CSF

The review indicated that the majority of SFS Themes show strong potential to align with Strategic fit and business needs. Themes that may support biodiversity, climate resilience, ecosystem improvement, and improved economic outcomes generally align well with the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023. However, the level of alignment is conditional on Scheme implementation.

Overall, the reviewed evidence suggests Themes to have high potential alignment with this CSF, with evidence indicating high potential alignment for 13 Themes, and medium

potential alignment for 4 Themes. The Themes that were assessed as medium may have aligned well with strategic objectives, yet the evidence identified may have failed to cover farmers' views of their economic feasibility or support amongst stakeholders.

High potential alignment:

- Enhanced Woodland Management
- Enhanced Biosecurity
- Implementation of Designated Site Management Plans
- Hedgerow Creation or Restoration
- Advanced Continuous Professional Development (CPD)
- Sustainable Production
- Organic Farming (Support and Conversion)
- Creation of Temporary and Permanent Habitats
- Improved Water Quality, Water Usage and Flood Mitigation
- Improved Air Quality and Lowering Ammonia Emissions
- Collaborative Innovation, Research and Development
- Collaborative Landscape Scale Activity
- Collaborative Market and Supply Chain

Medium potential alignment:

- Woodland and Agroforestry Creation
- Enhanced Habitat Management,
- Improved Soil Health and Introduce Multispecies Crop Cover
- Improved Public Access to the Countryside

Low potential alignment: None

Potential Alignment with Value for money CSF

Evidence for the Themes reviewed demonstrated a generally high potential for alignment with Value for money due to their potential to deliver economic, social, and environmental benefits, and encourage farmer engagement. As stated previously this is potential alignment determined through a review of evidence from similar interventions, delivery of Value for money will depend on effective implementation of the Themes.

Overall, the reviewed evidence suggests Themes to have high to medium potential alignment with this CSF, with evidence indicating high potential alignment for 9 Themes, and medium potential alignment for 8 Themes.

High potential alignment:

- Enhanced Woodland Management
- Hedgerow Creation or Restoration
- Advanced Continuous Professional Development (CPD)
- Sustainable Production
- Creation of Temporary and Permanent Habitats
- Improved Public Access to the Countryside
- Improved Air Quality and Lowering Ammonia Emissions
- Collaborative Innovation, Research and Development
- Collaborative Landscape Scale Activity

Medium potential alignment:

- Woodland and Agroforestry Creation
- Enhanced Biosecurity
- Enhanced Habitat Management
- Implementation of Designated Site Management Plans
- Improved Soil Health and Multispecies Crop Cover
- Organic Farming (Support and Conversion)
- Improved Water Quality, Water Usage and Flood Mitigation
- Collaborative Market and Supply Chain

Low potential alignment: None

Potential Alignment with Supply side capacity and capability CSF

Overall, the review found limited evidence for the current alignment between Themes and the Supply side capacity and capability CSF. The methodology sets out that the REA's assessment of alignment with the Supply side capacity and capability CSF was intended to be limited. It focused on exploring evidence related to farmer capability, the provision of advisory services and support networks, and encouragement of farmers to collaborate

where relevant. Therefore, absence of evidence in the REA does not indicate low alignment with this CSF, but a result of the limited nature of the evidence reviewed. It is important to note then that those Themes that are assigned low potential alignment may be assigned so as a result of the priorities of the academic literature rather than the supply side capacity and capability of the sector.

Overall, the reviewed evidence suggests Themes to have low to medium potential alignment with this CSF with evidence indicating high potential alignment for one Theme, medium potential alignment for 8 Themes, and low potential alignment for 8 Themes.

High potential alignment:

- Advanced Continuous Professional Development (CPD)

Medium potential alignment:

- Enhanced Woodland Management
- Woodland and Agroforestry Creation
- Improved Soil Health and Multispecies Crop Cover
- Sustainable Production
- Organic Farming (Support and Conversion)
- Improved Water Quality, Water Usage and Flood Mitigation
- Collaborative Landscape Scale Activity
- Collaborative Market and Supply Chain

Low potential alignment:

- Enhanced Biosecurity
- Enhanced Habitat Management
- Implementation of Designated Site Management Plans
- Hedgerow Creation or Restoration
- Creation of Temporary and Permanent Habitats
- Improved Public Access to the Countryside
- Improved Air Quality and Lowering Ammonia Emissions

- Collaborative Innovation, Research and Development

Potential Alignment with the Affordability CSF

The evidence reviewed suggests that Affordability, as it relates to farmer costs of participating and access to additional investment, could present a barrier to implementation for several Themes.

Overall, the reviewed evidence suggests Themes to have medium potential alignment with this CSF, with evidence indicating high potential alignment for 4 Themes, medium potential alignment for 9 Themes, and low potential alignment for 4 Themes.

High potential alignment:

- Enhanced Woodland Management
- Woodland and Agroforestry Creation
- Implementation of Designated Site Management Plans
- Collaborative Innovation, Research and Development

Medium potential alignment:

- Enhanced Habitat Management
- Hedgerow Creation or Restoration
- Advanced Continuous Professional Development (CPD)
- Sustainable Production
- Organic Farming (Support and Conversion)
- Improved Public Access to the Countryside
- Improved Water Quality, Water Usage and Flood Mitigation
- Collaborative Landscape Scale Activity
- Collaborative Market and Supply Chain

Low potential alignment:

- Enhanced Biosecurity

- Improved Soil Health and Multispecies Crop Cover
- Creation of Temporary and Permanent Habitats
- Improved Air Quality and Lowering Ammonia Emissions

Overall, the findings suggest that each SFS Theme has potential to align with the SFS CSFs, but realising this potential will depend on policy and implementation, including how the Scheme addresses barriers related to capacity, cost, and confidence within the farming sector.

Potential Impacts

In addition to alignment with CSFs, the REAs also highlighted a wide range of economic, environmental, and social impacts which have arisen from activities similar to the Optional and Collaborative Themes. These have been considered in reference to purposes of support [footnote ²] outlined in The Agriculture (Wales) Act 2023:

- 15 Themes were identified as potentially contributing towards purpose (a), encouraging the production of food in an environmentally sustainable manner
- the evidence reviewed suggested that 14 Themes were identified as potentially contributing towards purpose (j) improving water quality

² (a)encouraging the production of food in an environmentally sustainable manner;
 (b)helping rural communities to thrive and strengthening links between agricultural businesses and their communities;
 (c)improving the resilience of agricultural businesses;
 (d)sustaining the Welsh language and promoting and facilitating its use;
 (e)reducing emissions of greenhouse gases;
 (f)maximising carbon sequestration and storage;
 (g)maintaining and enhancing the resilience of ecosystems;
 (h)conserving and enhancing landscapes and the historic environment;
 (i)improving air quality;
 (j)improving water quality;
 (k)maintaining and enhancing public access to and engagement with the countryside and the historic environment;
 (l)mitigating flood and drought risks;
 (m)achieving and promoting high standards of animal health and welfare;
 (n)maximising resource efficiency;
 (o)encouraging agricultural businesses to manage energy effectively (including by adopting energy efficiency and energy saving practices, and generating renewable energy on their land).

- 13 Themes were found to potentially contribute towards purposes (c) improving the resilience of agricultural businesses and (g), maintaining and enhancing the resilience of ecosystems
- 10 Themes were identified as potentially contributing towards the purpose (n) maximising resource efficiency
- 9, 8, 7 and 6 Themes were identified as potentially contributing towards purposes (h) conserving and enhancing landscapes and historic environment, (l) mitigating flood and drought risks, (f) maximizing carbon sequestration and storage, and (b) helping rural communities to thrive and strengthening links between agricultural businesses and their communities respectively.
- 5 Themes were identified as potentially contributing towards purpose (e) reducing emissions of greenhouse gases, and (m) achieving and promoting high standards of animal health and welfare
- 4 Themes were identified as potentially contributing towards purpose (i) improving air quality
- 3 Themes were identified as potentially contributing towards purpose (o) encouraging agricultural businesses to manage energy effectively (including by adopting energy efficiency and energy saving practices, and generating renewable energy on their land)
- 1 Theme was identified as potentially contributing towards purpose (k) maintaining and enhancing public access to and engagement with the countryside and the historic environment
- 0 Themes were identified as potentially contributing towards purpose (d), sustaining the Welsh language and promoting and facilitating its uses

It should be noted that no searches returned evidence related to impacts on the Welsh language. As discussed in relation to the limitations of the research in the methodology, conclusion, and throughout, this does not mean that these Themes will not sustain, promote, or facilitate the use of the Welsh Language.

These findings suggest that the SFS Optional and Collaborative Themes have the potential to provide economic, social, and environmental benefits that align with the purposes of support set out in the Agriculture (Wales) Act 2023. In addition, the alignment outlined with the CSFs suggests that the Themes may align with the broader goals of the Well-being of Future Generations (Wales) Act 2015, especially when Themes are carefully targeted and supported.

The strategic potential of many SFS Optional and Collaborative Themes is well-supported by the literature, however realising this potential will depend on a number of factors. Implementation of the Themes will be important to ensure that on-farm practices are targeted at appropriate sites to maximise benefits and avoid unintended consequences, as will proper application of on-farm practices by farmers. The full impact of the Scheme will depend upon the level of uptake, while those managing the Scheme must ensure that uptake for each Theme and on-farm practice is appropriate to balance potentially conflicting objectives. Targeting interventions to appropriate locations, farm types and sectors will be important to ensure the balance between objectives, and delivery of Value for money. Across each of the Themes, the evidence identified repeatedly highlighted the need for advisory support to ensure correct application of on-farm practices and encourage uptake through knowledge exchange including demonstrating the social, economic and environmental benefits of the Themes.

Introduction

The Sustainable Farming Scheme (SFS) is being developed by the Welsh Government (WG) as a replacement for agricultural support from the EU's Common Agricultural Policy (CAP), which contained several financial support and environmental schemes for farm businesses. Based on the Sustainable Land Management (SLM) framework, as set out in the Agriculture (Wales) Act 2023, the SFS will support farmers to deliver social, economic, and environmental benefits for the people of Wales.

The SFS has undergone an extensive period of consultation and co-design, including 5 public consultations [footnote ³] and 2 phases of co-design [footnote ⁴]. In November 2024 Welsh Government published the Sustainable Farming Scheme: Proposed Scheme Outline [footnote ⁵] which built on the structure proposed in the 2023 consultation [footnote ⁶] and feedback received from stakeholders, including the Officials Group(s) and Carbon Sequestration Panel. At launch, the Scheme will contain a suite of 12 Universal Actions (UAs), which all farmers who participate in the SFS will have to complete where they are applicable to their farm business, and a range of Optional and Collaborative Themes. Optional and Collaborative Themes are actions that farmers can take beyond the Universal Actions to deliver SLM objectives for which they will receive a payment.

The Welsh Government is producing a full Five Case Business Case in line with HM Treasury's Five Case Model which is the "required framework for considering the use of public resources" [footnote ⁷]. This project has supported the development of the SFS Business Case by, where possible, providing Welsh Government with additional evidence in relation to each Optional and Collaborative Theme. This report is a summary of the evidence provided to Welsh Government by this research project.

The research:

³ Sustainable Farming Scheme: previous consultations and responses (gov.wales)

⁴ Sustainable Farming Scheme Co-design Final Report, May 2023 (gov.wales)

⁵ Sustainable Farming Scheme: proposed scheme outline, November 2024 (gov.wales)

⁶ Sustainable Farming Scheme: Keeping farmers farming, December 2023 (gov.wales)

⁷ HM Treasury, [Better business cases: investment decision-making framework](#), 2018

- assesses the potential alignment of the Optional and Collaborative Themes with Critical Success Factors (CSFs) chosen by the Welsh Government for the Business Case
- identifies evidence associated with each Optional and Collaborative Theme
- provides insights into the potential economic, environmental and social costs and benefits of the Optional and Collaborative Themes.

Methodology

Introduction

The approach to this Rapid Evidence Assessment (REA) was informed by best practices in REA methodology, the requirements of the Business Case, and the requirement to provide a structured assessment of evidence across a large number of Themes within a short period of time. An REA approach produces a thorough assessment of evidence in a short period of time while providing readers with a transparent description of each step of the research, reducing the possibility of bias in the process. It is not a systematic review which aims to understand all of the evidence related to a particular topic, nor is it a modelling exercise, which would aim to quantify the impacts of Themes. It is an approach which aims to understand the scale and quality of the evidence related to a Theme and synthesise the key findings within a relatively narrow timeframe.

This study has been limited by the breadth of Themes requiring an assessment – an REA would normally provide a thorough and deep understanding of a clearly defined Theme within a distinct context. This project required an assessment of the evidence related to 17 Themes with an REA conducted for each. Themes differed in how clearly they were defined and the number of specific practices included in the scope of each Theme. For example, the Theme Sustainable Production contained 3 clear practices at the time of the evidence assessment, whilst the Theme Implementation of Designated Site Management Plans contained upwards of 300. While this could mean that the SFS is more flexible for farmers, it is more challenging to assess and requires adjustments to the REA approach.

The review is also reflective of the Optional and Collaborative Themes during a particular period in their development, with the possibility that ongoing policy development may to some extent change the details of farm practices under consideration within Themes. Furthermore, this review includes actions intended to be available from day one of the rollout of Optional and Collaborative Themes. Additional Themes may be available at a later date, and these are not considered in this review.

17 REAs were conducted, one for each of the Themes and an additional one for peatland management which is now included under Enhanced Habitat Management in the Scheme outline. The REAs were:

- Enhanced Woodland Management
- Woodland and Agroforestry Creation
- Enhanced Biosecurity
- Enhanced Habitat Management
- Peatland Management and Restoration
- Implementation of Designated Site Management Plans
- Hedgerow Creation or Restoration
- Advanced Continuous Professional Development (CPD)
- Improved Soil Health and Multispecies Crop Cover
- Sustainable Production
- Organic Farming (Support and Conversion)
- Creation of Temporary and Permanent Habitats
- Improved Public Access to the Countryside
- Improved Water Quality, Water Usage and Flood Mitigation.
- Improved Air Quality and Lowering Ammonia Emissions
- Collaborative Innovation, Research and Development.
- Collaborative Landscape Scale Activity
- Collaborative Market and Supply Chain

Approach

The approach was divided into 5 stages:

- Stage 1: Planning – inception, policy refinement and research framework development

- Stage 2: Scoping – search, quality and relevance analysis
- Stage 3: Evidence review
- Stage 4: Critical Success Factors (CSFs) and Purposes of Support analysis
- Stage 5: Reporting.

Planning

The project began with an inception meeting with Welsh Government which discussed:

- overview of project aims, scope, and intended outcomes
- background and context
- proposed methodology, approach, and any changes needed
- timeline and deliverables, including milestones
- risk mitigation and management
- communication and project management details
- next steps and immediate priorities.

An inception report was written as an output of the meeting which included a confirmed timeline and risk management strategy, and agreed ways of working with the wider policy team. Amendments to the methodology were outlined, which included an agreement to undertake each Theme assessment sequentially to align with the policy development timeline. Due to time constraints of the project, it was also decided that expert interviews would no longer be conducted.

Research Framework

As this research was intended to support the development of a Business Case, research questions were designed to align with the Sustainable Farming Scheme's CSFs developed by Welsh Government.

The CSFs in the Business Case were aligned with the Five Case Business Case Model (which includes a strategic case, an economic case, a commercial case, a financial case and a management case) as follows:

Strategic fit and business needs (strategic case):

- aligns with the WG's objectives reflected in the Well-being of Future Generations (Wales) Act 2015 and the Environment (Wales) Act 2016, especially in relation to Sustainable Land Management
- is approved of and supported by key stakeholders, in particular those directly impacted by the SFS (such as farmers and rural communities) and wider groups across Wales
- provision of financial support is linked to delivery of measurable economic, environmental, and social outcomes
- farmers see sustainable practices as economically feasible with SFS support.

Value for money (economic case):

- the SFS is accessible to all farms and farmers
- farmers receive clear, accessible information about the direct and wider benefits and requirements of the SFS
- farmers are incentivised to change their behaviour to adopt more sustainable farming practices to the benefit of [disadvantaged] rural or farming communities
- farmers are encouraged to act to adapt to and mitigate the effects of climate change.

Supply side capacity and capability (commercial case):

- farmers are equipped to undertake a holistic assessment/appraisal of the potential value of adopting [more] sustainable farming practices
- farmers are encouraged to develop the skills needed to enable them to adopt more sustainable farming practices

- farmers have sufficient access to advisory services and support networks (including peer-to-peer learning and demonstration projects)
- farmers are encouraged to collaborate to improve the efficiency of agricultural (and food) supply chains.

Affordability (financial case):

- payment rates are consistent with achieving desired levels of farm participation in the SFS within the available budget [constraint]
- the allocation of funding between UAs, OTs and CTs maximises value for farmers and society
- the WG's costs of administering the SFS are minimised (e.g. they are consistent with international best practice [less than 10% of the budget])
- farmers' costs of participating in the SFS are minimised
- farmers are able to supplement SFS support by attracting additional funding from investors other than WG.

Achievability (management case):

- An appropriate governance structure is established which builds trust with farmers and other stakeholders
- The SFS enables a smooth transition from the Basic Payment Scheme (BPS)
- The SFS can be delivered [largely] based on existing WG infrastructure and systems
- The SFS is managed in a flexible enough way that it can be adapted to changes in the external environment (as required)
- SMART targets provide focus and direction for the SFS and support effective benefit realisation based on effective monitoring and evaluation of environmental, economic, and social impacts against an established baseline.

After discussion with WG it was agreed that the REAs would assess potential CSF alignment to the strategic and economic cases, as well as to the commercial and financial

cases. Potential contributions toward the commercial and financial cases were limited to sections that were deemed potentially relevant, these were as follows.

Supply side capacity and capability:

- farmers are equipped to undertake a holistic assessment/appraisal of the potential value of adopting [more] sustainable farming practices
- farmers have sufficient access to advisory services and support networks (including peer-to-peer learning and demonstration projects)
- farmers are encouraged to collaborate to improve the efficiency of agricultural (and food) supply chains.

Affordability:

- farmers' costs of participating in the SFS are minimised
- farmers are able to supplement SFS support by attracting additional funding from investors other than WG.

Therefore, the research framework was designed to support the development of the Business Case by assessing Theme alignment with:

- Strategic fit and business needs (strategic case)
- Value for money (economic case)
- Supply side capacity and capability (commercial case)
- Affordability (financial case).

Research questions were developed to ensure that each REA consistently reviewed the identified evidence with the aim to determine whether each Theme has the potential to align with the CSFs. The research framework developed based on the CSFs focussed on determining whether the evidence, often including studies outside of Wales, identified any potential impacts of similar interventions, the potential uptake of on-farm practices, and considerations for the design of an intervention. The research questions were:

- does the evidence base identify differing approaches to designing an intervention? If so, are these associated with different outcomes?
- does the evidence base identify the scale of uptake of this practice? If so, does it identify factors impacting the uptake of the practice?
- does the evidence offer any indication of the cost-effectiveness of this intervention?
- does the evidence base indicate that this intervention will have economic impacts? If yes, what economic impacts?
- does the evidence base indicate that this intervention will have environmental impacts? If yes, what environmental impacts?
- does the evidence base indicate that this intervention will have social impacts? If yes, what social impacts?
- does the evidence base identify any barriers to the uptake of this practice? Or, barriers, linked to uptake, to maximising the benefits of this practice?
- does the evidence base identify any evidence gaps in relation to this practice?

These questions were kept at this high level across the 17 REAs due to the breadth of Themes and differing level of detail. It is important to note that the REAs were Theme driven with research questions designed to identify evidence related to what impacts may be achieved by specific Themes and on-farm practices. This is opposed to an outcome-oriented approach where research would focus on identifying the on-farm practices that may be adopted to achieve a certain outcome, for example, carbon emission reduction or sequestration. Outcome driven research has been carried out across a range of areas including through the aforementioned Carbon Sequestration Evidence Review Panel [footnote ⁸] and the Welsh Soil Evidence Review [footnote ⁹].

⁸ [Carbon Sequestration Evidence Review Panel](#), 2024

⁹ [Welsh Soil Evidence Review](#), 2022

To maximise evidence gathered, each REA was adapted to meet the specific requirements of the Theme. REA adaptations are described in each section, with the adaptations made in the REAs for the following Themes described below:

- Implementation of Designated Site Management Plans
- Advanced Continuous Professional Development (CPD)
- Improved Water Quality, Water Usage and Flood Mitigation
- Improved Air Quality and Lowering Ammonia Emissions
- Collaborative Innovation, Research and Development
- Collaborative Market and Supply Chain

The effectiveness of the REAs for the Themes implementation of Designated Site Management Plans, Improved Water Quality, Water Usage and Flood Mitigation, and Improved Air Quality and Lowering Ammonia Emissions were affected by the number of on-farm practices listed under each Theme meaning that there were too many on-farm practices to assess all of them. For these Themes the specific focus of each REA is described under the relevant Theme. The Themes Advanced Continuous Professional Development (CPD), Collaborative Innovation, Research and Development, and Collaborative Market and Supply Chain differed from other Themes as they tended towards facilitating or improving the implementation of other Themes, for example by supporting CPD in relation to woodland creation. For this reason, more emphasis was placed on the effectiveness of these Themes in facilitating increased impact regardless of the nature of that impact.

The research questions were developed into an evidence register. The evidence register included:

- a front page explaining the background of the research and the purpose of the evidence register
- a content page to assist readers in navigating the register

- an REA interaction evidence page where readers can identify relevant evidence to a Theme in other REAs
- an evidence review sheet for each REA which included a literature tracker with key details about each article and with a cell for each research question and each article.

Policy and Evidence Review

As the policy for each Theme was being developed in parallel to the REA, a policy review was undertaken to develop definitions for Themes as clearly as possible. This involved detailed discussions with the Welsh Government, a review of policy papers of related UAs, and a review of policy papers for the OTs and CTs.

An evidence review was conducted for each of the Themes to determine the scale of evidence already gathered by the Welsh Government through partnerships such as the Environment and Rural Affairs Monitoring and Modelling Programme (ERAMMP). ERAMMP is a partnership led by the UK Centre for Ecology and Hydrology that provides Welsh Government with business-critical evidence and expertise through 3 components: monitoring (the National Field Survey), modelling (the Integrated Modelling Platform), and the provision of evidence and expert advice. Since 2019, 105 reports have been published through ERAMMP covering a range of relevant topics such as soil carbon and ammonia.

Search Strategies

Building on the research question design and policy review, search strategies were developed for each Theme (these can be found in Annex A) which identified:

- Exclusion and inclusion criteria: filtering only studies focussed on a relevant topic
- Boundaries and thresholds for quality and relevance: only those studies which were peer reviewed were included at the initial search phase, systematic reviews and meta-analyses were prioritised, and studies were limited to those from Wales and temperate farming contexts comparable to Wales such as the UK, northern Europe, New Zealand, and parts of North America
- Keywords for searching: the keywords and secondary terms associated with each Theme which would be used to draw out relevant evidence.

Initial search strings were then developed using these criteria. There are 2 limitations to the chosen search strategy: replicability and a limited evidence base. Replicability is a limitation due to the breadth of on-farm practices within Themes. During scoping, search terms were repeatedly adjusted using the keywords outlined in the search strategies in Annex A to maximise relevant evidence, meaning no one search that will replicate the pool of evidence that was analysed, nor can the number of hits received for each Theme be presented.

The final evidence base for each REA was limited to ensure the project was achievable due to the large number of Themes and level of detail for each Theme. Searches were restricted to Scopus [footnote ¹⁰], a database that includes scholarly literature linked to a range of disciplines such as environmental science and social sciences. Scopus was selected due to its advanced search features which allowed for restricting searches to the most relevant results. While Scopus is the largest abstract and citation database of peer-reviewed literature, it is not exhaustive. Other databases such as Web of Science have access to literature not available to those using Scopus meaning that using only Scopus limits the available evidence for the REAs.

Websites were identified that would be used to search for grey literature such as evaluations and government reports to supplement the evidence (Annex B). The agreed approach included the option of using Google Scholar to access wider resources, and snowballing from the evidence base using citations where necessary.

Scoping

An initial search was conducted using the approved search string for each REA. If the search returned more than 500 results it was narrowed using filtering options such as limiting the search to Theme related keywords or limiting the geography to UK and Ireland to limit returns to between 250 and 500 results. Articles were then selected based on whether their titles met the inclusion criteria and for relevance. Each article selected at this stage was then further reviewed by reading the abstract. If at this stage an article was

¹⁰ [Scopus is an abstract and citation database of peer-reviewed literature including scientific journals, books, and conference proceedings. Scopus provides a comprehensive overview of worldwide research output in the fields of science, technology, medicine, social sciences, and arts and humanities.](#)

determined to meet the inclusion, quality, and relevance criteria it was logged in the evidence register.

Articles were scored on quality from 1 to 5 (1 being lowest quality 5 being highest quality) on the following criteria [footnote ¹¹]:

- 5: peer reviewed systematic review, meta-analysis, literature review
- 4: peer reviewed study with multiple sites, high threshold of participation, controls, or modelling
- 3: peer reviewed study on pilot project or low number of participants
- 2: non-peer reviewed review or study with multiple sites, high threshold of participants or control
- 1: non-peer reviewed study or pilot project or low number of participants.

Articles were scored on relevance from 1-4 (1 being least relevant 4 being most relevant) on the following criteria [footnote¹²]:

- 4: Wales
- 3: UK/Ireland
- 2: Other temperate farming region or UK/Ireland regarding less prevalent farming system such as horticulture
- 1: Other temperate farming region regarding less prevalent farming system such as horticulture.

Once an article was logged in the register it was reviewed based on the abstract against how relevant the article was for each research question. This analysis, alongside relevance and quality scoring allowed for the sampling of the evidence base to ensure each research question was addressed at the evidence review stage and that the most relevant and

¹¹ This is not a judgement of these articles but a common method of filtering studies to achieve a manageable database within a tight timescale.

¹² As above, this does not mean that these studies are not relevant to Wales and therefore not of value, they are just less relevant than others which were prioritised.

highest quality evidence was included in the review. There will be cases where evidence that scores less highly on quality will be included due to its relevance to Wales.

Evidence Review

Each article was reviewed against the research questions with relevant key findings extracted and inserted into the evidence register.

CSF Analysis

Each Theme was analysed against the strategic, economic, commercial and financial CSFs to determine their potential alignment with each. Potential alignment with a CSF was determined by reviewing the evidence present in each section against the corresponding CSF.

Evidence related to potential impacts of Themes was particularly relevant to the strategic fit and business needs CSF (strategic case) when assessing alignment with WG objectives and the delivery of measurable outcomes. Evidence related to barriers, cost-effectiveness, and uptake of the practice was relevant for considering stakeholder approval and whether farmers see the practices as economically feasible with SFS support.

Evidence related to potential impacts of Themes as they relate to sustainable farming practices and adaptation to and mitigation of the effects of climate change was used to assess alignment with the Value for money CSF (economic case). Barriers, uptake of the practice and costs research questions were also used to assess alignment.

Evidence related to barriers, design of the intervention and uptake of practice was used to assess alignment with Supply side capacity and capability (commercial case), and Affordability (financial case). Although evidence regarding the latter 2 cases was anticipated to be limited and related to only 2 of the Affordability criteria below:

- farmers' costs of participating in the SFS are minimised
- farmers are able to supplement SFS support by attracting additional funding from investors other than WG.

Assessments of potential Optional and Collaborative Theme (OT/CT) alignment with CSFs was necessarily subjective using the following framework:

- high – the majority of applicable evidence suggested that similar Themes fit the criteria of the CSFs
- medium – some of the applicable evidence suggested that similar Themes fit the criteria of the CSFs
- low – the applicable evidence suggested that similar Themes did not fit the criteria of the CSFs, or there was not enough evidence to assess potential alignment.

Reporting

Each Theme has a chapter in the report which includes:

- a definition of the OT or CT including relevant on-farm practices
- a description of the evidence base including;
 - the number of articles returned in a representative Scopus search
 - the number of articles selected for scoping analysis
 - the number of articles selected for evidence review
 - the characteristics of articles selected for evidence reviewing, including, their geographic scope, the practice concerned, and their origin, for example, Scopus, citation analysis, Google Scholar or third-party website.
- a summary of evidence as it relates to;
 - design of the intervention
 - uptake of a practice
 - environmental, social, and economic impact
 - barriers
 - gaps in the evidence base
 - cost-effectiveness
- a summary of evidence as it relates to the CSFs.

Transparency

To conduct this research with as much transparency as possible, the search strategies include each of the search terms that were used during the scoping process. However, in the review process, due to the scale of the project it would be impossible to provide an exactly replicable process which would be the clearest way to guarantee transparency and minimise bias. The research has been quality assured and bias minimised by processes of senior review and inter-coder reliability testing.

Limitations

A number of limitations have impacted the study, with key limitations having been:

- the timescale of the project, which required REAs to be conducted in as efficient a manner as possible
- the broad scope of a number of the Themes, which limited the depth to which the REAs could probe the literature
- the number of on-farm practices within a number of the Themes, limiting the extent to which individual practices could be explored in depth
- the REAs used a restricted evidence base using only one academic database
- the REAs were not exhaustive and did not identify all relevant evidence
- the REAs did not critically evaluate the strength of evidence behind each on-farm practice

Based on the limitations, the REAs were not conducted on every possible on-farm practice open to farmers participating in the SFS, nor did the REAs consider the different ways each of these practices may interact with particular farm types, landscapes, or habitats amongst other things. An REA of a narrow band of on-farm practices would be able to take these considerations into account, and while this research identified that many impacts may be site specific it was unable to address these specifics further, however, factors which may restrict the relevance of the evidence have been highlighted where possible. Therefore, this review is not systematic, comprehensive or

representative of a model; but it draws on the evidence base to identify findings which may support an understanding of the potential impacts of each Theme.

Enhanced Woodland Management

The objective of the Enhanced Woodland Management Theme is to support the active management of existing on-farm woodland to bring it into good economic and environmental condition. The on-farm practices available under this Theme include:

- production of a Woodland Management Plan
- woodland thinning
- coppicing and pollarding control of invasive species.

Due to overlaps in on-farm practices with other Themes additional evidence for this Theme can be found in:

- Woodland and Agroforestry Creation
- Enhanced Habitat Management
- Implementation of Designated Site Management Plans
- Hedgerow Creation or Restoration
- Advanced Continuous Professional Development (CPD)
- Improved Public Access to the Countryside
- Improved Water Quality, Water Usage and Flood Mitigation
- Collaborative Landscape Scale Activity

REA Exclusion / Inclusion Criteria

Inclusion: Studies on woodland management, woodland and tree conservation and agroforestry. Specific focus on agricultural land and management alongside crops and livestock. Studies on woodland management for small-scale timber production.

Exclusion: Studies on industrial forestry; timber production. Studies on solely theoretical aspects without a practical focus.

Evidence Base

Using Scopus 91 studies were identified as in scope of the evidence assessment. An additional 15 studies were sourced using Google Scholar and websites identified in Annex B. Using quality and relevance criteria 98 articles were analysed. Of these, 10 were based in Wales and 28 were based in the rest of the UK. The evidence base focussed particularly on woodland management practices (silviculture) and the benefits of retaining and managing trees and woodland on farms.

Design of the Intervention (69 studies)

4 studies [footnote¹³] highlighted the importance of bringing unmanaged woodland under active management, though others suggested that patches of minimally-managed woodland should be preserved to allow continued succession [footnote ¹⁴] and to protect those

¹³ Alder, D C and others. '[Implications of Transformation to Irregular Silviculture for Woodland Birds: A Stand Wise Comparison in an English Broadleaf Woodland](#)'. Forest Ecology and Management volume 422 (2018): pages 69 to 78.

Roellig, M and others. '[Post Hoc Assessment of Stand Structure Across European Wood-Pastures: Implications for Land Use Policy](#)'. Rangeland Ecology and Management volume 71, number 5 (2018): pages 526 to 535;

Brzeziecki, B and others. '[Structural and Compositional Dynamics of Strictly Protected Woodland Communities with Silvicultural Implications, Using Białowieża Forest as an Example](#)'. Annals of Forest Science volume 75, number 3 (2018): article 89.;

Müller, J and others. '[Effects of Forest Management on Bryophyte Species Richness in Central European Forests](#)'. Forest Ecology and Management volume 432 (2019): pages 850 to 859.

¹⁴ Götzmark, Frank. '[Habitat Management Alternatives for Conservation Forests in the Temperate Zone: Review, Synthesis, and Implications](#)'. Forest Ecology and Management volume 306 (15 October 2013): pages 292 to 307.

species favouring dense stand structures [footnote ¹⁵]. The retention of mature trees [footnote ¹⁶] and deadwood [footnote ¹⁷] was recommended, as well as preferentially preserving broadleaved trees for their pollination benefits [footnote ¹⁸]. Additionally, maintaining hedgerows and tree shelterbelts between woodland patches was recommended for habitat connectivity [footnote ¹⁹] and landscape heterogeneity [footnote ²⁰].

Multiple studies highlighted the importance of management to replicate the semi-open structure present in 'natural' woodlands [footnote ²¹] and to improve heterogeneity through 'irregular' silviculture [footnote ²²]. This consists of patchy group harvesting [footnote ²³]

¹⁵ Vymazalová, P and others. '[Positive Impact of Traditional Coppicing Restoration on Biodiversity of Ground-Dwelling Spiders in a Protected Lowland Forest](#)'. Forest Ecology and Management volume 490 (2021): article 119084.

¹⁶ Edo, M and others. '[Agroforestry Systems Favor Bat Conservation but Only When Old and Grazed](#)'. Global Ecology and Conservation volume 57 (2025): article e03369.

¹⁷ Müller, J and others. '[Effects of Forest Management on Bryophyte Species Richness in Central European Forests](#)';

Mölder, A and others. '[Integrative Management to Sustain Biodiversity and Ecological Continuity in Central European Temperate Oak \(Quercus Robur, Q. Petraea\) Forests: An Overview](#)'. Forest Ecology and Management volume 437 (2019): pages 324 to 339.

¹⁸ Alison, J and others. '[Woodland, Cropland and Hedgerows Promote Pollinator Abundance in Intensive Grassland Landscapes, with Saturating Benefits of Flower Cover](#)'. Journal of Applied Ecology volume 59, number 1 (2022): pages 342 to 354.

¹⁹ Maskell, L C and others. '[Exploring Relationships between Land Use Intensity, Habitat Heterogeneity and Biodiversity to Identify and Monitor Areas of High Nature Value Farming](#)'. Biological Conservation volume 231 (1 March 2019): pages 30 to 38.;

Moffat, Andy and others. '[Adaptation of Native Woodlands in Scotland. Issues Paper](#)'. Climate X Change, Forest Research, Scottish Natural Heritage, 2012.https://www.climatechange.org.uk/wp-content/uploads/2023/09/native_woodlands_adaptation_-_issues_paper.pdf

²⁰ Duflot, R and others. '[Adjacent Woodlands Rather than Habitat Connectivity Influence Grassland Plant, Carabid and Bird Assemblages in Farmland Landscapes](#)'. Biodiversity and Conservation volume 27, number 8 (2018): pages 1925 to 1942.

²¹ Alder, D C and others. '[Implications of Transformation to Irregular Silviculture for Woodland Birds: A Stand Wise Comparison in an English Broadleaf Woodland](#)';

Roellig, M and others. '[Post Hoc Assessment of Stand Structure Across European Wood-Pastures: Implications for Land Use Policy](#)'.

²² Alder, D C and others. '[Irregular Silviculture and Stand Structural Effects on the Plant Community in an Ancient Semi-Natural Woodland](#)'. Forest Ecology and Management volume 527 (2023): article 120622.;

Alder, D C and others. '[Irregular Silviculture Positively Influences Multiple Bat Species in a Lowland Temperate Broadleaf Woodland](#)'. Forest Ecology and Management volume 483 (2021): article 118786.

Cook, P and others. '[Seeing the Wood for the Trees, Irregular Silviculture Supports Bat Populations in Conifer Plantations](#)'. Forest Ecology and Management volume 544 (2023): article 121214.

²³ Alder, D C and others. '[Irregular Silviculture Positively Influences Multiple Bat Species in a Lowland Temperate Broadleaf Woodland](#)'

which increases vertical structure [footnote ²⁴] and natural regeneration [footnote ²⁵]. Controlling grazing pressure is important to maintain understorey habitats [footnote ²⁶] and encourage regeneration [footnote ²⁷].

Thinning

Woodland thinning is recommended to open the canopy and increase light availability to the understorey [footnote ²⁸], especially important for oak seedling regeneration [footnote ²⁹]. Variable density thinning is recommended [footnote ³⁰] to replicate natural stand structure [footnote ³¹] and a thinning intensity of no more than 50% is recommended to avoid invasive species colonisation [footnote ³²]. However, higher thinning densities may be preferred if targeting shrub-layer bird species [footnote ³³]. Thinning around old oaks should be moderated to avoid exposing the trees to drought stress [footnote ³⁴].

²⁴ Cook, P and others. '[Seeing the Wood for the Trees, Irregular Silviculture Supports Bat Populations in Conifer Plantations](#)'.

²⁵ Alder, D C and others. '[Irregular Silviculture and Stand Structural Effects on the Plant Community in an Ancient Semi-Natural Woodland](#)'

²⁶ Dadam, D, and G M Siriwardena. '[Agri-Environment Effects on Birds in Wales: Tir Gofal Benefited Woodland and Hedgerow Species](#)'. Agriculture, Ecosystems and Environment volume 284 (2019): article 106587.

²⁷ Roellig, M and others. '[Post Hoc Assessment of Stand Structure Across European Wood-Pastures: Implications for Land Use Policy](#)'.

²⁸ Bassett, T J and others. '[Effects of Experimental Prescribed Fire and Tree Thinning on Oak Savanna Understory Plant Communities and Ecosystem Structure](#)'. Forest Ecology and Management volume 464 (2020): article 118047.;

Carr, A and others. '[The Effects of Thinning Management on Bats and Their Insect Prey in Temperate Broadleaved Woodland](#)'. Forest Ecology and Management volume 457 (2020): article 117682.

²⁹ Pastick, J and others. '[Testing the Effect of Restoration-Focused Silviculture on Oak Regeneration and Groundlayer Plant Communities in Urban–Exurban Oak Woodlands](#)'. Restoration Ecology volume 29, number 1 (2021): article e13307.

³⁰ Phillips, D L and others. '[Spatial Patterns of Stand Structure and Canopy Disturbance in a Fire-Maintained Pinus Palustris Woodland](#)'. Applied Vegetation Science volume 25, number 2 (2022): article e12657.

³¹ English, C J, S E Younger, J B Cannon, S T Brantley, D Markewitz, and P Dwivedi. '[Forest Management for Water Yield: Assessing the Barriers and Impacts of Privately-Owned Open Pine Woodlands in the Southeastern United States](#)'. Trees, Forests and People volume 17 (2024): article 100600.

³² Bassett, T J and others. '[Effects of Experimental Prescribed Fire and Tree Thinning on Oak Savanna Understory Plant Communities and Ecosystem Structure](#)'.

³³ Bellamy, P E and others. '[Impact of Woodland Agri-Environment Management on Woodland Structure and Target Bird Species](#)'. Journal of Environmental Management volume 316 (2022): article 115221.

³⁴ Drobyshev, I and others. '[Thinning around Old Oaks in Spruce Production Forests: Current Practices Show No Positive Effect on Oak Growth Rates and Need Fine Tuning](#)'. Scandinavian Journal of Forest Research volume 34, number 2 (2019): pages 126 to 132.

Coppicing

Coppicing, the repeated harvesting of shoots sprouting from cut stumps, is another method recommended to open up woodlands [footnote ³⁵]. The coppice-with-standards method produces coppice stands of varying ages and successional stages [footnote ³⁶], supporting differently adapted species [footnote ³⁷]. Short rotation cycles of between 5 and 10 years are recommended [footnote ³⁸] to maintain light levels. Short-rotation coppice can be effective in improving the productivity of riparian corridors in both timber production [footnote ³⁹] and nutrient removal from agricultural runoff [footnote ⁴⁰].

Pollarding

Pollarding is recommended for older trees to protect against drought stress [footnote ⁴¹] and avoid collapse [footnote ⁴²]. Uneven-aged management is recommended to improve structural diversity [footnote ⁴³], and managers are recommended to choose trees with lots

³⁵ Weiss, M and others. [‘The Effect of Coppicing on Insect Biodiversity. Small-Scale Mosaics of Successional Stages Drive Community Turnover’](#). Forest Ecology and Management volume 483 (2021): article 118774.

³⁶ Martini, M and others. [‘A Case Study on the Impact of Coppicing on Small Mammal Diversity: First Evidence from the High Agri Valley in the Basilicata Region, Italy’](#). Journal for Nature Conservation volume 82 (2024): article 126732.

³⁷ Buckley, P. [‘Coppice Restoration and Conservation: A European Perspective’](#). Journal of Forest Research volume 25, number 3 (2020): pages 125 to 133.

³⁸ Hamřík, T, O Košulič, R Gallé, N Gallé-Szpisjak, and R Hédli. [‘Opening the Canopy to Restore Spider Biodiversity in Protected Oakwoods’](#). Forest Ecology and Management volume 541 (2023): article 121064.

³⁹ Adams, R, and C Johnston. [‘Evaluating the Impacts of SRC Willows on Phosphorus Export from a Temperate Grassland Micro-Catchment’](#). Nature-Based Solutions volume 5 (2024): article 100118.

⁴⁰ Herron, J, T P Curran, A P Moloney, M McGee, E G O’Riordan, and D O’Brien. [‘Life Cycle Assessment of Pasture-Based Suckler Steer Weanling-to-Beef Production Systems: Effect of Breed and Slaughter Age’](#). Animal volume 15, number 7 (July 2021): article 100247.

⁴¹ Colangelo, M, C Valeriano, E G de Andrés, M Pizarro, E Murria, and J Julio Camarero. [‘Lack of Management, Land-Use Changes, Poor Site Conditions and Drought Contribute to the Decline of Old Pollarded Oaks’](#). Dendrochronologia volume 86 (2024): article 126232.

Camarero, J J, C Valeriano, J A Sánchez-Sancho, and C de Jaime Loren. [‘Pollarding May Relieve Drought Stress in Black Poplars’](#). Forests volume 15, number 11 (2024): article 1869.;

Camarero, J J, C Valeriano, and A Rubio-Cuadrado. [‘Old Oaks Show Increasing Growth Synchrony after Pollarding Cessation as Climate Becomes More Arid’](#). Forest Ecology and Management volume 569 (2024): article 122189.

⁴² Colangelo et al., [‘Lack of Management, Land-Use Changes, Poor Site Conditions and Drought Contribute to the Decline of Old Pollarded Oaks’](#); V. Bengtsson et al., [‘Responses of Oak Pollards to Pruning’](#), Arboricultural Journal 43, no. 3 (2021): 156–70,

⁴³ Astigarraga et al., [‘Forest Structural Diversity Modulates Tree Growth Synchrony in Response to Climate Change’](#), Forest Ecology and Management 579 (2025),.

of branches as an indicator of vitality and likely success [footnote ⁴⁴]. Managers should leave long stubs and some branches uncut, while concentrating on cutting branches under 30cm in diameter [footnote ⁴⁵].

Replanting

3 studies made recommendations on replanting, also known as restocking, methods for harvested woodlands. Selective harvesting to create small gaps/patches aids natural regeneration [footnote ⁴⁶]. A minimum clearing width of 40 metres is recommended [footnote ⁴⁷]. Site preparation is recommended to aid natural regeneration. Soil scarification, a method of disturbing the soil to break up compacted layers, of between 10 to 20% surface area is recommended [footnote ⁴⁸].

Invasive species control

Several studies mentioned the importance of controlling invasive mammal species for woodland integrity. Fencing to protect woodlands is widely used in Scotland [footnote ⁴⁹] but may be less effective than culling, which should be targeted at the landscape level. An adaptive management framework is recommended with deer browsing impact monitored and culling intensity targeted in response [footnote ⁵⁰]. Grey squirrels are best controlled using live trapping with a density of 0.25 traps per hectare [footnote ⁵¹]. Trapping American

⁴⁴ H. Read et al., '[Restoration of Lapsed Beech Pollards in the Basque Region of Spain: Comparison of Different Cutting Techniques](#)', *Arboricultural Journal* 43, no. 3 (2021): 140–55,

⁴⁵ Read et al.

⁴⁶ Sauli Valkonen and Juha Siitonen, '[Tree Regeneration in Patch Cutting in Norway Spruce Stands in Northern Finland](#)', *Scandinavian Journal of Forest Research*, 2 April 2016,;

H. Hökkä et al., '[Seedling Establishment on Small Cutting Areas with or without Site Preparation in A Drained Spruce Mire - a Case Study in Northern Finland](#)', *Silva Fennica* 46, no. 5 (2012): 695–705,.

⁴⁷ Janne Miettinen et al., '[Natural Regeneration and Early Development of Scots Pine Seedlings after Gap Cutting in Northern Finland](#)', *Scandinavian Journal of Forest Research* 39, no. 2 (17 February 2024): 89–100, <https://doi.org/10.1080/02827581.2024.2303022>.

⁴⁸ Miettinen et al.

⁴⁹ N. Fattorini et al., '[The Scale-Dependent Effectiveness of Wildlife Management: A Case Study on British Deer](#)', *Journal of Environmental Management* 276 (2020)

⁵⁰ P.R. Gullett et al., '[Woodland Expansion in the Presence of Deer: 30 Years of Evidence from the Cairngorms Connect Landscape Restoration Partnership](#)', *Journal of Applied Ecology* 60, no. 11 (2023)

⁵¹ S. Croft et al., '[A Spatially Explicit Population Model to Compare Management Using Culling and Fertility Control to Reduce Numbers of Grey Squirrels](#)', *Ecological Modelling* 440 (2021),

mink is recommended along watercourses using live raft trapping [footnote ⁵²], with traps being regularly moved to target new areas [footnote ⁵³].

Uptake of the Practice (19 studies)

A review of woodland management in Wales suggests that, as of 2020, 47% of woodlands in Wales (approximately 146,000 hectares) are managed according to the UK Forestry Standard; however, it is possible that woodlands on private lands are managed but not certified [footnote ⁵⁴]. Another study suggested the proportion of managed woodland in Wales is 57% [footnote ⁵⁵]. This implies that approximately 40% of woodlands in Wales remain unmanaged [footnote ⁵⁶], following a trend of reduced woodland management over the past century due to changes in local economies and markets for timber [footnote ⁵⁷]. Current woodland management practice in Wales is dominated by stock exclusion and Rhododendron control [footnote ⁵⁸].

15 studies identified factors influencing the uptake of woodland management practices by farmers. The most relevant factor was economic, with woodland management and crop production competing for space and labour [footnote ⁵⁹]. Studies of European and Canadian

⁵² Reynolds, J C, S M Richardson, B J E Rodgers, and O R K Rodgers. '[Effective Control of Non-Native American Mink by Strategic Trapping in a River Catchment in Mainland Britain](#)'. Journal of Wildlife Management 77, number 3 (2013): pages 545 to 554.;

Martin, A R, and V J Lea. '[A Mink-Free GB: Perspectives on Eradicating American Mink Neovison Vison from Great Britain and Its Islands](#)'. Mammal Review 50, number 2 (2020): pages 170 to 179.

⁵³ López, R, B K Clapperton, and G Medina-Vogel. '[A Global Review of the American Mink \(Neovison Vison\) Removal Techniques – Patagonia as a Case Study for Their Potential Application](#)'. Gayana 87, number 1 (2023): pages 43 to 62;

Medina-Vogel, G, F Muñoz, M Moeggenberg, C Calvo-Mac, M Barros-Lama, N Ulloa, D J Pons, and B K Clapperton. '[Improving Trapping Efficiency for Control of American Mink \(Neovison Vison\) in Patagonia](#)'. Animals 12, number 2 (2022)..

⁵⁴ Kerr, G. (2020). [ERAMMP Report-34: National Forest Evidence Annex-2](#). Report to Welsh Government (Contract C210/2016/2017)(UKCEH 06297)

⁵⁵ Royal Forestry Society (2019) [Bringing woodland into management. The missed opportunity in England and Wales](#). January 2019. Royal Forestry Society

⁵⁶ Kerr, G. (2020). [ERAMMP Report-34: National Forest Evidence Annex-2](#). Report to Welsh Government (Contract C210/2016/2017)(UKCEH 06297)

⁵⁷ Royal Forestry Society (2019) [Bringing woodland into management. The missed opportunity in England and Wales](#). January 2019. Royal Forestry Society

⁵⁸ Emmett, B.A. & the ERAMMP team, '[ERAMMP Report-105: Wales National Trends and Glastir Evaluation](#)'. Report to Welsh Government ((UKCEH 08435), 2025),

⁵⁹ Jouf, C, and L A Lawson. '[European Farmers' Responses to Higher Commodity Prices: Cropland Expansion or Forestlands Preservation?](#)' Ecological Economics volume 191 (2022): article 107243.,

farmers found that they are reluctant to maintain or manage woodland if it risks encroaching on agricultural production [footnote ⁶⁰]. However, a Tasmanian study suggested that, when the ecosystem benefits of woodland management are communicated to farmers, uptake is more likely [footnote ⁶¹]. The tension between private and public interests can affect farmer buy-in for certain practices. For example, in Scotland farmers are encouraged to keep high numbers of deer on their land for recreational shooting, whereas the public interest supports deer culling for woodland protection [footnote ⁶²].

Payment Schemes which reward farmers for maintaining on-farm woodland are recommended to improve uptake [footnote ⁶³]. Additionally, knowledge and skill levels are important; farmers are not always aware of the benefits of on-farm woodland for productivity and ecosystem services [footnote ⁶⁴] or the skills needed to effectively manage their existing

Elalamy, Y, L Doyen, and L Mouysset. '[Contribution of the Land Use Allocation Model for Agroecosystems: The Case of Torrecchia Vecchia](#)'. Journal of Environmental Management volume 252 (2019): article 109607., de Zwaan et al., '[Balancing Conservation Priorities for Grassland and Forest Specialist Bird Communities in Agriculturally Dominated Landscapes](#)', Biological Conservation 265 (2022)

B. Keenleyside et al., '[Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience](#). Sustainable Farming Scheme. Evidence Review.', Publication - Report (Bangor: NERC/Centre for Ecology & Hydrology, 8 July 2019),

⁶⁰ Jouf, C, and L A Lawson. '[European Farmers' Responses to Higher Commodity Prices: Cropland Expansion or Forestlands Preservation?](#)' Ecological Economics volume 191 (2022);

de Zwaan et al., '[Balancing Conservation Priorities for Grassland and Forest Specialist Bird Communities in Agriculturally Dominated Landscapes](#)'.

⁶¹ Baker et al., '[The Role of Open Woodland in Mitigating Microclimatic Extremes in Agricultural Landscapes](#)', Ecological Management and Restoration 22, no. S2 (2021): 118–26;

Elalamy, Y, L Doyen, and L Mouysset. '[Contribution of the Land Use Allocation Model for Agroecosystems: The Case of Torrecchia Vecchia](#)';

de Zwaan et al., '[Balancing Conservation Priorities for Grassland and Forest Specialist Bird Communities in Agriculturally Dominated Landscapes](#)'.

⁶² Hare, D., Daniels, M. and Blossey, B. '[Public Perceptions of Deer Management in Scotland](#)', Frontiers in Conservation Science 2 (2021);

Kirkland et al., '[Successful Deer Management in Scotland Requires Less Conflict Not More](#)', Frontiers in Conservation Science 2 (2021),

⁶³ Jouf and Lawson, '[European Farmers' Responses to Higher Commodity Prices: Cropland Expansion or Forestlands Preservation?](#)';

B. Nordén et al., '[The Economy of Selective Cutting in Recent Mixed Stands during Restoration of Temperate Deciduous Forest](#)', Scandinavian Journal of Forest Research 34, no. 8 (2019): 709–17;

Wood, J.M., Tegeler, A.K. and Ross, B.E '[Vegetation Management on Private Forestland Can Increase Avian Species Richness and Abundance](#)', Condor 122, no. 4 (2020).

⁶⁴ Keenleyside et al., '[Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience](#)'.

woodland [footnote ⁶⁵]. Capacity building and knowledge transfer are required to build farmer confidence in woodland management practices [footnote ⁶⁶].

Additionally, markets for woodland-based products are important drivers of uptake; forestry products can provide uncertain returns at market [footnote ⁶⁷] which, along with high establishment costs [footnote ⁶⁸], can put off farmers.

Economic Impacts (27 studies)

The economic impacts of woodland management identified include;

- increased yield due to: increased pollination services as woodland and tree patches provide habitats for pollinating species [footnote ⁶⁹], and improved soil fertility through nitrogen fixation and leaf litter decomposition [footnote ⁷⁰]. These impacts could potentially mitigate concerns about short-term yield impacts of losing productive agricultural land to woodland

⁶⁵ Keenleyside and Old, '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 9: Flood Mitigation. Sustainable Farming Scheme Evidence Review](#)', Publication - Report (Bangor: NERC/Centre for Ecology & Hydrology, 7 July 2019),

⁶⁶ Stadig, L M, et al. '[Opportunities for Short Rotation Coppice Production on Free-Range Chicken Farms in Flanders: Farmers' Perceptions and Cost-Benefit Analysis](#)'. Renewable Agriculture and Food Systems volume 35, number 3 (2020): pages 286 to 295 52–63

⁶⁷ Euan. A. D. Bowditch, Rob McMorran, and Melanie. A. Smith, '[Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty](#)', Land Use Policy 124 (1 January 2023): 106437,

⁶⁸ Stadig, L M, et al. '[Opportunities for Short Rotation Coppice Production on Free-Range Chicken Farms in Flanders: Farmers' Perceptions and Cost-Benefit Analysis](#)'.

⁶⁹ Orczewska, Anna, Aleksander Dulik, Patryk Długosz, and Łukasz Depa. '[Intensive Agriculture vs. Invertebrate Biodiversity: A Case Study of Woodland Islets in a Matrix of Arable Land](#)'. Agriculture volume 14, number 8 (August 2024): article 1400;

Tammaru, T, D Valdma, A Tiitsaar, A Kaasik, E Õunap, J Remm, and T Teder. '[Landscape-Level Determinants of Butterfly Species Richness in Northern Europe: A Country-Wide Survey Reveals the Paramount Importance of Forest Land](#)'. Biological Conservation volume 286 (2023): article 110294.;

'de Zwaan et al., '[Balancing Conservation Priorities for Grassland and Forest Specialist Bird Communities in Agriculturally Dominated Landscapes](#)'.

⁷⁰ Keenleyside et al., '[Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience](#)'. Rubio-Delgado et al., '[Small Woody Features in Agricultural Areas: Agroforestry Systems of Overlooked Significance in Europe](#)'.

- woodlands act as reservoirs for pest predators, increasing the potential for control of common agricultural pests [footnote ⁷¹]
- woodland shelterbelts protect crops and livestock through microclimatic regulation, leading to improved growth and productivity [footnote ⁷²]
- there is a potential for Payments for Ecosystem Services (PES) through implementing woodland management regimes which deliver ecosystem benefits [footnote ⁷³]

⁷¹ Edo et al., '[Agroforestry Systems Favor Bat Conservation but Only When Old and Grazed](#)'; Orczewska et al., '[Intensive Agriculture vs. Invertebrate Biodiversity: A Case Study of Woodland Islets in a Matrix of Arable Land](#)'; Rubio-Delgado et al., '[Small Woody Features in Agricultural Areas: Agroforestry Systems of Overlooked Significance in Europe](#)'.

de Zwaan et al., '[Balancing Conservation Priorities for Grassland and Forest Specialist Bird Communities in Agriculturally Dominated Landscapes](#)'.

⁷² Stadig et al., '[Opportunities for Short Rotation Coppice Production on Free-Range Chicken Farms in Flanders: Farmers' Perceptions and Cost-Benefit Analysis](#)';

Baker et al., '[The Role of Open Woodland in Mitigating Microclimatic Extremes in Agricultural Landscapes](#)';

de Zwaan et al., '[Balancing Conservation Priorities for Grassland and Forest Specialist Bird Communities in Agriculturally Dominated Landscapes](#)';

Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)', Publication - Report (Bangor: UK Centre for Ecology & Hydrology, 28 August 2020);

Rubio-Delgado et al., '[Small Woody Features in Agricultural Areas: Agroforestry Systems of Overlooked Significance in Europe](#)'.

⁷³ Livingstone, D, B M Smyth, E Sherry, S T Murray, A M Foley, G A Lyons, and C R Johnston. '[Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications](#)', Sustainable Production and Consumption 36 (2023): 281–91;

Ranacher, Lea, Barbora Pollakova, Peter Schwarzbauer, Sandra Liebal, Norbert Weber, and Franziska Hesser. '[Farmers' Willingness to Adopt Short Rotation Plantations on Marginal Lands: Qualitative Study About Incentives and Barriers in Slovakia](#)'.

- income diversification through sale of woodland or coppice products including timber [footnote ⁷⁴], fruit crops [footnote ⁷⁵] and sale of ‘woodland livestock’ - livestock reared in woodland settings – products [footnote ⁷⁶]. A review of woodland management in Wales suggests that 53Kha of unmanaged woodland in Wales could feasibly be brought back into management, with 16Kha of this being on-farm woodland, potentially bringing over £1 million into the Welsh economy through timber production [footnote ⁷⁷].

The evidence reviewed also highlighted a range of costs associated with implementing woodland management actions on farms. These include increased management and labour

⁷⁴ Livingstone, D, B M Smyth, G Lyons, A M Foley, S T Murray, and C Johnston. ‘[Life Cycle Assessment of a Short-Rotation Coppice Willow Riparian Buffer Strip for Farm Nutrient Mitigation and Renewable Energy Production](#)’. Renewable and Sustainable Energy Reviews volume 158 (2022): article 112154.; Bowditch, Euan A D, Rob McMorran, and Melanie A Smith. ‘[Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty](#)’; Dufour, L, M Gosme, J Le Bec, and C Dupraz. ‘[Does Pollarding Trees Improve the Crop Yield in a Mature Alley-Cropping Agroforestry System?](#)’ Journal of Agronomy and Crop Science volume 206, number 5 (2020): pages 640 to 649; Keenleyside et al., ‘[Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience](#).’; Palik, B J, and D N Kastendick. ‘[Restoration of Woody Plant Communities in Red Pine Plantations on Abandoned Agricultural Land in Northern Minnesota, USA](#)’, Forest Ecology and Management 541 (2023); Kamp, J. ‘[Coppice Loss and Persistence in Germany](#)’, Trees, Forests and People 8 (2022); Geoghegan, C, and C O’Donoghue. ‘[A Spatial Analysis of the Economic Returns to Land-Use Change from Agriculture to Renewable Energy Production: Evidence from Ireland](#)’. GCB Bioenergy volume 16, number 9 (2024); Livingstone, D, B M Smyth, E Sherry, S T Murray, A M Foley, G A Lyons, and C R Johnston. ‘[Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications](#)’; Ranacher, Lea, Barbora Pollakova, Peter Schwarzbauer, Sandra Liebal, Norbert Weber, and Franziska Hesser. ‘[Farmers’ Willingness to Adopt Short Rotation Plantations on Marginal Lands: Qualitative Study About Incentives and Barriers in Slovakia](#)’.

⁷⁵ Keenleyside et al., ‘[Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience](#).’; Liqueste, Garcia Maria Del Camino, Sona Prakash, Anna Addamo, Michael Assouline, CANO Jose Ignacio Barredo, Simona Bosco, JESUS CARDOSO Ana De, and others. ‘[Scientific Evidence Showing the Impacts of Nature Restoration Actions on Food Productivity](#)’. Joint Research Centre (European Commission), 2022.,

⁷⁶ Stadig, L M, et al. ‘[Opportunities for Short Rotation Coppice Production on Free-Range Chicken Farms in Flanders: Farmers’ Perceptions and Cost-Benefit Analysis](#)’.

⁷⁷ Royal Forestry Society (2019) [Bringing woodland into management. The missed opportunity in England and Wales](#). January 2019. Royal Forestry Society

costs of agroforestry systems [footnote ⁷⁸] and invasive species control [footnote ⁷⁹]. However, the costs associated with invasive species control may be balanced by the mitigation of damage and crop losses [footnote ⁸⁰].

Environmental Impacts (78 studies)

On-farm woodland has been found to increase the structural diversity and heterogeneity of the overall farmland system [footnote ⁸¹], while evidence has shown that management of woodland, through actions like thinning, coppicing and agroforestry, can produce structurally complex, multifunctional ecosystems [footnote ⁸²]. These ecosystems often provide habitats

⁷⁸ Beauchamp, K, L O'Brien, C Hall, R Swetnam, T A R Jenkins, K J Doick, T R Nisbet, and others. [‘Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services’](#). Publication - Report. Bangor: UK Centre for Ecology & Hydrology, 28 August 2020.

⁷⁹ López, R, B K Clapperton, and G Medina-Vogel. [‘A Global Review of the American Mink \(Neovison Vison\) Removal Techniques – Patagonia as a Case Study for Their Potential Application’](#). Gayana volume 87, number 1 (2023): pages 43 to 62;

Croft, S, J N Aegerter, S Beatham, J Coats, and G Massei. [‘A Spatially Explicit Population Model to Compare Management Using Culling and Fertility Control to Reduce Numbers of Grey Squirrels’](#).

⁸⁰ Cooke, A S. [‘Colonisation, Impacts in Conservation Woodland and Management of Reeves’ Muntjac \(Muntiacus Reevesi\) in an English County’](#). European Journal of Wildlife Research volume 67, number 3 (2021): article 35.

⁸¹ Rubio-Delgado et al., [‘Small Woody Features in Agricultural Areas: Agroforestry Systems of Overlooked Significance in Europe’](#).

⁸² Götmark, Frank. [‘Habitat Management Alternatives for Conservation Forests in the Temperate Zone: Review, Synthesis, and Implications’](#);

Alder, D C and others. [‘Implications of Transformation to Irregular Silviculture for Woodland Birds: A Stand Wise Comparison in an English Broadleaf Woodland’](#);

Brzeziecki, B, K Bielak, L Bolibok, S Drozdowski, J Zajączkowski, and H Żybura. [‘Structural and Compositional Dynamics of Strictly Protected Woodland Communities with Silvicultural Implications, Using Białowieża Forest as an Example’](#);

Alder, D C, A Poore, J Norrey, S E Newson, and S J Marsden. [‘Irregular Silviculture Positively Influences Multiple Bat Species in a Lowland Temperate Broadleaf Woodland’](#);

Vymazalová, P, O Košulič, T Hamřík, J Šipoš, and R Hédli. [‘Positive Impact of Traditional Coppicing Restoration on Biodiversity of Ground-Dwelling Spiders in a Protected Lowland Forest’](#);

Košulič, O, J Procházka, I H Tuf, and R Michalko. [‘Intensive Site Preparation for Reforestation Wastes Multi-Trophic Biodiversity Potential in Commercial Oak Woodlands’](#). Journal of Environmental Management volume 300 (2021);

Cook, P, L Hordley, D Alder, K Powell, and D Pengelly. [‘Moths Respond to Key Habitat Structures in Conifer Plantations Managed as Irregular High Forest’](#). Forest Ecology and Management volume 569 (2024);

Carr, A, A Weatherall, and G Jones. [‘The Effects of Thinning Management on Bats and Their Insect Prey in Temperate Broadleaved Woodland’](#).

for invertebrates [footnote ⁸³], birds [footnote ⁸⁴], mammals [footnote ⁸⁵], bats [footnote ⁸⁶], bryophytes and lichen [footnote ⁸⁷], and fungi [footnote ⁸⁸], contributing to improved biodiversity [footnote ⁸⁹].

-
- ⁸³ Tammaru, T, D Valdma, A Tiitsaar, A Kaasik, E Õunap, J Remm, and T Teder. '[Landscape-Level Determinants of Butterfly Species Richness in Northern Europe: A Country-Wide Survey Reveals the Paramount Importance of Forest Land](#)'; Mölder, A, P Meyer, and R V Nagel. '[Integrative Management to Sustain Biodiversity and Ecological Continuity in Central European Temperate Oak \(Quercus Robur, Q. Petraea\) Forests: An Overview](#)'; Sturtevant, B R, and B B Hanberry. '[Processes Underlying Restoration of Temperate Savanna and Woodland Ecosystems: Emerging Themes and Challenges](#)'. Forest Ecology and Management volume 481 (2021); Weiss, M, P Kozel, M Zapletal, D Hauck, J Prochazka, J Benes, L Cizek, and P Sebek. '[The Effect of Coppicing on Insect Biodiversity. Small-Scale Mosaics of Successional Stages Drive Community Turnover](#)'; Kamp, J. '[Coppice Loss and Persistence in Germany](#)'; Alison, J, M Botham, L C Maskell, A Garbutt, F M Seaton, J Skates, S M Smart, and others. '[Woodland, Cropland and Hedgerows Promote Pollinator Abundance in Intensive Grassland Landscapes, with Saturating Benefits of Flower Cover](#)'; Liqueste, Garcia Maria Del Camino, Sona Prakash, Anna Addamo, Michael Assouline, CANO Jose Ignacio Barredo, Simona Bosco, Jesus Cardoso Ana De, and others. '[Scientific Evidence Showing the Impacts of Nature Restoration Actions on Food Productivity](#)'; Orczewska, Anna, Aleksander Dulik, Patryk Długosz, and Łukasz Depa. '[Intensive Agriculture vs. Invertebrate Biodiversity: A Case Study of Woodland Islets in a Matrix of Arable Land](#)'; Graser et al., '[Habitat Quality, Not Patch Isolation, Drives Distribution and Abundance of Two Light-Demanding Butterflies in Fragmented Coppice Landscapes](#)', Journal of Insect Conservation 27, no. 5 (2023): 743–58,; Hamřík et al., '[Opening the Canopy to Restore Spider Biodiversity in Protected Oakwoods](#)'; S. Breland et al., '[Restoration Increases Bee Abundance and Richness but Not Pollination in Remnant and Post-Agricultural Woodlands](#)', Ecosphere 9, no. 9 (2018).
- ⁸⁴ Manon Edo, Martin H. Entling, and Verena Rösch, '[Agroforestry Supports High Bird Diversity in European Farmland](#)', Agronomy for Sustainable Development 44, no. 1 (20 December 2023): 1; Alder, D C and others. '[Implications of Transformation to Irregular Silviculture for Woodland Birds: A Stand Wise Comparison in an English Broadleaf Woodland](#)'; Camarero, J J, C Valeriano, J A Sánchez-Sancho, and C de Jaime Loren. '[Pollarding May Relieve Drought Stress in Black Poplars](#)'; Keenleyside et al., '[Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience](#)'; de Zwaan et al., '[Balancing Conservation Priorities for Grassland and Forest Specialist Bird Communities in Agriculturally Dominated Landscapes](#)'; Dadam, D, and G M Siriwardena. '[Agri-Environment Effects on Birds in Wales: Tir Gofal Benefited Woodland and Hedgerow Species](#)'; Kamp, J. '[Coppice Loss and Persistence in Germany](#)'; Klaus, N A, S S Rush, S L Weitzel, and M C Holdrege. '[Changes in Tree Canopy, Groundcover, and Avian Community Following Restoration of a Montane Longleaf Pine Woodland](#)'; Bellamy, P E, E C Charman, N Riddle, W B Kirby, A C Broome, G M Siriwardena, P V Grice, W J Peach, and R D Gregory. '[Impact of Woodland Agri-Environment Management on Woodland Structure and Target Bird Species](#)'.
⁸⁵ Roellig, M and others. '[Post Hoc Assessment of Stand Structure Across European Wood-Pastures: Implications for Land Use Policy](#)'; Sturtevant, B R, and B B Hanberry. '[Processes Underlying Restoration of Temperate Savanna and Woodland](#)

Ecosystems: Emerging Themes and Challenges’;

Martini, M and others. ‘[A Case Study on the Impact of Coppicing on Small Mammal Diversity: First Evidence from the High Agri Valley in the Basilicata Region, Italy](#)’;

Buckley, P. ‘[Coppice Restoration and Conservation: A European Perspective](#)’.

⁸⁶ Cook, P and others. ‘[Seeing the Wood for the Trees, Irregular Silviculture Supports Bat Populations in Conifer Plantations](#)’;

Carr, A, A Weatherall, and G Jones. ‘[The Effects of Thinning Management on Bats and Their Insect Prey in Temperate Broadleaved Woodland](#)’.

⁸⁷ Camarero, J J, C Valeriano, J A Sánchez-Sancho, and C de Jaime Loren. ‘[Pollarding May Relieve Drought Stress in Black Poplars](#)’;

Camarero, J J, C Valeriano, and A Rubio-Cuadrado. ‘[Old Oaks Show Increasing Growth Synchrony after Pollarding Cessation as Climate Becomes More Arid](#)’.

⁸⁸ Bengtsson et al., ‘[Responses of Oak Pollards to Pruning](#)’.

⁸⁹ Zitzmann and Rode, ‘[Short-Rotation Coppice Managed According to Ecological Guidelines—What Are the Benefits for Phytodiversity?](#)’, *Forests* 12;

Rubio-Delgado et al., ‘[Small Woody Features in Agricultural Areas: Agroforestry Systems of Overlooked Significance in Europe](#)’;

Duflot et al., ‘[Adjacent Woodlands Rather than Habitat Connectivity Influence Grassland Plant, Carabid and Bird Assemblages in Farmland Landscapes](#)’;

Šálek, M., K. Kalinová, and J. Reif, ‘[Conservation Potential of Semi-Natural Habitats for Birds in Intensively-Used Agricultural Landscapes](#)’, *Journal for Nature Conservation* 66 (2022);

Beauchamp et al., ‘[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)’, 28 August 2020;

Mölder, Meyer, and Nagel, ‘[Integrative Management to Sustain Biodiversity and Ecological Continuity in Central European Temperate Oak \(Quercus Robur, Q. Petraea\) Forests: An Overview](#)’ (Quercus Robur, Q. Petraea) Forests’;

Alder, D C and others. ‘[Irregular Silviculture Positively Influences Multiple Bat Species in a Lowland Temperate Broadleaf Woodland](#)’;

Vymazalová et al., ‘[Positive Impact of Traditional Coppicing Restoration on Biodiversity of Ground-Dwelling Spiders in a Protected Lowland Forest](#)’;

Martini et al., ‘[A Case Study on the Impact of Coppicing on Small Mammal Diversity: First Evidence from the High Agri Valley in the Basilicata Region, Italy](#)’;

Kozdasová et al., ‘[Coppice Reintroduction in the Czech Republic: Extent, Motivation and Obstacles](#)’, *European Journal of Forest Research* 143, no. 1 (1 February 2024): 305–17;

Buckley, P. ‘[Coppice Restoration and Conservation: A European Perspective](#)’;

Livingstone et al., ‘[Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications](#)’;

Livingstone et al., ‘[Life Cycle Assessment of a Short-Rotation Coppice Willow Riparian Buffer Strip for Farm Nutrient Mitigation and Renewable Energy Production](#)’;

Ranacher et al., ‘[Farmers’ Willingness to Adopt Short Rotation Plantations on Marginal Lands: Qualitative Study About Incentives and Barriers in Slovakia](#)’;

Camarero, J J, C Valeriano, J A Sánchez-Sancho, and C de Jaime Loren. ‘[Pollarding May Relieve Drought Stress in Black Poplars](#)’;

Colangelo et al., ‘[Lack of Management, Land-Use Changes, Poor Site Conditions and Drought Contribute to the Decline of Old Pollarded Oaks](#)’;

Astigarraga et al., ‘[Forest Structural Diversity Modulates Tree Growth Synchrony in Response to Climate Change](#)’;

Bassett, Landis, and Brudvig, ‘[Effects of Experimental Prescribed Fire and Tree Thinning on Oak Savanna Understory Plant Communities and Ecosystem Structure](#)’;

Woodland patches and tree corridors can improve the connectivity of farm landscapes and provide ecological corridors for species to move between habitats [footnote ⁹⁰].

Some species, such as Curlew, with preference for open/farmland habitats may be negatively impacted by woodland management or expansion [footnote ⁹¹], while those preferring dense, closed forest stands, such as some invertebrates, may be impacted by management methods to open up woodlands [footnote ⁹²].

In addition to biodiversity, on-farm woodland can deliver a number of ecosystem services which have public benefit [footnote ⁹³] including:

- woodlands, tree rows and riparian buffers have been shown to improve water retention in agricultural soils [footnote ⁹⁴] and contribute to flood alleviation by storing excess water, slowing the flow of surface water and reducing peak flows [footnote ⁹⁵]

Harrington, T.B. '[Long-Term Effects of Thinning and Woody Control on Longleaf Pine Plantation Development, Understory Abundance, and Tree Damage from an Ice Storm](#)', *Forest Ecology and Management* 459 (2020); Carr, A, A Weatherall, and G Jones. '[The Effects of Thinning Management on Bats and Their Insect Prey in Temperate Broadleaved Woodland](#)'.

⁹⁰ Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)', 28 August 2020;

Rubio-Delgado et al., '[Small Woody Features in Agricultural Areas: Agroforestry Systems of Overlooked Significance in Europe](#)'.

Maskell et al., '[Exploring Relationships between Land Use Intensity, Habitat Heterogeneity and Biodiversity to Identify and Monitor Areas of High Nature Value Farming](#)'.

Alder, D C and others. '[Implications of Transformation to Irregular Silviculture for Woodland Birds: A Stand Wise Comparison in an English Broadleaf Woodland](#)'.

⁹¹ Vymazalová et al., '[Positive Impact of Traditional Coppicing Restoration on Biodiversity of Ground-Dwelling Spiders in a Protected Lowland Forest](#)'.

Duflot et al., '[Adjacent Woodlands Rather than Habitat Connectivity Influence Grassland Plant, Carabid and Bird Assemblages in Farmland Landscapes](#)'.

Šálek, Kalinová, and Reif, '[Conservation Potential of Semi-Natural Habitats for Birds in Intensively-Used Agricultural Landscapes](#)'.

⁹² Hamřík et al., '[Opening the Canopy to Restore Spider Biodiversity in Protected Oakwoods](#)'.

⁹³ A. Hardaker, T. Pagella, and M. Rayment, '[Integrated Assessment, Valuation and Mapping of Ecosystem Services and Dis-Services from Upland Land Use in Wales](#)', *Ecosystem Services* 43 (2020);

Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)', 28 August 2020.

⁹⁴ '[Agroforestry Systems Favor Bat Conservation but Only When Old and Grazed](#)'.

Liquete et al., '[Scientific Evidence Showing the Impacts of Nature Restoration Actions on Food Productivity](#)'.

English et al., '[Forest Management for Water Yield: Assessing the Barriers and Impacts of Privately-Owned Open Pine Woodlands in the Southeastern United States](#)'.

⁹⁵ Keenleyside and Old, '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 9: Flood Mitigation. Sustainable Farming Scheme Evidence Review](#)'.

- the inclusion of trees and woodland patches on farmland has been shown to improve water quality [footnote ⁹⁶], primarily through absorbing nutrients from agricultural runoff [footnote ⁹⁷]
- trees reduce soil erosion by improving the soil structure, preventing surface soils from being washed away and into watercourses [footnote ⁹⁸]
- the presence of trees improves soil quality and fertility by supporting soil microorganisms and providing leaf litter for topsoil creation [footnote ⁹⁹]

Livingstone et al., '[Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications](#)';

Livingstone et al., '[Life Cycle Assessment of a Short-Rotation Coppice Willow Riparian Buffer Strip for Farm Nutrient Mitigation and Renewable Energy Production](#)';

Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)', 28 August 2020.

⁹⁶ Ranacher et al., '[Farmers' Willingness to Adopt Short Rotation Plantations on Marginal Lands: Qualitative Study About Incentives and Barriers in Slovakia](#)';

Livingstone et al., '[Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications](#)'.

⁹⁷ Livingstone et al., '[Reducing the Time-Dependent Climate Impact of Intensive Agriculture with Strategically Positioned Short Rotation Coppice Willow](#)', Journal of Cleaner Production 419 (2023), '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)', 28 August 2020;

Adams and Johnston, '[Evaluating the Impacts of SRC Willows on Phosphorus Export from a Temperate Grassland Micro-Catchment](#)';

Livingstone et al., '[Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications](#)';

Livingstone et al., '[Life Cycle Assessment of a Short-Rotation Coppice Willow Riparian Buffer Strip for Farm Nutrient Mitigation and Renewable Energy Production](#)';

Livingstone et al., '[Willow Coppice in Intensive Agricultural Applications to Reduce Strain on the Food-Energy-Water Nexus](#)', Biomass and Bioenergy 144 (2021);

Stadig, L M, et al. '[Opportunities for Short Rotation Coppice Production on Free-Range Chicken Farms in Flanders: Farmers' Perceptions and Cost-Benefit Analysis](#)'.

⁹⁸ Rubio-Delgado et al., '[Small Woody Features in Agricultural Areas: Agroforestry Systems of Overlooked Significance in Europe](#)'.

Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)' 28 August 2020;

Liquete et al., '[Scientific Evidence Showing the Impacts of Nature Restoration Actions on Food Productivity](#)';

Livingstone et al., '[Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications](#)';

Ranacher et al., '[Farmers' Willingness to Adopt Short Rotation Plantations on Marginal Lands: Qualitative Study About Incentives and Barriers in Slovakia](#)'.

⁹⁹ Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)', 28 August 2020;

Rubio-Delgado et al., '[Small Woody Features in Agricultural Areas: Agroforestry Systems of Overlooked](#)

- trees can regulate the local microclimate by reducing wind speeds and increasing temperature and humidity which can aid species growth and survival [footnote ¹⁰⁰]
- trees and woodlands act as carbon sinks and contribute to reducing net farm emissions; management like coppicing and thinning which removes carbon stored in wood and encourages new growth is particularly effective for carbon sequestration [footnote ¹⁰¹].

[Significance in Europe](#)’;

Elalamy, Doyen, and Mouysset, [‘Contribution of the Land Use Allocation Model for Agroecosystems: The Case of Torrecchia Vecchia’](#);

Liquete et al., [‘Scientific Evidence Showing the Impacts of Nature Restoration Actions on Food Productivity’](#);

Livingstone et al., [‘Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications’](#);

Livingstone et al., [‘Life Cycle Assessment of a Short-Rotation Coppice Willow Riparian Buffer Strip for Farm Nutrient Mitigation and Renewable Energy Production’](#).

¹⁰⁰ Baker et al., [‘The Role of Open Woodland in Mitigating Microclimatic Extremes in Agricultural Landscapes’](#);

B. Keenleyside et al., [‘Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience’](#);

Košulič et al., [‘Intensive Site Preparation for Reforestation Wastes Multi-Trophic Biodiversity Potential in Commercial Oak Woodlands’](#);

Livingstone et al., [‘Reducing the Time-Dependent Climate Impact of Intensive Agriculture with Strategically Positioned Short Rotation Coppice Willow’](#).

¹⁰¹ Astigarraga et al., [‘Forest Structural Diversity Modulates Tree Growth Synchrony in Response to Climate Change’](#);

B. Keenleyside et al., [‘Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience’](#);

C. B. Keenleyside and G. H. Old, [‘Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 9: Flood Mitigation. Sustainable Farming Scheme Evidence Review’](#);

Liquete et al., [‘Scientific Evidence Showing the Impacts of Nature Restoration Actions on Food Productivity’](#);

V. Strauss et al., [‘Carbon Farming for Climate Change Mitigation and Ecosystem Services – Potentials and Influencing Factors’](#), *Journal of Environmental Management* 372 (2024);

Livingstone et al., [‘Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications’](#);

Livingstone et al., [‘Life Cycle Assessment of a Short-Rotation Coppice Willow Riparian Buffer Strip for Farm Nutrient Mitigation and Renewable Energy Production’](#);

Livingstone et al., [‘Willow Coppice in Intensive Agricultural Applications to Reduce Strain on the Food-Energy-Water Nexus’](#);

Irene Guerrero et al., [‘Quantifying the Impact of Sustainable Farming Practices on Environment and Climate’](#), JRC Publications Repository, 2024,

Social Impacts (8 studies)

The evidence base identified several social impacts of woodland management in the farmed landscape. These include the importance of woodland for recreation [footnote ¹⁰²] and the cultural value of woodland management techniques like pollarding [footnote ¹⁰³] and coppicing [footnote ¹⁰⁴] as connections to ancient management practices which produce unique woodland features. 2 studies highlighted the impact on-farm woodlands can have on food security through securing higher crop yields [footnote ¹⁰⁵] via improved soil fertility and pollination services [footnote ¹⁰⁶], and diversifying crop production via agroforestry [footnote ¹⁰⁷] and short rotation forestry [footnote ¹⁰⁸]. With regards to invasive species control for woodland management, negative social impacts were present where local communities may oppose lethal methods of grey squirrel control [footnote ¹⁰⁹]. In contrast, live trapping of American mink is publicly accepted [footnote ¹¹⁰].

¹⁰² Sturtevant, B R, and B B Hanberry. [‘Processes Underlying Restoration of Temperate Savanna and Woodland Ecosystems: Emerging Themes and Challenges’](#);

Roellig, M and others. [‘Post Hoc Assessment of Stand Structure Across European Wood-Pastures: Implications for Land Use Policy’](#).

¹⁰³ Camarero, J J, C Valeriano, J A Sánchez-Sancho, and C de Jaime Loren. [‘Pollarding May Relieve Drought Stress in Black Poplars’](#).

¹⁰⁴ Buckley, P. [‘Coppice Restoration and Conservation: A European Perspective’](#).

¹⁰⁵ Rubio-Delgado et al., [‘Small Woody Features in Agricultural Areas: Agroforestry Systems of Overlooked Significance in Europe’](#).

¹⁰⁶ Orczewska, Anna, Aleksander Dulik, Patryk Długosz, and Łukasz Depa. [‘Intensive Agriculture vs. Invertebrate Biodiversity: A Case Study of Woodland Islets in a Matrix of Arable Land’](#), Agriculture 14, no. 8 (August 2024): 1400;

Tammaru et al., [‘Landscape-Level Determinants of Butterfly Species Richness in Northern Europe: A Country-Wide Survey Reveals the Paramount Importance of Forest Land’](#), Biological Conservation 286 (2023);

de Zwaan, D R de, N Alavi, G W Mitchell, D R Lapen, J Duffe, and S Wilson. [‘Balancing Conservation Priorities for Grassland and Forest Specialist Bird Communities in Agriculturally Dominated Landscapes’](#);

Keenleyside et al., [‘Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience.’](#);

Rubio-Delgado et al., [‘Small Woody Features in Agricultural Areas: Agroforestry Systems of Overlooked Significance in Europe’](#).

¹⁰⁷ Soil Association, 2022. [Trees and Woodland in the farmed landscape: A farmer-led approach towards a diverse, resilient and vibrant agroforestry and farm woodland economy for England](#).

¹⁰⁸ Ranacher et al., [‘Farmers’ Willingness to Adopt Short Rotation Plantations on Marginal Lands: Qualitative Study About Incentives and Barriers in Slovakia’](#).

¹⁰⁹ Croft et al., [‘A Spatially Explicit Population Model to Compare Management Using Culling and Fertility Control to Reduce Numbers of Grey Squirrels’](#).

¹¹⁰ López, Clapperton, and Medina-Vogel, [‘A Global Review of the American Mink \(Neovison Vison\) Removal Techniques – Patagonia as a Case Study for Their Potential Application’](#).

Barriers (35 studies)

A number of barriers were identified in the evidence reviewed. They are as follows:

- for woodlands in protected areas, management may be restricted, this was identified as a barrier to management by a study in Canada [footnote ¹¹¹] and Europe [footnote ¹¹²]
- 3 studies pointed to the potential impact of climate change on woodland management effectiveness. One study undertaken in Spain highlighted the risk that drought and water shortages would constrain woodland management [footnote ¹¹³] and 2 suggested that some woodlands may have passed critical thresholds of degradation, the effects of which could be difficult to reverse [footnote ¹¹⁴]
- 3 studies highlighted possible unintended effects of woodland management. 2 studies mentioned the theory that canopy thinning might release stored nitrogen from woodlands into the atmosphere, although the likelihood of this is unknown [footnote ¹¹⁵]. One study suggested that canopy thinning could encourage invasive plant species colonisation of woodlands due to higher light availability [footnote ¹¹⁶]

¹¹¹ de Zwaan et al., '[Balancing Conservation Priorities for Grassland and Forest Specialist Bird Communities in Agriculturally Dominated Landscapes](#)';

Vymazalová et al., '[Positive Impact of Traditional Coppicing Restoration on Biodiversity of Ground-Dwelling Spiders in a Protected Lowland Forest](#)'.

¹¹² Vymazalová et al., '[Positive Impact of Traditional Coppicing Restoration on Biodiversity of Ground-Dwelling Spiders in a Protected Lowland Forest](#)', Forest Ecology and Management 490 (2021).

¹¹³ Colangelo, M, C Valeriano, E G de Andrés, M Pizarro, E Murria, and J Julio Camarero. '[Lack of Management, Land-Use Changes, Poor Site Conditions and Drought Contribute to the Decline of Old Pollarded Oaks](#)'. Dendrochronologia volume 86 (2024): article 126232.

¹¹⁴ Bassett, Landis, and Brudvig, '[Effects of Experimental Prescribed Fire and Tree Thinning on Oak Savanna Understory Plant Communities and Ecosystem Structure](#)';

Cooke, '[Colonisation, Impacts in Conservation Woodland and Management of Reeves' Muntjac \(Muntiacus Reevesi\) in an English County](#)'.

¹¹⁵ Alder, D C and others. '[Irregular Silviculture and Stand Structural Effects on the Plant Community in an Ancient Semi-Natural Woodland](#)';

Buckley, P. '[Coppice Restoration and Conservation: A European Perspective](#)'.

¹¹⁶ Kozdasová et al., '[Coppice Reintroduction in the Czech Republic: Extent, Motivation and Obstacles](#)'.

- several studies highlighted time and labour constraints [footnote ¹¹⁷] and a lack of sufficient knowledge and skills in woodland management within the farming community [footnote ¹¹⁸]
- economic barriers were well-covered in the literature reviewed; high upfront costs of bringing woodland under management were cited as barriers to uptake [footnote ¹¹⁹], alongside uncertainty of economic return over a long payback period [footnote ¹²⁰]. Insufficient local markets for woodland products in Ireland [footnote ¹²¹] and Europe [footnote ¹²²] were also cited
- perceived productivity impacts were highlighted as key barriers to undertaking woodland management for farmers. Allocating land to woodland management is perceived as potentially impacting on productivity through diverted resource use and

¹¹⁷ Keenleyside et al., '[Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience](#)';

Kozdasová et al., '[Coppice Reintroduction in the Czech Republic: Extent, Motivation and Obstacles](#)'; Stadig et al., '[Opportunities for Short Rotation Coppice Production on Free-Range Chicken Farms in Flanders: Farmers' Perceptions and Cost-Benefit Analysis](#)'.

¹¹⁸ Keenleyside et al., '[Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience](#)';

Keenleyside and Old, '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 9: Flood Mitigation. Sustainable Farming Scheme Evidence Review](#)'.

¹¹⁹ Ranacher et al., '[Farmers' Willingness to Adopt Short Rotation Plantations on Marginal Lands: Qualitative Study About Incentives and Barriers in Slovakia](#)';

B. Keenleyside et al., '[Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience](#)';

Livingstone et al., '[Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications](#)';

Nordén et al., '[The Economy of Selective Cutting in Recent Mixed Stands during Restoration of Temperate Deciduous Forest](#)';

Soil Association, 2022. [Trees and Woodland in the farmed landscape: A farmer-led approach towards a diverse, resilient and vibrant agroforestry and farm woodland economy for England](#).

¹²⁰ Livingstone et al., '[Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications](#)';

Stadig et al., '[Opportunities for Short Rotation Coppice Production on Free-Range Chicken Farms in Flanders: Farmers' Perceptions and Cost-Benefit Analysis](#)';

Bowditch, McMorran, and Smith, '[Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty](#)'.

¹²¹ Geoghegan and O'Donoghue, '[A Spatial Analysis of the Economic Returns to Land-Use Change from Agriculture to Renewable Energy Production: Evidence from Ireland](#)'.

¹²² Ranacher et al., '[Farmers' Willingness to Adopt Short Rotation Plantations on Marginal Lands: Qualitative Study About Incentives and Barriers in Slovakia](#)'.

crop shading and was considered to put farmers off [footnote ¹²³], regardless of whether these perceived impacts on productivity are accurate. 3 studies highlighted the reluctance of farmers to commit to a shifted management type, for example by bringing woodland under management like coppicing [footnote ¹²⁴]. Productivity impacts are linked to socio-cultural identity, with some farmers reluctant to alter their identity as food producers by undertaking woodland management [footnote ¹²⁵]

- regarding invasive species control, costs and labour inputs were cited by 4 studies [footnote ¹²⁶] as barriers to uptake, alongside public pushback against lethal control methods [footnote ¹²⁷]
- competing private and public values can impact the uptake of deer control, with landowners encouraged to keep higher deer numbers on their land for recreational shooting purposes [footnote ¹²⁸]. These studies were undertaken in the Scottish context and so may be less relevant in Wales.

¹²³ Ranacher et al., [Farmers' Willingness to Adopt Short Rotation Plantations on Marginal Lands: Qualitative Study About Incentives and Barriers in Slovakia](#);

Dufour et al., [Does Pollarding Trees Improve the Crop Yield in a Mature Alley-Cropping Agroforestry System?](#);

Soil Association, 2022. [Trees and Woodland in the farmed landscape: A farmer-led approach towards a diverse, resilient and vibrant agroforestry and farm woodland economy for England](#).

¹²⁴ Strauss et al., [Carbon Farming for Climate Change Mitigation and Ecosystem Services – Potentials and Influencing Factors](#);

Geoghegan and O'Donoghue, [A Spatial Analysis of the Economic Returns to Land-Use Change from Agriculture to Renewable Energy Production: Evidence from Ireland](#);

Ranacher et al., [Farmers' Willingness to Adopt Short Rotation Plantations on Marginal Lands: Qualitative Study About Incentives and Barriers in Slovakia](#).

¹²⁵ Ranacher et al., [Farmers' Willingness to Adopt Short Rotation Plantations on Marginal Lands: Qualitative Study About Incentives and Barriers in Slovakia](#).

¹²⁶ López, Clapperton, and Medina-Vogel, [A Global Review of the American Mink \(Neovison Vison\) Removal Techniques – Patagonia as a Case Study for Their Potential Application](#);

Reynolds et al., [Effective Control of Non-Native American Mink by Strategic Trapping in a River Catchment in Mainland Britain](#);

Martin and Lea, [A Mink-Free GB: Perspectives on Eradicating American Mink Neovison Vison from Great Britain and Its Islands](#);

Mill et al., [The Challenges of Long-Term Invasive Mammal Management: Lessons from the UK](#)

¹²⁷ Dunn et al., [Public Attitudes towards "Pest" Management: Perceptions on Squirrel Management Strategies in the UK](#).

¹²⁸ Hare, Daniels, and Blossey, [Public Perceptions of Deer Management in Scotland](#);

Kirkland et al., [Successful Deer Management in Scotland Requires Less Conflict Not More](#).

Evidence Gaps (20 studies)

Evidence gaps and areas for further research were identified in the literature reviewed as:

- The short-term impacts of converting to agroforestry systems as most studies focus on established systems [footnote ¹²⁹]
- The differential impacts of woody linear features along field boundaries vs within fields as agroforestry systems [footnote ¹³⁰]
- Increased observational studies of the impacts of floodplain woodland on peak water flows [footnote ¹³¹]
- Trade-offs and synergies in the restoration of coppicing; impacts on biodiversity, cultural heritage, forest resilience and local economies [footnote ¹³²]
- Long-term studies of woodland management under changing climatic conditions [footnote ¹³³]
- Supply chain and market requirements for sale of woodland products. [footnote ¹³⁴].

¹²⁹ Edo et al., '[Agroforestry Systems Favor Bat Conservation but Only When Old and Grazed](#)'.

¹³⁰ Rubio-Delgado et al., '[Small Woody Features in Agricultural Areas: Agroforestry Systems of Overlooked Significance in Europe](#)'.

¹³¹ Keenleyside and Old, '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 9: Flood Mitigation. Sustainable Farming Scheme Evidence Review](#)'; Livingstone et al., '[Willow Coppice in Intensive Agricultural Applications to Reduce Strain on the Food-Energy-Water Nexus](#)'.

¹³² Kamp, J. '[Coppice Loss and Persistence in Germany](#)'.

¹³³ Alder, D C and others. '[Irregular Silviculture and Stand Structural Effects on the Plant Community in an Ancient Semi-Natural Woodland](#)';

Livingstone et al., '[Life Cycle Assessment of a Short-Rotation Coppice Willow Riparian Buffer Strip for Farm Nutrient Mitigation and Renewable Energy Production](#)';

Colangelo et al., '[Lack of Management, Land-Use Changes, Poor Site Conditions and Drought Contribute to the Decline of Old Pollarded Oaks](#)'.

¹³⁴ Livingstone et al., '[Life Cycle Assessment of a Short-Rotation Coppice Willow Riparian Buffer Strip for Farm Nutrient Mitigation and Renewable Energy Production](#)';

Livingstone et al., '[Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications](#)';

Livingstone et al., '[Willow Coppice in Intensive Agricultural Applications to Reduce Strain on the Food-Energy-Water Nexus](#)';

Camarero, J J, C Valeriano, and A Rubio-Cuadrado. '[Old Oaks Show Increasing Growth Synchrony after Pollarding Cessation as Climate Becomes More Arid](#)'.

Cost-effectiveness Evidence (8 studies)

4 studies focussed on the benefits of implementing short-rotation coppicing on buffer strips or woodland patches which are already on unused land, meaning no loss to agricultural productivity would be needed to produce timber products for sale and deliver the associated ecosystem services [footnote ¹³⁵]. Additionally, as evidenced under economic impacts of woodland management, ecosystem service delivery can improve yields. This, combined with managing woodland on existing unused land, thereby preventing any productive land being lost, could mitigate farmer concerns over productivity impacts of woodland management.

2 studies highlighted the impacts of thinning on improving woodland resilience to damage from extreme weather events [footnote ¹³⁶] and delivering ecosystem services [footnote ¹³⁷]. One study based in the United States found that woodlands managed for timber production can deliver biodiversity benefits for bird species without compromising on production levels [footnote ¹³⁸]. One European study highlighted the cost-effectiveness of methods to encourage natural regeneration of woodlands under thinning and cutting regimes [footnote ¹³⁹].

¹³⁵ Strauss et al., '[Carbon Farming for Climate Change Mitigation and Ecosystem Services – Potentials and Influencing Factors](#)';

Livingstone et al., '[Reducing the Time-Dependent Climate Impact of Intensive Agriculture with Strategically Positioned Short Rotation Coppice Willow](#)';

Livingstone et al., '[Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications](#)';

Livingstone et al., '[Willow Coppice in Intensive Agricultural Applications to Reduce Strain on the Food-Energy-Water Nexus](#)'.

¹³⁶ Bowditch, McMorran, and Smith, '[Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty](#)'.

¹³⁷ Sturtevant and Hanberry, '[Processes Underlying Restoration of Temperate Savanna and Woodland Ecosystems: Emerging Themes and Challenges](#)'.

¹³⁸ Wood, Tegeler, and Ross, '[Vegetation Management on Private Forestland Can Increase Avian Species Richness and Abundance](#)'.

¹³⁹ Nordén et al., '[The Economy of Selective Cutting in Recent Mixed Stands during Restoration of Temperate Deciduous Forest](#)'.

Critical Success Factors

Strategic fit and business needs: High alignment

The evidence base suggests that on-farm woodland management has the potential to deliver a range of environmental benefits which align with the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023. This Theme also has the potential to deliver measurable economic and social benefits for farmers and the wider public. There is evidence that on-farm woodland management is an economically feasible option for farmers and can deliver multiple productivity benefits to the farm business. However, costs to the farmer should be mitigated through economic support. This Theme therefore highly aligns with the Strategic fit and business needs CSF.

Value for money: High alignment

The evidence base suggests that, with financial support, uptake of woodland management on farms is accessible to farmers and can deliver environmental benefits (depending on the existing conditions of the woodland), including improving the resilience of on-farm ecosystems. The evidence suggests that this Theme would contribute to mitigation and adaptation to climate change, and that farmers can be encouraged to undertake woodland management to achieve both individual and community-level benefits. This Theme therefore highly aligns with the Value for money CSF.

Supply side capacity and capability: Medium alignment

The evidence base for this Theme suggests medium alignment with Supply side capacity and capability. While uptake is supported by increased awareness of the benefits of woodland management, the evidence base suggests that further education and capacity building is needed in the farming community.

Affordability: High alignment

The evidence base highlights a range of economic benefits for farmers bringing woodland under control, which could mitigate the costs associated, especially if this Theme is supported financially through participation in the SFS.

Woodland and Agroforestry Creation

The objective of the Theme Woodland and Agroforestry Creation is to support the creation of woodland and agroforestry/low-density planting on farmland. The on-farm practices available under this Theme include:

- production of a Woodland Creation Plan
- creation of woodland under 1.99ha in 'low risk areas'
- creation of woodland over 0.1ha via Small Grants Woodland Creation Grant and 0.25ha via Woodland Creation Grant.

Due to overlaps in on-farm practices with other Themes additional evidence for this Theme can be found in:

- Enhanced Woodland Management
- Hedgerow Creation or Restoration
- Advanced Continuous Professional Development (CPD)
- Improved Water Quality, Water Usage and Flood Mitigation.

REA Exclusion / Inclusion Criteria

Inclusion: Studies on tree planting, woodland creation, increased tree cover and woodland planning. Specific focus on agricultural land. Studies on woodland management for small-scale timber production. Studies on agroforestry systems.

Exclusion: Studies on industrial forestry; timber production. Studies on solely theoretical aspects without a practical focus.

Evidence Base

Using Scopus, 83 studies were identified as in scope of the evidence assessment. An additional 22 studies were sourced using Google Scholar and websites identified in Annex B. Using quality and relevance criteria, 105 articles were analysed. Of these, 14 were from Wales and 57 were from the rest of the UK. The evidence base focussed particularly on tree planting, natural regeneration and agroforestry.

Design of the Intervention (60 studies)

Several publications highlighted the importance of tailoring woodland creation plans to local contexts [footnote ¹⁴⁰] through collaboration and co-design with landowners [footnote ¹⁴¹]. These methods involve listening to farmers concerns [footnote ¹⁴²] and giving them agency in the design of woodland creation schemes on their land [footnote ¹⁴³]. One study (UK) highlighted the need to tailor planting schemes for lower densities associated with agroforestry practices [footnote ¹⁴⁴].

Deciding where to plant trees is important, the impacts of creating woodland differ depending on the location of planting [footnote ¹⁴⁵], which can affect the delivery of environmental, social and economic benefits [footnote ¹⁴⁶].

This review identified multiple recommended locations for creating new woodland:

¹⁴⁰ Burton et al., '[Green Gold to Wild Woodlands: Understanding Stakeholder Visions for Woodland Expansion in Scotland](#)', Landscape Ecology 34, no. 7 (1 July 2019): 1693–1713;

Iversen et al., '[Using the Ecosystem Services Assessment Tool TESSA to Balance the Multiple Landscape Demands of Increasing Woodlands in a UK National Park](#)', Ecosystem Services 68 (1 August 2024): 101644;

Bowditch, McMorran, and Smith, '[Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty](#);

Weston and Lorna J. '[The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?](#)'

¹⁴¹ Burton et al., '[Green Gold to Wild Woodlands: Understanding Stakeholder Visions for Woodland Expansion in Scotland](#)';

Follett et al., '[Working for the Environment: Farmer Attitudes towards Sustainable Farming Actions in Rural Wales, UK](#)', Environment, Development and Sustainability, 2024, Sally Westaway et al.,

¹⁴² Burton et al., '[Reviewing the Evidence Base for the Effects of Woodland Expansion on Biodiversity and Ecosystem Services in the United Kingdom](#)', Forest Ecology and Management 430 (15 December 2018): 366–79;

Iversen et al., '[Why Understanding Stakeholder Perspectives and Emotions Is Important in Upland Woodland Creation – A Case Study from Cumbria, UK](#)'

¹⁴³ Burton et al., '[Green Gold to Wild Woodlands: Understanding Stakeholder Visions for Woodland Expansion in Scotland](#)';

Follett et al., '[Working for the Environment: Farmer Attitudes towards Sustainable Farming Actions in Rural Wales, UK](#)'.

¹⁴⁴ Saunders et al., '[Can Silvo-Pastoral Agroforestry Systems Contribute to Scotland's Emission Reduction Targets?](#)', ClimateXChange (2023).

¹⁴⁵ Nthambi, Mary, Katherine Simpson, Tom Bradfer-Lawrence, Andrew Dobson, Tom Finch, Elisa Fuentes-Montemayor, Kirsty Park, Kevin Watts, and Nick Hanley. '[Economic Incentives for Woodland Creation on Farmland: Modelling the Impacts on Biodiversity](#)'. Ecological Economics volume 224 (1 October 2024)

¹⁴⁶ Burke et al., '[Spatially Targeting National-Scale Afforestation for Multiple Ecosystem Services](#)', Applied Geography 159 (1 October 2023): 103064,

- planting on unimproved hill grassland at larger scales, and planting on improved grassland in strategic locations like gullies and cross-slope shelterbelts [footnote ¹⁴⁷]
- planting on marginal/unproductive land which will not impact on agricultural productivity [footnote ¹⁴⁸]
- planting along field boundaries and watercourses to intercept pollutant runoff like fertilisers and pesticides [footnote ¹⁴⁹]
- planting near the existing hedgerow and woodland matrix to enhance connectivity for species dispersal [footnote ¹⁵⁰]
- targeted planting around livestock sheds, silage and slurry storage and other pollutant sources and pathways to intercept air and water pollution [footnote ¹⁵¹]

¹⁴⁷ Spray et al., [Land Management for Increased Flood Resilience](#) (Aberdeen: Centre of Expertise for Waters (CREW) Facilitation Team, James Hutton Institute, 2016);

Burton et al., [Reviewing the Evidence Base for the Effects of Woodland Expansion on Biodiversity and Ecosystem Services in the United Kingdom](#)

¹⁴⁸ Irwin et al., '[Increasing Tree Cover on Irish Dairy and Drystock Farms: The Main Attitudes, Influential Bodies and Barriers That Affect Agroforestry Uptake](#)', *Environmental Science and Policy* 146 (2023): 76–89; Irwin, Á.N. Dhubháin, and I. Short, '[Irish Dairy and Drystock Farmers' Attitudes and Perceptions to Planting Trees and Adopting Agroforestry Practices on Their Land](#)', *Environmental Challenges* 9 (2022),

¹⁴⁹ Woodland Expansion Advisory Group 2012 [Report of the Woodland Expansion Advisory Group](#) to the Cabinet Secretary for Rural Affairs and Environment, Richard Lochhead MSP. Scottish Forestry. Nisbet, T., Silgram, M., Shah, N., Morrow, K., and Broadmeadow, S. (2011) [Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#). Forest Research Monograph, 4, Forest Research, Surrey, 156pp.

¹⁵⁰ Nelson, Nelson, and Montgomery, '[Colonisation of Farmland Deciduous Plantations by Woodland Ground Flora](#)', *Arboricultural Journal* 43, no. 2 (3 April 2021): 115–33;

Fuentes-Montemayor et al., '[Small Mammal Responses to Long-Term Large-Scale Woodland Creation: The Influence of Local and Landscape-Level Attributes](#)', *Ecological Applications* 30;

Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Report-33: National Forest in Wales - Evidence Review Annex-1: Biodiversity](#)', Publication - Report (Bangor: UK Centre for Ecology & Hydrology, 28 August 2020),

¹⁵¹ Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)', Publication - Report (Bangor: UK Centre for Ecology & Hydrology, 28 August 2020);

Jones et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 8: Improving Air Quality and Well-Being. Sustainable Farming Scheme. Evidence Review](#)', Publication - Report (Bangor: NERC/Centre for Ecology & Hydrology, 4 July 2019);

Nisbet et al., '[Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#)'.

- when planting along field edges or within fields for agroforestry, planting in a north-south orientation to minimise pasture shading but still offer wind protection (New Zealand) [footnote ¹⁵²]
- for pollination benefits, plant multiple, smaller woodland plots which are evenly distributed in the landscape. This creates more edge habitat which supports a wider range of pollinators [footnote ¹⁵³]
- avoid planting on peat exceeding 50cm depth to avoid disrupting the hydrology of those sites and causing carbon release [footnote ¹⁵⁴]
- avoid planting on organic soils where possible; if unavoidable, limit soil disturbance to avoid carbon release [footnote ¹⁵⁵]
- avoid planting on open sites which are known habitats for ground-nesting birds such as Curlew; if planting near these sites, larger blocks on flatter ground and near managed habitats is preferred to mitigate the impacts on these species [footnote ¹⁵⁶].

Several studies made recommendations for site preparation pre-planting:

- removal of invasive species to prevent competition [footnote ¹⁵⁷]

¹⁵² Velarde Pajares et al., '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)', *Journal of New Zealand Grasslands* 86 (2024): 223–35,

¹⁵³ Image, Gardner, and Breeze, '[Co-Benefits from Tree Planting in a Typical English Agricultural Landscape: Comparing the Relative Effectiveness of Hedgerows, Agroforestry and Woodland Creation for Improving Crop Pollination Services](#)', *Land Use Policy* 125 (1 February 2023): 106497,

¹⁵⁴ Scottish Forestry. '[Woodland Expansion Advisory Group - June 2012](#)'

¹⁵⁵ Baggio-Compagnucci et al., '[Barking up the Wrong Tree? Can Forest Expansion Help Meet Climate Goals?](#)', *Environmental Science and Policy* 136 (2022): 237–49,.

¹⁵⁶ McGrory et al., '[Impacts of Forest Extent, Configuration and Landscape Context on Presence of Declining Breeding Eurasian Curlew Numenius Arquata and Implications for Planning New Woodland](#)', *Forest Ecology and Management* 572 (2024);

Scottish Forestry. '[Woodland Expansion Advisory Group - June 2012](#)'

¹⁵⁷ Nelson, Nelson, and Montgomery, '[Colonisation of Farmland Deciduous Plantations by Woodland Ground Flora](#)';

Mathieu, Cogliastro, and Rivest, '[Drivers of Tree Establishment in Planted Windbreaks and Riparian Buffers: A Case Study of Farms in Southern Quebec, Canada](#)', *Geoderma Regional* 37 (2024).

- minimising ground disturbance to avoid carbon release [footnote ¹⁵⁸]. Hand preparation via screefing was suggested by one study (UK) to remove the top vegetation layer and form a shallow scrape for direct planting without disturbing the soil structure or requiring application of fertilisers, herbicides or pesticides [footnote ¹⁵⁹]
- targeting lower risk soils [footnote ¹⁶⁰]. Alkaline soils should be avoided as they have fewer nutrients and so tree survival rate is reduced (Canada) [footnote ¹⁶¹]
- limiting browsing in the planting area, for example by using fencing or tree guards [footnote ¹⁶²].

Several studies made recommendations about which species to plant depending on the desired outcome of the planting scheme:

- planting native species is preferred as they are more likely to be adapted to the local environment and to support other native species and deliver multiple ecosystem benefits [footnote ¹⁶³]

¹⁵⁸ Bradfer-Lawrence et al., [‘The Potential Contribution of Terrestrial Nature-Based Solutions to a National “Net Zero” Climate Target’](#), Journal of Applied Ecology 58, no. 11 (2021): 2349–60;

O’Neill et al., [‘Forest Regeneration on European Sheep Pasture Is an Economically Viable Climate Change Mitigation Strategy’](#), Environmental Research Letters 15, no. 10 (October 2020): 104090;

Mölder, Meyer, and Nagel, [‘Integrative Management to Sustain Biodiversity and Ecological Continuity in Central European Temperate Oak \(Quercus Robur, Q. Petraea\) Forests: An Overview’](#).

¹⁵⁹ Watts, [‘Montane Willow Scrub Restoration in Scotland: Reviewing 30 Years of Progress to Reestablish the Altitudinal Treeline’](#), Restoration Ecology 33, no. 1 (2025).

¹⁶⁰ Bradfer-Lawrence et al., [‘The Potential Contribution of Terrestrial Nature-Based Solutions to a National “Net Zero” Climate Target’](#).

¹⁶¹ Mathieu, Cogliastro, and Rivest, [‘Drivers of Tree Establishment in Planted Windbreaks and Riparian Buffers: A Case Study of Farms in Southern Quebec, Canada’](#).

¹⁶² Scottish Forestry. [‘Woodland Expansion Advisory Group - June 2012’](#);

Fuentes-Montemayor et al., [‘The Long-Term Development of Temperate Woodland Creation Sites: From Tree Saplings to Mature Woodlands’](#), Forestry 95, no. 1 (2022): 28–37,;

O’Neill et al., [‘Forest Regeneration on European Sheep Pasture Is an Economically Viable Climate Change Mitigation Strategy’](#).

¹⁶³ Baggio-Compagnucci et al., [‘Barking up the Wrong Tree? Can Forest Expansion Help Meet Climate Goals?’](#);

Małgorzata Bożek et al., [‘Non-Forest Woody Vegetation: A Critical Resource for Pollinators in Agricultural Landscapes—A Review’](#), Sustainability 15, no. 11 (January 2023): 8751;

Sutherland and Huttunen, [‘Linking Practices of Multifunctional Forestry to Policy Objectives: Case Studies in Finland and the UK’](#), Forest Policy and Economics 86 (1 January 2018): 35–44,;

- planting a mix of tree species creates a diverse woodland structure which provides biodiversity and cultural benefits [footnote ¹⁶⁴]
- broadleaved species are preferred over conifers when planting for wildlife as they support higher species biodiversity [footnote ¹⁶⁵]
- when planting for carbon sequestration, the evidence is mixed. One paper suggested that broadleaved woodlands store more carbon, associated with their greater lifespan and wood density; however, coniferous species can sequester carbon more rapidly in the short to medium term. Coniferous species are also favoured as more appropriate for wetter, more acidic soils as commonly found in Wales, and so may be the preferred choice where carbon sequestration is the goal [footnote ¹⁶⁶]. Research into sustainable forestry, however, found that slower-growing broadleaf woodland could sequester an average 1.3tCO₂ per year until 2050, compared to 4.9tCO₂ per year for the same period by moderate-growing coniferous woodland. The report indicated that planting conifers could sequester larger amounts of carbon in the short term, but that broadleaved woodlands begin to reach comparative levels over the long term, in line with the previous evidence. However, high-yielding conifer sites harvested for timber products could contribute to further emissions reductions through the use of wood for buildings in place of other materials [footnote ¹⁶⁷].
- broadleaved species should be planted at lower altitudes to improve survival rate [footnote ¹⁶⁸]

Brown, '[Challenges in Delivering Climate Change Policy through Land Use Targets for Afforestation and Peatland Restoration](#)', Environmental Science and Policy 107 (2020): 36–45,.

¹⁶⁴ Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)', 28 August 2020.

¹⁶⁵ Flack, Lukac, and Todman, '[Woodland Planting on UK Pasture Land Is Not Economically Feasible, yet Is More Profitable than Some Traditional Farming Practices](#)', Central European Forestry Journal 68, no. 2 (2022): 61–71;

Burton et al., '[Reviewing the Evidence Base for the Effects of Woodland Expansion on Biodiversity and Ecosystem Services in the United Kingdom](#)'.

¹⁶⁶ Flack, Lukac, and Todman, '[Woodland Planting on UK Pasture Land Is Not Economically Feasible, yet Is More Profitable than Some Traditional Farming Practices](#)', Central European Forestry Journal 68, no. 2 (2022): 61–71

¹⁶⁷ Matthews, R. (2022) [Quantifying the sustainable forestry carbon cycle](#). Forest Research.

¹⁶⁸ Nelson, Nelson, and Montgomery, '[Colonisation of Farmland Deciduous Plantations by Woodland Ground Flora](#)'.

- tree species should be selected to account for the moisture and nutrient levels of the soil [footnote ¹⁶⁹]. Wetter, acidic soils better suit coniferous species, while broadleaved species prefer drier soils [footnote ¹⁷⁰]. Conifer species should be avoided where water levels are low as they have high water use and can concentrate nitrates in groundwater [footnote ¹⁷¹]
- one study indicated that, under future climate scenarios, beech will be unsuitable for planting, whereas sessile oak will be suitable across Wales, except in upland areas [footnote ¹⁷²]
- willow and poplar are highly productive species and so are well-suited for carbon sequestration and timber production [footnote ¹⁷³]
- alder is a nitrogen-fixer and can enhance nitrogen concentrations in soils, and so it should be avoided in areas at risk of nutrient pollution or acidification [footnote ¹⁷⁴]
- if promoting pollination is the goal, choose species like willow, horse chestnut, sour cherry, hawthorn, bird cherry, black elder and Rubus species (blackberries and raspberries) [footnote ¹⁷⁵]

Several studies made recommendations about planting patch size:

¹⁶⁹ [‘Land Use: Reducing Emissions and Preparing for Climate Change’](#), Publication - Report (London: Committee on Climate Change, 15 November 2018),

¹⁷⁰ Flack, Lukac, and Todman, [‘Woodland Planting on UK Pasture Land Is Not Economically Feasible, yet Is More Profitable than Some Traditional Farming Practices’](#).

¹⁷¹ Nisbet, T., Silgram, M., Shah, N., Morrow, K., and Broadmeadow, S. (2011) [Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#). Forest Research Monograph, 4, Forest Research, Surrey, 156pp.

¹⁷² Beauchamp, K., Bathgate, S., Burton, V., Jenkins, T.A.R., Morison, J., Nicoll, B. & Perks, M.P. (2020). [Environment and Rural Affairs Monitoring & Modelling Programme \(ERAMMP\) - Technical Annex 3: Soil Carbon Management. Sustainable Farming Scheme Evidence Review](#). Report to Welsh Government (Contract C210/2016/2017)(UK Centre for Ecology & Hydrology Project 06297)

¹⁷³ Nisbet, T., Silgram, M., Shah, N., Morrow, K., and Broadmeadow, S. (2011) [Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#). Forest Research Monograph, 4, Forest Research, Surrey, 156pp.

¹⁷⁴ Nisbet, T., Silgram, M., Shah, N., Morrow, K., and Broadmeadow, S. (2011) [Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#)

¹⁷⁵ Božek et al., [‘Non-Forest Woody Vegetation: A Critical Resource for Pollinators in Agricultural Landscapes—A Review’](#).

- when the aim is to benefit woodland bird communities, patches larger than 5 hectares should be prioritised. However, woodland specialists will benefit more from much larger patches of 30 hectares or more [footnote ¹⁷⁶]
- another study recommended that small farm woodlands or shelterbelts should be between 0.25 to 2 hectares and at least 15 metres wide [footnote ¹⁷⁷]
- for the width of riparian woodlands/buffer strips, recommendations vary from 5 metres [footnote ¹⁷⁸], 15 metres [footnote ¹⁷⁹], 20 metres [footnote ¹⁸⁰] up to 30 metres for maximal nutrient removal [footnote ¹⁸¹]. One article suggested that even narrows strips of below 3 metres can be beneficial [footnote ¹⁸²], but the wider the strips can be, the better for nutrient absorption [footnote ¹⁸³]
- facilitating natural regeneration of woodlands is recommended to augment active planting, as it can lead to more structurally diverse and complex woodland structures [footnote ¹⁸⁴]. This can be achieved through applied nucleation, where clumps of newly planted trees act as focal points for colonisation by providing shelter and seed

¹⁷⁶ Whytock et al., '[Bird-Community Responses to Habitat Creation in a Long-Term, Large-Scale Natural Experiment](#)', Conservation Biology 32, no. 2 (2018): 345–54.

¹⁷⁷ Scottish Forestry. '[Woodland Expansion Advisory Group - June 2012](#)'

¹⁷⁸ Keenleyside and G. H. Old, '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 9: Flood Mitigation. Sustainable Farming Scheme Evidence Review](#)';

Cooper et al., '[Role of Forested Land for Natural Flood Management in the UK: A Review](#)', Wiley Interdisciplinary Reviews: Water 8, no. 5 (2021),

¹⁷⁹ Scottish Forestry. '[Woodland Expansion Advisory Group - June 2012](#)'

¹⁸⁰ Cooper et al., '[Role of Forested Land for Natural Flood Management in the UK: A Review](#)';

Nisbet, T., Silgram, M., Shah, N., Morrow, K., and Broadmeadow, S. (2011) [Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#). Forest Research Monograph, 4, Forest Research, Surrey, 156pp.

¹⁸¹ Stiles, W. '[Are Riparian Buffer Strips an Opportunity to Increase Tree Cover on UK Farms Whilst Simultaneously Reducing the Impact of Agricultural Pollution?](#)', Farming Connect, 30 January 2025,.

¹⁸² Ibid.

¹⁸³ Adams and Johnston, '[Evaluating the Impacts of SRC Willows on Phosphorus Export from a Temperate Grassland Micro-Catchment](#)'.

¹⁸⁴ Fletcher et al., '[The Carbon Sequestration Potential of Scottish Native Woodland](#)', Environmental Research Communications 3, no. 4 (April 2021): 041003,;

Fuentes-Montemayor et al., '[The Long-Term Development of Temperate Woodland Creation Sites: From Tree Saplings to Mature Woodlands](#)';

Bowditch, McMorran, and Smith, '[Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty](#)'.

stock for newly colonising seedlings [footnote ¹⁸⁵]. Applied nucleation is important in areas without existing trees as seed sources may be scarce, limiting natural regeneration [footnote ¹⁸⁶]. Where possible, planting should occur near existing woodlands to improve colonisation by woodland plants and create wildlife corridors for woodland species [footnote ¹⁸⁷]. Removing sheep from these areas is important to allow regeneration; cattle can be allowed to graze as they do not impede regeneration. This has been attributed to their less selective browsing behaviour, cattle do not preferentially graze tree seedlings or plants with higher nutritional value, as sheep do, and so have lesser impact on tree seedlings [footnote ¹⁸⁸].

- several studies made recommendations for designing agroforestry systems; 3 studies highlighted the importance of considering the delivery of multiple ecosystem services including social and economic benefits [footnote ¹⁸⁹]

¹⁸⁵ O'Neill et al., '[Forest Regeneration on European Sheep Pasture Is an Economically Viable Climate Change Mitigation Strategy](#)';

Hughes et al., '[New Woodlands Created Adjacent to Existing Woodlands Grow Faster, Taller and Have Higher Structural Diversity than Isolated Counterparts](#)', Restoration Ecology 31, no. 4 (2023);

Morris and Davies, '[Drivers of Natural Colonisation and Regeneration within Planted Woodlands in England: Towards an Integrated Approach to Increase Resilience](#)', Forest Ecology and Management 579 (2025).

¹⁸⁶ Porton et al., '[Natural Colonisation Rates in a UK Upland Landscape under Different Conservation Management Approaches Following Sheep Removal](#)', Ecological Solutions and Evidence 5, no. 2 (2024): e12338.

¹⁸⁷ Waddell et al., '[Larger and Structurally Complex Woodland Creation Sites Provide Greater Benefits for Woodland Plants](#)', Ecological Solutions and Evidence 5, no. 2 (2024): e12339,;

Pedersen, Schmidt, and Kepfer-Rojas, '[Drivers of Tree Colonization, Species Richness, and Structural Variation during the Initial Three Decades of Natural Forest Colonization in Abandoned Agricultural Soils](#)', Forest Ecology and Management 543 (2023),;

Hughes et al., '[Spatial Targeting of Woodland Creation Can Reduce the Colonisation Credit of Woodland Plants](#)', Ecological Solutions and Evidence 4, no. 3 (2023),;

Hughes et al., '[New Woodlands Created Adjacent to Existing Woodlands Grow Faster, Taller and Have Higher Structural Diversity than Isolated Counterparts](#)';

O'Neill et al., '[Forest Regeneration on European Sheep Pasture Is an Economically Viable Climate Change Mitigation Strategy](#)';

Nelson, Nelson, and Montgomery, '[Colonisation of Farmland Deciduous Plantations by Woodland Ground Flora](#)';

Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Report-33: National Forest in Wales - Evidence Review Annex-1: Biodiversity](#)'.

¹⁸⁸ Ibid.

¹⁸⁹ Varah et al., '[Temperate Agroforestry Systems Provide Greater Pollination Service than Monoculture](#)', Agriculture, Ecosystems and Environment 301 (2020);

Sollen-Norrlin, Ghaley, and Rintoul, '[Agroforestry Benefits and Challenges for Adoption in Europe and Beyond](#)', Sustainability (Switzerland) 12, no. 17 (2020),;

- for silvoarabale systems, which combine trees with crop growth [footnote ¹⁹⁰], trees can be planted in rows between crop rows. One study (UK) recommended making these rows at least 24 metres wide to allow machinery access [footnote ¹⁹¹], while another (EU-based) study recommended 48 metres wide rows to prevent shading and competition for light and soil resources [footnote ¹⁹²]
- silvopastoral systems involve the integration of trees with grazing livestock [footnote ¹⁹³]. One UK report recommended planting 4400 stems/hectare, individually protected, to allow livestock to graze between them [footnote ¹⁹⁴]. One article recommended that, when integrating trees into free-range poultry farming, trees should be spaced wider than usual woodland creation spacing to allow development of a shrub layer for poultry to graze and hide in [footnote ¹⁹⁵].

Uptake of the Practice (29 studies)

Multiple studies cited economic factors as influencing uptake, with grant assistance for planting cited in 5 articles as important in encouraging farmers to plant trees [footnote ¹⁹⁶]. This was linked to farmer concerns about the economic impact of losing productive

Elbakidze et al., [‘Perceived Benefits from Agroforestry Landscapes across North-Eastern Europe: What Matters and for Whom?’](#), Landscape and Urban Planning 209 (2021),

¹⁹⁰ Cutress, D. [‘Agroforestry Options’](#), Farming Connect, 30 January 2025,.

¹⁹¹ Staton et al., [‘Productivity, Biodiversity Trade-Offs, and Farm Income in an Agroforestry versus an Arable System’](#), Ecological Economics 191 (2022),.

¹⁹² Veldkamp et al., [‘Multifunctionality of Temperate Alley-Cropping Agroforestry Outperforms Open Cropland and Grassland’](#), Communications Earth and Environment 4, no. 1 (2023),.

¹⁹³ Cutress, D. [‘Agroforestry Options’](#).

¹⁹⁴ Scottish Forestry. [‘Woodland Expansion Advisory Group - June 2012’](#)

¹⁹⁵ Amir, S. [‘Silvopoultry: Three Birds, One Stone’](#), Farming Connect, 30 January 2025.

¹⁹⁶ Kaine et al., [‘Who Knew Afforestation Was Such a Challenge? Motivations and Impediments to Afforestation Policy in New Zealand’](#), Forest Policy and Economics 154 (2023),;

Hardaker, [‘Is Forestry Really More Profitable than Upland Farming? A Historic and Present Day Farm Level Economic Comparison of Upland Sheep Farming and Forestry in the UK’](#), Land Use Policy 71 (2018): 98–120,;

Lawrence and Dandy, [‘Private Landowners’ Approaches to Planting and Managing Forests in the UK: What’s the Evidence?’](#), Land Use Policy 36 (1 January 2014): 351–60,;

Sutherland and Huttunen, [‘Linking Practices of Multifunctional Forestry to Policy Objectives: Case Studies in Finland and the UK’](#);

Cooper et al., [‘Role of Forested Land for Natural Flood Management in the UK: A Review’](#);

Nisbet, T., Silgram, M., Shah, N., Morrow, K., and Broadmeadow, S. (2011) [Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#). Forest Research Monograph, 4, Forest Research, Surrey, 156pp.

land/yields to tree planting [footnote ¹⁹⁷]. One study identified the ‘productivism’ mindset of many Welsh farmers as influential in this decision not to use workable land for planting trees [footnote ¹⁹⁸]. Planting large areas of land was found to be less popular by 3 studies [footnote ¹⁹⁹], with one study highlighting farmers reluctance to commit to permanent land use changes associated with planting large numbers of trees [footnote ²⁰⁰]. One study cited woodland products as a motivator for Scottish farmers to plant trees, provided they could receive payments for products like timber, or for carbon sequestration benefits delivered by woodlands [footnote ²⁰¹]. This approach however requires a long-term attitude as the economic benefits from planting trees, in the case of wood or fruit products, are delayed [footnote ²⁰²].

The uptake of grants for woodland creation is impacted by the application and scheme design processes. High levels of administrative burden [footnote ²⁰³], complexity [footnote

¹⁹⁷ Jordon, Winter, and Petrokofsky, ‘[Advantages, Disadvantages, and Reasons for Non-Adoption of Rotational Grazing, Herbal Leys, Trees on Farms and Ley-Arable Rotations on English Livestock Farms](#)’, *Agroecology and Sustainable Food Systems* 47, no. 3 (16 March 2023): 330–54,; Spray et al., [Land Management for Increased Flood Resilience](#)’; Hardaker, ‘[Is Forestry Really More Profitable than Upland Farming? A Historic and Present Day Farm Level Economic Comparison of Upland Sheep Farming and Forestry in the UK](#)’.

¹⁹⁸ Follett et al., ‘[Working for the Environment: Farmer Attitudes towards Sustainable Farming Actions in Rural Wales, UK](#)’.

¹⁹⁹ Ford, Bale, and Taylor, ‘[The Factors Determining Uptake of Energy Crop Cultivation and Woodland Creation in England: Insights from Farmers and Landowners](#)’, *Biomass and Bioenergy* 180 (1 January 2024): 107021,;

J. Alison et al., [Environment and Rural Affairs Monitoring & Modelling Programme \(ERAMMP\) - Technical Annex 3: Soil Carbon Management. Sustainable Farming Scheme Evidence Review.](#)’, Publication - Report (Bangor: NERC/Centre for Ecology & Hydrology, 5 July 2019),; Nisbet, T., Silgram, M., Shah, N., Morrow, K., and Broadmeadow, S. (2011) [Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#). Forest Research Monograph, 4, Forest Research, Surrey, 156pp.

²⁰⁰ Alison et al., [Environment and Rural Affairs Monitoring & Modelling Programme \(ERAMMP\) - Technical Annex 3: Soil Carbon Management. Sustainable Farming Scheme Evidence Review.](#)’.

²⁰¹ Bowditch, McMorran, and Smith, ‘[Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty](#)’.

²⁰² Bradfer-Lawrence et al., ‘[The Potential Contribution of Terrestrial Nature-Based Solutions to a National “Net Zero” Climate Target](#)’;

Lawrence and Dandy, ‘[Private Landowners’ Approaches to Planting and Managing Forests in the UK: What’s the Evidence?](#)’.

²⁰³ Hardaker, ‘[Is Forestry Really More Profitable than Upland Farming? A Historic and Present Day Farm Level Economic Comparison of Upland Sheep Farming and Forestry in the UK?](#)’

^{204]} and inflexibility [footnote ^{205]} of support schemes can prevent farmers from applying. A study based in New Zealand suggested that, to mitigate administrative barriers, government support with applications should be made available [footnote ^{206]}. This is a particular concern as the 2025 Glastir Evaluation found that “93% of respondents in scheme stated they would not have proceeded with Woodland restoration or creation without Glastir support” [footnote ^{207]}.

Farmers are motivated by non-economic benefits of tree planting (as outlined in the environmental and social impacts sections), provided the evidence for these benefits can be demonstrated [footnote ^{208]}. The 2025 Glastir Evaluation found that, between 2010 and 2021, “[w]hilst there has been a significant creation of new Woodland(23,600ha, +7%), Glastir was responsible for just 3,780ha”. This suggests that while Glastir payments were important in incentivising some farmers to plant trees, much of the woodland creation during the time period measured was driven by other factors, which were not captured in the report. This indicates that woodland creation is influenced by a wide range of factors – including non-financial benefits. [footnote ^{209]}. Carbon sequestration was a low priority for farmers in 2 studies [footnote ^{210]}. One UK study showed that 77% of farmers surveyed (224 respondents) cited wildlife habitat improvement as their reason for planting trees, followed by reducing greenhouse gas emissions which received half as many responses [footnote

²⁰⁴ Westaway et al., ‘[Meeting Tree Planting Targets on the UK’s Path to Net-Zero: A Review of Lessons Learnt from 100 Years of Land Use Policies](#)’.

²⁰⁵ Markiewicz-Keszycka et al., ‘[Pro-Environmental Diversification of Pasture-Based Dairy and Beef Production in Ireland, the United Kingdom and New Zealand: A Scoping Review of Impacts and Challenges](#)’, Renewable Agriculture and Food Systems 38 (January 2023): e5.

²⁰⁶ Polyakov et al., ‘[Evaluating Incentives to Encourage Native Afforestation on Private Lands in Aotearoa–New Zealand](#)’, Landscape and Urban Planning 244 (2024).

²⁰⁷ Emmett, B.A. & the ERAMMP team, ‘[ERAMMP Report-105: Wales National Trends and Glastir Evaluation.](#)’

²⁰⁸ Nisbet, T., Silgram, M., Shah, N., Morrow, K., and Broadmeadow, S. (2011) [Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#). Forest Research Monograph, 4, Forest Research, Surrey, 156pp.

²⁰⁹ Emmett, B.A. & the ERAMMP team, ‘[ERAMMP Report-105: Wales National Trends and Glastir Evaluation.](#)’

²¹⁰ Felton et al., ‘[Farmers’ Attitudes towards, and Intentions to Adopt, Agroforestry on Farms in Lowland South-East and East England](#)’, Land Use Policy 131 (2023),;

Flack, Lukac, and Todman, ‘[Woodland Planting on UK Pasture Land Is Not Economically Feasible, yet Is More Profitable than Some Traditional Farming Practices](#)’.

²¹¹]. Wind protection was cited as a major motivator of agroforestry uptake in one EU study [footnote ²¹²].

One study (UK) found that tenants were less likely to plant trees [footnote ²¹³] because of a reluctance to make long-term commitments or changes to the land they rent. Support to reduce tenancy constraints on planting trees was suggested by one author (UK) to improve uptake among tenant farmers [footnote ²¹⁴].

Access to education, training and capacity building was mentioned by 3 studies as an important factor in encouraging farmers to create woodland on their land [footnote ²¹⁵]. The role of trusted advisors was cited by 4 studies as important in farmer uptake of tree planting [footnote ²¹⁶]. Discussions with family, friends, other farmers and business partners are an important part of the decision-making process for farmers [footnote ²¹⁷], with social norms and traditions being cited as highly influential [footnote ²¹⁸].

²⁰⁹ Felton et al., [‘Farmers’ Attitudes towards, and Intentions to Adopt, Agroforestry on Farms in Lowland South-East and East England’](#).

²¹² Veldkamp et al., [‘Multifunctionality of Temperate Alley-Cropping Agroforestry Outperforms Open Cropland and Grassland’](#).

²¹³ Ford, Bale, and Taylor, [‘The Factors Determining Uptake of Energy Crop Cultivation and Woodland Creation in England: Insights from Farmers and Landowners’](#).

²¹⁴ Westaway et al., [‘Meeting Tree Planting Targets on the UK’s Path to Net-Zero: A Review of Lessons Learnt from 100 Years of Land Use Policies’](#).

²¹⁵ Ambrose-Oji et al., [“‘We’re Farmers Not Foresters’: Farmers’ Decision-Making and Behaviours towards Managing Trees for Pests and Diseases’](#), *Forests* 13, no. 7 (2022);

Westaway et al., [Meeting Tree Planting Targets on the UK’s Path to Net-Zero: A Review of Lessons Learnt from 100 Years of Land Use Policies](#) ;

Nelson, Nelson, and Montgomery, [‘Colonisation of Farmland Deciduous Plantations by Woodland Ground Flora’](#).

²¹⁶ Ambrose-Oji et al., [“‘We’re Farmers Not Foresters’: Farmers’ Decision-Making and Behaviours towards Managing Trees for Pests and Diseases’](#);

Follett et al., [Working for the Environment: Farmer Attitudes towards Sustainable Farming Actions in Rural Wales, UK](#);

Irwin et al., [‘Increasing Tree Cover on Irish Dairy and Drystock Farms: The Main Attitudes, Influential Bodies and Barriers That Affect Agroforestry Uptake’](#);

Irwin, Dhubháin, and Short, [‘Irish Dairy and Drystock Farmers’ Attitudes and Perceptions to Planting Trees and Adopting Agroforestry Practices on Their Land’](#).

²¹⁷ Follett et al., [Working for the Environment: Farmer Attitudes towards Sustainable Farming Actions in Rural Wales, UK](#) ;

Irwin, Dhubháin, and Short, [‘Irish Dairy and Drystock Farmers’ Attitudes and Perceptions to Planting Trees and Adopting Agroforestry Practices on Their Land’](#).

²¹⁸ Irwin et al., [‘Increasing Tree Cover on Irish Dairy and Drystock Farms: The Main Attitudes, Influential Bodies and Barriers That Affect Agroforestry Uptake’](#).

Economic Impacts (47 studies)

16 studies cited negative impacts on productivity through loss of workable land for growing crops/rearing livestock [footnote ²¹⁹] and competition between trees and crops [footnote ²²⁰]. A systematic review of temperate agroforestry impacts on sheep and cattle productivity found that 53% of studies identified a negative impact of agroforestry integration on productivity [footnote ²²¹]. Another study assessed the financial impact of integrating woodland on farms and found losses were highest in high-value productive areas but lower in upland areas [footnote ²²²]. This was also the case in areas where agricultural production was highly subsidised, with transitioning to tree growing reducing input costs, meaning the leftover payout from subsidies was higher [footnote ²²³].

Additional costs of creating woodland on farms include upfront establishment costs of buying and planting trees [footnote ²²⁴] and ongoing management costs for on-farm

²¹⁹ Porton et al., '[Natural Colonisation Rates in a UK Upland Landscape under Different Conservation Management Approaches Following Sheep Removal](#)';

Spray et al., '[Land Management for Increased Flood Resilience](#)';

Bowditch, McMorran, and Smith, '[Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty](#)';

Bradfer-Lawrence et al., '[The Potential Contribution of Terrestrial Nature-Based Solutions to a National "Net Zero" Climate Target](#)';

Jordon, Winter, and Petrokofsky, '[Implications of Temperate Agroforestry on Sheep and Cattle Productivity, Environmental Impacts and Enterprise Economics. A Systematic Evidence Map](#)';

Hardaker, Bodner, and Dandy, '[Tree Planting for Climate Change: Coverage in the UK Farming Sector Press](#)', Journal of Rural Studies 94 (1 August 2022): 140–49;

Brown, '[Challenges in Delivering Climate Change Policy through Land Use Targets for Afforestation and Peatland Restoration](#)';

Irwin et al., '[Increasing Tree Cover on Irish Dairy and Drystock Farms: The Main Attitudes, Influential Bodies and Barriers That Affect Agroforestry Uptake](#)';

Crous-Duran et al., '[Modelling Tree Density Effects on Provisioning Ecosystem Services in Europe](#)', Agroforestry Systems 93, no. 5 (2019): 1985–2007;

Albanito et al., '[Agroecology – a Rapid Evidence Review](#)'. University of Aberdeen, 2022., n.d.;

Bertsch-Hoermann et al., '[Agroforestry Trade-Offs between Biomass Provision and Aboveground Carbon Sequestration in the Alpine Eisenwurzen Region, Austria](#)', Regional Environmental Change, September 2021.

²²⁰ Sprenkle-Hyppolite et al., '[Maximizing Tree Carbon in Croplands and Grazing Lands While Sustaining Yields](#)', Carbon Balance and Management 19, no. 1 (2024).

²²¹ Jordon et al., '[Implications of Temperate Agroforestry on Sheep and Cattle Productivity, Environmental Impacts and Enterprise Economics. A Systematic Evidence Map](#)', Forests 11, no. 12 (2020): 1–29

²²² Spray et al., '[Land Management for Increased Flood Resilience](#)'.

²²³ Nthambi et al., '[Economic Incentives for Woodland Creation on Farmland: Modelling the Impacts on Biodiversity](#)'.

²²⁴ Flack, Lukac, and Todman, '[Woodland Planting on UK Pasture Land Is Not Economically Feasible, yet Is More Profitable than Some Traditional Farming Practices](#)';

woodlands [footnote ²²⁵]. Additionally, several studies identified long lead times on financial return from woodland products [footnote ²²⁶], one study suggested 15 to 20 years for agroforestry systems [footnote ²²⁷], as a significant factor affecting farmers decisions to create woodland.

Several studies highlighted the possibilities for revenue creation by planting trees; these depend on location-specific valuation and market availability for the sale of products [footnote ²²⁸]:

- payment for public goods in the form of carbon sequestration [footnote ²²⁹] and biodiversity [footnote ²³⁰] credits. These are still emerging systems and based on predictive modelling, but one UK study estimated a potential payment rate of between 44 and 83 euros per hectare for carbon sequestration [footnote ²³¹]

Felton, M, P Jones, R Tranter, J Clark, T Quaife, and M Lukac. '[Farmers' Attitudes towards, and Intentions to Adopt, Agroforestry on Farms in Lowland South-East and East England](#)';

Smith et al., '[Assessing the Multidimensional Elements of Sustainability in European Agroforestry Systems](#)', Agricultural Systems 197 (2022),.

²²⁵ Spray et al., '[Land Management for Increased Flood Resilience](#)'.

²²⁶ Felton et al., '[Farmers' Attitudes towards, and Intentions to Adopt, Agroforestry on Farms in Lowland South-East and East England](#)';

Paut et al., '[How to Reconcile Short-Term and Long-Term Objectives in Mixed Farms? A Dynamic Model Application to Mixed Fruit Tree - Vegetable Systems](#)', Agricultural Systems 187 (2021),

²²⁷ Saraev et al., '[The Potential for Agroforestry to Reduce Net GHG Emissions in Scotland through the Woodland Carbon Code](#)', Climate X Change, Forest Research, 2022.

²²⁸ Smith et al., '[Assessing the Multidimensional Elements of Sustainability in European Agroforestry Systems](#)';

Kay et al., '[Spatial Similarities between European Agroforestry Systems and Ecosystem Services at the Landscape Scale](#)', Agroforestry Systems 92, no. 4 (2018): 1075–89,.

²²⁹ Hardaker, Bodner, and Dandy, '[Tree Planting for Climate Change: Coverage in the UK Farming Sector Press](#)';

Staton et al., '[Productivity, Biodiversity Trade-Offs, and Farm Income in an Agroforestry versus an Arable System](#)'.

²³⁰ Velarde Pajares et al., '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)'.

²³¹ Staton et al., '[Productivity, Biodiversity Trade-Offs, and Farm Income in an Agroforestry versus an Arable System](#)'.

- timber production for sale or personal fuelwood use [footnote ²³²]. This depends on the availability of markets and timber prices, which vary over time [footnote ²³³]
- production and sale of tree crops such as fruits and nuts [footnote ²³⁴]
- private revenue generation and local economy benefits through recreation and nature-based tourism to on-farm woodlands [footnote ²³⁵]
- premium prices for silvoarabale products, e.g. ‘free-range woodland eggs’ [footnote ²³⁶]
- the integration of trees on farms to generate revenue represents an opportunity to diversify on-farm income, providing resilience to economic changes [footnote ²³⁷].

²³² Litschel et al., ‘[Key Actors’ Perspectives on Agroforestry’s Potential in North Eastern Germany](#)’, Land 12, no. 2 (2023),;

Burton et al., ‘[Green Gold to Wild Woodlands: Understanding Stakeholder Visions for Woodland Expansion in Scotland](#)’;

Lawrence and Dandy, ‘[Private Landowners’ Approaches to Planting and Managing Forests in the UK: What’s the Evidence?](#)’;

Weston and Philip, ‘[The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?](#)’;

Beauchamp et al., ‘[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)’, 28 August 2020;

Jebari et al., ‘[Feasibility of Mitigation Measures for Agricultural Greenhouse Gas Emissions in the UK. A Systematic Review](#)’, Agronomy for Sustainable Development 44, no. 1 (2024),;

Ford, Bale, and Taylor, ‘[The Factors Determining Uptake of Energy Crop Cultivation and Woodland Creation in England: Insights from Farmers and Landowners](#)’.

²³³ Kerr, G. (2020). [ERAMMP Report-34: National Forest Evidence Annex-2](#). Report to Welsh Government (Contract C210/2016/2017)(UKCEH 06297)

²³⁴ Chapman et al., ‘[Large Climate Mitigation Potential from Adding Trees to Agricultural Lands](#)’, Global Change Biology 26, no. 8 (2020): 4357–65,;

Beauchamp et al., ‘[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)’, 28 August 2020.

²³⁵ Felton, M, P Jones, R Tranter, J Clark, T Quaife, and M Lukac. ‘[Farmers’ Attitudes towards, and Intentions to Adopt, Agroforestry on Farms in Lowland South-East and East England](#)’;

Beauchamp et al., ‘[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)’, 28 August 2020;

Sollen-Norrlin, Ghaley, and Rintoul, ‘[Agroforestry Benefits and Challenges for Adoption in Europe and Beyond](#)’;

Jebari et al., ‘[Feasibility of Mitigation Measures for Agricultural Greenhouse Gas Emissions in the UK. A Systematic Review](#)’.

²³⁶ Amir, S. ‘[Silvopoultry: Three Birds, One Stone](#)’.

²³⁷ Chapman et al., ‘[Large Climate Mitigation Potential from Adding Trees to Agricultural Lands](#)’;

Jordon, Winter, and Petrokofsky, ‘[Advantages, Disadvantages, and Reasons for Non-Adoption of Rotational Grazing, Herbal Leys, Trees on Farms and Ley-Arable Rotations on English Livestock Farms](#)’;

Integrating woodland on farms can also have indirect impacts on farm revenue by increasing the yield of crops and livestock. This is achieved through the delivery of ecosystem services including pollination [footnote ²³⁸] and microclimatic regulation – direct sheltering of livestock [footnote ²³⁹] and crops [footnote ²⁴⁰] can improve their growth and survival. One study modelling the ecosystem service benefits of afforestation in the Welsh

Jordon et al., '[Implications of Temperate Agroforestry on Sheep and Cattle Productivity, Environmental Impacts and Enterprise Economics. A Systematic Evidence Map](#)';

Weston and Philip, '[The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?](#)';

Felton, M, P Jones, R Tranter, J Clark, T Quaife, and M Lukac '[Farmers' Attitudes towards, and Intentions to Adopt, Agroforestry on Farms in Lowland South-East and East England](#)';

Staton et al., '[Productivity, Biodiversity Trade-Offs, and Farm Income in an Agroforestry versus an Arable System](#)';

Fatima et al., '[Sustainable Forestry and Environmental Impacts: Assessing the Economic, Environmental, and Social Benefits of Adopting Sustainable Agricultural Practices](#)', Ecological Frontiers 44, no. 6 (2024): 1119–27;

Albanito et al., '[Agroecology – a Rapid Evidence Review](#)'; Saraev et al., '[The Potential for Agroforestry to Reduce Net GHG Emissions in Scotland through the Woodland Carbon Code](#)'.

²³⁸ Božek et al., '[Non-Forest Woody Vegetation: A Critical Resource for Pollinators in Agricultural Landscapes—A Review](#)';

Image, Gardner, and Breeze, '[Co-Benefits from Tree Planting in a Typical English Agricultural Landscape: Comparing the Relative Effectiveness of Hedgerows, Agroforestry and Woodland Creation for Improving Crop Pollination Services](#)', 1 February 2023.

²³⁹ Jordon et al., '[Implications of Temperate Agroforestry on Sheep and Cattle Productivity, Environmental Impacts and Enterprise Economics. A Systematic Evidence Map](#)';

Ford, Bale, and Taylor, '[The Factors Determining Uptake of Energy Crop Cultivation and Woodland Creation in England: Insights from Farmers and Landowners](#)';

Velarde Pajares et al., '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)'; Smith, L Westaway, S Mullender, B B Ghaley, Y Xu, L M Lehmann, A Pisanelli, '[Assessing the Multidimensional Elements of Sustainability in European Agroforestry Systems](#)';

Amorim et al., '[Temperate Silvopastures Provide Greater Ecosystem Services than Conventional Pasture Systems](#)', Scientific Reports 13, no. 1 (2023);

Saraev et al., '[The Potential for Agroforestry to Reduce Net GHG Emissions in Scotland through the Woodland Carbon Code](#)'.

²⁴⁰ Saraev et al., '[The Potential for Agroforestry to Reduce Net GHG Emissions in Scotland through the Woodland Carbon Code](#)';

Burgess and Rosati, '[Advances in European Agroforestry: Results from the AGFORWARD Project](#)', Agroforestry Systems 92, no. 4 (1 August 2018): 801–10;

Mathieu, Cogliastro, and Rivest, '[Drivers of Tree Establishment in Planted Windbreaks and Riparian Buffers: A Case Study of Farms in Southern Quebec, Canada](#)';

Fatima et al., '[Sustainable Forestry and Environmental Impacts: Assessing the Economic, Environmental, and Social Benefits of Adopting Sustainable Agricultural Practices](#)';

Kay et al., '[Spatial Similarities between European Agroforestry Systems and Ecosystem Services at the Landscape Scale](#)'.

uplands estimated that £2.1 billion worth of ecosystem service benefits could be attributed to the sale of timber and sheltering livestock [footnote ²⁴¹].

Creating woodland on farms was also shown to save money in some cases, through reduced feed costs for livestock as on-farm trees provide extra fodder [footnote ²⁴²], reduced nutrient transfer out of productive soils, reducing the need for fertiliser application [footnote ²⁴³], and reduced labour costs associated with growing fruit trees over arable crops [footnote ²⁴⁴].

Environmental Impacts (77 studies)

The environmental impacts of woodland creation on farms identified include:

²⁴¹ Hardaker, Tim Pagella, and Mark Rayment, '[Ecosystem Service and Dis-Service Impacts of Increasing Tree Cover on Agricultural Land by Land-Sparing and Land-Sharing in the Welsh Uplands](#)', *Ecosystem Services* 48 (1 April 2021): 101253,.

²⁴² Weston and Philip, '[The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?](#)' ;

Saraev et al., '[The Potential for Agroforestry to Reduce Net GHG Emissions in Scotland through the Woodland Carbon Code](#)'.

²⁴³ Velarde Pajares et al., '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)'.

²⁴⁴ Paut et al., '[How to Reconcile Short-Term and Long-Term Objectives in Mixed Farms? A Dynamic Model Application to Mixed Fruit Tree - Vegetable Systems](#)'

- increased biodiversity [footnote ²⁴⁵] through creation of habitats for woodland plants [footnote ²⁴⁶], fungi [footnote ²⁴⁷], invertebrates [footnote ²⁴⁸] including pollinators

²⁴⁵ Miralles-Wilhelm, '[Nature-Based Solutions in Agricultural Landscapes for Reducing Tradeoffs between Food Production, Climate Change, and Conservation Objectives](#)', *Frontiers in Water* 5 (19 December 2023); Burton et al., '[Green Gold to Wild Woodlands: Understanding Stakeholder Visions for Woodland Expansion in Scotland](#)'; Watts, '[Montane Willow Scrub Restoration in Scotland: Reviewing 30 Years of Progress to Reestablish the Altitudinal Treeline](#)'; Morris and Davies, '[Drivers of Natural Colonisation and Regeneration within Planted Woodlands in England: Towards an Integrated Approach to Increase Resilience](#)'; Fletcher et al., '[The Carbon Sequestration Potential of Scottish Native Woodland](#)'; Burton et al., ; Lawrence and Dandy, '[Private Landowners' Approaches to Planting and Managing Forests in the UK: What's the Evidence?](#)'; Jordon, Winter, and Petrokofsky, '[Advantages, Disadvantages, and Reasons for Non-Adoption of Rotational Grazing, Herbal Leys, Trees on Farms and Ley-Arable Rotations on English Livestock Farms](#)'; Mathieu, Cogliastro, and Rivest, '[Drivers of Tree Establishment in Planted Windbreaks and Riparian Buffers: A Case Study of Farms in Southern Quebec, Canada](#)'; Irwin et al., '[Increasing Tree Cover on Irish Dairy and Drystock Farms: The Main Attitudes, Influential Bodies and Barriers That Affect Agroforestry Uptake](#)'; Weston and Philip, '[The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?](#)'; Markiewicz-Keszycka et al., '[Pro-Environmental Diversification of Pasture-Based Dairy and Beef Production in Ireland, the United Kingdom and New Zealand: A Scoping Review of Impacts and Challenges](#)'; Mölder, Meyer, and Nagel, '[Integrative Management to Sustain Biodiversity and Ecological Continuity in Central European Temperate Oak \(Quercus Robur, Q. Petraea\) Forests: An Overview](#)'; Burgess and Rosati, '[Advances in European Agroforestry: Results from the AGFORWARD Project](#)'.
²⁴⁶ Mölder, Meyer, and Nagel, '[Integrative Management to Sustain Biodiversity and Ecological Continuity in Central European Temperate Oak \(Quercus Robur, Q. Petraea\) Forests: An Overview](#)'.
²⁴⁷ Mölder, Meyer, and Nagel, '[Integrative Management to Sustain Biodiversity and Ecological Continuity in Central European Temperate Oak \(Quercus Robur, Q. Petraea\) Forests: An Overview](#)'; Veldkamp et al., '[Multifunctionality of Temperate Alley-Cropping Agroforestry Outperforms Open Cropland and Grassland](#)'.
²⁴⁸ Velarde Pajares et al., '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)'; Božek et al., '[Non-Forest Woody Vegetation: A Critical Resource for Pollinators in Agricultural Landscapes—A Review](#)'; Fuentes-Montemayor et al., '[The Long-Term Development of Temperate Woodland Creation Sites: From Tree Saplings to Mature Woodlands](#)'; Alison et al., '[Woodland, Cropland and Hedgerows Promote Pollinator Abundance in Intensive Grassland Landscapes, with Saturating Benefits of Flower Cover](#)'; Fuller et al., '[Local-Scale Attributes Determine the Suitability of Woodland Creation Sites for Diptera](#)', *Journal of Applied Ecology* 55, no. 3 (2018): 1173–84; Veldkamp et al., '[Multifunctionality of Temperate Alley-Cropping Agroforestry Outperforms Open Cropland and Grassland](#)'.

[footnote ²⁴⁹], birds [footnote ²⁵⁰], bats [footnote ²⁵¹] and other small mammals [footnote ²⁵²]

- woodland sites can contribute to pest control by providing habitats for biological control agents such as predators of crop pests [footnote ²⁵³]
- woodland patches, when properly sited, increase habitat connectivity and provide corridors for species dispersal [footnote ²⁵⁴]
- trees absorb air pollutants such as ammonia, contributing to improved air quality [footnote ²⁵⁵]

²⁴⁹ Bentrup et al., '[Temperate Agroforestry Systems and Insect Pollinators: A Review](#)', *Forests* 10, no. 11 (2019);

Varah et al., '[Temperate Agroforestry Systems Provide Greater Pollination Service than Monoculture](#)'; Kay et al., '[Spatial Similarities between European Agroforestry Systems and Ecosystem Services at the Landscape Scale](#)'.

²⁵⁰ Westlake, S. '[Land Use: Policies for a Net Zero UK](#)', 16 January 2020;

Edo, Entling, and Rösch, '[Agroforestry Supports High Bird Diversity in European Farmland](#)';

Fuentes-Montemayor et al., '[The Long-Term Development of Temperate Woodland Creation Sites: From Tree Saplings to Mature Woodlands](#)'.

²⁵¹ Fuentes-Montemayor et al., '[The Long-Term Development of Temperate Woodland Creation Sites: From Tree Saplings to Mature Woodlands](#)'.

²⁵² Fuentes-Montemayor et al.; Fuentes-Montemayor et al., '[Small Mammal Responses to Long-Term Large-Scale Woodland Creation: The Influence of Local and Landscape-Level Attributes](#)'.

²⁵³ Velarde Pajares et al., '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)'; Perks et al., '[Agroforestry in Scotland – Potential Benefits in a Changing Climate](#)', 2018,

²⁵⁴ Baggio-Compagnucci et al., '[Barking up the Wrong Tree? Can Forest Expansion Help Meet Climate Goals?](#)';

Božek et al., '[Non-Forest Woody Vegetation: A Critical Resource for Pollinators in Agricultural Landscapes—A Review](#)';

Image, Gardner, and Breeze, '[Co-Benefits from Tree Planting in a Typical English Agricultural Landscape: Comparing the Relative Effectiveness of Hedgerows, Agroforestry and Woodland Creation for Improving Crop Pollination Services](#)';

Fuentes-Montemayor et al., '[The Long-Term Development of Temperate Woodland Creation Sites: From Tree Saplings to Mature Woodlands](#)';

Miralles-Wilhelm, '[Nature-Based Solutions in Agricultural Landscapes for Reducing Tradeoffs between Food Production, Climate Change, and Conservation Objectives](#)';

Westlake, S. '[Land Use: Policies for a Net Zero UK](#)', 16 January 2020.

²⁵⁵ Velarde Pajares et al., '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)';

Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)';

Jones et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 8: Improving Air Quality and Well-Being. Sustainable Farming Scheme. Evidence Review](#)';

Westlake, S. '[Land Use: Policies for a Net Zero UK](#)', 16 January 2020;

- on-farm woodland plays a role in absorbing and cycling nutrients from agricultural soils, preventing nutrient pollution [footnote ²⁵⁶] and feeding the soil microbiome [footnote ²⁵⁷]. Tree roots stabilise the soil [footnote ²⁵⁸], preventing soil erosion and sediment deposition into watercourses [footnote ²⁵⁹]

Nisbet, T., Silgram, M., Shah, N., Morrow, K., and Broadmeadow, S. (2011) [Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#). Forest Research Monograph, 4, Forest Research, Surrey, 156pp.

²⁵⁶ Kay et al., '[Spatial Similarities between European Agroforestry Systems and Ecosystem Services at the Landscape Scale](#)';

Giannitsopoulos et al., '[Whole System Valuation of Arable, Agroforestry and Tree-Only Systems at Three Case Study Sites in Europe](#)', Journal of Cleaner Production 269 (2020);

Stiles, W. '[Are Riparian Buffer Strips an Opportunity to Increase Tree Cover on UK Farms Whilst Simultaneously Reducing the Impact of Agricultural Pollution?](#)';

Pedersen, Schmidt, and Kepfer-Rojas, '[Drivers of Tree Colonization, Species Richness, and Structural Variation during the Initial Three Decades of Natural Forest Colonization in Abandoned Agricultural Soils](#)';

Mathieu, Cogliastro, and Rivest, '[Drivers of Tree Establishment in Planted Windbreaks and Riparian Buffers: A Case Study of Farms in Southern Quebec, Canada](#)';

Markiewicz-Keszycka et al., '[Pro-Environmental Diversification of Pasture-Based Dairy and Beef Production in Ireland, the United Kingdom and New Zealand: A Scoping Review of Impacts and Challenges](#)';

Velarde Pajares et al., '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)';

Adams and Johnston, '[Evaluating the Impacts of SRC Willows on Phosphorus Export from a Temperate Grassland Micro-Catchment](#)';

Livingstone et al., '[Life Cycle Assessment of a Short-Rotation Coppice Willow Riparian Buffer Strip for Farm Nutrient Mitigation and Renewable Energy Production](#)';

Sollen-Norrin, Ghaley, and Rintoul, '[Agroforestry Benefits and Challenges for Adoption in Europe and Beyond](#)';

García de Jalón et al., '[Modelling and Valuing the Environmental Impacts of Arable, Forestry and Agroforestry Systems: A Case Study](#)', Agroforestry Systems 92, no. 4 (2018): 1059–73;

Nisbet, T., Silgram, M., Shah, N., Morrow, K., and Broadmeadow, S. (2011) [Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#). Forest Research Monograph, 4, Forest Research, Surrey, 156pp.

²⁵⁷ Westlake, S. '[Land Use: Policies for a Net Zero UK](#)', 16 January 2020,.

²⁵⁸ Mathieu, Cogliastro, and Rivest, '[Drivers of Tree Establishment in Planted Windbreaks and Riparian Buffers: A Case Study of Farms in Southern Quebec, Canada](#)';

Pedersen, Schmidt, and Kepfer-Rojas, '[Drivers of Tree Colonization, Species Richness, and Structural Variation during the Initial Three Decades of Natural Forest Colonization in Abandoned Agricultural Soils](#)';

Jordon, Winter, and Petrokofsky, '[Advantages, Disadvantages, and Reasons for Non-Adoption of Rotational Grazing, Herbal Leys, Trees on Farms and Ley-Arable Rotations on English Livestock Farms](#)';

Stiles, W. '[Are Riparian Buffer Strips an Opportunity to Increase Tree Cover on UK Farms Whilst Simultaneously Reducing the Impact of Agricultural Pollution?](#)'

²⁵⁹ Jordon et al., '[Implications of Temperate Agroforestry on Sheep and Cattle Productivity, Environmental Impacts and Enterprise Economics. A Systematic Evidence Map](#)';

Baggio-Compagnucci et al., '[Barking up the Wrong Tree? Can Forest Expansion Help Meet Climate Goals?](#)';

Stiles, W. '[Are Riparian Buffer Strips an Opportunity to Increase Tree Cover on UK Farms Whilst Simultaneously Reducing the Impact of Agricultural Pollution?](#)';

Cooper et al., '[Role of Forested Land for Natural Flood Management in the UK: A Review](#)';

- lines of trees and woodland patches can act as buffers for pollutants and pesticides from agricultural activity, preventing their spread in the landscape [footnote ²⁶⁰]
- on-farm woodland contributes to flood mitigation through increased water storage and reduced peak flows [footnote ²⁶¹]

Markiewicz-Keszycka et al., [‘Pro-Environmental Diversification of Pasture-Based Dairy and Beef Production in Ireland, the United Kingdom and New Zealand: A Scoping Review of Impacts and Challenges’](#);

Velarde Pajares et al., [‘Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms’](#);

Scottish Forestry. [‘Woodland Expansion Advisory Group - June 2012’](#)

Beauchamp et al., [‘Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services’](#);

Litschel et al., [‘Key Actors’ Perspectives on Agroforestry’s Potential in North Eastern Germany’](#);

Kay et al., [‘Spatial Similarities between European Agroforestry Systems and Ecosystem Services at the Landscape Scale’](#);

García de Jalón et al., [‘Modelling and Valuing the Environmental Impacts of Arable, Forestry and Agroforestry Systems: A Case Study’](#);

Cutress, David. [‘Agroforestry Options’](#);

Nisbet, T., Silgram, M., Shah, N., Morrow, K., and Broadmeadow, S. (2011) [Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#). Forest Research Monograph, 4, Forest Research, Surrey, 156pp.

²⁶⁰ Beauchamp et al., [‘Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services’](#), 28 August 2020;

Božek et al., [“Non-Forest Woody Vegetation: A Critical Resource for Pollinators in Agricultural Landscapes—A Review”](#).

²⁶¹ Hardaker, Pagella, and Rayment, [‘Ecosystem Service and Dis-Service Impacts of Increasing Tree Cover on Agricultural Land by Land-Sparing and Land-Sharing in the Welsh Uplands’](#);

Keenleyside and Old, [‘Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 9: Flood Mitigation. Sustainable Farming Scheme Evidence Review’](#);

Cooper et al., [‘Role of Forested Land for Natural Flood Management in the UK: A Review’](#);

Burke et al., [‘Spatially Targeting National-Scale Afforestation for Multiple Ecosystem Services’](#);

Burton et al., [‘Green Gold to Wild Woodlands; Understanding Stakeholder Visions for Woodland Expansion in Scotland’](#); Burton et al.,

- lines of trees and woodland provide shelter and regulate the microclimate [footnote ²⁶²], protecting crops and livestock and contributing to improved animal welfare outcomes [footnote ²⁶³]

²⁶² Sprenkle-Hyppolite et al., [‘Maximizing Tree Carbon in Croplands and Grazing Lands While Sustaining Yields’](#);

Weston and Philip, [The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland? ‘Increasing Tree Cover on Irish Dairy and Drystock Farms: The Main Attitudes, Influential Bodies and Barriers That Affect Agroforestry Uptake’](#);

Baggio-Compagnucci et al., [‘Barking up the Wrong Tree? Can Forest Expansion Help Meet Climate Goals?’](#); Scottish Forestry. [‘Woodland Expansion Advisory Group - June 2012’](#);

Litschel et al., [‘Key Actors’ Perspectives on Agroforestry’s Potential in North Eastern Germany’](#);

Veldkamp et al., [‘Multifunctionality of Temperate Alley-Cropping Agroforestry Outperforms Open Cropland and Grassland’](#);

Georgie, [‘Can Silvo-Pastoral Agroforestry Systems Contribute to Scotland’s Emission Reduction Targets?’](#);

Ghaffariyan, [‘Silvopastoral Systems as a Strategy for Drought Resilience: A Short International Review’](#), Silva Balcanica 26, no. 1 (6 January 2025): 29–37,;

Cooper et al., [‘Role of Forested Land for Natural Flood Management in the UK: A Review’](#);

Lawrence and Dandy, [‘Private Landowners’ Approaches to Planting and Managing Forests in the UK: What’s the Evidence?’](#);

Božek et al., [‘Non-Forest Woody Vegetation: A Critical Resource for Pollinators in Agricultural Landscapes—A Review’](#)..

²⁶³ Jordon, Winter, and Petrokofsky, [‘Advantages, Disadvantages, and Reasons for Non-Adoption of Rotational Grazing, Herbal Leys, Trees on Farms and Ley-Arable Rotations on English Livestock Farms’](#);

Burgess and Rosati, [‘Advances in European Agroforestry: Results from the AGFORWARD Project’](#);

Westlake, S. [‘Land Use: Policies for a Net Zero UK’](#), 16 January 2020,.

- on-farm trees and woodland contribute to carbon sequestration via direct absorption of carbon dioxide [footnote ²⁶⁴] and methane [footnote ²⁶⁵] and through improved soil organic carbon storage [footnote ²⁶⁶]. Several studies have attempted to quantify the carbon sequestration potential of woodland creation on agricultural land. A global study estimated that increasing tree cover in 2.6 billion hectares of agricultural landscape could remove up to 3.3 billion tons of CO₂ per year [footnote ²⁶⁷]. A review

²⁶⁴ Jebari et al., '[Feasibility of Mitigation Measures for Agricultural Greenhouse Gas Emissions in the UK. A Systematic Review](#)';

Fatima et al., '[Sustainable Forestry and Environmental Impacts: Assessing the Economic, Environmental, and Social Benefits of Adopting Sustainable Agricultural Practices](#)';

Irwin et al., '[Increasing Tree Cover on Irish Dairy and Drystock Farms: The Main Attitudes, Influential Bodies and Barriers That Affect Agroforestry Uptake](#)';

Chapman et al., '[Large Climate Mitigation Potential from Adding Trees to Agricultural Lands](#)';

Bradfer-Lawrence et al., '[The Potential Contribution of Terrestrial Nature-Based Solutions to a National "Net Zero" Climate Target](#)';

Fletcher et al., '[The Carbon Sequestration Potential of Scottish Native Woodland](#)';

Burton et al., '[Green Gold to Wild Woodlands: Understanding Stakeholder Visions for Woodland Expansion in Scotland](#)';

O'Neill et al., '[Forest Regeneration on European Sheep Pasture Is an Economically Viable Climate Change Mitigation Strategy](#)';

Sutherland and Huttunen, '[Linking Practices of Multifunctional Forestry to Policy Objectives: Case Studies in Finland and the UK](#)';

Hardaker, Pagella, and Rayment, '[Ecosystem Service and Dis-Service Impacts of Increasing Tree Cover on Agricultural Land by Land-Sparing and Land-Sharing in the Welsh Uplands](#)';

Giannitsopoulos et al., '[Whole System Valuation of Arable, Agroforestry and Tree-Only Systems at Three Case Study Sites in Europe](#)';

K. Golicz et al., '[The Role of Small Woody Landscape Features and Agroforestry Systems for National Carbon Budgeting in Germany](#)', Land 10, no. 10 (2021);

Veldkamp et al., '[Multifunctionality of Temperate Alley-Cropping Agroforestry Outperforms Open Cropland and Grassland](#)';

Perks et al., '[Agroforestry in Scotland – Potential Benefits in a Changing Climate](#)'.

²⁶⁵ G. Shao et al., '[Conversion of Cropland Monoculture to Agroforestry Increases Methane Uptake](#)', Agronomy for Sustainable Development 45, no. 1 (2025),.

²⁶⁶ Bertsch-Hoermann et al., '[Agroforestry Trade-Offs between Biomass Provision and Aboveground Carbon Sequestration in the Alpine Eisenwurzen Region, Austria](#)';

Alison et al., '[Environment and Rural Affairs Monitoring & Modelling Programme \(ERAMMP\) - Technical Annex 3: Soil Carbon Management. Sustainable Farming Scheme Evidence Review.](#)';

Amorim et al., '[Temperate Silvopastures Provide Greater Ecosystem Services than Conventional Pasture Systems](#)';

Kay et al., '[Spatial Similarities between European Agroforestry Systems and Ecosystem Services at the Landscape Scale](#)';

Jebari et al., '[Feasibility of Mitigation Measures for Agricultural Greenhouse Gas Emissions in the UK. A Systematic Review](#)';

Saraev et al., '[The Potential for Agroforestry to Reduce Net GHG Emissions in Scotland through the Woodland Carbon Code](#)'.

²⁶⁷ Sprenkle-Hyppolite et al., '[Maximizing Tree Carbon in Croplands and Grazing Lands While Sustaining Yields](#)', Carbon Balance and Management 19, no. 1 (2024),.

of climate mitigation potential for Wales suggests that woodland creation could mitigate between 1 and 3.5 tonnes of CO₂e per hectare planted [footnote ²⁶⁸]

- one UK study highlighted the potential negative impact of woodland creation on farms where ground-nesting birds are present, the study found that woodland creation negatively impacts Curlew density and activity. The study suggests that proximity to woodland patches increases predation pressure on ground nesting birds, potentially impacting on breeding success and/or causing avoidance of those areas. The appropriateness of woodland creation should therefore be carefully considered in agricultural landscapes supporting vulnerable ground-nesting birds species such as Curlew [footnote ²⁶⁹].

Social Impacts (21 studies)

The positive social impacts of woodland creation identified in the evidence base include:

- improvements to the aesthetic value of farmland landscapes [footnote ²⁷⁰], which can have knock-on impacts of increased tourism [footnote ²⁷¹]
- several studies highlighted the importance of trees for their cultural value in the landscape, encouraging connection to place for farmers and locals [footnote ²⁷²]
- woodlands on farms can be used as sites of recreation and education [footnote ²⁷³]

²⁶⁸ Matthews, R. (2020). Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP). [ERAMMP Report-36: National Forest in Wales - Evidence Review Annex-4: Climate Change Mitigation](#). Report to Welsh Government (Contract C210/2016/2017)(UK Centre for Ecology & Hydrology Project 06297).

²⁶⁹ McGrory et al., '[Impacts of Forest Extent, Configuration and Landscape Context on Presence of Declining Breeding Eurasian Curlew Numenius Arquata and Implications for Planning New Woodland](#)'.

²⁷⁰ Ford, Bale, and Taylor, '[The Factors Determining Uptake of Energy Crop Cultivation and Woodland Creation in England: Insights from Farmers and Landowners](#)';

²⁷¹ Velarde Pajares et al., '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)'.

²⁷² Bowditch, McMorran, and Smith, '[Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty](#)';

Jordon, Winter, and Petrokofsky, '[Advantages, Disadvantages, and Reasons for Non-Adoption of Rotational Grazing, Herbal Leys, Trees on Farms and Ley-Arable Rotations on English Livestock Farms](#)';

Elbakidze et al., '[Perceived Benefits from Agroforestry Landscapes across North-Eastern Europe: What Matters and for Whom?](#)';

Smith et al., '[Assessing the Multidimensional Elements of Sustainability in European Agroforestry Systems](#)'.

²⁷³ Lawrence and Dandy, '[Private Landowners' Approaches to Planting and Managing Forests in the UK: What's the Evidence?](#)';

- the presence of trees and woodlands are cited as having benefits for both physical and mental health [footnote ²⁷⁴]
- for those who visit and/or manage woodlands as community groups, they can have positive impacts in terms of community cohesion and resilience [footnote ²⁷⁵]
- woodland contribution to flood mitigation can have downstream positive impacts on communities and private property owners [footnote ²⁷⁶]
- however, the addition of trees to agricultural landscapes can negatively impact farmers by threatening their identity as food producers, as growing and managing woodlands can be seen as opposing food production [footnote ²⁷⁷].

Scottish Forestry. '[Woodland Expansion Advisory Group - June 2012](#)';

Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)', 28 August 2020;

Kreitzman et al., '[Local Knowledge and Relational Values of Midwestern Woody Perennial Polyculture Farmers Can Inform Tree-Crop Policies](#)', *People and Nature* 4, no. 1 (2022): 180–200,.

²⁷⁴ Fletcher et al., '[The Carbon Sequestration Potential of Scottish Native Woodland](#)';

Burke et al., '[Spatially Targeting National-Scale Afforestation for Multiple Ecosystem Services](#)';

Velarde Pajares et al., '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)';

Scottish Forestry. '[Woodland Expansion Advisory Group - June 2012](#)';

Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)';

Hall, C. et al. (2021). '[ERAMMP Report-54: National Forest in Wales Evidence Review Annex-8: Benefits to Society](#)'. Report to Welsh Government (Contract C210/2016/2017) (UKCEH 06297/06810).

²⁷⁵ 'Woodland Expansion Advisory Group - June 2012'; Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)';

Hall, C. et al. (2021). '[ERAMMP Report-54: National Forest in Wales Evidence Review Annex-8: Benefits to Society](#)'. Report to Welsh Government (Contract C210/2016/2017) (UKCEH 06297/06810).

²⁷⁶ Cooper et al., '[Role of Forested Land for Natural Flood Management in the UK: A Review](#)'.

²⁷⁷ O'Neill et al., '[Forest Regeneration on European Sheep Pasture Is an Economically Viable Climate Change Mitigation Strategy](#)';

Lawrence and Dandy, '[Private Landowners' Approaches to Planting and Managing Forests in the UK: What's the Evidence?](#)';

Bradfer-Lawrence et al., '[The Potential Contribution of Terrestrial Nature-Based Solutions to a National "Net Zero" Climate Target](#)'.

Barriers (49 studies)

Environmental barriers:

A range of potential environmental barriers were identified in the evidence considered, including the following:

- both UK and European studies highlight that natural regeneration is limited by the local availability of seed sources from existing on-farm woodland [footnote ²⁷⁸]
- ecological lead times for woodland creation are long, meaning the environmental or ecosystems service benefits can take time to be seen, impacting on farmer motivation to create and maintain woodlands [footnote ²⁷⁹]
- woodland creation may be restricted in protected landscapes to preserve their ecological integrity [footnote ²⁸⁰] and in peaty habitats, where natural regeneration is hindered by a lack of seed sources and competition from grasses. Tree planting in peaty soils can lead to a loss of soil carbon and produce net emissions [footnote ²⁸¹]
- woodland creation may introduce novel pests and diseases to farm ecosystems [footnote ²⁸²]
- the soil and climatic conditions on a farm may not be suitable for tree growth, potentially leading to planting failure [footnote ²⁸³].

²⁷⁸ Watts, '[Montane Willow Scrub Restoration in Scotland: Reviewing 30 Years of Progress to Reestablish the Altitudinal Treeline](#)';

Fletcher et al., '[The Carbon Sequestration Potential of Scottish Native Woodland](#)';

Mölder, Meyer, and Nagel, '[Integrative Management to Sustain Biodiversity and Ecological Continuity in Central European Temperate Oak \(Quercus Robur, Q. Petraea\) Forests: An Overview](#)';

Fuller et al., '[Local-Scale Attributes Determine the Suitability of Woodland Creation Sites for Diptera](#)'.

²⁷⁹ Fuller et al., '[Local-Scale Attributes Determine the Suitability of Woodland Creation Sites for Diptera](#)';

Hughes et al., '[Spatial Targeting of Woodland Creation Can Reduce the Colonisation Credit of Woodland Plants](#)'.

²⁸⁰ Ford, Bale, and Taylor, '[The Factors Determining Uptake of Energy Crop Cultivation and Woodland Creation in England: Insights from Farmers and Landowners](#)'.

²⁸¹ Fletcher et al., '[The Carbon Sequestration Potential of Scottish Native Woodland](#)'.

²⁸² Bowditch, McMorran, and Smith, '[Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty](#)'.

²⁸³ Lawrence and Dandy, '[Private Landowners' Approaches to Planting and Managing Forests in the UK: What's the Evidence?](#)';

Social barriers:

Potential social barriers were also identified in the evidence reviewed, including the following:

- several studies highlighted a general negative attitude towards woodland creation from British farmers [footnote ²⁸⁴]. This was commonly attributed to perceptions of woodland creation as negatively impacting on a farmer's identity as a food producer [footnote ²⁸⁵]

Weston and Philip, [The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?](#); Fatima et al., [‘Sustainable Forestry and Environmental Impacts: Assessing the Economic, Environmental, and Social Benefits of Adopting Sustainable Agricultural Practices’](#).

²⁸⁴ Burton et al., [‘Green Gold to Wild Woodlands; Understanding Stakeholder Visions for Woodland Expansion in Scotland?’](#)

²⁸⁵ Irwin et al., [‘Increasing Tree Cover on Irish Dairy and Drystock Farms: The Main Attitudes, Influential Bodies and Barriers That Affect Agroforestry Uptake’](#);

Flack, Lukac, and Todman, [‘Woodland Planting on UK Pasture Land Is Not Economically Feasible, yet Is More Profitable than Some Traditional Farming Practices’](#);

Brown, [‘Challenges in Delivering Climate Change Policy through Land Use Targets for Afforestation and Peatland Restoration’](#);

Weston and Philip, [The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?](#);

Felton et al [‘Farmers’ Attitudes towards, and Intentions to Adopt, Agroforestry on Farms in Lowland South-East and East England’](#);

Burke et al., [‘Spatially Targeting National-Scale Afforestation for Multiple Ecosystem Services’](#);

Sutherland and Huttunen, [‘Linking Practices of Multifunctional Forestry to Policy Objectives: Case Studies in Finland and the UK’](#);

Fatima et al., [‘Sustainable Forestry and Environmental Impacts: Assessing the Economic, Environmental, and Social Benefits of Adopting Sustainable Agricultural Practices’](#);

Saraev et al., [‘The Potential for Agroforestry to Reduce Net GHG Emissions in Scotland through the Woodland Carbon Code’](#).

- several studies highlighted farmer reluctance to commit to a permanent land use change which would reduce flexibility in the future [footnote ²⁸⁶], especially in relation to their inheritors [footnote ²⁸⁷]
- difficulties around the application process for woodland creation grants [footnote ²⁸⁸] were cited by multiple studies from the UK, Europe and New Zealand
- grants were also highlighted for their impact on farmer autonomy [footnote ²⁸⁹], with some grant requirements restricting what species farmers could plant and in what locations; this was cited as a barrier in 4 UK-based studies [footnote ²⁹⁰]

²⁸⁶ Ford, Bale, and Taylor, [‘The Factors Determining Uptake of Energy Crop Cultivation and Woodland Creation in England: Insights from Farmers and Landowners’](#);

Jordon, Winter, and Petrokofsky, [‘Advantages, Disadvantages, and Reasons for Non-Adoption of Rotational Grazing, Herbal Leys, Trees on Farms and Ley-Arable Rotations on English Livestock Farms’](#);

Brown, [‘Challenges in Delivering Climate Change Policy through Land Use Targets for Afforestation and Peatland Restoration’](#);

Irwin et al., [‘Increasing Tree Cover on Irish Dairy and Drystock Farms: The Main Attitudes, Influential Bodies and Barriers That Affect Agroforestry Uptake’](#);

Irwin, Dhubháin, and Short, [‘Irish Dairy and Drystock Farmers’ Attitudes and Perceptions to Planting Trees and Adopting Agroforestry Practices on Their Land’](#);

Burke et al., [‘Spatially Targeting National-Scale Afforestation for Multiple Ecosystem Services’](#);

O’Neill et al., [‘Forest Regeneration on European Sheep Pasture Is an Economically Viable Climate Change Mitigation Strategy’](#).

²⁸⁷ Markiewicz-Keszycka et al., [‘Pro-Environmental Diversification of Pasture-Based Dairy and Beef Production in Ireland, the United Kingdom and New Zealand: A Scoping Review of Impacts and Challenges’](#).

²⁸⁸ Ford, Bale, and Taylor, [‘The Factors Determining Uptake of Energy Crop Cultivation and Woodland Creation in England: Insights from Farmers and Landowners’](#);

Hardaker, Bodner, and Dandy, [‘Tree Planting for Climate Change: Coverage in the UK Farming Sector Press’](#);

O’Neill et al., [‘Forest Regeneration on European Sheep Pasture Is an Economically Viable Climate Change Mitigation Strategy’](#);

Kaine et al., [‘Who Knew Afforestation Was Such a Challenge? Motivations and Impediments to Afforestation Policy in New Zealand’](#);

Westaway, Sally, Ian Grange, Jo Smith, and Laurence G Smith. [‘Meeting Tree Planting Targets on the UK’s Path to Net-Zero: A Review of Lessons Learnt from 100 Years of Land Use Policies’](#);

Burke et al., [‘Spatially Targeting National-Scale Afforestation for Multiple Ecosystem Services’](#);

Litschel et al., [‘Key Actors’ Perspectives on Agroforestry’s Potential in North Eastern Germany’](#).

²⁸⁹ Sutherland and Huttunen, [‘Linking Practices of Multifunctional Forestry to Policy Objectives: Case Studies in Finland and the UK’](#);

Follett et al., [‘Working for the Environment: Farmer Attitudes towards Sustainable Farming Actions in Rural Wales, UK’](#).

²⁹⁰ Irwin, Dhubháin, and Short, [‘Irish Dairy and Drystock Farmers’ Attitudes and Perceptions to Planting Trees and Adopting Agroforestry Practices on Their Land’](#);

Weston and Philip, [‘The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?’](#);

- multiple studies, including several UK-based as well as global, highlighted that farmers are restricted in undertaking woodland creation by a lack of knowledge, skills, time and labour resource for woodland creation and management methods [footnote ²⁹¹]
- one study (UK) suggested that farmers can be sceptical of the environmental benefits delivered by planting trees [footnote ²⁹²].

Economic barriers:

A number of economic barriers were identified in the evidence reviewed, including the following:

Jordon, Winter, and Petrokofsky, '[Advantages, Disadvantages, and Reasons for Non-Adoption of Rotational Grazing, Herbal Leys, Trees on Farms and Ley-Arable Rotations on English Livestock Farms](#)';
 Ford, Bale, and Taylor, '[The Factors Determining Uptake of Energy Crop Cultivation and Woodland Creation in England: Insights from Farmers and Landowners](#)'.

²⁹¹ Keenleyside and Old, '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 9: Flood Mitigation. Sustainable Farming Scheme Evidence Review](#)';

Weston and Philip, '[The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?](#)';
 Bowditch, McMorran, and Smith, '[Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty](#)';

Lawrence and Dandy, '[Private Landowners' Approaches to Planting and Managing Forests in the UK: What's the Evidence?](#)';

Mathieu, Cogliastro, and Rivest, '[Drivers of Tree Establishment in Planted Windbreaks and Riparian Buffers: A Case Study of Farms in Southern Quebec, Canada](#)';

Irwin, Dhubháin, and Short, '[Irish Dairy and Drystock Farmers' Attitudes and Perceptions to Planting Trees and Adopting Agroforestry Practices on Their Land](#)';

Velarde Pajares et al., '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)';

Castle et al., '[Evidence for the Impacts of Agroforestry on Ecosystem Services and Human Well-Being in High-Income Countries: A Systematic Map](#)', Environmental Evidence 11, no. 1 (2022);

Litschel et al., '[Key Actors' Perspectives on Agroforestry's Potential in North Eastern Germany](#)';

Fatima et al., '[Sustainable Forestry and Environmental Impacts: Assessing the Economic, Environmental, and Social Benefits of Adopting Sustainable Agricultural Practices](#)'.

²⁹² Iversen et al., '[Why Understanding Stakeholder Perspectives and Emotions Is Important in Upland Woodland Creation – A Case Study from Cumbria, UK](#)'.

- upfront costs of creation woodland were cited in several articles [footnote ²⁹³]. These costs include fencing to protect newly planted saplings [footnote ²⁹⁴] and employing external labour and expertise for planning, planting and managing woodlands [footnote ²⁹⁵]. 2 (UK) studies suggested that woodland creation grants were insufficient to mitigate these costs [footnote ²⁹⁶]
- 2 studies, one UK and one European, highlighted that grants were often not available for planting at lower densities, as is often required for agroforestry systems [footnote ²⁹⁷]

²⁹³ Georgie, '[Can Silvo-Pastoral Agroforestry Systems Contribute to Scotland's Emission Reduction Targets?](#)'; Polyakov et al., '[Evaluating Incentives to Encourage Native Afforestation on Private Lands in Aotearoa–New Zealand](#)';

Velarde Pajares et al., '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)';

Beauchamp et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)', 28 August 2020;

Kreitzman et al., '[Local Knowledge and Relational Values of Midwestern Woody Perennial Polyculture Farmers Can Inform Tree-Crop Policies](#)';

Litschel et al., '[Key Actors' Perspectives on Agroforestry's Potential in North Eastern Germany](#)';

Sollen-Norrin, Ghaley, and Rintoul, '[Agroforestry Benefits and Challenges for Adoption in Europe and Beyond](#)';

Veldkamp et al., '[Multifunctionality of Temperate Alley-Cropping Agroforestry Outperforms Open Cropland and Grassland](#)'.

²⁹⁴ Georgie, '[Can Silvo-Pastoral Agroforestry Systems Contribute to Scotland's Emission Reduction Targets?](#)';

Weston and Philip, '[The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?](#)';

Stiles, W. '[Are Riparian Buffer Strips an Opportunity to Increase Tree Cover on UK Farms Whilst Simultaneously Reducing the Impact of Agricultural Pollution?](#)'

²⁹⁵ Weston and Philip, '[The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?](#)';

Kaine et al., '[Who Knew Afforestation Was Such a Challenge? Motivations and Impediments to Afforestation Policy in New Zealand](#)';

O'Neill et al., '[Forest Regeneration on European Sheep Pasture Is an Economically Viable Climate Change Mitigation Strategy](#)'.

²⁹⁶ Lawrence and Dandy, '[Private Landowners' Approaches to Planting and Managing Forests in the UK: What's the Evidence?](#)';

Jordon, Winter, and Petrokofsky, '[Advantages, Disadvantages, and Reasons for Non-Adoption of Rotational Grazing, Herbal Leys, Trees on Farms and Ley-Arable Rotations on English Livestock Farms](#)'.

²⁹⁷ Giannitsopoulos et al., '[Whole System Valuation of Arable, Agroforestry and Tree-Only Systems at Three Case Study Sites in Europe](#)';

Westaway et al., '[Meeting Tree Planting Targets on the UK's Path to Net-Zero: A Review of Lessons Learnt from 100 Years of Land Use Policies](#)'

- several studies highlighted farmer reluctance to sacrifice ‘good’ or productive land for planting trees due to the potential loss of yield [footnote ²⁹⁸]
- long lead times for financial return on woodland products [footnote ²⁹⁹] and uncertainty or lack of markets for woodland products [footnote ³⁰⁰] were cited as barriers
- several studies identified land tenure security as a factor affecting uptake, with tenant farmers finding it more difficult to plant trees on their land and having to consult with landowners to make changes [footnote ³⁰¹].

²⁹⁸ Baggio-Compagnucci et al., [‘Barking up the Wrong Tree? Can Forest Expansion Help Meet Climate Goals?’](#);

Bowditch, McMorran, and Smith, [‘Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty’](#);

Hardaker, [‘Is Forestry Really More Profitable than Upland Farming? A Historic and Present Day Farm Level Economic Comparison of Upland Sheep Farming and Forestry in the UK’](#);

Stiles, W. [‘Are Riparian Buffer Strips an Opportunity to Increase Tree Cover on UK Farms Whilst Simultaneously Reducing the Impact of Agricultural Pollution?’](#);

Burke et al., [‘Spatially Targeting National-Scale Afforestation for Multiple Ecosystem Services’](#).

²⁹⁹ Ford, Bale, and Taylor, [‘The Factors Determining Uptake of Energy Crop Cultivation and Woodland Creation in England: Insights from Farmers and Landowners’](#);

Bowditch, McMorran, and Smith, [‘Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty’](#);

Brown, [‘Challenges in Delivering Climate Change Policy through Land Use Targets for Afforestation and Peatland Restoration’](#);

Felton et al., [‘Farmers’ Attitudes towards, and Intentions to Adopt, Agroforestry on Farms in Lowland South-East and East England’](#);

Burke et al., [‘Spatially Targeting National-Scale Afforestation for Multiple Ecosystem Services’](#);

Staton et al., [‘Productivity, Biodiversity Trade-Offs, and Farm Income in an Agroforestry versus an Arable System’](#);

Ghaffariyan, [‘Silvopastoral Systems as a Strategy for Drought Resilience: A Short International Review’](#).

³⁰⁰ Sollen-Norrlin, Ghaley, and Rintoul, [‘Agroforestry Benefits and Challenges for Adoption in Europe and Beyond’](#);

Smith et al., [‘Assessing the Multidimensional Elements of Sustainability in European Agroforestry Systems’](#);

Veldkamp et al., [‘Multifunctionality of Temperate Alley-Cropping Agroforestry Outperforms Open Cropland and Grassland’](#);

Fatima et al., [‘Sustainable Forestry and Environmental Impacts: Assessing the Economic, Environmental, and Social Benefits of Adopting Sustainable Agricultural Practices’](#).

³⁰¹ Brown, [‘Challenges in Delivering Climate Change Policy through Land Use Targets for Afforestation and Peatland Restoration’](#);

Follett et al., [‘Working for the Environment: Farmer Attitudes towards Sustainable Farming Actions in Rural Wales, UK’](#);

Weston and Philip, [‘The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?’](#);

Fatima et al., [‘Sustainable Forestry and Environmental Impacts: Assessing the Economic, Environmental, and Social Benefits of Adopting Sustainable Agricultural Practices’](#).

Evidence Gaps (31 studies)

With respect to woodland creation on farms, the following research gaps in the literature reviewed were identified:

- long-term monitoring of the impacts of farmland woodland on flood mitigation, especially in reference to peak flows [footnote ³⁰²]
- the impacts of woodland creation on air pollution mitigation, specifically where best to plant for greatest impact [footnote ³⁰³]
- research into more mature woodland creation sites and whether they can replicate structural diversity and resilience of old-growth woodlands [footnote ³⁰⁴]
- the role of scrub colonisation in planted woodlands and its impact on tree seedlings [footnote ³⁰⁵]
- data on the carbon sequestration potential of woodlands of different soil types, age and species composition [footnote ³⁰⁶]

³⁰² Cooper et al., '[Role of Forested Land for Natural Flood Management in the UK: A Review](#)'; C. B. Keenleyside and G. H. Old, '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 9: Flood Mitigation. Sustainable Farming Scheme Evidence Review](#)',

³⁰³ Jones et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 8: Improving Air Quality and Well-Being. Sustainable Farming Scheme. Evidence Review](#)'.

³⁰⁴ Waddell et al., '[Larger and Structurally Complex Woodland Creation Sites Provide Greater Benefits for Woodland Plants](#)';

Fuentes-Montemayor et al., '[The Long-Term Development of Temperate Woodland Creation Sites: From Tree Saplings to Mature Woodlands](#)';

Bertsch-Hoermann et al., '[Agroforestry Trade-Offs between Biomass Provision and Aboveground Carbon Sequestration in the Alpine Eisenwurzen Region, Austria](#)'.

³⁰⁵ Morris and Davies, '[Drivers of Natural Colonisation and Regeneration within Planted Woodlands in England: Towards an Integrated Approach to Increase Resilience](#)'.

³⁰⁶ Fletcher et al., '[The Carbon Sequestration Potential of Scottish Native Woodland](#)';

Flack, Lukac, and Todman, '[Woodland Planting on UK Pasture Land Is Not Economically Feasible, yet Is More Profitable than Some Traditional Farming Practices](#)'.

- more research on the non-economic impacts of woodland creation [footnote ³⁰⁷], including cultural services of woodlands [footnote ³⁰⁸], and how these can be used to encourage uptake without targeting solely financial outcomes [footnote ³⁰⁹]
- development of qualitative measures of woodland benefits and how these align with quantitative measures, such as carbon sequestration and economic output [footnote ³¹⁰]
- research into the social networking and knowledge sharing networks of farmers and how these can be used to encourage woodland creation [footnote ³¹¹]
- local and regional variation in farmer attitudes towards woodland creation [footnote ³¹²].

Several studies outlined gaps in the research around agroforestry systems specifically:

- the impacts of integrating woodland within farming systems, e.g. agroforestry compared to land sparing approaches [footnote ³¹³]
- the specific impacts of agroforestry systems on carbon sequestration compared to traditional agriculture and/or on-farm woodland creation separate from production [footnote ³¹⁴]

³⁰⁷ Kaine et al., [‘Who Knew Afforestation Was Such a Challenge? Motivations and Impediments to Afforestation Policy in New Zealand’](#);

Nthambi et al., [‘Economic Incentives for Woodland Creation on Farmland: Modelling the Impacts on Biodiversity’](#).

³⁰⁸ Burton et al., [‘Reviewing the Evidence Base for the Effects of Woodland Expansion on Biodiversity and Ecosystem Services in the United Kingdom’](#).

³⁰⁹ Irwin et al., [‘Increasing Tree Cover on Irish Dairy and Drystock Farms: The Main Attitudes, Influential Bodies and Barriers That Affect Agroforestry Uptake’](#).

³¹⁰ Burton et al., [‘Green Gold to Wild Woodlands: Understanding Stakeholder Visions for Woodland Expansion in Scotland’](#).

³¹¹ Lawrence and Dandy, [‘Private Landowners’ Approaches to Planting and Managing Forests in the UK: What’s the Evidence?’](#).

³¹² Flack, Lukac, and Todman, [‘Woodland Planting on UK Pasture Land Is Not Economically Feasible, yet Is More Profitable than Some Traditional Farming Practices’](#).

³¹³ Hardaker, Pagella, and Rayment, [‘Ecosystem Service and Dis-Service Impacts of Increasing Tree Cover on Agricultural Land by Land-Sparing and Land-Sharing in the Welsh Uplands’](#).

³¹⁴ Golicz et al., [‘The Role of Small Woody Landscape Features and Agroforestry Systems for National Carbon Budgeting in Germany’](#);

Saraev et al., [‘The Potential for Agroforestry to Reduce Net GHG Emissions in Scotland through the Woodland Carbon Code’](#).

- the impact of agroforestry on pollinator abundance and diversity on farms [footnote ³¹⁵]
- impacts of silvopastoral systems on pasture and livestock productivity [footnote ³¹⁶]
- the health, food security and social well-being impacts of agroforestry systems [footnote ³¹⁷]
- data on costs of transitioning from traditional agricultural systems to agroforestry [footnote ³¹⁸]
- the long-term impacts of transitioning to agroforestry on farm yields [footnote ³¹⁹]
- market structures to support the uptake of agroforestry through selling tree products [footnote ³²⁰].

Cost-effectiveness Evidence (10 studies)

One study (UK) highlighted the value of incorporating natural regeneration in woodland creation, as a lower cost option to manual planting and with equivalent environmental outcomes [footnote ³²¹].

Planting undertaken on ‘marginal’ land already excluded from production constitutes a net benefit [footnote ³²²], especially when it delivers benefits for pollinators which have knock-on

³¹⁵ Bentrup et al., [‘Temperate Agroforestry Systems and Insect Pollinators: A Review’](#);

Sollen-Norrlin, Ghaley, and Rintoul, [‘Agroforestry Benefits and Challenges for Adoption in Europe and Beyond’](#);

Varah et al., [‘Temperate Agroforestry Systems Provide Greater Pollination Service than Monoculture’](#).

³¹⁶ Jordon et al., [‘Implications of Temperate Agroforestry on Sheep and Cattle Productivity, Environmental Impacts and Enterprise Economics. A Systematic Evidence Map’](#);

Velarde Pajares et al., [‘Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms’](#).

³¹⁷ Castle et al., [‘Evidence for the Impacts of Agroforestry on Ecosystem Services and Human Well-Being in High-Income Countries: A Systematic Map’](#).

³¹⁸ Cutress, David. [‘Agroforestry Options’](#).

³¹⁹ Staton et al., [‘Productivity, Biodiversity Trade-Offs, and Farm Income in an Agroforestry versus an Arable System’](#).

³²⁰ Sollen-Norrlin, Ghaley, and Rintoul, [‘Agroforestry Benefits and Challenges for Adoption in Europe and Beyond’](#);

Litschel et al., [‘Key Actors’ Perspectives on Agroforestry’s Potential in North Eastern Germany’](#).

³²¹ Morris and Davies, [‘Drivers of Natural Colonisation and Regeneration within Planted Woodlands in England: Towards an Integrated Approach to Increase Resilience’](#).

³²² Ford, Bale, and Taylor, [‘The Factors Determining Uptake of Energy Crop Cultivation and Woodland Creation in England: Insights from Farmers and Landowners’](#).

impacts on crop productivity [footnote ³²³]. Similarly, incorporating agroforestry on poor quality soils can be more economically viable than trying to grow crops there, due to the low maintenance of agroforestry systems [footnote ³²⁴].

Agroforestry systems can deliver greater economic benefits than agricultural production alone, due to diversification of products and the potential to gain higher prices for woodland products [footnote ³²⁵]. This is in addition to the ecosystem service benefits delivered by agroforestry for crop production [footnote ³²⁶].

One study assessed the profitability of afforesting upland sheep farming in the UK, and found that, although afforestation would be limited by low timber prices and high establishment costs, it was economically more feasible than upland sheep farming when the subsidisation of that form of agriculture was removed [footnote ³²⁷].

A review of the value of tree planting in the UK suggested that the net social value, when considering ecosystem service benefits such as carbon sequestration, flood mitigation and recreation, of planting broadleaves is £89,900 per hectare and £130,100 per hectare for conifers. However, the private financial costs to farmers without subsidies to plant outweigh the benefits they receive by between £2,800 and £3,500 per hectare [footnote ³²⁸].

Critical Success Factors

Strategic fit and business needs: Medium alignment

The identified evidence base outlines a range of environmental benefits of creating on-farm woodland, which align with the objectives of the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act

³²³ Alison et al., '[Woodland, Cropland and Hedgerows Promote Pollinator Abundance in Intensive Grassland Landscapes, with Saturating Benefits of Flower Cover](#)'.

³²⁴ Strauss et al., '[Carbon Farming for Climate Change Mitigation and Ecosystem Services – Potentials and Influencing Factors](#)'.

³²⁵ Jones et al., '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 8: Improving Air Quality and Well-Being. Sustainable Farming Scheme. Evidence Review](#)'.

³²⁶ Giannitsopoulos et al., '[Whole System Valuation of Arable, Agroforestry and Tree-Only Systems at Three Case Study Sites in Europe](#)'.

³²⁷ Hardaker, '[Is Forestry Really More Profitable than Upland Farming? A Historic and Present Day Farm Level Economic Comparison of Upland Sheep Farming and Forestry in the UK?](#)'

³²⁸ Westlake, S. '[Land Use: Policies for a Net Zero UK](#)', 16 January 2020,

2023. Evidence suggests that uptake of woodland creation is mixed, but can be improved through tailored support, particularly that which can improve its economic feasibility. Woodland creation can deliver a range of environmental, social and economic benefits to farmers and the wider public.

Value for money: Medium alignment

The evidence suggests that financial support for woodland creation and the promotion of economic and environmental benefits of planting can improve uptake among farmers. This includes benefits to ecosystem resilience and the role of woodland creation in mitigating climate change. Cultural and social barriers still exist, meaning potential alignment with this Critical Success Factor is medium.

Supply side capacity and capability: Medium alignment

The evidence base suggests medium alignment of this Theme with the Supply side capacity and capability Critical Success Factor. The evidence suggests that uptake of on-farm tree planting is affected by multiple factors outside financial, which represent barriers to this Theme. Improvements in advisory support and knowledge around woodland creation benefits are suggested to mitigate these barriers and support closer alignment with this Themes objectives. Evidence suggests that peer-to-peer learning is effective in improving uptake and should be harnessed.

Affordability: High alignment

The evidence base suggests that, with financial support, the economic costs of undertaking woodland creation can be reduced – although this does not consider social and cultural barriers. However, additional economic benefits can be derived from woodland creation through payment for ecosystem services (PES) and carbon and biodiversity credit payment models. This Theme therefore has high alignment with the Affordability Critical Success Factor.

Enhanced Biosecurity

The objective of the Theme Enhanced Biosecurity is to contribute to disease control on farms and the promotion of animal health and welfare-in keeping with a key Animal Health and Welfare Framework objective: 'Prevention is better than cure'. This aims to lower the risk of diseases entering the farm and improve the health and productivity of livestock. Reduced burden of disease will reduce antibiotic use and reduce the risk of antimicrobial resistance and threats to public health through zoonotic infections. Promotion of farm productivity will support resilience for individual farm and rural communities.

The Universal Action for Animal Health and Welfare (UA12) includes the requirement for vet and farmer to assess and manage the risk from incoming animals, further biosecurity support in the optional layer will facilitate this and help manage other potential risk pathways.

On farm actions will be able to support improved Biosecurity to help prevent diseases being brought onto the farm and manage the risk of any diseases spreading if they do enter the farm.

Appropriate optional actions a farmer can undertake include:

- isolation of stock arriving on farm from elsewhere in a suitable facility
- prevent vermin or wildlife diseases vectors entering feed stores or areas of the farm populated by livestock
- storage of deadstock in areas that don't pose infectious diseases risk to farm livestock
- cleaning and disinfection of vehicles, personnel and equipment on entry/exit of farm premises and buildings
- minimise the risk of straying or transmission of infection to or from neighbouring livestock by ensuring adequate fencing.

Capital grants will be available for a range of infrastructure items. These include:

- isolation facilities for incoming stock

- wildlife and vermin proofing of buildings and feed stores
- secure deadstock Storage to reduce risk of disease transmission
- cleaning and Disinfection points to promote best practice on farm hygiene
- double fencing of boundaries to reduce the risk of disease spread to and from neighbours (consistent offer through hedgerow creation/restoration).

Other support may include:

- using slurry injection/placement equipment to reduce airborne transmission and sward contamination
- ultraviolet (UV) treatment of water, used for livestock drinking water or irrigation of horticultural crops. This is where ultraviolet light is used to disinfect water by damaging the DNA of microorganisms, rendering them unable to replicate
- fencing and mains water provision to prevent livestock access to drinking water from watercourses.

Since the Rapid Evidence Assessment for the Theme Enhanced Biosecurity was undertaken, the detail of this Theme has been further developed such that the searches included in this review and the prioritisation of evidence presented in this report may differ slightly from the priority of on-farm practices for this Theme.

Due to overlaps in on-farm practices with other Themes additional evidence for this Theme can be found in:

- Improved Water Quality, Water Usage and Flood Mitigation
- Improved Air Quality and Lowering Ammonia Emissions

REA Exclusion / Inclusion Criteria

Inclusion: Studies on the implementation of biosecurity measures and livestock disease prevention.

Exclusion: Studies without a practical focus.

Evidence Base

Using Scopus, 23 studies were identified as in scope of the evidence assessment. An additional 27 studies were sourced using Google Scholar. Using quality and relevance criteria 35 articles were analysed. The evidence base focused particularly on animal and human health, disease prevention and containment in animals and humans, and the contamination of feed and water.

Design of the Intervention (31 studies)

The evidence identified suggested that slurry injection reduces airborne disease transmission [footnote ³²⁹], but using a contractor may increase the risk of bovine tuberculosis outbreaks [footnote ³³⁰], as *M. bovis* can survive in slurry for up to 6 months [footnote ³³¹]. One study in Northern Ireland surveyed cattle farmers between December 2010 and June 2011 and found that less than a third of respondents reported that contractors disinfected their equipment between farms [footnote ³³²]. Equipment should be dedicated to each premises [footnote ³³³] or, if a contractor is used, the equipment should be disinfected before being used on another farm [footnote ³³⁴].

³²⁹ Tomlinson, '[Holistic Approach to Bovine Tuberculosis – There Is More to Control than Just Testing](#)', In Practice 45, no. 7 (September 2023): 369–440.

³³⁰ O'Hagan et al., '[Herd-Level Risk Factors for Bovine Tuberculosis and Adoption of Related Biosecurity Measures in Northern Ireland: A Case-Control Study](#)', The Veterinary Journal 213 (July 2016): 26–32; Tomlinson, '[Holistic Approach to Bovine Tuberculosis – There Is More to Control than Just Testing](#)', In Practice 45, no. 7 (September 2023): 369–440.

³³¹ O'Hagan et al., '[Herd-Level Risk Factors for Bovine Tuberculosis and Adoption of Related Biosecurity Measures in Northern Ireland: A Case-Control Study](#)', (2016); Tomlinson, '[Holistic Approach to Bovine Tuberculosis – There Is More to Control than Just Testing](#)', In Practice 45, no. 7 (September 2023): 369–440.

³³² O'Hagan et al., '[Herd-Level Risk Factors for Bovine Tuberculosis and Adoption of Related Biosecurity Measures in Northern Ireland: A Case-Control Study](#)', (2016).

³³³ Scollo et al., '[Monitoring Means and Results of Biosecurity in Pig Fattening Farms: Systematic Assessment of Measures in Place and Exploration of Biomarkers of Interest](#)', Animals 12, no. 19 (October 2022): 2655.

³³⁴ O'Hagan et al., '[Herd-Level Risk Factors for Bovine Tuberculosis and Adoption of Related Biosecurity Measures in Northern Ireland: A Case-Control Study](#)', (2016).

Several studies highlighted ways to improve UV water treatment, such as filtering and purifying water before UV treatment [footnote ³³⁵], installing mechanical filters [footnote ³³⁶], designing systems to prevent re-contamination [footnote ³³⁷] and combining Ultrafiltration (UF) and UV treatment [footnote ³³⁸]. One study suggested that UV systems should avoid low radiation doses relative to water flow and transparency, as the disinfection will not be as effective [footnote ³³⁹]. Another paper suggested that farmers need support and information to choose the best UV lamps for their needs [footnote ³⁴⁰].

Exclusion measures were identified in the evidence base as an approach to preventing contamination and increasing biosecurity. These included vermin-proof buildings/feed stores which aim to prevent contamination by different species of wildlife, however, the literature reviewed focused predominantly on badgers. The literature reviewed highlighted that badger-proofed gates, feed stores, and doors have been shown to provide 100% protection of feed stores and cattle housing from badger incursion when they were used consistently and adequately maintained [footnote ³⁴¹]. The greatest protective effect from the evidence identified, however, was suggested to result from the presence of exclusion measures on both feed stores and cattle housing [footnote ³⁴²].

Several studies highlighted the importance of isolating and restricting movement between groups of animals, and only purchasing animals from farms with known disease histories, to prevent transmission of diseases [footnote ³⁴³]. For example, a study of *E. coli* transmission

³³⁵ Adhikari et al., '[Evaluation of Ultraviolet \(UV-C\) Light Treatment for Microbial Inactivation in Agricultural Waters with Different Levels of Turbidity](#)', Food Science & Nutrition 8, no. 2 (2020): 1237–43;

Miglena Paneva and Peter Panev, '[Methods of Cleaning and Disinfection of Drinking Water in Livestock Farms](#)', Bulgarian Journal of Agricultural Science 30, no. 3 (2024): 547–51.

³³⁶ Paneva and Panev, '[Methods of Cleaning and Disinfection of Drinking Water in Livestock Farms](#)' (2024).

³³⁷ Banach et al., '[Application of Water Disinfection Technologies for Agricultural Waters](#)', Agricultural Water Management 244 (2021).

³³⁸ Terré et al., '[Exploring the Use of Tertiary Reclaimed Water in Dairy Cattle Production](#)', Journal of Cleaner Production 229 (August 2019): 964–73.

³³⁹ Paneva and Panev, '[Methods of Cleaning and Disinfection of Drinking Water in Livestock Farms](#)', Bulgarian Journal of Agricultural Science 30, no. 3 (2024): 547–51.

³⁴⁰ Haley et al., '[Developing a Decision-Making Tool for Agricultural Surface Water Decontamination Using Ultraviolet-C Light](#)', Journal of Food Protection 86 (2023).

³⁴¹ Wilson, Stephen P. Carter, and Richard J. Delahay, '[Advances and Prospects for Management of TB Transmission between Badgers and Cattle](#)', Veterinary Microbiology 151, no. 1–2 (July 2011): 43–50,.

³⁴² Judge et al., '[Effectiveness of Biosecurity Measures in Preventing Badger Visits to Farm Buildings](#)', ed. Justin David Brown, PLoS ONE 6, no. 12 (29 December 2011): e28941,.

³⁴³ Brennan and Christley, '[Biosecurity on Cattle Farms: A Study in North-West England](#)', PLOS ONE 7, no. 1 (3 January 2012): e28139.

in dairy farms in England and Wales found that farms that operated a 'closed herd policy' whereby animals were not allowed to move between herds or new animals introduced, resulted in a significantly reduced risk of *E. coli* infection of those animals [footnote ³⁴⁴]. A study of dairy farms in Wales found that 'open' herds of cattle were 10 times more likely to have bovine viral diarrhoea virus antibodies and 16.7 times more likely to have bovine herpesvirus type 1 antibodies when tested compared to closed herds [footnote ³⁴⁵]. Another study found that keeping young cattle in the same groups through rearing and providing a constant supply of dry bedding were identified as important factors in reducing *E. Coli* risk in cattle[footnote ³⁴⁶].

One study suggested that biosecurity methods, including isolation of stock, should be implemented contextually to be appropriate to the farm and the diseases most likely to impact it. Similarly, measures should be flexible and adaptable, as enforcement of unsuitable measures can lead to non-compliance among farmers [footnote ³⁴⁷].

A range of disinfection measures were identified in the literature to prevent the transmission of diseases among livestock. A study on *E. coli* transmission on UK cattle farms suggest that measures such as boot dips, herd isolation, keeping animals clean and providing dry bedding, were especially effective in reducing *E. coli* transmission [footnote ³⁴⁸]. Another study found that disinfection of calf feeding equipment more than once per month was associated with a 4 times lower risk of *E. coli* detection among those animals [footnote ³⁴⁹]. An EU study of salmonella transmission in pigs identified measures such as putting organic acids in feed and water, boot disinfection when entering and leaving farm areas, PPE and

³⁴⁴ Snow et al., '[Risk Factors Associated with Extended Spectrum Beta-Lactamase *Escherichia Coli* \(CTX-M\) on Dairy Farms in North West England and North Wales](#)', *Preventive Veterinary Medicine* 106, no. 3 (1 October 2012): 225–34,.

³⁴⁵ Bishop, Erkelens, and Van Winden, '[Indications of a Relationship between Buying-in Policy and Infectious Diseases on Dairy Farms in Wales](#)', *Veterinary Record* 167, no. 17 (2010): 644–47,.

³⁴⁶ Ellis-Iversen et al., '[Farm Practices to Control *E. Coli* O157 in Young Cattle - A Randomised Controlled Trial](#)', *Veterinary Research* 39, no. 1 (1 January 2008): 1–12,

³⁴⁷ Brennan and Christley, '[Biosecurity on Cattle Farms: A Study in North-West England](#)'.

³⁴⁸ Ellis-Iversen et al., '[Farm Practices to Control *E. Coli* O157 in Young Cattle - A Randomised Controlled Trial](#)'.

³⁴⁹ Snow et al., '[Risk Factors Associated with Extended Spectrum Beta-Lactamase *Escherichia Coli* \(CTX-M\) on Dairy Farms in North West England and North Wales](#)'.

vehicle wheel disinfection as effective for reducing salmonella transmission in the pork production chain [footnote ³⁵⁰].

Several studies on diseases in poultry identified disinfection protocols as effective preventative measures. A study on avian influenza on UK poultry farms recommended disinfection measures including:

- restriction of non-essential people from poultry areas
- disinfection routines when entering and leaving the farm including boot dips and wheel washers
- workers changing clothing when moving between bird and non-bird areas of the farm
- farm-specific rubber boots to be worn when entering the farm, and shed-specific rubber boots to be worn when entering poultry sheds

One UK study highlighted the importance of biosecurity measures to reduce salmonella infection and transmission on poultry farms [footnote ³⁵¹]. These measures included:

- vaccination
- boot and hand hygiene
- rodent, fly and mite control
- cleaning and disinfection of sheds between different flocks of birds

A study of *Campylobacter* spread among broiler chickens suggested that chlorinated drinking water, bacteriophage therapy and vaccination were effective measures for reducing the disease transmission among chickens on UK farms. The use of protective clothing and shed-specific equipment were also highlighted as important to prevent disease transmission [footnote ³⁵²]. Another study on UK farms identified farm hygiene as an important risk factor for *Campylobacter* spread due to its short-range transmission. This study recommended the

³⁵⁰ Bester et al., '[Identification of Cost-Effective Biosecurity Measures to Reduce Salmonella along the Pork Production Chain](#)', *Frontiers in Veterinary Science* 11 (18 March 2024),

³⁵¹ Gosling et al., '[Assessment of Producers' Response to Salmonella Biosecurity Issues and Uptake of Advice on Laying Hen Farms in England and Wales](#)', *British Poultry Science* 55, no. 5 (3 September 2014): 559–68,

³⁵² Georgiev, Beauvais, and Guitian, '[Effect of Enhanced Biosecurity and Selected On-Farm Factors on *Campylobacter* Colonization of Chicken Broilers](#)', *Epidemiology & Infection* 145, no. 3 (February 2017): 553–6.

implementation of mask wearing, hand sanitisation, and disinfection of poultry houses between flocks to reduce spread [footnote ³⁵³].

Finally, the evidence identified did not discuss in detail the design of fencing and mains water provision.

Uptake of the Practice (22 studies)

While the benefits of biosecurity measures are discussed in the literature [footnote ³⁵⁴], one study of cattle farmers in Northern Ireland, published in 2016, suggested that the adoption of biosecurity measures by farmers was not widespread [footnote ³⁵⁵]. One study surveyed cattle farmers in western England and found that most farmers included in their study had not implemented biosecurity measures to reduce the direct and indirect contact between wildlife, cattle, and feed [footnote ³⁵⁶]. The paper suggested that farmers may be reluctant to improve biosecurity due to inaccuracy in previous biosecurity advice from the UK Ministry of Agriculture, Fisheries and Food (MAFF), which may have undermined the overall message [footnote ³⁵⁷]. Barriers to implementation are discussed in more detail in a later section. Another study noted slow adoption of technologies like UV water treatment amongst growers in the United States [footnote ³⁵⁸], and a third highlighted variable compliance with badger-proof gates and feed stores in England, indicating that there may be some cultural and behavioural barriers to change, particularly when measures change current day to day working practices [footnote ³⁵⁹]. However, one study highlighted that measures such as using badger-proof mineral licks, tidying feed spillages, covering troughs, and closing feed store doors at night were among the top 10 TB Advisory Service recommendations

³⁵³ Taylor et al., '[Farm Level Risk Factors for Fluoroquinolone Resistance in E. Coli and Thermophilic Campylobacter Spp. on Poultry Farms](#)', *Avian Pathology* 45, no. 5 (2 September 2016): 559–68,.

³⁵⁴ Smith et al., '[Assessing Pig Farm Biosecurity Measures for the Control of Salmonella on European Farms](#)', *Epidemiology and Infection* 151 (2023): e130.

³⁵⁵ O'Hagan et al., '[Herd-Level Risk Factors for Bovine Tuberculosis and Adoption of Related Biosecurity Measures in Northern Ireland: A Case-Control Study](#)', (2016).

³⁵⁶ Ward et al., '[Survey of Badger Access to Farm Buildings and Facilities in Relation to Contact with Cattle](#)', *The Veterinary Record* 163 (26 July 2008): 107–11.

³⁵⁷ Ward et al., '[Survey of Badger Access to Farm Buildings and Facilities in Relation to Contact with Cattle](#)', *The Veterinary Record* 163 (26 July 2008): 107–11.

³⁵⁸ Haley et al., '[Developing a Decision-Making Tool for Agricultural Surface Water Decontamination Using Ultraviolet-C Light](#)' (2023).

³⁵⁹ Wilson, Carter, and Delahay, '[Advances and Prospects for Management of TB Transmission between Badgers and Cattle](#)', *Veterinary Microbiology* 151, no. 1–2 (July 2011): 43–50,.

completed by farmers of cattle, deer, goats, camelids, pigs, or sheep in England who received advice[footnote ³⁶⁰]. This suggests that these measures are more commonly implemented by these farmers than other biosecurity measures targeting bovine tuberculosis (bTB) [footnote ³⁶¹].

A study investigating psoriatic mange, or ‘sheep scab’ on UK farms found that adherence to biosecurity measures to prevent mange transmission was mixed, with ¾ of farmers surveyed quarantining new sheep, but just 28% quarantining returning sheep. 43% of farmers did not quarantine sheep for the suggested minimum of 21 days, and nearly 25% of farmers quarantined only some or none of their new sheep. 43% of farmers treated all new sheep on arrival with a preventative medication. The study suggested that high levels of sheep scab in the UK can be attributed to these relatively low levels of uptake of biosecurity measures [footnote ³⁶²].

Similarly, a study of biosecurity measures on English cattle farms found that over 50% of farmers in the study did not isolate incoming stock as recommended, and farms showed significant variation in the implementation of biosecurity measures. Routine treatment of stock was found to be implemented by 28% of farms, and just 9% of farmers performed health checks on newly imported stock [footnote ³⁶³].

A UK study trialling various biosecurity measures to limit E. coli transmission in cattle found that ‘not buying in new animals’ was the most complied with measure for farmers engaged in the trial, but that none of the farmers were fully compliant with the recommended actions [footnote ³⁶⁴].

Several studies highlighted the uptake of disinfection measures to prevent disease spread on UK livestock farms. A study on avian influenza on UK poultry farms found that uptake of measures tended to improve following outbreaks of disease – especially the implementation

³⁶⁰ Tomlinson, ‘[Holistic Approach to Bovine Tuberculosis – There Is More to Control than Just Testing](#)’, In Practice 45, no. 7 (September 2023): 369–440.

³⁶¹ Tomlinson, ‘[Holistic Approach to Bovine Tuberculosis – There Is More to Control than Just Testing](#)’, In Practice 45, no. 7 (September 2023): 369–440.

³⁶² Smith et al., ‘[A Survey of British Sheep Farmers: Practices, Opinions and Knowledge Surrounding the Management of Sheep Scab](#)’, *Preventive Veterinary Medicine* 214 (1 May 2023): 105898,

³⁶³ Brennan and Christley, ‘[Biosecurity on Cattle Farms: A Study in North-West England](#)’.

³⁶⁴ Ellis-Iversen et al., ‘[Farm Practices to Control E. Coli O157 in Young Cattle - A Randomised Controlled Trial](#)’.

of foot dips, isolation of animals and the provision of PPE and changing areas for workers. No evidence pointed towards whether this improved uptake was sustained or just temporary, however. Measures seen frequently across farms in this study included foot dips, regular disinfection routines, changing of PPE and rubber boots and restrictions around the movements of visitors and vehicles. Internal biosecurity measures were reported as less common than external biosecurity, and independently owned farms reported the strongest measures [footnote ³⁶⁵].

A UK study on biosecurity measures to prevent Salmonella transmission among laying hens found that uptake of biosecurity measures after receiving an “advice card” ranged from 54% to 80% of the 60 farms included in this study. The percentage of farms depended on the specific advice card given with the most frequently implemented actions included boot and hand hygiene, red mite control, site entrance control and cleaning and disinfection. Those farms with previous cases of Salmonella demonstrated stronger biosecurity measures [footnote ³⁶⁶].

A study of antibiotic resistance of E. coli and Campylobacter on UK poultry farms found that uptake of measures to prevent disease transmission, including foot and wheel dips and cleaning and disinfection of ante rooms between farm and sheds, were limited and varied between farms [footnote ³⁶⁷].

Despite advice to do so, a study on UK cattle farms found that measures to clean and disinfect farm vehicles were infrequently undertaken. Similarly, movement of workers between different herds was common and cleaning protocols and clothing changes were rarely observed [footnote ³⁶⁸].

Costs of implementing biosecurity measures were highlighted by several studies. A study of UK poultry farms found that measures which could be managed more frequently and were less costly, such as disinfection routines, were more common than measures to modernise

³⁶⁵ Hosseini et al., ‘[Qualitative Studies on Farm Managers Perception of Risk from HPAIV and Implementation of Biosecurity Measures on UK Poultry Farms](#)’, *Preventive Veterinary Medicine* 239 (1 June 2025): 106445,.

³⁶⁶ Gosling et al., ‘[Assessment of Producers’ Response to Salmonella Biosecurity Issues and Uptake of Advice on Laying Hen Farms in England and Wales](#)’.

³⁶⁷ Taylor et al., ‘[Fluoroquinolone Resistance in E. Coli and Thermophilic Campylobacter Spp. on Poultry Farms](#)’.

³⁶⁸ Brennan and Christley, ‘[Biosecurity on Cattle Farms: A Study in North-West England](#)’.

farm buildings or add new disinfection facilities [footnote ³⁶⁹]. This was supported by another study which found that periodic actions with low cost were undertaken more frequently than one-off actions of higher cost, such as building refurbishments [footnote ³⁷⁰].

Finally, the evidence identified did not discuss in detail the uptake of slurry injection/placement equipment or fencing and mains water provision.

Economic Impacts (29 studies)

Slurry injection/placement equipment can reduce the airborne spread of diseases like bTB, easing financial burdens on farmers and governments [footnote ³⁷¹]. One study highlighted that recycling manure reduces the need for artificial fertilisers, which can cut costs for farmers [footnote ³⁷²]. Proper slurry management can decrease pathogen spread and prevent financial losses from diseases [footnote ³⁷³], including epizootic diseases (diseases that are temporarily prevalent and widespread in an animal population) [footnote ³⁷⁴]. However, using contractors for slurry application has been identified as a risk factor for bTB transmission [footnote ³⁷⁵], highlighting the need to disinfect equipment to prevent cross-contamination [footnote ³⁷⁶].

³⁶⁹ Hosseini et al., '[Qualitative Studies on Farm Managers Perception of Risk from HPAIV and Implementation of Biosecurity Measures on UK Poultry Farms](#)'.

³⁷⁰ Gosling et al., '[Assessment of Producers' Response to Salmonella Biosecurity Issues and Uptake of Advice on Laying Hen Farms in England and Wales](#)'.

³⁷¹ Albiñ and Vinnerås, '[Biosecurity and Arable Use of Manure and Biowaste — Treatment Alternatives](#)', *Livestock Science, Recycling of Livestock Manure in a Whole-Farm Perspective*, 112, no. 3 (1 December 2007): 232–39;

Duncan et al., '[Nitrous Oxide and Ammonia Emissions from Injected and Broadcast-Applied Dairy Slurry](#)', *Journal of Environmental Quality* 46, no. 1 (2017): 36–44;

O'Hagan et al., '[Herd-Level Risk Factors for Bovine Tuberculosis and Adoption of Related Biosecurity Measures in Northern Ireland: A Case-Control Study](#)', (2016).

³⁷² Albiñ and Vinnerås, '[Biosecurity and Arable Use of Manure and Biowaste — Treatment Alternatives](#)' (2007).

³⁷³ Scollo et al., '[Monitoring Means and Results of Biosecurity in Pig Fattening Farms: Systematic Assessment of Measures in Place and Exploration of Biomarkers of Interest](#)', *Animals* 12, no. 19 (October 2022): 2655.

³⁷⁴ Albiñ and Vinnerås, '[Biosecurity and Arable Use of Manure and Biowaste — Treatment Alternatives](#)' (2007).

³⁷⁵ O'Hagan et al '[Herd-Level Risk Factors for Bovine Tuberculosis and Adoption of Related Biosecurity Measures in Northern Ireland: A Case-Control Study](#)', (2016).

³⁷⁶ O'Hagan et al., '[Herd-Level Risk Factors for Bovine Tuberculosis and Adoption of Related Biosecurity Measures in Northern Ireland: A Case-Control Study](#)', (2016).

The studies reviewed relating to UV water treatment highlighted economic benefits, including reducing microbial contamination, minimising disease transmission, and ensuring high-quality drinking water for livestock [footnote ³⁷⁷]. UV disinfection offers long-term savings by reducing the need for costly disease control measures [footnote ³⁷⁸] and eliminates the need for chemicals like chlorine that could have adverse effects on livestock, thereby avoiding potential costly health issues, which could lead to additional costs for farmers [footnote ³⁷⁹].

Fencing off watercourses and providing wildlife-proof water sources can reduce disease risk by minimising wildlife-livestock contact [footnote ³⁸⁰]. These measures can substantially reduce direct and indirect contact between cattle and wildlife, reducing the opportunity for bTB transmission and leading to a reduction in bTB incidence [footnote ³⁸¹]. By reducing infection, these biosecurity measures can offer economic benefits and improve productivity on farms [footnote ³⁸²].

Biosecurity measures to prevent disease transmission, including isolation of new stock, have been suggested to potentially mitigate costs of such diseases, but also incur costs for farmers implementing them. For example, a study on sheep scab on UK farms estimated the annual cost of the disease to the sheep industry to be between £78 and £202 million [footnote ³⁸³]. Similarly, diseases impacting cattle, such as bovine viral diarrhoea, infectious bovine rhinotracheitis and leptospirosis can have significant economic impacts on farmers, associated with the cost of treating infected animals, the loss of stock via mortality, and the

³⁷⁷ Adhikari et al., '[Evaluation of Ultraviolet \(UV-C\) Light Treatment for Microbial Inactivation in Agricultural Waters with Different Levels of Turbidity](#)' (2020);

Paneva and Panev, '[Methods of Cleaning and Disinfection of Drinking Water in Livestock Farms](#)' (2024).

³⁷⁸ Paneva and Panev, '[Methods of Cleaning and Disinfection of Drinking Water in Livestock Farms](#)' (2024).

³⁷⁹ Paneva and Panev, '[Methods of Cleaning and Disinfection of Drinking Water in Livestock Farms](#)' (2024); Terré et al., '[Exploring the Use of Tertiary Reclaimed Water in Dairy Cattle Production](#)' (2019).

³⁸⁰ Galipó et al., '[Prioritization of Pig Farm Biosecurity for Control of Salmonella and Hepatitis E Virus Infections: Results of a European Expert Opinion Elicitation](#)', Porcine Health Management 9, no. 1 (2023);

³⁸¹ Barasona et al., '[Effectiveness of Cattle Operated Bump Gates and Exclusion Fences in Preventing Ungulate Multi-Host Sanitary Interaction](#)', Preventive Veterinary Medicine 111, no. 1–2 (August 2013): 42–50;

³⁸² Alarcón, Alberto, and Mateu, '[Biosecurity in Pig Farms: A Review](#)', Porcine Health Management 7, no. 1 (2021);

Shortall et al., '[Exploring Expert Opinion on the Practicality and Effectiveness of Biosecurity Measures on Dairy Farms in the United Kingdom Using Choice Modeling](#)', Journal of Dairy Science 100, no. 3 (March 2017): 2225–39.

³⁸³ Smith et al., '[A Survey of British Sheep Farmers](#)'.

potential to put off buyers [footnote ³⁸⁴]. A UK-based study on biosecurity on cattle farms suggested that biosecurity measures to reduce disease transmission on livestock farms could contribute to improved productivity, resulting in greater profits for farmers [footnote ³⁸⁵].

However, one study of E. coli prevention on UK cattle farms indicated that, without financial incentives, compliance with recommended measures reduced due to the costs associated with undertaking them [footnote ³⁸⁶].

An EU study on Salmonella on pig farms highlighted that Salmonella illness among humans in Europe was associated with economic losses of up to €90 million annually. This is balanced against the cost of biosecurity measures, including manpower and equipment purchase, installation and maintenance. Specific on-farm practices such as vehicle wheel disinfection, boot disinfection and rodent control were associated with high on-farm costs of between €7 and €44 million per year [footnote ³⁸⁷].

Finally, vermin-proof buildings/feed stores which prevent wildlife access can reduce disease transmission, notably bTB, which has significant economic implications for the farming industry [footnote ³⁸⁸]. Exclusion measures can protect stored feed from contamination, reducing the risk of disease spread and improving farm productivity [footnote ³⁸⁹]. Several studies highlighted that badgers and foxes have been recorded visiting farmyards and buildings to access cattle feed [footnote ³⁹⁰] and have been observed defecating and

³⁸⁴ Bishop, Erkelens, and Van Winden, '[Indications of a Relationship between Buying-in Policy and Infectious Diseases on Dairy Farms in Wales](#)'.

³⁸⁵ Brennan and Christley, '[Biosecurity on Cattle Farms: A Study in North-West England](#)'.

³⁸⁶ Ellis-Iversen et al., '[Farm Practices to Control E. Coli O157 in Young Cattle - A Randomised Controlled Trial](#)'.

³⁸⁷ Bester et al., '[Identification of Cost-Effective Biosecurity Measures to Reduce Salmonella along the Pork Production Chain](#)'.

³⁸⁸ Judge et al., '[Effectiveness of Biosecurity Measures in Preventing Badger Visits to Farm Buildings](#)' (2011); Tolhurst, Ward, and Delahay, '[A Study of Fox \(Vulpes Vulpes\) Visits to Farm Buildings in Southwest England and the Implications for Disease Management](#)', European Journal of Wildlife Research 57, no. 6 (2011): 1227–30.

³⁸⁹ Judge et al., '[Effectiveness of Biosecurity Measures in Preventing Badger Visits to Farm Buildings](#)' (2011); Tolhurst, Ward, and Delahay, '[A Study of Fox \(Vulpes Vulpes\) Visits to Farm Buildings in Southwest England and the Implications for Disease Management](#)' (2011);

Ward et al., '[Survey of Badger Access to Farm Buildings and Facilities in Relation to Contact with Cattle](#)' (2008).

³⁹⁰ Skuce, Allen, and McDowell, '[Herd-Level Risk Factors for Bovine Tuberculosis: A Literature Review](#)' (2012).

urinating in buildings, sometimes directly onto feed [footnote ³⁹¹]. One study in England observed that most of the excretion and scent-marking by badgers observed in buildings was in feed stores, suggesting that focus on preventing access to feed could be effective in reducing the risk of disease transmission [footnote ³⁹²]. Ensuring that feed is safe from contamination by wildlife, through vermin-proof buildings/feed stores can prevent costs associated with animal disease, as well as the direct economic cost of the loss of feed due to contamination [footnote ³⁹³].

Environmental Impacts (5 studies)

The evidence base identified several ways in which implementing higher standard biosecurity measures could contribute to environmental impacts, such as the following.

- Reducing air and water pollution [footnote ³⁹⁴]: Whilst slurry injection is associated with higher N₂O emissions in comparison to broadcasting manure [footnote ³⁹⁵], slurry injection leads to reduced ammonia emissions [footnote ³⁹⁶] and is overall considered to have the greatest potential to reduce air and water pollution in comparison to other manure application practices, such as broadcast application [footnote ³⁹⁷]

³⁹¹ Tolhurst, Ward, and Delahay, '[A Study of Fox \(Vulpes Vulpes\) Visits to Farm Buildings in Southwest England and the Implications for Disease Management](#)' (2011);

Ward, Judge, and Delahay, '[Farm Husbandry and Badger Behaviour: Opportunities to Manage Badger to Cattle Transmission of Mycobacterium Bovis?](#)' (2010);

Wilson, Carter, and Delahay, '[Advances and Prospects for Management of TB Transmission between Badgers and Cattle](#)' (2011).

³⁹² Ward et al., '[Survey of Badger Access to Farm Buildings and Facilities in Relation to Contact with Cattle](#)' (2008).

³⁹³ Tolhurst, Ward, and Delahay, '[A Study of Fox \(Vulpes Vulpes\) Visits to Farm Buildings in Southwest England and the Implications for Disease Management](#)' (2011).

³⁹⁴ Duncan et al., '[Nitrous Oxide and Ammonia Emissions from Injected and Broadcast-Applied Dairy Slurry](#)' (2017).

³⁹⁵ Duncan et al., '[Nitrous Oxide and Ammonia Emissions from Injected and Broadcast-Applied Dairy Slurry](#)' (2017).

³⁹⁶ Dal Ferro et al., '[Identifying NH₃ Emission Mitigation Techniques from Farm to Field Using a Bayesian Network](#)', Journal of Environmental Management 373 (January 2025);

Duncan et al., '[Nitrous Oxide and Ammonia Emissions from Injected and Broadcast-Applied Dairy Slurry](#)' (2017);

O'Hagan et al., '[Herd-Level Risk Factors for Bovine Tuberculosis and Adoption of Related Biosecurity Measures in Northern Ireland: A Case-Control Study](#)', (2016).

³⁹⁷ Duncan et al., '[Nitrous Oxide and Ammonia Emissions from Injected and Broadcast-Applied Dairy Slurry](#)' (2017).

- Water efficiency and the reuse of water [footnote ³⁹⁸]: UV treatment of water can allow the safe use of recycled water, contributing to supporting a circular economy [footnote ³⁹⁹]
- Replacing chemical sanitisers: Replacing chemical sanitisers used to disinfect agricultural waters with UV disinfection will reduce the negative toxic by-products of the disinfection process, which can have adverse effects on plant health [footnote ⁴⁰⁰].

Social Impacts (14 studies)

The main theme throughout the literature reviewed was that biosecurity measures have a positive social impact on disease prevention and human health [footnote ⁴⁰¹]. Biosecurity measures can reduce the risk of zoonotic pathogens and infectious diseases being passed to humans through the food chain [footnote ⁴⁰²]. The positive impact on human health is

³⁹⁸ Terré et al., '[Exploring the Use of Tertiary Reclaimed Water in Dairy Cattle Production](#)' (2019).

³⁹⁹ Banach et al., '[Application of Water Disinfection Technologies for Agricultural Waters](#)' (2021).

⁴⁰⁰ Haley et al., '[Developing a Decision-Making Tool for Agricultural Surface Water Decontamination Using Ultraviolet-C Light](#)' (2023).

⁴⁰¹ Adhikari et al., '[Evaluation of Ultraviolet \(UV-C\) Light Treatment for Microbial Inactivation in Agricultural Waters with Different Levels of Turbidity](#)' (2020);

Alarcón, Alberto, and Mateu, '[Biosecurity in Pig Farms: A Review](#)' (2021);

Ann Albiñ and Björn Vinnerås, '[Biosecurity and Arable Use of Manure and Biowaste — Treatment Alternatives](#)' (2007);

Banach et al., '[Application of Water Disinfection Technologies for Agricultural Waters](#)' (2021);

Davies and Wales, '[Salmonella Contamination of Cereal Ingredients for Animal Feeds](#)', *Veterinary Microbiology* 166, no. 3–4 (October 2013): 543–49;

Galipó et al., '[Prioritization of Pig Farm Biosecurity for Control of Salmonella and Hepatitis E Virus Infections: Results of a European Expert Opinion Elicitation](#)' (2023);

O'Hagan et al., '[Herd-Level Risk Factors for Bovine Tuberculosis and Adoption of Related Biosecurity Measures in Northern Ireland: A Case-Control Study](#)', (2016);

Skuce, Allen, and McDowell, '[Herd-Level Risk Factors for Bovine Tuberculosis: A Literature Review](#)' (2012);

Smith et al., '[Assessing Pig Farm Biosecurity Measures for the Control of Salmonella on European Farms](#)' (2023);

Tomlinson, '[Holistic Approach to Bovine Tuberculosis – There Is More to Control than Just Testing](#)', *In Practice* 45, no. 7 (September 2023): 369–440.

⁴⁰² Adhikari et al., '[Evaluation of Ultraviolet \(UV-C\) Light Treatment for Microbial Inactivation in Agricultural Waters with Different Levels of Turbidity](#)' (2020);

Alarcón, Alberto, and Mateu, '[Biosecurity in Pig Farms: A Review](#)' (2021);

Albiñ and Vinnerås, '[Biosecurity and Arable Use of Manure and Biowaste — Treatment Alternatives](#)' (2007);

Banach et al., '[Application of Water Disinfection Technologies for Agricultural Waters](#)' (2021);

Smith et al., '[Assessing Pig Farm Biosecurity Measures for the Control of Salmonella on European Farms](#)' (2023);

included in papers which discuss vermin-proof buildings/feed stores [footnote ⁴⁰³], slurry injection/placement equipment [footnote ⁴⁰⁴], UV treatment of water [footnote ⁴⁰⁵], fencing and mains water provision [footnote ⁴⁰⁶].

Several diseases can infect humans who eat contaminated meat, including Salmonella [footnote ⁴⁰⁷], Campylobacter [footnote ⁴⁰⁸] and E. coli [footnote ⁴⁰⁹]. Salmonella illness among humans has been attributed to infection via contaminated meat, with laying hens and pork being the most important sources of the disease [footnote ⁴¹⁰]. Human campylobacteriosis was identified as the most common gastrointestinal infection in the EU,

Galipó et al., '[Prioritization of Pig Farm Biosecurity for Control of Salmonella and Hepatitis E Virus Infections: Results of a European Expert Opinion Elicitation](#)' (2023);

Walgern et al., '[Farmers' Attitudes in Connection with the Potential for Rodent Prevention in Livestock Farming in a Municipality in North Rhine-Westphalia, Germany](#)', *Animals* 13 (December 2023): 3809.

⁴⁰³ Davies and Wales, '[Salmonella Contamination of Cereal Ingredients for Animal Feeds](#)' (2013);

Galipó et al., '[Prioritization of Pig Farm Biosecurity for Control of Salmonella and Hepatitis E Virus Infections: Results of a European Expert Opinion Elicitation](#)' (2023);

Skuce, Allen, and McDowell, '[Herd-Level Risk Factors for Bovine Tuberculosis: A Literature Review](#)' (2012);

Tomlinson, '[Holistic Approach to Bovine Tuberculosis – There Is More to Control than Just Testing](#)', *In Practice* 45, no. 7 (September 2023): 369–440.;

Walgern et al., '[Farmers' Attitudes in Connection with the Potential for Rodent Prevention in Livestock Farming in a Municipality in North Rhine-Westphalia, Germany](#)' (2023).

⁴⁰⁴ Albiñá and Vinnerås, '[Biosecurity and Arable Use of Manure and Biowaste — Treatment Alternatives](#)' (2007);

O'Hagan et al., '[Herd-Level Risk Factors for Bovine Tuberculosis and Adoption of Related Biosecurity Measures in Northern Ireland: A Case-Control Study](#)', (2016);

Tomlinson, '[Holistic Approach to Bovine Tuberculosis – There Is More to Control than Just Testing](#)', *In Practice* 45, no. 7 (September 2023): 369–440.

⁴⁰⁵ Adhikari et al., '[Evaluation of Ultraviolet \(UV-C\) Light Treatment for Microbial Inactivation in Agricultural Waters with Different Levels of Turbidity](#)' (2020);

Alarcón, Alberto, and Mateu, '[Biosecurity in Pig Farms: A Review](#)' (2021);

Banach et al., '[Application of Water Disinfection Technologies for Agricultural Waters](#)' (2021).

⁴⁰⁶ Alarcón, Alberto, and Mateu, '[Biosecurity in Pig Farms: A Review](#)' (2021);

Galipó et al., '[Prioritization of Pig Farm Biosecurity for Control of Salmonella and Hepatitis E Virus Infections: Results of a European Expert Opinion Elicitation](#)' (2023);

Smith et al., '[Assessing Pig Farm Biosecurity Measures for the Control of Salmonella on European Farms](#)' (2023).

⁴⁰⁷ Bester et al., '[Identification of Cost-Effective Biosecurity Measures to Reduce Salmonella along the Pork Production Chain](#)'.'

⁴⁰⁸ Georgiev, Beauvais, and Guitian, '[Effect of Enhanced Biosecurity and Selected On-Farm Factors on Campylobacter Colonization of Chicken Broilers](#)'.

⁴⁰⁹ Ellis-Iversen et al., '[Farm Practices to Control E. Coli O157 in Young Cattle - A Randomised Controlled Trial](#)'.

⁴¹⁰ Bester et al., '[Identification of Cost-Effective Biosecurity Measures to Reduce Salmonella along the Pork Production Chain](#)'.'

with poultry meat identified as the main source of infection [footnote ⁴¹¹]. Similarly, cattle have been identified as the main reservoir for *E. coli* infection in humans via contaminated meat [footnote ⁴¹²]. Biosecurity measures to reduce the prevalence of disease outbreaks among livestock could therefore mitigate these impacts on humans.

Another study found that avian influenza outbreaks on UK farms resulted in significant emotional and mental health impacts for farmers, including stress and anxiety around the possibility of having an outbreak. Farmers expressed distress around the suffering and loss of birds which could lead to low mood and in some cases, depression. Outbreaks could also lead to workload increases or decreases, worries about incomes, and isolation of farmers [footnote ⁴¹³].

Other social impacts discussed include:

- reducing ammonia emissions through slurry injection would reduce the adverse effects of ammonia exposure on human health [footnote ⁴¹⁴]
- manure has been found to carry antibiotic-resistant bacteria so more effective manure treatment (such as slurry injection) would minimise the risk of spreading antibiotic-resistant bacteria, reducing negative impacts on human health [footnote ⁴¹⁵].
- replacing chemical sanitisers used to disinfect agricultural waters with UV disinfection will reduce the negative toxic by-products of the disinfection process, which can have adverse effects on wildlife [footnote ⁴¹⁶]

⁴¹¹ Georgiev, Beauvais, and Guitian, '[Effect of Enhanced Biosecurity and Selected On-Farm Factors on *Campylobacter* Colonization of Chicken Broilers](#)'.

⁴¹² Ellis-Iversen et al., '[Farm Practices to Control E. Coli O157 in Young Cattle - A Randomised Controlled Trial](#)'.

⁴¹³ Hosseini et al., '[Qualitative Studies on Farm Managers Perception of Risk from HPAIV and Implementation of Biosecurity Measures on UK Poultry Farms](#)'.

⁴¹⁴ Dal Ferro et al., '[Identifying NH3 Emission Mitigation Techniques from Farm to Field Using a Bayesian Network](#)' (2025).

⁴¹⁵ Albiñá and Vinnerås, '[Biosecurity and Arable Use of Manure and Biowaste — Treatment Alternatives](#)' (2007).

⁴¹⁶ Haley et al., '[Developing a Decision-Making Tool for Agricultural Surface Water Decontamination Using Ultraviolet-C Light](#)' (2023).

- preventing diseases in animals and promoting animal welfare can have a positive impact on the welfare of affected farming families [footnote ⁴¹⁷].

Barriers (19 studies)

A range of potential barriers were identified in the evidence considered. A key theme throughout was the cost of implementing higher standard biosecurity measures, including vermin-proof buildings/feed stores [footnote ⁴¹⁸], slurry injection/placement equipment [footnote ⁴¹⁹], UV treatment of water [footnote ⁴²⁰], fencing and mains water provision [footnote ⁴²¹].

Another barrier discussed in the literature reviewed was a lack of information and awareness of biosecurity measures [footnote ⁴²²]. Farmers are less likely to adopt measures if they believe the technologies are too advanced for them to implement [footnote ⁴²³] and if they have limited information on the resource and capital inputs required to implement measures [footnote ⁴²⁴]. Similarly, the literature reviewed highlighted that without proof of the link between improving biosecurity and reduced disease breakouts and without a cost-benefit analysis of biosecurity measures, convincing farmers to implement measures is a

⁴¹⁷ Skuce, Allen, and McDowell, '[Herd-Level Risk Factors for Bovine Tuberculosis: A Literature Review](#)' (2012).

⁴¹⁸ Ward, Judge, and Delahay, '[Farm Husbandry and Badger Behaviour: Opportunities to Manage Badger to Cattle Transmission of Mycobacterium Bovis?](#)' (2010);

Walgerm et al., '[Farmers' Attitudes in Connection with the Potential for Rodent Prevention in Livestock Farming in a Municipality in North Rhine-Westphalia, Germany](#)' (2023);

Wilson, Carter, and Delahay, '[Advances and Prospects for Management of TB Transmission between Badgers and Cattle](#)' (2011).

⁴¹⁹ Dal Ferro et al., '[Identifying NH3 Emission Mitigation Techniques from Farm to Field Using a Bayesian Network](#)' (2025).

⁴²⁰ Haley et al., '[Developing a Decision-Making Tool for Agricultural Surface Water Decontamination Using Ultraviolet-C Light](#)' (2023);

Marta Terré et al., '[Exploring the Use of Tertiary Reclaimed Water in Dairy Cattle Production](#)' (2019).

⁴²¹ Ward, Judge, and Delahay, '[Farm Husbandry and Badger Behaviour: Opportunities to Manage Badger to Cattle Transmission of Mycobacterium Bovis?](#)' (2010);

Walgerm et al., '[Farmers' Attitudes in Connection with the Potential for Rodent Prevention in Livestock Farming in a Municipality in North Rhine-Westphalia, Germany](#)' (2023).

⁴²² Alarcón, Alberto, and Mateu, '[Biosecurity in Pig Farms: A Review](#)' (2021).

⁴²³ Dal Ferro et al., '[Identifying NH3 Emission Mitigation Techniques from Farm to Field Using a Bayesian Network](#)' (2025).

⁴²⁴ Haley et al., '[Developing a Decision-Making Tool for Agricultural Surface Water Decontamination Using Ultraviolet-C Light](#)' (2023).

significant challenge [footnote ⁴²⁵]. Farmers are also highly unlikely to implement biosecurity measures if they are unaware of them [footnote ⁴²⁶] and one study in Germany highlighted that potential barriers to uptake include a lack of education, training, extension services, advice and support for farmers [footnote ⁴²⁷]. The same study suggested that if farmers in Germany were provided with more practical information and advisory services, then the uptake of biosecurity measures would increase [footnote ⁴²⁸].

It is more difficult to convince farmers to implement biosecurity measures if they are regarded as impractical or unfeasible [footnote ⁴²⁹]. One study highlighted that surveyed cattle farmers in England said they would not implement certain biosecurity measures even if grants covered the cost, with the most common reason being the impracticality of implementing biosecurity measures [footnote ⁴³⁰]. Another study with cattle farmers in England found that measures that required changes to existing working patterns and measures that required maintenance were the least likely to be implemented and used consistently [footnote ⁴³¹]. Another study suggested that fencing and mains water provision and vermin-proof buildings/feed stores were seen as impractical, noting that farmers are unlikely to implement measures that are considered impractical, even if they are effective [footnote ⁴³²].

One study on E. coli transmission on UK dairy farms indicated that definitions of ‘quarantine’ varied between farms, resulting in differences to quarantine measures and their potential

⁴²⁵ Ward, Judge, and Delahay, [‘Farm Husbandry and Badger Behaviour: Opportunities to Manage Badger to Cattle Transmission of Mycobacterium Bovis?’](#) (2010);

Wilson, Carter, and Delahay, [‘Advances and Prospects for Management of TB Transmission between Badgers and Cattle’](#) (2011).

⁴²⁶ Dal Ferro et al., [‘Identifying NH3 Emission Mitigation Techniques from Farm to Field Using a Bayesian Network’](#) (2025).

⁴²⁷ Walgern et al., [‘Farmers’ Attitudes in Connection with the Potential for Rodent Prevention in Livestock Farming in a Municipality in North Rhine-Westphalia, Germany’](#) (2023).

⁴²⁸ Ibid.

⁴²⁹ Galipó et al., [‘Prioritization of Pig Farm Biosecurity for Control of Salmonella and Hepatitis E Virus Infections: Results of a European Expert Opinion Elicitation’](#) (2023).

⁴³⁰ Ward, Judge, and Delahay, [‘Farm Husbandry and Badger Behaviour: Opportunities to Manage Badger to Cattle Transmission of Mycobacterium Bovis?’](#) (2010).

⁴³¹ Judge et al., [‘Effectiveness of Biosecurity Measures in Preventing Badger Visits to Farm Buildings’](#) (2011).

⁴³² Shortall et al., [‘Exploring Expert Opinion on the Practicality and Effectiveness of Biosecurity Measures on Dairy Farms in the United Kingdom Using Choice Modeling’](#) (2017).

efficacy [footnote ⁴³³]. 2 UK studies cited a lack of awareness and knowledge on the impacts of livestock diseases and the role of biosecurity on farms among some farmers as limiting the uptake of disease prevention measures [footnote ⁴³⁴]. A study on sheep scab on UK farms found that variation in data collection and incorrect diagnostics for sheep scab may be skewing the data on its spread, with potential knock-on impacts for biosecurity implementation [footnote ⁴³⁵].

Some other barriers include structural barriers to modernising buildings for better infection control [footnote ⁴³⁶], a lack of knowledge around the symptoms of certain diseases and measures to prevent their transmission [footnote ⁴³⁷], costs and practicalities of undertaking certain actions [footnote ⁴³⁸], and inconsistency in recommendations and advice for biosecurity measures in the research, leading to confusion and different measures being adopted by farmers [footnote ⁴³⁹].

Other barriers discussed include:

- inaccuracies in previous biosecurity advice, provided by the UK MAFF, may have undermined the overall message [footnote ⁴⁴⁰]
- the behaviour of neighbouring farmers can impact on willingness to implement biosecurity measures, for example, farmers may feel that their actions are futile and therefore be less likely to implement biosecurity measures if they have neighbours who are seen to buy in 'risky' livestock [footnote ⁴⁴¹]

⁴³³ Snow et al., '[Risk Factors Associated with Extended Spectrum Beta-Lactamase *Escherichia Coli* \(CTX-M\) on Dairy Farms in North West England and North Wales](#)'.

⁴³⁴ Smith et al., '[A Survey of British Sheep Farmers](#)';

Bishop, Erkelens, and Van Winden, '[Indications of a Relationship between Buying-in Policy and Infectious Diseases on Dairy Farms in Wales](#)'.

⁴³⁵ Smith et al., '[A Survey of British Sheep Farmers](#)'.

⁴³⁶ Hosseini et al., '[Qualitative Studies on Farm Managers Perception of Risk from HPAIV and Implementation of Biosecurity Measures on UK Poultry Farms](#)'.

⁴³⁷ Ibid.

⁴³⁸ Gosling et al., '[Assessment of Producers' Response to Salmonella Biosecurity Issues and Uptake of Advice on Laying Hen Farms in England and Wales](#)'.

⁴³⁹ Brennan and Christley, '[Biosecurity on Cattle Farms: A Study in North-West England](#)';

Ellis-Iversen et al., '[Farm Practices to Control E. Coli O157 in Young Cattle - A Randomised Controlled Trial](#)'.

⁴⁴⁰ Ward et al., '[Survey of Badger Access to Farm Buildings and Facilities in Relation to Contact with Cattle](#)' (2008).

⁴⁴¹ Tomlinson, '[Holistic Approach to Bovine Tuberculosis – There Is More to Control than Just Testing](#)', In Practice 45, no. 7 (September 2023): 369–440.

- long-term barriers to maintaining biosecurity measures, for example, if measures are effective then nothing will happen, which can lead to a false feeling of lack of risk and to measures being relaxed [footnote ⁴⁴²]
- the time required to implement measures, particularly exclusion measures which may require opening/closing every day [footnote ⁴⁴³].

Evidence Gaps (17 studies)

The literature reviewed identified several gaps in the research requiring further work. These included a strong focus on measures to keep pathogens out of farms but a lack of understanding of pathogen spread within farms (internal biosecurity) [footnote ⁴⁴⁴]. Another study suggested that cost-benefit studies of biosecurity measures were lacking, and that studies focussed on single measures, such as disinfectant foot baths, or single diseases, rather than a suite of measures to prevent multiple common diseases on farms [footnote ⁴⁴⁵]. As study on broiler chickens suggested that existing studies into *Campylobacter* infections were limited by difference-s in on-farm implementation of measures and poor study design [footnote ⁴⁴⁶].

No studies identified for this review spoke to the isolation and storage of deadstock for diseases prevention. One study suggested that further research was required to investigate which measures, including isolation of herds and limiting contact with neighbouring cattle, provided a truly protective effect when introducing new cattle to herds, to ensure farmers were provided with accurate advice [footnote ⁴⁴⁷].

Studies identified the following gaps:

⁴⁴² Alarcón, Alberto, and Mateu, '[Biosecurity in Pig Farms: A Review](#)' (2021).

⁴⁴³ Wilson, Carter, and Delahay, '[Advances and Prospects for Management of TB Transmission between Badgers and Cattle](#)' (2011).

⁴⁴⁴ Hosseini et al., '[Qualitative Studies on Farm Managers Perception of Risk from HPAIV and Implementation of Biosecurity Measures on UK Poultry Farms](#)'.

⁴⁴⁵ Brennan and Christley, '[Biosecurity on Cattle Farms: A Study in North-West England](#)'.

⁴⁴⁶ Georgiev, Beauvais, and Guitian, '[Effect of Enhanced Biosecurity and Selected On-Farm Factors on *Campylobacter* Colonization of Chicken Broilers](#)'.

⁴⁴⁷ Bishop, Erkelens, and Van Winden, '[Indications of a Relationship between Buying-in Policy and Infectious Diseases on Dairy Farms in Wales](#)'.

- a) Benefits of biosecurity measures at a larger scale [footnote ⁴⁴⁸]
- b) Technical feasibility of implementing measures at a larger scale [footnote ⁴⁴⁹]
- c) Long-term effects on animal health [footnote ⁴⁵⁰]
- d) Farmer barriers to implementation [footnote ⁴⁵¹], including feasibility [footnote ⁴⁵²]
- How to effectively include veterinarians in the implementation of biosecurity measures [footnote ⁴⁵³].

Cost-effectiveness Evidence (7 studies)

Whilst several studies reviewed highlighted that the cost of implementing biosecurity measures may be a barrier to uptake, the economic benefits are clear. In terms of slurry injection/placement equipment, discussions on cost-effectiveness are mixed. One study conducted in northeastern Italy highlighted that slurry injection was considered the most expensive intervention out of various ammonia emission mitigation techniques, whilst also being the most effective approach to mitigate NH₃ volatilization out of the 9 proposed field management interventions [footnote ⁴⁵⁴]. Another study conducted in the United States found that shallow disk injection has the greatest potential to reduce both air and water pollution in comparison to other manure application practices, such as broadcast application, while imposing minimal costs on producers [footnote ⁴⁵⁵].

On the topic of UV water treatment, one study emphasised that UV lamps for disinfecting water offer a favour cost to benefit ratio due to their minimal maintenance requirements and

⁴⁴⁸ Duncan et al., '[Nitrous Oxide and Ammonia Emissions from Injected and Broadcast-Applied Dairy Slurry](#)' (2017).

⁴⁴⁹ Banach et al., '[Application of Water Disinfection Technologies for Agricultural Waters](#)' (2021).

⁴⁵⁰ Terré et al., '[Exploring the Use of Tertiary Reclaimed Water in Dairy Cattle Production](#)' (2019).

⁴⁵¹ Galipó et al., '[Prioritization of Pig Farm Biosecurity for Control of Salmonella and Hepatitis E Virus Infections: Results of a European Expert Opinion Elicitation](#)' (2023).

⁴⁵² Ibid.

⁴⁵³ Walgern et al., '[Farmers' Attitudes in Connection with the Potential for Rodent Prevention in Livestock Farming in a Municipality in North Rhine-Westphalia, Germany](#)' (2023).

⁴⁵⁴ Dal Ferro et al., '[Identifying NH₃ Emission Mitigation Techniques from Farm to Field Using a Bayesian Network](#)' (2025).

⁴⁵⁵ Duncan et al., '[Nitrous Oxide and Ammonia Emissions from Injected and Broadcast-Applied Dairy Slurry](#)' (2017).

relatively small initial investment [footnote ⁴⁵⁶]. Similarly, another study compared UV, ozone, and ultrafiltration (UF) technologies, concluding that UV treatment is the most cost-effective, with a treatment cost of just €0.09 per cubic metre [footnote ⁴⁵⁷]. Further, the literature reviewed suggested that Ultraviolet-C (a short-wavelength and high-energy form of ultraviolet radiation) decontamination could be more cost-effective than chlorination, particularly due to its lower ongoing costs after the initial investment, although cost-effectiveness can vary between different devices [footnote ⁴⁵⁸].

Finally, studies reviewed also discussed vermin-proof buildings/feed stores as a cost-effective solution to preventing feed contamination, noting their minimal reliance on external power [footnote ⁴⁵⁹]. Another study pointed out that preventing wildlife access to farm buildings and feed stores can involve simple and inexpensive measures [footnote ⁴⁶⁰].

Critical Success Factors

Strategic fit and business needs: High alignment

The evidence reviewed suggests the potential for impacts which would align with the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023. Enhanced Biosecurity also has the potential to create economic benefits by reducing disease transmission to livestock and increasing productivity on farms, depending on the specific on-farm practice undertaken. The evidence suggested environmental benefits for slurry injection and UV treatment of water, but did not highlight environmental benefits for all of the on-farm practices. The cost of implementing higher standard farm biosecurity measures differs between on-farm practices but it was highlighted as a key barrier to implementation, suggesting farmers may not see this Theme as economically feasible, depending on the level of financial support offered. However, the cost savings associated with preventing and limiting disease spread and its impacts on

⁴⁵⁶ Paneva and Panev, '[Methods of Cleaning and Disinfection of Drinking Water in Livestock Farms](#)' (2024).

⁴⁵⁷ Banach et al., '[Application of Water Disinfection Technologies for Agricultural Waters](#)' (2021).

⁴⁵⁸ Haley et al., '[Developing a Decision-Making Tool for Agricultural Surface Water Decontamination Using Ultraviolet-C Light](#)' (2023).

⁴⁵⁹ Barasona et al., '[Effectiveness of Cattle Operated Bump Gates and Exclusion Fences in Preventing Ungulate Multi-Host Sanitary Interaction](#)' (2013).

⁴⁶⁰ Ward et al., '[Survey of Badger Access to Farm Buildings and Facilities in Relation to Contact with Cattle](#)' (2008).

livestock yield and farm businesses may outweigh the costs of implementing biosecurity measures. This suggests high alignment with Strategic fit and business needs.

Value for money: Medium alignment

In terms of Value for money, the economic benefits of implementing Enhanced Biosecurity have the potential to be substantial. The Theme may also encourage farmers to enhance the resilience of farms, particularly against biosecurity threats. However, the cost of biosecurity measures was raised as a significant barrier throughout the literature reviewed, with cost varying between the specific on-farm practices reviewed, suggesting that affordability will depend on the level of financial support offered. This suggests medium alignment with Value for money.

Supply side capacity and capability: Low alignment

The evidence reviewed did not discuss in detail the level of current uptake of higher standard biosecurity measures in Wales, however it indicated that uptake is generally low in wider farming population with provision of guidance and support recommended to improve supply side capacity, and therefore alignment with Supply side capacity and capability appears low.

Affordability: Low alignment

Alignment with Affordability is also low without financial support due to the costs associated with implementing the practices which could be undertaken. Therefore, the level of affordability will depend on the level of payment offered for implementing these actions.

Enhanced Habitat Management

The Universal Action (UA5) for existing habitats focuses on “retain and maintain” and thus Enhanced Habitat Management is designed to encourage active management and enhancement of habitats in order to meet Welsh Government commitments to tackle the nature emergency and deliver against the Global Biodiversity Framework targets including 30x30. The on-farm practices covered by this REA that may be available under this Theme include:

- Grassland: do not use avermectins (avermectins are a group of pharmaceutical drugs, such as ivermectin, and moxidectin, widely used in livestock to treat both ectoparasites, such as fleas and ticks, and endoparasites, such as tapeworms and flukes)
- Wet grassland: management for breeding waders (waders are a category of bird with long legs that finds its food in water, such as herons) and management for wintering waders and waterbirds
- Arable: fallow margins (fallow plots are uncropped areas within arable fields), unharvested conservation headlands (conservation headland management involves restricted fertiliser, herbicide and insecticide spraying in a 6 metre margin of sown arable crop), unsprayed crops (unsprayed refers to lack of chemical fertiliser used) and retain stubble after unsprayed crops (after harvest leave stubble of any combinable crop unploughed and untreated).

These on-farm practices are those which may be available as part of the offer for this Optional Theme from scheme launch in 2026. Any practices which may be available at a later stage are not considered in this review,

Due to overlaps in on-farm practices with other Themes additional evidence for this Theme can be found in:

- Enhanced Woodland Management
- Implementation of Designated Site Management Plans
- Hedgerow Creation or Restoration

- Advanced Continuous Professional Development (CPD)
- Creation of Temporary and Permanent Habitats
- Improved Water Quality, Water Usage and Flood Mitigation.
- Collaborative Landscape Scale Activity.

REA Exclusion / Inclusion Criteria:

Inclusion: Studies about the management of habitat types included within the defined list.

Exclusion: Studies concerning management of habitats not included within the defined list. Studies detailing the creation of habitats as opposed to the management of them.

Evidence Base

Using Scopus, 29 articles were identified as in scope of the evidence assessment. An additional 26 articles were sourced using Google Scholar and websites identified in Annex B. Using the quality and relevance criteria 55 articles were analysed.

4 of the studies were conducted in Wales, 35 were conducted in the rest of the UK, one was conducted in the Republic of Ireland, 5 were conducted in Northern Europe, one was conducted in Northern America and the remaining 9 articles did not use an experimental design.

Design of the Intervention (13 studies)

Grassland management and avermectins (1 study)

One study suggested that replacing the use of avermectins will require long-term strategies with sustainable strategies requiring control plans which will need to be tailored and “ever evolving” for each farm [footnote ⁴⁶¹].

⁴⁶¹ Kerr, Charlotte L., David R. Armstrong, and Alison J. Anderson. '[Short Communication: A Practical Farm-Based Trial to Compare Ewe Nematode Control Strategies in Peri-Parturient Ewes](#)'. Edited by Arda Yildirim. PLOS ONE 15, no. 8 (13 August 2020): e0236143..

Design considerations include:

- using targeted selective treatment to maintain refugia worm populations and reduce resistance development. The refugia population of worms consists of individuals that are not exposed to avermectins during targeted selective treatment. As a result, they are less likely to develop resistance genes, helping to slow the development and spread of avermectin resistance in the population
- incorporating rotational or deferred grazing to support varied sward structure and ecological niches
- avoiding excessive anthelmintic use during sensitive periods, such as breeding seasons in the spring and summer, to minimise impacts on dung beetles and soil invertebrates.

Wet grassland management for waders (9 studies)

Wet grassland management for breeding waders like Lapwing and Redshank is dependent on a combination of hydrological control, predator mitigation, and habitat structure. Tall vegetation in verges and patches near nesting areas can attract small mammals, diverting predators from wader nests, and reduce nest predation [footnote ⁴⁶²]. Additionally, wetter conditions paired with verge creation in areas of high wader density significantly reduced nest predation rates [footnote ⁴⁶³].

Design insights include:

- strategic placement of tall verges near wader nesting areas to increase nest survival [footnote ⁴⁶⁴]

⁴⁶² Laidlaw, R.A., J. Smart, M.A. Smart, and J.A. Gill. '[The Influence of Landscape Features on Nest Predation Rates of Grassland-Breeding Waders](#)'. Ibis 157, no. 4 (2015): 700–712.

⁴⁶³ Laidlaw, Rebecca A., Jennifer Smart, Mark A. Smart, and Jennifer A. Gill. '[Scenarios of Habitat Management Options to Reduce Predator Impacts on Nesting Waders](#)'. Edited by Richard Fuller. Journal of Applied Ecology 54, no. 4 (August 2017): 1219–29.

⁴⁶⁴ Laidlaw, R.A., J. Smart, M.A. Smart, and J.A. Gill. '[The Influence of Landscape Features on Nest Predation Rates of Grassland-Breeding Waders](#)'. Ibis 157, no. 4 (2015): 700–712.

- use of low-intensity grazing and delayed mowing to promote vegetation heterogeneity and maintain chick foraging habitat [footnote ⁴⁶⁵]
- avoiding early-season mowing, which can destroy nests or reduce food availability for chicks [footnote ⁴⁶⁶]
- considering predator fencing in key locations, which has been shown to significantly increase breeding numbers of key species
- in both collaborative and coordinative schemes, the role of facilitators and trusted advisors [footnote ⁴⁶⁷].

Arable land management (3 studies)

Permanent, and temporary to a lesser extent, arable field margin and in-field habitat interventions can offer significant biodiversity benefits, particularly for birds and invertebrates, dependent on varying factors. Structurally diverse, floristically rich margins provide winter seed resources, summer insect forage, and shelter for pollinators and small mammals [footnote ⁴⁶⁸]. These margins also complement hedgerows and uncropped patches to enhance overall landscape functionality.

Design considerations include:

- prioritising uncropped margins or wildflower strips over grass-only margins to deliver year-round resources [footnote ⁴⁶⁹]

⁴⁶⁵ Żmihorski, Michał, Tomas Pärt, Tomas Gustafson, and Åke Berg. '[Effects of Water Level and Grassland Management on Alpha and Beta Diversity of Birds in Restored Wetlands](#)'. *Journal of Applied Ecology* 53, no. 2 (2016): 587–95.

⁴⁶⁶ Franks, Samantha E., Maja Roodbergen, Wolf Teunissen, Anne Carrington Cotton, and James W. Pearce-Higgins. '[Evaluating the Effectiveness of Conservation Measures for European Grassland-Breeding Waders](#)'. *Ecology and Evolution* 8, no. 21 (2018): 10555–68.

⁴⁶⁷ Sinner et al., '[Great Expectations for Collective Management: The Mismatch between Supply and Demand for Catchment Groups](#)', *Ecology and Society* 30, no. 1 (2025),;
Jellesmark et al., '[The Effect of Conservation Interventions on the Abundance of Breeding Waders within Nature Reserves in the United Kingdom](#)', *Ibis* 165, no. 1 (2023): 69–81,.

⁴⁶⁸ Vickery, Juliet A., Ruth E. Feber, and Robert J. Fuller. '[Arable Field Margins Managed for Biodiversity Conservation: A Review of Food Resource Provision for Farmland Birds](#)'. *Agriculture, Ecosystems & Environment* 133, no. 1 (1 September 2009): 1–13.

⁴⁶⁹ Ibid.

- incorporating structurally complex hedgerows and adjacent grassy banks to boost nesting habitat and invertebrate overwintering sites [footnote ⁴⁷⁰]
- reducing pesticide use in preceding crops to improve stubble use and overwinter food availability for farmland birds [footnote ⁴⁷¹]
- providing a diversity of margin types across the farm to meet the varying seasonal needs of target species.

These interventions, while often low-cost relative to full-field approaches, must be contextualised within Welsh arable systems, where uptake and landscape integration remain critical to achieving ecological benefits [footnote ⁴⁷²].

Uptake of the Practice (19 studies)

Grassland management and avermectins

It is widely known that avermectins, such as ivermectin, are used across the world as a broad-spectrum anti-parasitic drug for livestock, yet anthelmintic resistance (AR) continues to grow [footnote ⁴⁷³]. A group of UK researchers and practitioners established a set of guidelines in 2003, known as the Sustainable Control of Parasites in Sheep (SCOPS), to help preserve the effectiveness of anthelmintics on farms [footnote ⁴⁷⁴]. SCOPS guidelines include recommendations such as work out a control strategy with your veterinarian or

⁴⁷⁰ Vickery, Juliet A., Ruth E. Feber, and Robert J. Fuller. '[Arable Field Margins Managed for Biodiversity Conservation: A Review of Food Resource Provision for Farmland Birds](#)'. *Agriculture, Ecosystems & Environment* 133, no. 1 (1 September 2009): 1–13..

⁴⁷¹ McKenzie, Ailsa J., Juliet A. Vickery, Carlo Leifert, Peter Shotton, and Mark J. Whittingham. '[Disentangling the Effects of Fertilisers and Pesticides on Winter Stubble Use by Farmland Birds](#)'. *Basic and Applied Ecology* 12, no. 1 (1 February 2011): 80–88.

⁴⁷² MacDonald, Michael A., Ruth Angell, Trevor D. Dines, Stephen Dodd, Karen A. Haysom, Russel Hobson, Ian G. Johnstone, et al. '[Have Welsh Agri-Environment Schemes Delivered for Focal Species? Results from a Comprehensive Monitoring Programme](#)'. *Journal of Applied Ecology* 56, no. 4 (2019): 812–23.

⁴⁷³ Sutton, Gemma, James Bennett, and Mark Bateman. '[Effects of Ivermectin Residues on Dung Invertebrate Communities in a UK Farmland Habitat](#)'. *Insect Conservation and Diversity* 7, no. 1 (2014): 64–72.

⁴⁷⁴ McMahon, C., M. McCoy, S.E. Ellison, J.P. Barley, H.W.J. Edgar, R.E.B. Hanna, F.E. Malone, G.P. Brennan, and I. Fairweather. '[Anthelmintic Resistance in Northern Ireland \(III\): Uptake of “SCOPS” \(Sustainable Control of Parasites in Sheep\) Recommendations by Sheep Farmers](#)'. *Veterinary Parasitology* 193, no. 1–3 (March 2013): 179–84.

advisor, test for anthelmintic resistance on your farm and administer anthelmintics effectively and only when necessary, amongst others [footnote ⁴⁷⁵].

One study [footnote ⁴⁷⁶] (UK) comparing SCOPS adherent farms to traditionally managed ones show that SCOPS farms are using anthelmintics less frequently and more selectively, without compromising animal performance or increasing worm burdens. However, reviewed evidence suggests that farmer adoption of alternative parasite control strategies generally remains inconsistent. Research [footnote ⁴⁷⁷] across organic sheep and goat farms in 5 European countries found that, although many were well-informed about targeted selective treatment, few had implemented it regularly. A study in Northern Ireland between 2005 and 2011 saw some improvements, such as a rise in farmers leaving part of the flock untreated to maintain in refugia populations, but also a 15.9% increase in flocks at risk of under-dosing due to poor weight estimation, and a 14.3% increase from uncalibrated dosing equipment, both of which contribute to resistance [footnote ⁴⁷⁸]. Adoption of more long-term alternatives remains especially limited with a 2016 study of English sheep farmers [footnote ⁴⁷⁹] revealing only 22% engaged in selective breeding for resistance, and just 18% used bioactive forages (plants that contain compounds with beneficial effects on animal health, beyond their direct nutritional value). These methods were more common on larger farms and among those with formal agricultural qualifications.

⁴⁷⁵ Learmount, Jane, Mike J. Glover, and Mike A. Taylor. '[Resistance Delaying Strategies on UK Sheep Farms: A Cost Benefit Analysis](#)'. *Veterinary Parasitology* 254 (30 April 2018): 64–71.

⁴⁷⁶ Learmount, Jane, Nathalie Stephens, Valerie Boughtflower, Alba Barrecheguren, Kayleigh Rickell, Giovanna Massei, and Mike Taylor. '[Three-Year Evaluation of Best Practice Guidelines for Nematode Control on Commercial Sheep Farms in the UK](#)'. *Veterinary Parasitology* 226 (15 August 2016): 116–23.

⁴⁷⁷ Chylinski, Caroline, Spiridoula Athanasiadou, Susann Thüer, Christian Grovermann, Simon Moakes, Hervé Hoste, Saulius Petkevicius, Cynthia Verwer, Jan Verkaik, and Steffen Werne. '[Reducing Anthelmintic Inputs in Organic Farming: Are Small Ruminant Farmers Integrating Alternative Strategies to Control Gastrointestinal Nematodes?](#)' *Veterinary Parasitology* 315 (1 March 2023): 109864.

⁴⁷⁸ McMahon, C., M. McCoy, S.E. Ellison, J.P. Barley, H.W.J. Edgar, R.E.B. Hanna, F.E. Malone, G.P. Brennan, and I. Fairweather. '[Anthelmintic Resistance in Northern Ireland \(III\): Uptake of “SCOPS” \(Sustainable Control of Parasites in Sheep\) Recommendations by Sheep Farmers](#)'. *Veterinary Parasitology* 193, no. 1–3 (March 2013): 179–84.

⁴⁷⁹ Moore, Hope, Fanny Pandolfi, and Ilias Kyriazakis. '[Familiarity with and Uptake of Alternative Methods to Control Sheep Gastro-Intestinal Parasites on Farms in England](#)'. *Veterinary Parasitology* 221 (15 May 2016): 1–8.

Wet grassland management for waders

The majority of articles investigating wet grassland management and waders were of experimental design, taking place on RSPB or similar protected areas. While these sites inherently prioritise bird conservation, making the adoption of such practices more likely, they do not provide insight into the extent of uptake on farms.

3 studies gave better insight into farm practices, having examined the impact of agri-environment schemes (AES) on wader populations, indicating that certain AES interventions benefitted waders [footnote ⁴⁸⁰]. These studies suggest that farmers adopted wader-friendly management practices to some extent across Wales, the UK and Europe. However, the research focused primarily on identifying which AES measures correlated positively with wader populations rather than detailing specific uptake numbers.

Arable land management

6 articles investigated the arable management interventions in the defined list, encouraged by UK and European agri-environmental schemes. Uptake via AES is also highlighted by one study [footnote ⁴⁸¹] that emphasised the contrast between conventional arable management and AES-prescribed practices. The study suggested that these schemes enable the creation of habitats that would not otherwise exist, noting that farmers are generally willing to establish such habitats when paid to do so, but are unlikely to deviate from conventional practices without financial support. The Wales National Trends and Glastir Evaluation [footnote ⁴⁸²] offered further insight into the uptake of practices under Glastir, including fertiliser use, but provided little evidence that the scheme influenced fertiliser application on participating farms. Although fertiliser use in England and Wales has

⁴⁸⁰ Dadam, D, and G M Siriwardena. '[Agri-Environment Effects on Birds in Wales: Tir Gofal Benefited Woodland and Hedgerow Species](#)';

Wilson, Vickery, and Pendlebury, '[Agri-Environment Schemes as a Tool for Reversing Declining Populations of Grassland Waders: Mixed Benefits from Environmentally Sensitive Areas in England](#)', Biological Conservation 136, no. 1 (April 2007): 128–35,;

Franks et al., '[Evaluating the Effectiveness of Conservation Measures for European Grassland-Breeding Waders](#)', Ecology and Evolution 8, no. 21 (2018): 10555–68.

⁴⁸¹ MacDonald, Michael A., Ruth Angell, Trevor D. Dines, Stephen Dodd, Karen A. Haysom, Russel Hobson, Ian G. Johnstone, et al. '[Have Welsh Agri-Environment Schemes Delivered for Focal Species? Results from a Comprehensive Monitoring Programme](#)'. Journal of Applied Ecology 56, no. 4 (2019): 812–23.

⁴⁸² Emmett, B.A. & the ERAMMP team. '[ERAMMP Report-105: Wales National Trends and Glastir Evaluation](#)'. Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP), 2025.

declined by 25% since 2010, this reduction is primarily attributed to rising input costs rather than AES. Data from the ADAS Farm Practice Survey showed no significant differences in fertiliser use between Glastir and non-Glastir farms during the later stages of the scheme, with only small reductions observed at the point of entry. While most farmers reported decreasing their use, a small number noted large increases, potentially explaining spikes in soil nutrient levels. Overall, the anticipated improvements outlined in Glastir's objectives have not been achieved. Additionally, small-scale changes, such as reduced fertiliser use on field margins, may be under-reported due to the whole-farm focus of current data collection methods, highlighting the importance of targeted monitoring to fully assess practice uptake.

Economic Impacts (9 studies)

Grassland management and avermectins

One 2012 study [footnote ⁴⁸³] reported that £84 million was spent annually on controlling internal parasites in the UK. However, increasing parasite resistance and growing insights into the long-term effects on ecosystem functioning suggests other methods may be more sustainable and economical in the long term.

Invertebrates offer important ecosystem functions such as nutrient cycling, improving pasture productivity and economically benefitting farms [footnote ⁴⁸⁴]. One study [footnote ⁴⁸⁵] highlighted the critical role of dung beetles in pasture health, estimating they annually save the UK cattle industry £367 million. However, avermectin use disrupts dung beetle populations, reducing dung decomposition and its associated benefits. The study suggested that discontinuing anthelmintic treatments in adult cattle during grazing could save the dairy and beef industries an additional £6.1 million annually, with additional savings on the cost of

⁴⁸³ Beynon, S.A. '[Potential Environmental Consequences of Administration of Anthelmintics to Sheep](#)'. *Veterinary Parasitology* 189, no. 1 (September 2012): 113–24.

⁴⁸⁴ Beynon, Warwick A. Wainwright, and Michael Christie, '[The Application of an Ecosystem Services Framework to Estimate the Economic Value of Dung Beetles to the U.K. Cattle Industry](#)', *Ecological Entomology* 40, no. S1 (2015): 124–35,;

Sands and Noll, '[Toxicity of Ivermectin Residues in Aged Farmyard Manure to Terrestrial and Freshwater Invertebrates](#)', *Insect Conservation and Diversity* 15, no. 1 (2022): 9–18,

⁴⁸⁵ Beynon, Sarah A., Warwick A. Wainwright, and Michael Christie. '[The Application of an Ecosystem Services Framework to Estimate the Economic Value of Dung Beetles to the U.K. Cattle Industry](#)'. *Ecological Entomology* 40, no. S1 (2015): 124–35.

the treatments themselves. However, alternative parasite control methods would then need to be considered, such as those recommended under SCOPS.

A 2016 survey of English farmers [footnote ⁴⁸⁶] revealed that while farmers in England are relatively aware of alternatives for controlling parasites, the uptake of these methods remains low due to real or perceived economic concerns and uncertainty about their long-term effectiveness. For example, the cost of faecal egg counts to monitor parasites on farms is significant, but there is currently no clear accurate and inexpensive pen-side diagnostic alternative [footnote ⁴⁸⁷]. Despite the costs associated with alternative diagnostic methods, adopting some SCOPS guidelines shows potential for long-term economic benefits through lower product purchases, decreased labour costs and reduced risk of AR, especially as farmers gain experience with these strategies [footnote ⁴⁸⁸].

2 studies explored the alternative control method of targeted avermectin administration versus full herd treatment [footnote ⁴⁸⁹], as outlined under SCOPS. The results indicated that this approach effectively reduced parasite numbers and maintained healthy sheep weights, leading to economic benefits through lower treatment costs, improved ecosystem services, and more sustainable long-term parasite control. One study [footnote ⁴⁹⁰] (UK) reported the economic costs of parasitic infections which can reduce sheep weight by 15%, costing the UK sheep industry over £80 million annually. When reviewing options for parasite control, including multiple avermectin options, the study suggested long acting moxidectin was the most economically beneficial sheep worming treatment due to producing the lowest faecal egg counts and reducing pasture larval loads, therefore

⁴⁸⁶ Moore, Hope, Fanny Pandolfi, and Ilias Kyriazakis. '[Familiarity with and Uptake of Alternative Methods to Control Sheep Gastro-Intestinal Parasites on Farms in England](#)'. *Veterinary Parasitology* 221 (15 May 2016): 1–8.

⁴⁸⁷ Learmount, Jane, Mike J. Glover, and Mike A. Taylor. '[Resistance Delaying Strategies on UK Sheep Farms: A Cost Benefit Analysis](#)'. *Veterinary Parasitology* 254 (30 April 2018): 64–71

⁴⁸⁸ Learmount, Jane, Nathalie Stephens, Valerie Boughtflower, Alba Barrecheguren, Kayleigh Rickell, Giovanna Massei, and Mike Taylor. '[Three-Year Evaluation of Best Practice Guidelines for Nematode Control on Commercial Sheep Farms in the UK](#)'. *Veterinary Parasitology* 226 (15 August 2016): 116–23.

⁴⁸⁹ Busin et al., '[Addressing Sustainable Sheep Farming: Application of a Targeted Selective Treatment Approach for Anthelmintic Use on a Commercial Farm](#)', *Small Ruminant Research* 110, no. 2–3 (March 2013): 100–103;

Cooke, Morgan, and Dungait, '[Modelling the Impact of Targeted Anthelmintic Treatment of Cattle on Dung Fauna](#)', *Environmental Toxicology and Pharmacology* 55 (October 2017): 94–98.

⁴⁹⁰ Kerr, Charlotte L., David R. Armstrong, and Alison J. Anderson. '[Short Communication: A Practical Farm-Based Trial to Compare Ewe Nematode Control Strategies in Peri-Parturient Ewes](#)'. Edited by Arda Yildirim. *PLOS ONE* 15, no. 8 (13 August 2020): e0236143..

lowering the need for multiple treatments and decreasing pasture contamination. This could cut economic costs, reduce labour, and slow the development of avermectin resistance.

Although reviewed evidence seems to be mixed on economic impact of avermectin use or lack thereof, some strategies like targeted treatments offer promising economic advantages if an accurate pen-side identification strategy could be identified.

Wet grassland management for waders

One study [footnote ⁴⁹¹] found that prioritising low-intensity grazing, particularly on temporarily flooded grasslands, could provide cost-effective benefits by increasing the diversity of wet grassland birds, including red-listed species. On grasslands with lower wetness and no flooding, mowing may serve as a more affordable alternative. Additionally, traditional management methods, such as combining mowing with late season grazing, could create a heterogeneous sward that benefits a range of wet grassland bird species, offering potential economic advantages in terms of biodiversity and ecosystem services [footnote ⁴⁹²].

Arable land management

The economic impact was not a primary focus of these studies.

⁴⁹¹ Żmihorski, Michał, Tomas Pärt, Tomas Gustafson, and Åke Berg. '[Effects of Water Level and Grassland Management on Alpha and Beta Diversity of Birds in Restored Wetlands](#)'. *Journal of Applied Ecology* 53, no. 2 (2016): 587–95.

⁴⁹² Smart, Jennifer, Jennifer A. Gill, William J. Sutherland, and Andrew R. Watkinson. '[Grassland-Breeding Waders: Identifying Key Habitat Requirements for Management](#)'. *Journal of Applied Ecology* 43, no. 3 (2006): 454–63.

Environmental Impacts (43 studies)

Grassland management and avermectins

Studies have shown that avermectin can persist in the environment for extended periods, affecting soil organisms and invertebrate biodiversity [footnote ⁴⁹³]. One study [footnote ⁴⁹⁴] found ivermectin residues, a type of avermectin, remain detectable in cowpats for up to 47 days, influencing dung beetle populations and potentially reducing their development and adult emergence [footnote ⁴⁹⁵]. This persistence of ivermectin can also reduce pasture productivity, with one study [footnote ⁴⁹⁶] reporting up to an 18 to 20% decrease in pasture productivity in areas treated with ivermectin-contaminated manure. As dung beetles and other invertebrates are key players in nutrient cycling and soil quality, this impact can undermine ecosystem services vital to agricultural systems [footnote ⁴⁹⁷].

Another study [footnote ⁴⁹⁸] (UK) explored the environmental impact of avermectin on flora, finding that it can affect the germination percentage and timing for many plant species. The residues from macrocyclic lactones, such as ivermectin, can reduce seedling growth by either accelerating or delaying germination, placing plants at a disadvantage when competing for resources like sunlight and water. Targeted treatments, resulting in the use of less avermectins overall may be able to reduce this environmental burden if used correctly

⁴⁹³ Laber et al., '[Effects of Macrocyclic Lactone Anthelmintics on Seed Germination of Temperate Grassland Species](#)', Plant Biology 25, no. 7 (2023): 1046–57.;

Sutton, Gemma, James Bennett, and Mark Bateman. '[Effects of Ivermectin Residues on Dung Invertebrate Communities in a UK Farmland Habitat](#)'. Insect Conservation and Diversity 7, no. 1 (2014): 64–72.;

Sands and Noll, '[Toxicity of Ivermectin Residues in Aged Farmyard Manure to Terrestrial and Freshwater Invertebrates](#)';

Beynon, Wainwright, and Christie, '[The Application of an Ecosystem Services Framework to Estimate the Economic Value of Dung Beetles to the U.K. Cattle Industry](#)'.

⁴⁹⁴ Sutton, Gemma, James Bennett, and Mark Bateman. '[Effects of Ivermectin Residues on Dung Invertebrate Communities in a UK Farmland Habitat](#)'. Insect Conservation and Diversity 7, no. 1 (2014): 64–72.

⁴⁹⁵ Beynon, Sarah A., Warwick A. Wainwright, and Michael Christie. '[The Application of an Ecosystem Services Framework to Estimate the Economic Value of Dung Beetles to the U.K. Cattle Industry](#)'. Ecological Entomology 40, no. S1 (2015): 124–35.

⁴⁹⁶ Sands, Bryony, and Madeleine Noll. '[Toxicity of Ivermectin Residues in Aged Farmyard Manure to Terrestrial and Freshwater Invertebrates](#)'. Insect Conservation and Diversity 15, no. 1 (2022): 9–18.

⁴⁹⁷ Beynon, Sarah A., Warwick A. Wainwright, and Michael Christie. '[The Application of an Ecosystem Services Framework to Estimate the Economic Value of Dung Beetles to the U.K. Cattle Industry](#)'. Ecological Entomology 40, no. S1 (2015): 124–35..

⁴⁹⁸ Laber, L., C. Eichberg, A. Zimmerbeutel, R.-A. Düring, and T. W. Donath. '[Effects of Macrocyclic Lactone Anthelmintics on Seed Germination of Temperate Grassland Species](#)'. Plant Biology 25, no. 7 (2023): 1046–57.

and with continued monitoring of livestock [footnote ⁴⁹⁹]. Alternatively, another study [footnote ⁵⁰⁰] (UK) reported that the use of whole-herd long acting moxidectin also reduces both parasite burden in sheep and decreased pasture contamination, similarly due to less treatments needed per season.

Wet grassland management for waders

Management techniques that enhance soil [footnote ⁵⁰¹], sward [footnote ⁵⁰²], and hydrological conditions [footnote ⁵⁰³] have been found to support chick growth by improving foraging opportunities. Pools, ditches, foot drains, and other wet features often have higher biomass of surface, aerial, and aquatic invertebrates, which are crucial for wader chicks [footnote ⁵⁰⁴]. These features provide essential feeding grounds, especially during the chick-rearing period when water levels fluctuate [footnote ⁵⁰⁵]. Low-intensity grazing regimes on temporary flooded grasslands has been suggested to manage these features and increase the diversity of wet grassland birds, including red-listed species [footnote ⁵⁰⁶].

⁴⁹⁹ Cooke, Morgan, and Dungait, '[Modelling the Impact of Targeted Anthelmintic Treatment of Cattle on Dung Fauna](#)';

Busin et al., '[Addressing Sustainable Sheep Farming: Application of a Targeted Selective Treatment Approach for Anthelmintic Use on a Commercial Farm](#)'.

⁵⁰⁰ Kerr, Charlotte L., David R. Armstrong, and Alison J. Anderson. '[Short Communication: A Practical Farm-Based Trial to Compare Ewe Nematode Control Strategies in Peri-Parturient Ewes](#)'. Edited by Arda Yildirim. PLOS ONE 15, no. 8 (13 August 2020): e0236143..

⁵⁰¹ Smart, Jennifer, Jennifer A. Gill, William J. Sutherland, and Andrew R. Watkinson. '[Grassland-Breeding Waders: Identifying Key Habitat Requirements for Management](#)'. Journal of Applied Ecology 43, no. 3 (2006): 454–63..

⁵⁰² Laidlaw et al., '[Scenarios of Habitat Management Options to Reduce Predator Impacts on Nesting Waders](#)', ed. Richard Fuller, Journal of Applied Ecology 54, no. 4 (August 2017): 1219–29, L.R.;

Mason and J. Smart, '[Wader Chick Condition Is Not Limited by Resource Availability on Wader-Friendly Lowland Wet Grassland Sites in the UK](#)', Wader Study 122, no. 3 (2015): 193–200,.

⁵⁰³ Mason, L.R., and J. Smart. '[Wader Chick Condition Is Not Limited by Resource Availability on Wader-Friendly Lowland Wet Grassland Sites in the UK](#)'. Wader Study 122, no. 3 (2015): 193–200.

⁵⁰⁴ Mason et al., '[Experimental Diversionary Feeding of Red Kites Reduces Chick Predation and Enhances Breeding Productivity of Northern Lapwings Vanellus Vanellus](#)', Journal for Nature Conservation 64 (1 December 2021): 126051,; Mason and Smart, '[Wader Chick Condition Is Not Limited by Resource Availability on Wader-Friendly Lowland Wet Grassland Sites in the UK](#)'.

⁵⁰⁵ Eglington, Sarah M., Jennifer A. Gill, Mark Bolton, Mark A. Smart, William J. Sutherland, and Andrew R. Watkinson. '[Restoration of Wet Features for Breeding Waders on Lowland Grassland](#)'. Journal of Applied Ecology 45, no. 1 (2008): 305–14.

⁵⁰⁶ Żmihorski, Michał, Tomas Pärt, Tomas Gustafson, and Åke Berg. '[Effects of Water Level and Grassland Management on Alpha and Beta Diversity of Birds in Restored Wetlands](#)'. Journal of Applied Ecology 53, no. 2 (2016): 587–95.

Predation, particularly from foxes and raptors, can pose a significant threat to wader populations. Predator diversion through measures like diversionary feeding has been shown to reduce predation rates on wader chicks [footnote ⁵⁰⁷]. Similarly, predator-exclusion fencing has been successful in preventing nest predation [footnote ⁵⁰⁸], especially when combined with lethal control [footnote ⁵⁰⁹]. However, the overall impact of predator control on population trends is mixed, with site-specific factors influencing its success.

At a landscape scale, the structure and availability of vegetation can also influence predator activity and nest survival. Tall vegetation patches near nests, for instance, provide shelter and increase alternative prey availability, reducing wader predation pressure [footnote ⁵¹⁰] [footnote ⁵¹¹]. Fields with less tall vegetation and more open areas tend to experience higher predation rates [footnote ⁵¹²]. Additionally, maintaining a high water table and managing flooding conditions are essential for creating suitable breeding and foraging environments for waders [footnote ⁵¹³].

Arable land management

Fallow and margin interventions have been identified as vital for enhancing pollination services and farmland birds, with strategic placement improving their effectiveness in

⁵⁰⁷ Mason, Lucy R., Rhys E. Green, Graham J. M. Hirons, Andrew M. J. Skinner, Stéphanie C. Peault, Emily V. Upcott, Erica Wells, David J. Wilding, and Jennifer Smart. '[Experimental Diversionary Feeding of Red Kites Reduces Chick Predation and Enhances Breeding Productivity of Northern Lapwings Vanellus Vanellus](#)'. *Journal for Nature Conservation* 64 (1 December 2021): 126051.

⁵⁰⁸ Malpas, L.R., R.J. Kennerley, G.J.M. Hirons, R.D. Sheldon, M. Ausden, J.C. Gilbert, and J. Smart. '[The Use of Predator-Exclusion Fencing as a Management Tool Improves the Breeding Success of Waders on Lowland Wet Grassland](#)'. *Journal for Nature Conservation* 21, no. 1 (2013): 37–47..

⁵⁰⁹ Jellesmark, Sean, Malcolm Ausden, Tim M. Blackburn, Mike Hoffmann, Louise McRae, Piero Visconti, and Richard D. Gregory. '[The Effect of Conservation Interventions on the Abundance of Breeding Waders within Nature Reserves in the United Kingdom](#)'. *Ibis* 165, no. 1 (2023): 69–81..

⁵¹⁰ Laidlaw, Rebecca A., Jennifer Smart, Mark A. Smart, and Jennifer A. Gill. '[Scenarios of Habitat Management Options to Reduce Predator Impacts on Nesting Waders](#)'. Edited by Richard Fuller. *Journal of Applied Ecology* 54, no. 4 (August 2017): 1219–29.

⁵¹¹ Laidlaw, R.A., J. Smart, M.A. Smart, T.W. Bodey, T. Coledale, and J.A. Gill. '[Foxes, Voles, and Waders: Drivers of Predator Activity in Wet Grassland Landscapes](#)'. *Avian Conservation and Ecology* 14, no. 2 (2019).

⁵¹² Laidlaw, R.A., J. Smart, M.A. Smart, and J.A. Gill. '[The Influence of Landscape Features on Nest Predation Rates of Grassland-Breeding Waders](#)'. *Ibis* 157, no. 4 (2015): 700–712.

⁵¹³ Franks, Samantha E., Maja Roodbergen, Wolf Teunissen, Anne Carrington Cotton, and James W. Pearce-Higgins. '[Evaluating the Effectiveness of Conservation Measures for European Grassland-Breeding Waders](#)'. *Ecology and Evolution* 8, no. 21 (2018): 10555–68.

intensively managed landscapes [footnote ⁵¹⁴]. One study [footnote ⁵¹⁵] (UK) found that uncropped margins sown with nectar and pollen-producing plants were more beneficial for bumblebee populations than grass mixes or conservation headlands. Another study [footnote ⁵¹⁶] (Northern Europe) emphasised the role of fallow margins in boosting both species and functional diversity.

The importance of reducing pesticide use is also underscored by several studies. One literature review [footnote ⁵¹⁷] found that stubble fields with no pesticide applications provided critical winter food resources for farmland birds like skylarks, which foraged most frequently in these areas due to higher weed seed densities. Similarly, pesticide restrictions in crop edges [footnote ⁵¹⁸] and unsprayed conservation headlands [footnote ⁵¹⁹] supported high weed abundance and a diverse range of invertebrates and arthropods. These areas not only provided better food resources for invertebrates but also led to higher productivity, as the invertebrates had a more varied diet. Another study [footnote ⁵²⁰] (UK) further compared unsprayed uncropped margins with fertilised conservation headlands, finding the former supported higher species diversity, particularly rare arable plants.

⁵¹⁴ Image, Mike, Emma Gardner, Yann Clough, William E. Kunin, Simon G. Potts, Henrik G. Smith, Graham N. Stone, Duncan B. Westbury, and Tom D. Breeze. '[Which Interventions Contribute Most to the Net Effect of England's Agri-Environment Schemes on Pollination Services?](#)' *Landscape Ecology* 38, no. 1 (1 January 2023): 271–91.

⁵¹⁵ Carvell, C., W. R. Meek, R. F. Pywell, D. Goulson, and M. Nowakowski. '[Comparing the Efficacy of Agri-Environment Schemes to Enhance Bumble Bee Abundance and Diversity on Arable Field Margins](#)'. *Journal of Applied Ecology* 44, no. 1 (2007): 29–40.

⁵¹⁶ Maohua, and Herzon. '[Plant Functional Diversity in Agricultural Margins and Fallow Fields Varies with Landscape Complexity Level: Conservation Implications](#)'. *Journal for Nature Conservation* 22, no. 6 (December 2014): 525–31.

⁵¹⁷ McKenzie, Ailsa J., Juliet A. Vickery, Carlo Leifert, Peter Shotton, and Mark J. Whittingham. '[Disentangling the Effects of Fertilisers and Pesticides on Winter Stubble Use by Farmland Birds](#)'. *Basic and Applied Ecology* 12, no. 1 (1 February 2011): 80–88.

⁵¹⁸ Frampton, G.K., and J.L.C.M. Dorne. '[The Effects on Terrestrial Invertebrates of Reducing Pesticide Inputs in Arable Crop Edges: A Meta-Analysis](#)'. *Journal of Applied Ecology* 44, no. 2 (2007): 362–73.

⁵¹⁹ Smith, Barbara M., Nicholas J. Aebischer, Julie Ewald, Steve Moreby, Caitlin Potter, and John M. Holland. '[The Potential of Arable Weeds to Reverse Invertebrate Declines and Associated Ecosystem Services in Cereal Crops](#)'. *Frontiers in Sustainable Food Systems* 3 (10 January 2020).

⁵²⁰ Walker, K. J., C. N. R. Critchley, A. J. Sherwood, R. Large, P. Nuttall, S. Hulmes, R. Rose, and J. O. Mountford. '[The Conservation of Arable Plants on Cereal Field Margins: An Assessment of New Agri-Environment Scheme Options in England, UK](#)'. *Biological Conservation* 136, no. 2 (1 April 2007): 260–70.

One study [footnote ⁵²¹] (UK) noted that despite wildflower and fallow margins showing trends of enhanced soil carbon, they did not significantly improve soil properties or reduce nutrient runoff or greenhouse gas emissions compared to conventional arable fields. However, this may be due to the short timeframe that margins were in place in this study (3 years) and changes in carbon content and other soil properties often occur slowly; more significant improvements may occur in longer-term or permanent margins.

Social Impacts (14 studies)

Grassland management and avermectins

A key social impact of avermectin use is the growing threat of resistance, largely due to its overuse and non-targeted application. One study [footnote ⁵²²] found that farmers in the Republic of Ireland commonly use albendazole, a broad-spectrum, to treat livestock because it is effective against multiple types of parasites, simplifying the process. However, this widespread reliance on broad-spectrum treatments and non-targeted use has accelerated the development of resistance, complicating effective parasite control [footnote ⁵²³].

One study [footnote ⁵²⁴] (UK) demonstrated that targeted treatment approaches in commercial farm settings could help slow resistance development while maintaining animal performance. Another study [footnote ⁵²⁵] (UK) emphasised the importance of integrated parasite management, combining targeted treatment with improved grazing management, and better nutritional practices. However, such strategies require additional time and effort

⁵²¹ Bullock, James M., Morag E. McCracken, Michael J. Bowes, Roselle E. Chapman, Anil R. Graves, Shelley A. Hinsley, Michael G. Hutchins, et al. '[Does Agri-Environmental Management Enhance Biodiversity and Multiple Ecosystem Services?: A Farm-Scale Experiment](#)'. Agriculture, Ecosystems & Environment 320 (October 2021): 107582.

⁵²² Selemetas et al., '[The Effects of Farm Management Practices on Liver Fluke Prevalence and the Current Internal Parasite Control Measures Employed on Irish Dairy Farms](#)', Veterinary Parasitology 207, no. 3–4 (January 2015): 228–40,.

⁵²³ Selemetas et al.; Sutton, Gemma, James Bennett, and Mark Bateman. '[Effects of Ivermectin Residues on Dung Invertebrate Communities in a UK Farmland Habitat](#)'. Insect Conservation and Diversity 7, no. 1 (2014): 64–72.

⁵²⁴ Busin, V., F. Kenyon, N. Laing, M.J. Denwood, D. McBean, N.D. Sargison, and K. Ellis. '[Addressing Sustainable Sheep Farming: Application of a Targeted Selective Treatment Approach for Anthelmintic Use on a Commercial Farm](#)'. Small Ruminant Research 110, no. 2–3 (March 2013): 100–103.

⁵²⁵ Kerr, Charlotte L., David R. Armstrong, and Alison J. Anderson. '[Short Communication: A Practical Farm-Based Trial to Compare Ewe Nematode Control Strategies in Peri-Parturient Ewes](#)'. Edited by Arda Yildirim. PLOS ONE 15, no. 8 (13 August 2020): e0236143..

from farmers, as frequent monitoring of animal body weight and parasite loads is needed to determine treatment necessity. Farmers therefore need to be consulted when considering parasitic control as they are directly involved in making decisions about the type and frequency of antiparasitic treatments [footnote ⁵²⁶].

Wet grassland / Arable land management

The social impacts of wet grassland and arable land management options were not considered in the reviewed evidence.

Barriers (21 studies)

Grassland management and avermectins

Several studies suggest a knowledge-action gap undermines efforts to reduce AR, where farmers may be informed but not fully convinced of the tangible benefits or feasibility of alternative methods [footnote ⁵²⁷]. One study [footnote ⁵²⁸] showed that more experienced farmers were less likely to employ sustainable parasite control measures, suggesting this may be due to a greater reliance on their own sense of judgement. This suggests that more experienced farmers may downplay the significance of parasite problems once identified and maybe less inclined to seek external guidance on alternative control methods.

As per a 2018 study [footnote ⁵²⁹] (UK), 72.2% of sheep farmers who obtain anthelmintics through veterinarians report using faecal egg count testing (FECs), suggesting that knowledge transfer through the point of sale, such as face to face with veterinarians, could

⁵²⁶ Beynon, '[Potential Environmental Consequences of Administration of Anthelmintics to Sheep](#)', Veterinary Parasitology 189, no. 1 (September 2012): 113–24,;

Morgans et al., '[A Participatory, Farmer-Led Approach to Changing Practices around Antimicrobial Use on UK Farms](#)', Journal of Dairy Science 104, no. 2 (2021): 2212–30,

⁵²⁷ Jack et al., '[A Quantitative Analysis of Attitudes and Behaviours Concerning Sustainable Parasite Control Practices from Scottish Sheep Farmers](#)', Preventive Veterinary Medicine, SVEPM 2016 - Annual Conference of The Society for Veterinary Epidemiology and Preventive Medicine, 139 (1 April 2017): 134–45,; Caroline Chylinski et al., '[Reducing Anthelmintic Inputs in Organic Farming: Are Small Ruminant Farmers Integrating Alternative Strategies to Control Gastrointestinal Nematodes?](#)', Veterinary Parasitology 315 (1 March 2023): 109864.

⁵²⁸ Jack et al., '[A Quantitative Analysis of Attitudes and Behaviours Concerning Sustainable Parasite Control Practices from Scottish Sheep Farmers](#)', Preventive Veterinary Medicine, SVEPM 2016 - Annual Conference of The Society for Veterinary Epidemiology and Preventive Medicine, 139 (1 April 2017): 134–45.

⁵²⁹ Easton, Stephanie, Gina L. Pinchbeck, David J. Bartley, Jane E. Hodgkinson, and Jacqueline B. Matthews. '[A Survey of Experiences of UK Cattle and Sheep Farmers with Anthelmintic Prescribers: Are Best Practice Principles Being Deployed at Farm Level?](#)' Preventive Veterinary Medicine 155 (July 2018): 27–37.

improve this. One study [footnote ⁵³⁰] suggested an option to further peer-to-peer learning models and facilitated group approaches. The study suggested that these have shown success in shifting behaviour around anthelmintic use, and similar methods could support better uptake of sustainable parasite control.

One study [footnote ⁵³¹] noted that targeted treatment as opposed to whole herd treatment is widely accepted as the best strategy for preserving avermectin effectiveness among scientists. The issue arises when attempting to identify animals experiencing infections severe enough to impact health or productivity. This experiment suggested tracking bodyweight of growing lambs could be one option to indicate infection, however, this would not necessarily be an appropriate method for ewes. Unfortunately, there is currently no low-cost, user-friendly diagnostic tool that offers quick results alongside high accuracy, precision, and sensitivity [footnote ⁵³²]. Future parasite management strategies for UK sheep farming must be practical and cost-effective to encourage widespread adoption [footnote ⁵³³].

Wet grassland management for waders

One study [footnote ⁵³⁴] (Northern Europe) suggested that temporary flooding and moderate wetness should be prioritised when selecting wetland sites for restoration to benefit waders. However, regulating flooding can be challenging due to the risk of flooding adjacent farmland, requiring financial compensation for affected farmers. Similarly, another study

⁵³⁰ Morgans, Lisa C., Sarah Bolt, Elizabeth Bruno-McClung, Lisa van Dijk, Maria P. Escobar, Henry J. Buller, David C. J. Main, and Kristen K. Reyher. '[A Participatory, Farmer-Led Approach to Changing Practices around Antimicrobial Use on UK Farms](#)'. *Journal of Dairy Science* 104, no. 2 (1 February 2021): 2212–30.

⁵³¹ Busin, V., F. Kenyon, N. Laing, M.J. Denwood, D. McBean, N.D. Sargison, and K. Ellis. '[Addressing Sustainable Sheep Farming: Application of a Targeted Selective Treatment Approach for Anthelmintic Use on a Commercial Farm](#)'. *Small Ruminant Research* 110, no. 2–3 (March 2013): 100–103.

⁵³² Sabatini, Gustavo Adolfo, Fernando de Almeida Borges, Edwin Claerebout, Leonor Sicalo Gianechini, Johan Höglund, Ray Matthew Kaplan, Welber Daniel Zanetti Lopes, et al. '[Practical Guide to the Diagnostics of Ruminant Gastrointestinal Nematodes, Liver Fluke and Lungworm Infection: Interpretation and Usability of Results](#)'. *Parasites & Vectors* 16 (8 February 2023): 58.

⁵³³ Kerr, Charlotte L., David R. Armstrong, and Alison J. Anderson. '[Short Communication: A Practical Farm-Based Trial to Compare Ewe Nematode Control Strategies in Peri-Parturient Ewes](#)'. Edited by Arda Yildirim. *PLOS ONE* 15, no. 8 (13 August 2020): e0236143..

⁵³⁴ Żmihorski, Michał, Tomas Pärt, Tomas Gustafson, and Åke Berg. '[Effects of Water Level and Grassland Management on Alpha and Beta Diversity of Birds in Restored Wetlands](#)'. *Journal of Applied Ecology* 53, no. 2 (2016): 587–95.

[footnote ⁵³⁵] (UK) emphasised that sustainable land management practices, such as foot drains, could help recover breeding waders, but careful hydrological management is crucial to ensure they remain effective without disrupting farming operations. Resistance from farmers to raise groundwater levels is also a key social challenge to address [footnote ⁵³⁶]. While higher water levels benefit wader populations, they can conflict with agricultural priorities. However, controlled flooding techniques have shown promise as a compromise, potentially making wetland restoration more acceptable to farmers in lowland areas across Europe.

One barrier to the diversionary feeding method is the extra staff time required for this feeding [footnote ⁵³⁷].

Exclusion fencing, a non-lethal method for reducing predation pressure, can be effective in protecting nests from larger mammals like foxes but has limitations [footnote ⁵³⁸], such as needing regular maintenance, offering no protection against avian predators and, most requiring mains electricity which may not be possible to implement in fields far from power sources [footnote ⁵³⁹].

One review [footnote ⁵⁴⁰] noted that while lethal control is an emotive and controversial method, it may be the only viable option in certain landscapes, particularly for species that breed at low densities and whose broods roam over large areas. However, the success of predator control and wader conservation methods seem to be generally context-dependent, depending on factors such as local predator populations, water features, and the specific

⁵³⁵ Eglington, Sarah M., Jennifer A. Gill, Mark Bolton, Mark A. Smart, William J. Sutherland, and Andrew R. Watkinson. '[Restoration of Wet Features for Breeding Waders on Lowland Grassland](#)'. *Journal of Applied Ecology* 45, no. 1 (2008): 305–14..

⁵³⁶ Ibid.

⁵³⁷ Mason, Lucy R., Rhys E. Green, Graham J. M. Hirons, Andrew M. J. Skinner, Stéphanie C. Peault, Emily V. Upcott, Erica Wells, David J. Wilding, and Jennifer Smart. '[Experimental Diversionary Feeding of Red Kites Reduces Chick Predation and Enhances Breeding Productivity of Northern Lapwings Vanellus Vanellus](#)'. *Journal for Nature Conservation* 64 (1 December 2021): 126051.

⁵³⁸ Laidlaw, Rebecca A. et al. '[Predator Management for Breeding Waders: A Review of Current Evidence and Priority Knowledge Gaps](#)'. *Wader Study* 128, no. 1 (15 April 2021).

⁵³⁹ Porteus, Tom A., Mike J. Short, Andrew N. Hoodless, and Jonathan C. Reynolds. '[Movement Ecology and Minimum Density Estimates of Red Foxes in Wet Grassland Habitats Used by Breeding Wading Birds](#)'. *European Journal of Wildlife Research* 70, no. 1 (28 December 2023): 8.

⁵⁴⁰ Laidlaw, Rebecca A. et al. 2021 '[Predator Management for Breeding Waders: A Review of Current Evidence and Priority Knowledge Gaps](#)'. *Wader Study* 128, no. 1 (15 April 2021).

environment. Additionally, due to the large-scale movement of predators [footnote ⁵⁴¹], as well as the influence of climate change on landscapes [footnote ⁵⁴²], a more comprehensive, landscape-scale approach is essential to effectively address the declining wader population.

Several studies highlighted the importance of considering the surrounding environment when implementing interventions, underscoring the need for careful landscape management [footnote ⁵⁴³]. This would necessitate increased coordination between policymakers, farmers, and landowners, as well as additional financial investment, planning, and administrative efforts, all of which could hinder the adoption of such measures. Understanding the values and attitudes of farmers is also crucial, as is identifying factors to encourage uptake such interventions [footnote ⁵⁴⁴]. 2 studies [footnote ⁵⁴⁵] (UK) emphasise that AESs offer potential solutions for facilitating large-scale conservation efforts and preventing the fragmentation of high-quality habitats.

⁵⁴¹ Bolton, Mark, Glen Tyler, Ken Smith, and Roy Bamford. '[The Impact of Predator Control on Lapwing Vanellus Vanellus Breeding Success on Wet Grassland Nature Reserves](#)'. *Journal of Applied Ecology* 44, no. 3 (2007): 534–44.

⁵⁴² Smart, Jennifer, Jennifer A. Gill, William J. Sutherland, and Andrew R. Watkinson. '[Grassland-Breeding Waders: Identifying Key Habitat Requirements for Management](#)'. *Journal of Applied Ecology* 43, no. 3 (2006): 454–63.

⁵⁴³ Dadam, D., and G M Siriwardena. '[Agri-Environment Effects on Birds in Wales: Tir Gofal Benefited Woodland and Hedgerow Species](#)';

Franks et al., '[Evaluating the Effectiveness of Conservation Measures for European Grassland-Breeding Waders](#)';

Manton et al., '[Wet Grasslands as a Green Infrastructure for Ecological Sustainability: Wader Conservation in Southern Sweden as a Case Study](#)', *Sustainability (Switzerland)* 8, no. 4 (2016);

Eglington et al., '[Habitat Management and Patterns of Predation of Northern Lapwings on Wet Grasslands: The Influence of Linear Habitat Structures at Different Spatial Scales](#)', *Biological Conservation* 142, no. 2 (1 February 2009): 314–24;

Rhymer et al., '[Can Ecosystem Services Be Integrated with Conservation? A Case Study of Breeding Waders on Grassland](#)', *Ibis* 152, no. 4 (2010): 698–712;

Laidlaw et al., '[The Influence of Landscape Features on Nest Predation Rates of Grassland-Breeding Waders](#)', *Ibis* 157, no. 4 (2015): 700–712,

⁵⁴⁴ Manton, M., P. Angelstam, P. Milberg, and M. Elbakidze. '[Wet Grasslands as a Green Infrastructure for Ecological Sustainability: Wader Conservation in Southern Sweden as a Case Study](#)'. *Sustainability (Switzerland)* 8, no. 4 (2016).

⁵⁴⁵ Laidlaw et al., '[Scenarios of Habitat Management Options to Reduce Predator Impacts on Nesting Waders](#)'; Eglington et al., '[Restoration of Wet Features for Breeding Waders on Lowland Grassland](#)', *Journal of Applied Ecology* 45, no. 1 (2008): 305–14,

Arable land management

While researchers suggested increasing thresholds of margins to be from 5% (the current threshold for Ecological Focus Areas in England) to over 10% of the total field area, this raised concerns about weeds and farmer resistance to them. While some arable weeds benefitted farmland biodiversity, careful management is needed to prevent the spread of undesirable species, which could hinder the adoption of certain arable AES interventions [footnote ⁵⁴⁶]. One study [footnote ⁵⁴⁷] (UK) found farmers were reluctant to adopt practices that encourage weeds, despite their potential benefits for biodiversity and pest control. Both studies suggested weeds can support beneficial invertebrates and provide ecosystem services without taking land out of production, yet farmers resist their presence due to concerns over crop productivity. This is reflected in the low uptake of English AES options like conservation headlands, which restrict agrochemical use. However, recent technology in remote sensing means that weed control can be increasingly targeted to balance biodiversity with crop protection and could address farmers' concerns [footnote ⁵⁴⁸].

One study suggested that whole-field parcels and linear elements with non-cropped vegetation contribute differently to functional diversity, meaning a policy that focuses on only one while neglecting the other may fall short of creating an ecologically sustainable landscape [footnote ⁵⁴⁹]. Expanding on this, one study [footnote ⁵⁵⁰] noted that the effectiveness of certain interventions depends on their placement relative to crops, other AES measures, and existing habitats. This adds complexity, as implementing these

⁵⁴⁶ Wagner et al., '[Cereal Density and N-Fertiliser Effects on the Flora and Biodiversity Value of Arable Headlands](#)', Biodiversity and Conservation 26, no. 1 (1 January 2017): 85–102,;

Smith et al., '[The Potential of Arable Weeds to Reverse Invertebrate Declines and Associated Ecosystem Services in Cereal Crops](#)', Frontiers in Sustainable Food Systems 3 (10 January 2020).

⁵⁴⁷ Wagner et al., '[Cereal Density and N-Fertiliser Effects on the Flora and Biodiversity Value of Arable Headlands](#)'; Smith et al., '[The Potential of Arable Weeds to Reverse Invertebrate Declines and Associated Ecosystem Services in Cereal Crops](#)'.

⁵⁴⁸ Smith, Barbara M., Nicholas J. Aebischer, Julie Ewald, Steve Moreby, Caitlin Potter, and John M. Holland. '[The Potential of Arable Weeds to Reverse Invertebrate Declines and Associated Ecosystem Services in Cereal Crops](#)'. Frontiers in Sustainable Food Systems 3 (10 January 2020).

⁵⁴⁹ Maohua, and Herzon. '[Plant Functional Diversity in Agricultural Margins and Fallow Fields Varies with Landscape Complexity Level: Conservation Implications](#)'. Journal for Nature Conservation 22, no. 6 (December 2014): 525–31.

⁵⁵⁰ Image, Mike, Emma Gardner, Yann Clough, William E. Kunin, Simon G. Potts, Henrik G. Smith, Graham N. Stone, Duncan B. Westbury, and Tom D. Breeze. '[Which Interventions Contribute Most to the Net Effect of England's Agri-Environment Schemes on Pollination Services?](#)' Landscape Ecology 38, no. 1 (1 January 2023): 271–91.

measures at a landscape scale would require increased coordination, planning, and administrative effort, potentially hindering their adoption.

Evidence Gaps (10 studies)

The following are gaps identified within the reviewed papers.

Grassland management and avermectins

The long-term impacts of avermectins are largely unknown despite the global threat of drug resistance. Future research should focus on assessing these impacts on biodiversity and include economic analysis to balance short-term production gains with long-term environmental consequences [footnote ⁵⁵¹].

Long-term strategies that balance effective parasite control, maximise livestock productivity, and preserve the efficacy of avermectin treatments require further investigation. In particular, there is a need for robust evidence on the development and implementation of adaptive, farm-specific control plans that account for local conditions, management practices, and resistance pressures [footnote ⁵⁵²].

Wet grassland management for waders

Landscape-scale research is a major gap [footnote ⁵⁵³], with a focus on maintaining functional habitat networks through governance and management of social–ecological

⁵⁵¹ Cooke, Andrew S., Eric R. Morgan, and Jennifer A.J. Dungait. '[Modelling the Impact of Targeted Anthelmintic Treatment of Cattle on Dung Fauna](#)'. *Environmental Toxicology and Pharmacology* 55 (October 2017): 94–98.

⁵⁵² Kerr, Charlotte L., David R. Armstrong, and Alison J. Anderson. '[Short Communication: A Practical Farm-Based Trial to Compare Ewe Nematode Control Strategies in Peri-Parturient Ewes](#)'. Edited by Arda Yildirim. *PLOS ONE* 15, no. 8 (13 August 2020): e0236143..

⁵⁵³ Wilson, Vickery, and Pendlebury, '[Agri-Environment Schemes as a Tool for Reversing Declining Populations of Grassland Waders: Mixed Benefits from Environmentally Sensitive Areas in England](#)'; Laidlaw et al., '[The Influence of Landscape Features on Nest Predation Rates of Grassland-Breeding Waders](#)'; Rhymer et al., '[Can Ecosystem Services Be Integrated with Conservation? A Case Study of Breeding Waders on Grassland](#)';

Manton et al., '[Wet Grasslands as a Green Infrastructure for Ecological Sustainability: Wader Conservation in Southern Sweden as a Case Study](#)';

Manton and Angelstam, '[Macroecology of North European Wet Grassland Landscapes: Habitat Quality, Waders, Avian Predators and Nest Predation](#)', *Sustainability* 13, no. 15 (January 2021): 8138,

systems [footnote ⁵⁵⁴]. Different landscape governance approaches need to be explored to understand how to sustain wader populations long-term [footnote ⁵⁵⁵].

More research on impacts of AES as current evidence supporting positive wader conservation impacts is mixed [footnote ⁵⁵⁶].

Predator density and impact on nest and chick survival need further investigation in each area/farm before implementing predator control measures due to the context-dependent success of these methods [footnote ⁵⁵⁷].

Long-term monitoring of the effects of diversionary feeding on kite abundance and predation rates, including non-target species [footnote ⁵⁵⁸].

A workshop held at the 2019 International Wader Study Group highlighted the need to [footnote ⁵⁵⁹]:

- increase knowledge of predators and their responses to management interventions
- bridge the gap between science, policy, practitioners, and the public
- establish clear and consistent goals for breeding wader populations to guide management tool development
- compare the economic costs, ethical implications, and effectiveness of culling to non-lethal approaches.

⁵⁵⁴ Manton, Michael, and Per Angelstam. '[Macroecology of North European Wet Grassland Landscapes: Habitat Quality, Waders, Avian Predators and Nest Predation](#)'. Sustainability 13, no. 15 (January 2021): 8138.

⁵⁵⁵ Manton, M., P. Angelstam, P. Milberg, and M. Elbakidze. '[Wet Grasslands as a Green Infrastructure for Ecological Sustainability: Wader Conservation in Southern Sweden as a Case Study](#)'. Sustainability (Switzerland) 8, no. 4 (2016)..

⁵⁵⁶ Franks, Samantha E., Maja Roodbergen, Wolf Teunissen, Anne Carrington Cotton, and James W. Pearce-Higgins. '[Evaluating the Effectiveness of Conservation Measures for European Grassland-Breeding Waders](#)'. Ecology and Evolution 8, no. 21 (2018): 10555–68.

⁵⁵⁷ Bolton et al., '[The Impact of Predator Control on Lapwing Vanellus Vanellus Breeding Success on Wet Grassland Nature Reserves](#)', Journal of Applied Ecology 44, no. 3 (2007): 534–44,; Eglington et al., '[Habitat Management and Patterns of Predation of Northern Lapwings on Wet Grasslands: The Influence of Linear Habitat Structures at Different Spatial Scales](#)'.

⁵⁵⁸ Manton, Michael, and Per Angelstam. '[Macroecology of North European Wet Grassland Landscapes: Habitat Quality, Waders, Avian Predators and Nest Predation](#)'. Sustainability 13, no. 15 (January 2021): 8138.

⁵⁵⁹ Laidlaw, Rebecca A. et al. '[Predator Management for Breeding Waders: A Review of Current Evidence and Priority Knowledge Gaps](#)'. Wader Study 128, no. 1 (15 April 2021).

Arable land management

Further experiments investigating conservation headlands should focus on establishing which management conditions offer the greatest benefit to rare and declining arable plants [footnote ⁵⁶⁰] and non-gamebird species [footnote ⁵⁶¹].

Cost-effectiveness Evidence (22 studies)

Grassland management and avermectins

A cost-benefit analysis of avermectin use should consider both the short-term and long-term impacts. While using avermectin ensures healthy-weight sheep and increased profits, it also contributes to the risk of resistance, leading to future economic losses. Conversely, avoiding avermectin use saves on treatment costs and reduces long-term resistance risks, but if not appropriately managed with an alternative method, may result in poorly livestock and financial losses for the farmers. One study [footnote ⁵⁶²] (UK) emphasised that alternative strategies to whole-herd treatments must be both practical and cost-effective to encourage widespread adoption among UK farmers. Another study [footnote ⁵⁶³] (UK) highlighted various methods for selectively targeting anthelmintic treatments, ranging from visual inspection to physiological markers. An ideal targeted treatment approach should be cost-effective, easy to use, require minimal training, and allow for quick, on-site decision-making.

While SCOPS farms significantly reduce anthelmintic use [footnote ⁵⁶⁴], lowering product and labour costs, adopting alternative control strategies can introduce new expenses. A

⁵⁶⁰ Wagner, Markus, James M. Bullock, Lucy Hulmes, Sarah Hulmes, and Richard F. Pywell. '[Cereal Density and N-Fertiliser Effects on the Flora and Biodiversity Value of Arable Headlands](#)'. Biodiversity and Conservation 26, no. 1 (1 January 2017): 85–102.

⁵⁶¹ Vickery, Juliet A., Ruth E. Feber, and Robert J. Fuller. 'Arable Field Margins Managed for Biodiversity Conservation: [A Review of Food Resource Provision for Farmland Birds](#)'. Agriculture, Ecosystems & Environment 133, no. 1 (1 September 2009): 1–13.

⁵⁶² Kerr, Charlotte L., David R. Armstrong, and Alison J. Anderson. '[Short Communication: A Practical Farm-Based Trial to Compare Ewe Nematode Control Strategies in Peri-Parturient Ewes](#)'. Edited by Arda Yildirim. PLOS ONE 15, no. 8 (13 August 2020): e0236143..

⁵⁶³ Busin, V., F. Kenyon, N. Laing, M.J. Denwood, D. McBean, N.D. Sargison, and K. Ellis. '[Addressing Sustainable Sheep Farming: Application of a Targeted Selective Treatment Approach for Anthelmintic Use on a Commercial Farm](#)'. Small Ruminant Research 110, no. 2–3 (March 2013): 100–103.

⁵⁶⁴ Learmount, Jane, Nathalie Stephens, Valerie Boughtflower, Alba Barrecheguren, Kayleigh Rickell, Giovanna Massei, and Mike Taylor. '[Three-Year Evaluation of Best Practice Guidelines for Nematode Control on Commercial Sheep Farms in the UK](#)'. Veterinary Parasitology 226 (15 August 2016): 116–23.

cost-benefit analysis of SCOPS recommendations [footnote ⁵⁶⁵] comparing best and worst-case scenarios across farm sizes found that medium and large farms could achieve a net economic gain, particularly when production benefits from effective worming were included. However, the low cost of older anthelmintics means that without improved productivity, the financial advantage may be marginal. These findings highlight the need for innovation in affordable diagnostics and clearer communication of SCOPS' long-term economic value to encourage adoption.

Wet grassland management for waders

Predator exclusion fencing can significantly reduce wader nest predation but is costly and requires ongoing maintenance [footnote ⁵⁶⁶]. Additionally, fencing is not effective against small or avian predators [footnote ⁵⁶⁷], and other interventions may need to be considered alongside fencing, increasing costs further.

A more cost-effective alternative may be habitat management strategies, such as increasing wetness and adding verges in high lapwing density areas, which could reduce nest predation from 70% to 50% [footnote ⁵⁶⁸]. While not as effective as full predator exclusion, these approaches are more practical over larger areas and more financially viable. Implementing verge addition through light cattle grazing and periodic mowing offers a relatively low-cost method to enhance nesting conditions while maintaining manageable upkeep expenses [footnote ⁵⁶⁹]. However, grazing must be managed appropriately as high stock cattle grazing can increase the risk of nest trampling. Reducing grazing intensity

⁵⁶⁵ Learmount, Jane, Mike J. Glover, and Mike A. Taylor. '[Resistance Delaying Strategies on UK Sheep Farms: A Cost Benefit Analysis](#)'. *Veterinary Parasitology* 254 (30 April 2018): 64–71

⁵⁶⁶ Jellesmark et al., '[The Effect of Conservation Interventions on the Abundance of Breeding Waders within Nature Reserves in the United Kingdom](#)';

Laidlaw et al., '[Scenarios of Habitat Management Options to Reduce Predator Impacts on Nesting Waders](#)';

Franks et al., '[Evaluating the Effectiveness of Conservation Measures for European Grassland-Breeding Waders](#)';

Manton et al., '[Wet Grasslands as a Green Infrastructure for Ecological Sustainability: Wader Conservation in Southern Sweden as a Case Study](#)'.

⁵⁶⁷ Laidlaw, Rebecca A. et al. '[Predator Management for Breeding Waders: A Review of Current Evidence and Priority Knowledge Gaps](#)'. *Wader Study* 128, no. 1 (15 April 2021).

⁵⁶⁸ Laidlaw, Rebecca A., Jennifer Smart, Mark A. Smart, and Jennifer A. Gill. '[Scenarios of Habitat Management Options to Reduce Predator Impacts on Nesting Waders](#)'. Edited by Richard Fuller. *Journal of Applied Ecology* 54, no. 4 (August 2017): 1219–29.

⁵⁶⁹ Ibid.

during peak nesting periods can minimise these losses but it may also lower agricultural productivity [footnote ⁵⁷⁰].

One study [footnote ⁵⁷¹] highlighted the costs of diversionary feeding of birds of prey to reduce wader predation at Otmoor Nature Reserve (UK), which ranged from £18,700 to £20,300 annually, mainly due to research staff salaries and monitoring transport. However, the actual cost of feeding was lower, around £4,600 per year. These costs varied based on predator presence, feeding logistics, and staffing, but were small relative to the annual costs of all activities relating to management of the reserve for breeding waders. Mason et al., therefore considered the activity economically beneficial.

Arable land management

Field margins may offer a more cost-effective approach to providing food resources for birds compared to whole-field options, though their effectiveness depends on the location of and the specific types of margins implemented [footnote ⁵⁷²].

Farmers typically make decisions based on individual cost assessments, which vary by farm size and local conditions. While options like field headlands can be highly effective for pollinators, their high costs often make them inefficient. In contrast, hedgerow management is more efficient due to its lower costs. This highlights a mismatch between effectiveness and efficiency, where the most impactful AES interventions are not always the most cost-

⁵⁷⁰ Smart, Jennifer, Jennifer A. Gill, William J. Sutherland, and Andrew R. Watkinson. '[Grassland-Breeding Waders: Identifying Key Habitat Requirements for Management](#)'. *Journal of Applied Ecology* 43, no. 3 (2006): 454–63.

⁵⁷¹ Mason, Lucy R., Rhys E. Green, Graham J. M. Hirons, Andrew M. J. Skinner, Stéphanie C. Peault, Emily V. Upcott, Erica Wells, David J. Wilding, and Jennifer Smart. '[Experimental Diversionary Feeding of Red Kites Reduces Chick Predation and Enhances Breeding Productivity of Northern Lapwings Vanellus Vanellus](#)'. *Journal for Nature Conservation* 64 (1 December 2021): 126051.

⁵⁷² Vickery, Juliet A., Ruth E. Feber, and Robert J. Fuller. '[Arable Field Margins Managed for Biodiversity Conservation: A Review of Food Resource Provision for Farmland Birds](#)'. *Agriculture, Ecosystems & Environment* 133, no. 1 (1 September 2009): 1–13.

effective [footnote ⁵⁷³]. Broad-scale evaluations are needed to assess arable options overall success in biodiversity conservation and cost-effectiveness [footnote ⁵⁷⁴].

Peatland Management and Restoration

An REA was conducted for a draft Optional Theme titled “Peatland Management and Restoration” which was intended to encourage Peatland Management and Restoration through optional aspects of the Sustainable Farming Scheme.

As policy development has progressed this Optional Theme was integrated into the Manage and Enhance Habitats Theme with the objective to encourage the “management of peatlands to help store and regulate water flow and reduce the risk and impacts of wildfires”. The peatland action will not involve restoration as restoring damaged peatlands and reinstating water tables is a complex process requiring specialist skills and machinery. For this reason, the Scheme does not propose to fund individual farmers to undertake peatland restoration. Large areas of complex and specialised peatland restoration are carried out as part of the National Peatland Action Programme (NPAP).

The REA represents a broader assessment of evidence related to restoration, as well as management. In line with this a search strategy was produced to identify search terms that would produce relevant evidence to the management and restoration of peatland (Annex A). These were supplemented with specific practices, such as rewetting and restoration, while searches were manually filtered to include only those studies which focussed on the specific practices.

The assessment of alignment with the CSFs for the full Optional Theme Manage and Enhance Habitats follows this review, which includes consideration of the evidence related to peatland management (as opposed to restoration).

Due to overlaps in on-farm practices with other Themes additional evidence related to Peatland Management and Restoration can be found in:

⁵⁷¹ Austin, Zoë, Maja Penic, David G. Raffaelli, and Piran C.L. White. ‘[Stakeholder Perceptions of the Effectiveness and Efficiency of Agri-Environment Schemes in Enhancing Pollinators on Farmland](#)’. Land Use Policy 47 (September 2015): 156–62.

⁵⁷⁴ Walker, K. J., C. N. R. Critchley, A. J. Sherwood, R. Large, P. Nuttall, S. Hulmes, R. Rose, and J. O. Mountford. ‘[The Conservation of Arable Plants on Cereal Field Margins: An Assessment of New Agri-Environment Scheme Options in England, UK](#)’. Biological Conservation 136, no. 2 (1 April 2007): 260–70.

- Improved Water Quality, Water Usage and Flood Mitigation.
- Collaborative Landscape Scale Activity

REA Exclusion / Inclusion Criteria

Inclusion: Studies on peatland management and / or restoration.

Exclusion: Studies outside farmland/agricultural contexts.

Evidence Base

Using the above search strategy returned 443 results. These underwent an initial scoping review for relevance and 74 studies were retained. In scope studies were prioritised based on quality and relevancy resulting in 45 in scope for an evidence review. Following the evidence review a further 10 studies were excluded due to a lower relevance to Wales. The search returned very limited results relating specifically to Welsh peatlands, with only 2 studies based in Wales. The evidence of the resulting 36 studies was then summarised here.

The searches for these actions were focussed on environmental, economic, and social benefits. Evidence of uptake and barriers were noted where applicable.

Design of the Intervention (6 studies)

6 papers addressed the impacts of payment schemes for farmers on wetland restoration. For individual farms in the UK, a variety of schemes were identified that also offer payments for ecosystem services, such as water provisioning, carbon sequestration and biodiversity services. These occur mostly through government intervention but also occasionally through private funding. One paper [footnote ⁵⁷⁵] suggested that these schemes require monitoring to properly implement restoration procedures. The outcomes of restoration efforts can be reliant upon a number of local factors and so monitoring can help evaluate their success. The funding mechanisms were identified as important, as financial uncertainty can prevent

⁵⁷⁵ Moxey and Moran, '[UK Peatland Restoration: Some Economic Arithmetic](#)', Science of The Total Environment 484 (June 2014): 114–20.

the uptake or success of the practice [footnote ⁵⁷⁶], especially when long term funding is not guaranteed.

Uptake of the Practice (2 studies)

Peatlands extend over at least 4% of Wales, most of which is upland, and the majority of Welsh peatlands remain undrained, however much of it remains in an unfavourable condition [footnote ⁵⁷⁷]. Peatland sites also make up the largest percentage of designated preservation sites in Wales. The Welsh Government has a current policy to ensure that peatlands with semi-natural vegetation undergo management or restoration and to restore a minimum of 25% of the most modified areas of peatland [footnote ⁵⁷⁸] The Glastir Evaluation from 2025 noted that 9000ha of peatland is in the process of being restored or actively managed, representing around 10% of total peatland coverage, with the majority of restoration work thought to have occurred since 2010 [footnote ⁵⁷⁹].

Economic Impacts (10 studies)

Studies primarily considered the additional ecosystem services provided by restored peatlands and the associated costs of restoration.

Ecosystem services provided by peatland restoration were the focus of 7 studies. The types of ecosystem services covered were reducing soil erosion and maintaining soil health, increasing space for pollinators and biodiversity, water provisioning, and recreation [footnote ⁵⁸⁰]. These ecosystem services and the value they provide in terms of water filtration, flood defence, and biodiversity services may lead to savings in the local area [footnote ⁵⁸¹]. While

⁵⁷⁶ Lloyd et al., '[State of Knowledge on UK Agricultural Peatlands for Food Production and the Net Zero Transition](#)', Sustainability 15, no. 23 (27 November 2023): 16347.

⁵⁷⁷ Natural Resources Wales. 2021. [State of Natural Resources Report \(SoNaRR\): Assessment of the achievement of sustainable management of natural resources](#). Mountains, moorlands and heaths. Natural Resources Wales.

⁵⁷⁸ Ibid.

⁵⁷⁹ Emmett, B.A. & the ERAMMP team, '[ERAMMP Report-105: Wales National Trends and Glastir Evaluation](#).'

⁵⁸⁰ Marr, Eric Joseph & Howley, Peter, 2018. '[Woodlots, wetlands or wheat fields? Agri-environmental land allocation preferences of stakeholder organisations in England and Ontario](#)', Land Use Policy, Elsevier, vol. 75(C), pages 673-681.

⁵⁸¹ Bonn, Aletta & Reed, Mark & Bain, Clifton & Evans, Chris & Joosten, Hans & Farmer, Jenny & Emmer, Igino & Couwenberg, John & Moxey, Andrew & Artz, Rebekka & Tanneberger, Franziska & Von Unger, Moritz & Smyth, Mary-Ann & R., Birnie. (2014). [Investing in nature: Developing ecosystem service markets for peatland restoration](#). Ecosystem Services.;

the impacts of these ecosystem services were acknowledged, direct monetary comparisons to trade-offs from agriculture were not generally presented in the studied literature. Commercial viability of peatland restoration was mentioned in 3 papers, which highlight the ancillary benefits to surrounding communities through the diversification of local economies, for example through recreational activities, nature conservation, or tourism-based activities. One paper [footnote ⁵⁸²] in the UK asked people how much money they would be willing to spend each year to restore peatlands. Willingness to pay means the maximum amount a person would be prepared to spend on a product, service or benefit, derived from hypothetical scenarios. It is a technique for the inference of value of a non-marketed good or service. In this study the maximum amount that participants stated they were willing to pay for the benefits they perceived from restored peatland, ranged from £127 to £414 for each hectare of peatland. It was also pointed out in another study [footnote ⁵⁸³] that restoration comes with not only up-front costs, but also long-term maintenance costs, for example for clearing scrub and re-seeding areas.

Environmental Impacts (11 studies)

The importance of peatlands for carbon sequestration was a topic covered by 11 papers, which highlighted their capacity for limiting and capturing carbon emissions. Peatlands in Wales, although covering only up to 4% of the land area, are responsible for 15% to 30% of the country's sequestered carbon stocks [footnote ⁵⁸⁴]. One paper [footnote ⁵⁸⁵] identified that the continued use of restored peatland for grazing may negatively impact the reduction of carbon emissions on the site. Another study [footnote ⁵⁸⁶] reiterated that peatland restoration will be required to meet the United Kingdom's net-zero emissions targets.

Fisher, B., Bradbury, R.B., Andrews, J.E. et al. [Impacts of species-led conservation on ecosystem services of wetlands: understanding co-benefits and tradeoffs](#). *Biodivers Conserv* 20, 2461–2481 (2011).

⁵⁸² Lloyd et al. '[State of Knowledge on UK Agricultural Peatlands for Food Production and the Net Zero Transition](#)', *Sustainability* 15, no. 23 (27 November 2023): 16347.

⁵⁸³ Moxey and Moran, '[UK Peatland Restoration: Some Economic Arithmetic](#)'.

⁵⁸⁴ Natural Resources Wales. 2021. [State of Natural Resources Report \(SoNaRR\): Assessment of the achievement of sustainable management of natural resources](#). Natural Resources Wales.

⁵⁸⁵ Worrall and Clay, '[The Impact of Sheep Grazing on the Carbon Balance of a Peatland](#)', *Science of The Total Environment* 438 (November 2012): 426–34,

⁵⁸⁶ Lloyd et al., '[State of Knowledge on UK Agricultural Peatlands for Food Production and the Net Zero Transition](#)', *Sustainability* 15, no. 23 (27 November 2023): 16347.'

Ten papers discussed how peatland restoration may come with a range of environmental benefits beyond carbon sequestration, such as an increase in local biodiversity, flood management, nutrient management, and water provisioning and filtration services. These ecosystems also provide habitats for a variety of iconic bird species, including curlews, golden plovers, black grouse, red grouse and ring ouzels [footnote ⁵⁸⁷].

The continued use of peatland areas for agricultural activities such as grazing at high levels of intensity which, depending on the scenario may lead to continued environmental degradation, as suggested by one study [footnote ⁵⁸⁸]. The level of restoration possible, and how long it will take is dependent upon several factors, including the condition of the peat and how long it was being damaged for, as well as the methods of restoration implemented, with more heavily damaged sites often being slower to recover.

Social Impacts (6 studies)

No studies identified social impacts specific to peatland in Wales, however the social benefits of peatland restoration in other parts of the UK were discussed in 6 studies, which focused on the cultural and recreation-based values revealed through human-nature interactions with peatland landscapes. For example, value was gained through associations with cultural practices and local biodiversity [footnote ⁵⁸⁹].

4 studies discussed recreation-based ecosystem services and other social impacts of restored peatlands, mentioning the high biodiversity value of peatlands, which contain rare habitats and represent a part of the natural and cultural heritage of their localities. Peatland restoration was noted to have substantial co-benefits, including improved water quality and aesthetic and accessibility benefits for recreation [footnote ⁵⁹⁰].

3 studies covered cultural and personal values regarding peatlands. In one paper based in Scotland [footnote ⁵⁹¹] personal experiences with peatbogs played an important role for

⁵⁸⁷ Natural Resources Wales. 2021. [State of Natural Resources Report \(SoNaRR\): Assessment of the achievement of sustainable management of natural resources](#). Natural Resources Wales.

⁵⁸⁸ Whitfield, S. *et al.* (2011) '[Managing Peatland Ecosystem Services: Current UK Policy and Future Challenges in a Changing World](#)', Scottish Geographical Journal, 8 November 2011, 1–22.

⁵⁸⁹ Ibid.

⁵⁹⁰ Fisher, B., Bradbury, R.B., Andrews, J.E. *et al.* [Impacts of species-led conservation on ecosystem services of wetlands: understanding co-benefits and tradeoffs](#). *Biodivers Conserv* 20, 2461–2481 (2011).

⁵⁹¹ Byg, Novo, and Kyle, '[Caring for Cinderella—Perceptions and Experiences of Peatland Restoration in Scotland](#)', ed. Barbara Muraca, *People and Nature* 5, no. 2 (April 2023): 302–12,.

many participants in defining their relationship with them and promoting a sense of care. Additionally, the presence of wildlife on reserves was a key source of attraction for visitors, with local visitors motivated to visit by general nature and outdoor interests, as suggested in one of the studies [footnote ⁵⁹²].

Barriers (5 studies)

No studies from the evidence identified focused on the barriers to Peatland Management and Restoration in Wales exclusively, however 5 studies were found that discussed the barriers in the United Kingdom as a whole.

3 papers addressed the costs of restoration efforts. Restoration work can incur additional expenses, especially in substantial upfront costs, as well as with maintenance costs over time. There is also the potential for the actions required in restoration schemes, such as rewetting, to incur costs due to the labour or resources needed to undertake activities such as erecting fencing, clearing scrub and stabilising surfaces [footnote ⁵⁹³]. These actions may also require changes in practices outside the restored area. These could include changes due to rising water tables such as when rewetting occurs, or land access when restoration efforts are underway or new species habitats are created [footnote ⁵⁹⁴]. However, while peatland restoration comes with these associated costs, it was noted that it has the potential to diversify rural economies through restoration work and recreational uses [footnote ⁵⁹⁵].

5 papers dealt with the economic trade-offs between maintaining peatlands as they are, and the restoration of said peatlands. It was identified that the provisioning of all ecosystem services associated with peatlands simultaneously is not possible both due to high costs and the mutually exclusive nature of certain use cases due to opposing changes required in water tables, organic composition and vegetation. 2 studies [footnote ⁵⁹⁶] mentioned the

⁵⁹² Fisher et al., '[Impacts of Species-Led Conservation on Ecosystem Services of Wetlands: Understanding Co-Benefits and Tradeoffs](#)', Biodiversity and Conservation 20, no. 11 (October 2011): 2461–81,.

⁵⁹³ Moxey and Moran. 2014, '[UK Peatland Restoration: Some Economic Arithmetic](#)', Science of the Total Environment, vol. 484, pp. 114 - 120.

⁵⁹⁴ Natural Resources Wales. 2021. '[State of Natural Resources Report \(SoNaRR\): Assessment of the achievement of sustainable management of natural resources](#)'. Natural Resources Wales.

⁵⁹⁵ Marr and Howley, 2018. '[Woodlots, wetlands or wheat fields? Agri-environmental land allocation preferences of stakeholder organisations in England and Ontario](#)', Land Use Policy, Elsevier, vol. 75(C), pages 673-681.

⁵⁹⁶ Whitfield et al., '[Managing Peatland Ecosystem Services: Current UK Policy and Future Challenges in a Changing World](#)', Scottish Geographical Journal, 8 November 2011, 1–22.

difficulty in maintaining the provision of all ecosystem services in all peatlands as in some situations the provisioning of those services may conflict with each other, for example where drainage may prevent economic activities on peatland or where restoration and conservation efforts may restrict access and therefore recreational activities. 2 studies [footnote ⁵⁹⁷] emphasised that the diversity of peatland ecosystems presents significant challenges for their management. This means that making restoration and management decisions is highly site-specific and dependent on a wide range of factors. These factors might include the hydrogeological makeup of the site, the various uses of the sites such as recreation or grazing [footnote ⁵⁹⁸].

Evidence Gaps (1 study)

While information from the wider UK area and further abroad was found in this review, sources specific to Welsh peatlands were underrepresented, suggesting a research gap in this area.

While many studies discussed the value of ecosystem services and agricultural production, there was a lack of quantifying evidence, either through direct comparison or monetary figures that related to Welsh Peatlands. Discussion of factors which encourage the uptake of wetland restoration on agricultural land was missing from the studies collected.

Cost-effectiveness Evidence (5 studies)

4 studies discussed the trade-offs involved with grazing on peatlands. Grazing may, in some cases, such as when practiced with high intensity, conflict with peatland restoration, and higher stocking numbers may have a cumulative effect on the damage effected to these sites [footnote ⁵⁹⁹]. While there are negative effects associated with grazing on peatlands,

⁵⁹⁷ Davies MG, Kettridge N, Stoof CR, Gray A, Marrs R, Ascoli D, Fernandes PM, Allen KA, Doerr SH, Clay GD, McMorrow J, Vandvik V (2016) [Informed debate on the use of fire for peatland management means acknowledging the complexity of socio-ecological systems](#). Nature Conservation 16: 59–77.;

Maltby, E.; Acreman, M.; Blackwell, M.S.A.; Everard, M.; Morris, J.. 2013 [The challenges and implications of linking wetland science to policy in agricultural landscapes – experience from the UK National Ecosystem Assessment](#). Ecological Engineering, 56. 121-133.

⁵⁹⁸ Maltby, E.; Acreman, M.; Blackwell, M.S.A.; Everard, M.; Morris, J.. 2013 [The challenges and implications of linking wetland science to policy in agricultural landscapes – experience from the UK National Ecosystem Assessment](#). Ecological Engineering, 56. 121-133.

⁵⁹⁹ Worrall F, Clay GD. [The Impact of Sheep Grazing on the Carbon Balance of a Peatland](#). Sci Total Environ. 2012 Nov 1;438:426-34.. Epub 2012 Sep 28. PMID: 23026149.

other studies mentioned the potential beneficial effects that grazing may have on restoration efforts in some cases, such as by preventing scrub encroachment [footnote ⁶⁰⁰], potentially limiting the potential financial impact on grazing activities in these areas.

One of the papers studied [footnote ⁶⁰¹] suggested that if greenhouse gas emissions are not curtailed, the likely resulting higher temperatures and lower rainfall may require changes in existing agricultural practices even if peatland restoration does not occur, and therefore inaction comes with an increased cost of its own.

Critical Success Factors

Strategic fit and business needs: Medium alignment

The evidence reviewed suggests that the Enhanced Habitat Management Theme has the potential to deliver a wide range of environmental benefits, particularly for biodiversity, soil health, pollination services, and ecosystem resilience. These align with the aims of the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023. However, the reviewed literature often focuses on the ecological effectiveness of specific practices rather than their uptake or feasibility at a farm level. While the Theme has clear strategic potential, particularly in contributing to the Global Biodiversity Framework targets (e.g. 30x30), alignment is assessed as medium based on the current evidence, which highlights positive impacts but lacks consistent data on stakeholder support and economic feasibility for farmers.

Value for money: Medium alignment

The evidence base for the practices currently included in the Enhanced Habitat Management Theme features multiple studies demonstrating the positive ecological impacts of habitat management options, particularly those supported under agri-environment schemes. However, the report also notes that many of these interventions, such as predator control, wetland creation, and reduced pesticide use, vary in their cost-effectiveness, and their outcomes are often context dependent. Economic impacts are generally inferred from

⁶⁰⁰ Moxey, A., & Moran, D. (2014). [UK Peatland Restoration: Some Economic Arithmetic](#). *Science of the Total Environment*, 484, 114 - 120. Advance online publication.

⁶⁰¹ Hough, Towers, and Aalders, 'The Risk of Peat Erosion from Climate Change: Land Management Combinations—An Assessment with Bayesian Belief Networks', *Human and Ecological Risk Assessment: An International Journal* 16, no. 5 (7 October 2010): 962–76,.

environmental gains rather than quantified in financial terms. Given these findings, the Enhanced Habitat Management Theme is assessed as having medium alignment with the Value for money CSF, reflecting the potential for positive outcomes where uptake is encouraged and well-targeted, but recognising the current lack of detailed economic evidence.

Supply side capacity and capability: Low alignment

Across the reviewed studies, there is limited evidence of widespread farmer engagement with habitat enhancement practices outside of agri-environment schemes, and few references to advisory services or collaborative delivery models. Much of the evidence identified comes from conservation sites or protected areas rather than working farms. Where uptake is mentioned, it is often linked to schemes rather than intrinsic farmer-led action. As such, there was little evidence identified that farmers are currently well-equipped to assess or adopt these Themes at scale, or that necessary support systems are in place. The Enhanced Habitat Management Theme is therefore assessed as having low alignment with this CSF based on the available evidence.

Affordability: Medium alignment

The evidence suggests that costs associated with the Enhanced Habitat Management Theme vary depending on the intervention, with some practices (e.g. fallow margins) being relatively low-cost and others (e.g. habitat restructuring or long-term maintenance) being more resource intensive. Additionally, the flexibility in implementation (ranging from small-scale habitat features to broader management changes) provides room for cost management, which supports medium alignment.

Implementation of Designated Site Management Plans

The objective of the Theme Implementation of Designated Site Management Plans is to support the management of designated sites, following the production of a management plan and an associated schedule of works. The Optional Theme involves implementing the schedule of works developed as part of Universal Action 7 for designated sites, delivering active management and enhancement of sites to improve their condition.

Due to overlaps in on-farm practices with other Themes additional evidence for this Theme can be found in:

- Enhanced Woodland Management
- Enhanced Habitat Management

REA Exclusion / Inclusion Criteria

Inclusion: Studies on the management and enhancement of designated sites, studies on the implementation of agri-environmental schemes aimed at improving biodiversity and nature recovery, and studies on the development and implementation of management plans.

Exclusion: Studies on climates and farming systems irrelevant to the Welsh context.

Evidence Base

Using Scopus 23 studies were identified as in scope of the evidence assessment. An additional 22 studies were sourced using Google Scholar and websites identified in Annex B. Using quality and relevance criteria 45 articles were analysed. The evidence search found few academic studies related specifically to designated sites, however some incorporated designated sites, such as Sites of Special Scientific Interest (SSSIs), Special Protection Areas (SPAs), or Special Areas of Conservation (SAC), within broader studies on agri-environmental schemes. This literature was analysed for findings relevant to the implementation of management plans for designated sites in Wales.

Intervention (39 studies)

Much of the literature focuses on the broader concept of Agri-environmental Schemes (AES), as historically they provide income to farmers for conservation, have become the main tool to conserve biodiversity on European farmland, and are often used to fund management in protected areas or designated sites [footnote ⁶⁰²]. Few studies focused on the specific management of designated sites, but some did focus on SSSIs, SSAC, SPAs or SACs .

Among critical features of effective AES is the targeting of interventions to the right areas, specific environmental assets and farm systems, and the of tailoring interventions based on ecological features of the designated sites [footnote ⁶⁰³]. Studies from the UK and Ireland assessing the efficacy of environmental schemes note that effectiveness is improved when action is focused on high-value areas, such as riparian zones or degraded habitats in areas with high biodiversity [footnote ⁶⁰⁴], or areas such as less disturbed landscapes which have a high conservation potential [footnote ⁶⁰⁵].

Studies from across Europe noted the importance of scheme flexibility to success, as it allows farmers to adapt the management practices to their specific farm conditions, encouraging better integration of environmental practices with agricultural productivity [footnote ⁶⁰⁶]. Flexibility offers farmers the freedom to choose how best to achieve the desired environmental outcomes, thus supporting innovation and local knowledge [footnote ⁶⁰⁷]. One study, a systematic review of AES from Europe, North America and Australia, identified that flexibility and support practices that align with farmers' existing practices is

⁶⁰² Batáry et al., '[The Role of Agri-environment Schemes in Conservation and Environmental Management](#)', Conservation Biology 29, no. 4 (August 2015): 1006–16,.

⁶⁰³ Schaub et al., '[The Role of Behavioural Factors and Opportunity Costs in Farmers' Participation in Voluntary Agri-environmental Schemes: A Systematic Review](#)', Journal of Agricultural Economics 74, no. 3 (September 2023): 617–60.

⁶⁰⁴ Ibid.

⁶⁰⁵ Cullen, '[The Economics of Agri-Environment Schemes in Ireland: Essays on Design and Participation](#)' (Doctoral Thesis, Galway, University of Galway, 2021).

⁶⁰⁶ McGurk, Hynes, and Thorne, '[Participation in Agri-Environmental Schemes: A Contingent Valuation Study of Farmers in Ireland](#)', Journal of Environmental Management 262 (May 2020): 110243.

⁶⁰⁷ Kleijn and Sutherland, '[How Effective Are European Agri-environment Schemes in Conserving and Promoting Biodiversity?](#)', Journal of Applied Ecology 40, no. 6 (December 2003): 947–69.

beneficial for scheme take-up [footnote ⁶⁰⁸]. However, while flexibility is crucial, it should be coupled with clear, measurable environmental goals to ensure that the intended outcomes are being achieved.

Nations such as Scotland, Germany, and Ireland, have adopted an outcome-based approach to some agri-environmental schemes,[footnote ⁶⁰⁹] with Scotland having piloted how to evaluate and monitor outcomes between 2020 and 2021, [footnote ⁶¹⁰] and Ireland having instigated outcome-based payments alongside capital payments for actions in its Locally Led Agri-Environmental Schemes (LLAES)[footnote ⁶¹¹]. In this approach the value of payments is tied to the extent of measurable environmental outcomes [footnote ⁶¹²], encouraging a greater focus on positive outcomes that can also be delivered more flexibly, [footnote ⁶¹³] moving away from payment based on a prescriptive model. Studies from across Europe have also set out the potential benefits from avoiding prescriptive or one-size-fits-all approaches, [footnote ⁶¹⁴] and note the potential for outcome-based payments to shift farmers' mindset to see environmental goods as 'non-commodity outputs' [footnote ⁶¹⁵].

The need for appropriate training to maximise the farmer's ability to deliver environmental goods as part of AES has been noted as critical, with one study of farmers in England exploring how training shifted the focus from the "how" of delivery to the "why" [footnote ⁶¹⁶].

⁶⁰⁸ Schaub et al., '[The Role of Behavioural Factors and Opportunity Costs in Farmers' Participation in Voluntary Agri-environmental Schemes: A Systematic Review](#)

⁶⁰⁹ Cole, '[Outcome-Based Agri-Environment and Climate Schemes](#)', Farm Advisory Service - Scottish Rural Development Programme (SRDP) (blog), 28 February 2024.

⁶¹⁰ '[Piloting an Outcomes Based Approach in Scotland \(POBAS\) Project](#), Phase 1 Report' (NatureScot, September 2020).

⁶¹¹ McDonagh, '[Designation, Incentivisation and Farmer Participation—Exploring Options for Sustainable Rural Landscapes](#)', Sustainability 14, no. 9 (5 May 2022): 5569.

⁶¹² Cole, '[Outcome-Based Agri-Environment and Climate Schemes](#)'.

⁶¹³ McDonagh, '[Designation, Incentivisation and Farmer Participation—Exploring Options for Sustainable Rural Landscapes](#)';

Matzdorf and Lorenz, '[How Cost-Effective Are Result-Oriented Agri-Environmental Measures?—An Empirical Analysis in Germany](#)', Land Use Policy 27, no. 2 (April 2010): 535–44,.

⁶¹⁴ McDonagh, '[Designation, Incentivisation and Farmer Participation—Exploring Options for Sustainable Rural Landscapes](#)'.

⁶¹⁵ Osbeck, Schwarz, and Morkvenas, '[Dialogue on Ecosystem Services, Payments and Outcome Based Approaches: Background Brief](#)' (Stockholm Environment Institute, March 2013),.

⁶¹⁶ Lobley et al., '[Training Farmers in Agri-Environmental Management: The Case of Environmental Stewardship in Lowland England](#)', 2013.

Training resulted in better attitudes towards environmental actions as well as improved technical skill [footnote ⁶¹⁷].

Finally, a study in Ireland found that a sense of farmer ownership over the model of delivery was important for the delivery of actions on land designated for conservation. A Locally Led AES model was taken in the management of the Burren LIFE programme. This study found that respect for farmer and local knowledge and expertise, combined with external expert input, achieved positive buy-in, addressing past issues of powerlessness among the landowners of these designated sites [footnote ⁶¹⁸].

Practice (15 studies)

A further issue identified relates to farmer choice in selecting actions under their management plan. One study looking at the uptake of agri-environmental schemes in England noted that the voluntary nature of the actions gives landowners considerable opportunity to choose options that they would have taken anyway or that they can do at minimal cost [footnote ⁶¹⁹]. However, the actions chosen were not regarded as maximising environmental benefit.

The identified evidence base in relation to Implementation of Designated Site Management Plans does not provide a great deal of detail on what affects uptake of management options specifically for the range of designated sites, but the wider literature does explore the scale of uptake of AES as well as the factors that affect uptake.

Significant variation exists in the type of farm and farmer that participates, with studies from the UK, Ireland, and further afield showing that intensive farming systems, particularly dairy farms, often have lower participation rates compared to more extensive systems [footnote ⁶²⁰]. For instance, extensive farms, such as those involved in cattle and sheep farming, have

⁶¹⁷ Lobley et al., '[Training Farmers in Agri-Environmental Management: The Case of Environmental Stewardship in Lowland England](#)', 2013.

⁶¹⁸ McDonagh, '[Designation, Incentivisation and Farmer Participation—Exploring Options for Sustainable Rural Landscapes](#)'.

⁶¹⁹ Hodge and Reader, '[The Introduction of Entry Level Stewardship in England: Extension or Dilution in Agri-Environment Policy?](#)', *Land Use Policy* 27, no. 2 (April 2010): 270–82.

⁶²⁰ Cullen, '[The Economics of Agri-Environment Schemes in Ireland: Essays on Design and Participation](#)'; Murphy et al., '[The Extent of Farmer Participation in the Rural Environment Protection Scheme – What Habitats Are Actually Being Protected?](#)', 2010;

historically been more likely to participate in AES due to the lower opportunity costs and more environmentally aligned practices [footnote ⁶²¹]. In contrast, intensive farms, which are often more focused on maximizing productivity and financial output, can face higher opportunity costs when adopting environmentally friendly practices, making them less inclined to join AES without sufficiently high compensation [footnote ⁶²²].

Participation can also be influenced by farm size, with one study showing that economically larger farms generally were in the Humber region in England [footnote ⁶²³]. This can be attributed to several factors, including the greater resources available to manage AES requirements, higher subsidy potential, and economies of scale in implementing environmental practices [footnote ⁶²⁴]. Conversely, smaller farms may face greater financial constraints or lack the staffing and infrastructure needed to meet AES requirements, limiting their ability to participate.

A further critical factor identified in the literature is the payments offered by schemes. Evidence shows that higher payment levels are associated with higher participation rates, particularly for farmers with intensive farming practices who face higher opportunity costs [footnote ⁶²⁵]. However, the structure of payments is also a determinant. AES that offer short-term payments for immediate implementation, as well as long-term payments for sustained environmental management, were found in Ireland to be more attractive to farmers [footnote ⁶²⁶]. Furthermore, as noted above, the flexibility of schemes, allowing farmers to tailor interventions to their farm-specific conditions and economic priorities, and aligning actions taken with existing farm practices, also increase uptake [footnote ⁶²⁷].

Schaub et al., [‘The Role of Behavioural Factors and Opportunity Costs in Farmers’ Participation in Voluntary Agri-environmental Schemes: A Systematic Review](#)

⁶²¹ Murphy et al., [‘The Extent of Farmer Participation in the Rural Environment Protection Scheme – What Habitats Are Actually Being Protected?’](#)

⁶²² Schaub et al., [‘The Role of Behavioural Factors and Opportunity Costs in Farmers’ Participation in Voluntary Agri-environmental Schemes: A Systematic Review](#)

⁶²³ Wool et al., [‘Delineating the Spatial Drivers of Agri-Environment Scheme Adoption at Field and Farm Levels’](#), Journal of Environmental Management 348 (December 2023): 119407,.

⁶²⁴ Ibid.

⁶²⁵ Murphy et al., [‘The Extent of Farmer Participation in the Rural Environment Protection Scheme – What Habitats Are Actually Being Protected?’](#)

⁶²⁶ Cullen, [‘The Economics of Agri-Environment Schemes in Ireland: Essays on Design and Participation’](#).

⁶²⁷ Schaub et al., [‘The Role of Behavioural Factors and Opportunity Costs in Farmers’ Participation in Voluntary Agri-environmental Schemes: A Systematic Review’](#)

Knowledge and support are additional factors that significantly impact AES uptake. Farmers with access to training, advice, and technical support are more likely to engage in AES [footnote ⁶²⁸]. Evidence suggests that farmers are more likely to participate when they understand the environmental benefits of the practices and feel confident in the feasibility of implementing them. However, the bureaucratic complexity of AES, including application procedures, administrative requirements such as burdensome paperwork, [footnote ⁶²⁹] and the need for ongoing monitoring, can act as barriers to participation [footnote ⁶³⁰].

Furthermore, farmer attitudes and motivations play a crucial role in determining whether they will participate in AES. Studies from Wales, Ireland, and further afield have highlighted that farmers who have a strong environmental ethos or a sense of stewardship [footnote ⁶³¹] are more inclined to adopt sustainable practices, regardless of financial factors [footnote ⁶³²]. One small-scale study from Wales also found some correlation between positive farmer mental health and participation in AES [footnote ⁶³³].

Economic Impacts (3 studies)

One study put forth that a focus on conservation and environmental management is shown to have long-term economic benefits in terms of ecosystem services, for example, through the protection of water quality, biodiversity, and soil health, which can enhance farm

⁶²⁸ Murphy et al., '[The Extent of Farmer Participation in the Rural Environment Protection Scheme – What Habitats Are Actually Being Protected?](#)'

⁶²⁹ Hounsomes, Edwards, and Edwards-Jones, '[A Note on the Effect of Farmer Mental Health on Adoption: The Case of Agri-Environment Schemes](#)', *Agricultural Systems* 91, no.

⁶³⁰ Murphy et al., '[The Extent of Farmer Participation in the Rural Environment Protection Scheme – What Habitats Are Actually Being Protected?](#)';

Batáry et al., '[The Role of Agri-environment Schemes in Conservation and Environmental Management](#)', *Conservation Biology* 29, no.

⁶³¹ McGurk, Hynes, and Thorne, '[Participation in Agri-Environmental Schemes: A Contingent Valuation Study of Farmers in Ireland](#)'.

⁶³² Cullen, '[The Economics of Agri-Environment Schemes in Ireland: Essays on Design and Participation](#)'; Murphy et al., '[The Extent of Farmer Participation in the Rural Environment Protection Scheme – What Habitats Are Actually Being Protected?](#)';

Hounsomes, Edwards, and Edwards-Jones, '[A Note on the Effect of Farmer Mental Health on Adoption: The Case of Agri-Environment Schemes](#)'.

⁶³³ Hounsomes, Edwards, and Edwards-Jones, '[A Note on the Effect of Farmer Mental Health on Adoption: The Case of Agri-Environment Schemes](#)'.

resilience and reduce costs associated with pest control, fertiliser use, and irrigation [footnote ⁶³⁴]. No studies identified contained analysis of direct economic benefits to farms.

Environmental Impacts (14 studies)

Some of the studies discuss how activities targeting high-value biodiversity areas have shown significant improvements in habitat quality and biodiversity. One meta-analysis identified some factors that heighten the environmental performance of AES. It found that schemes that focus on producing out-of-production areas, such as field margins or wildflower strips, tend to be more effective in enhancing biodiversity than those that target in-production areas like arable fields or managed grasslands [footnote ⁶³⁵]. This is because schemes promoting the establishment of out-of-production areas, such as wildflower strips, provide a larger increase in resource availability for a wider range of species than measures which keep the area in some form of production, creating a larger ecological contrast [footnote ⁶³⁶].

In contrast, in-production schemes (schemes that encourage shifts to more environmentally positive actions such as organic farming, reducing stocking rates, or restricting fertilizer application), while valuable, often have less measurable impact on biodiversity, particularly when they do not address the specific needs of declining species [footnote ⁶³⁷]. While in-production schemes such as organic farming or reduced stocking rates offer environmental benefits, [footnote ⁶³⁸] they can have more limited effectiveness in improving biodiversity, particularly for species-specific conservation efforts [footnote ⁶³⁹]. This limitation arises because these schemes do not always address the specific needs of declining or rare species, instead concentrating on more general environmental improvements. This evidence suggests that the greater environmental benefit is derived from schemes which focus on specific biodiversity needs.

⁶³⁴ Batáry et al., [‘The Role of Agri-environment Schemes in Conservation and Environmental Management’](#).

⁶³⁵ Ibid.

⁶³⁶ Ibid.

⁶³⁷ Kleijn and Sutherland, [‘How Effective Are European Agri-environment Schemes in Conserving and Promoting Biodiversity?’](#)

⁶³⁸ Hardman et al., [‘Delivery of Floral Resources and Pollination Services on Farmland under Three Different Wildlife-Friendly Schemes’](#), *Agriculture, Ecosystems & Environment* 220 (March 2016): 142–51,

⁶³⁹ Batáry et al., [‘The Role of Agri-environment Schemes in Conservation and Environmental Management’](#)

Social Impacts (1 study)

Only one article in the identified evidence base discussed the potential social impacts of managing designated sites, with one study from Germany reporting that involvement in an AES led to a sense of pride among participating farmers who produced colourful, species-rich meadows for people to enjoy [footnote ⁶⁴⁰]. This study notes the potential for such actions to communicate the farmers' environmental services to society [footnote ⁶⁴¹].

Barriers (7 studies)

A key barrier to involvement in AES identified in the literature is the opportunity costs associated with adopting practices aiming at habitat restoration or maintenance. The initial loss of productivity, particularly in intensive farming systems, can discourage farmers from participating in AES, as the compensation provided may not be perceived as sufficient to offset the potential financial losses [footnote ⁶⁴²].

Bureaucratic complexity and administrative barriers also represent significant challenges to AES uptake. The application process, ongoing monitoring, and compliance checks are often viewed as time-consuming and complicated [footnote ⁶⁴³].

The lack of adequate support and technical assistance is another barrier identified in the evidence. 2 sources [footnote ⁶⁴⁴] noted that farmers who do not receive sufficient advisory support may find it difficult to implement AES effectively.

Finally, policy design itself can either enable or hinder uptake. A study conducted in Ireland noted that schemes that are too rigid or fail to account for the specific needs of different

⁶⁴⁰ Matzdorf and Lorenz, '[How Cost-Effective Are Result-Oriented Agri-Environmental Measures?](#)'

⁶⁴¹ Ibid.

⁶⁴² Cullen, '[The Economics of Agri-Environment Schemes in Ireland: Essays on Design and Participation](#)'; Murphy et al., '[The Extent of Farmer Participation in the Rural Environment Protection Scheme – What Habitats Are Actually Being Protected?](#)'

⁶⁴³ Schaub et al., '[The Role of Behavioural Factors and Opportunity Costs in Farmers' Participation in Voluntary Agri-environmental Schemes: A Systematic Review](#)'; Hounscome, Edwards, and Edwards-Jones, '[A Note on the Effect of Farmer Mental Health on Adoption: The Case of Agri-Environment Schemes](#)'.

⁶⁴⁴ Schaub et al., '[The Role of Behavioural Factors and Opportunity Costs in Farmers' Participation in Voluntary Agri-environmental Schemes: A Systematic Review](#)'; Murphy et al., '[The Extent of Farmer Participation in the Rural Environment Protection Scheme – What Habitats Are Actually Being Protected?](#)'

farm systems may struggle to engage a wide range of farmers [footnote ⁶⁴⁵]. AES that provide flexibility and tailor interventions to local contexts, such as those that allow farmers to choose practices based on their farm's characteristics, are more likely to be successful in engaging a diverse group of farmers [footnote ⁶⁴⁶].

Evidence Gaps (4 studies)

Studies identified the following gaps:

- the literature is concerned with AES more broadly, with few sources specifically exploring the management of designated sites, including SSSIs, SACs, or other sites of significance.

Cost-effectiveness Evidence (3 studies)

A limited amount of evidence is available as of yet about the efficiency of an outcome-based payment model for managing sites. Certain studies assert that it can improve efficiency and cost effectiveness through offering farmers greater flexibility in their actions, withholding payment for a lack of delivery, [footnote ⁶⁴⁷] and improving farmers' motivation to achieve outcomes [footnote ⁶⁴⁸].

For example, an empirical study from Germany found some advantages to efficiency from a result-oriented model for delivering environmental good [footnote ⁶⁴⁹]. However, more research is needed to determine the extent of the improvement that an outcome-based payment system can achieve to environmental management of significant sites.

A further consideration is the level of payment needed to attract farmers who face higher opportunity costs through entry into the Optional Theme. As evidence indicates that higher payments are needed to attract more participation from intensive farming systems like dairy

⁶⁴⁵ Cullen, [‘The Economics of Agri-Environment Schemes in Ireland: Essays on Design and Participation’](#).

⁶⁴⁶ Schaub et al., [‘The Role of Behavioural Factors and Opportunity Costs in Farmers’ Participation in Voluntary Agri-environmental Schemes: A Systematic Review’](#).

⁶⁴⁷ McDonagh, [‘Designation, Incentivisation and Farmer Participation—Exploring Options for Sustainable Rural Landscapes’](#).

⁶⁴⁸ Matzdorf and Lorenz, [‘How Cost-Effective Are Result-Oriented Agri-Environmental Measures?’](#)

⁶⁴⁹ Ibid.

farms, [footnote ⁶⁵⁰] higher payments may be required to compensate for the initial loss of productivity that may result from adopting AES practices. However, this suggests that large-scale intensive farms, if their involvement to the same extent as less-intensive businesses is to be encouraged, may result in higher costs relative to the environmental benefits achieved.

Critical Success Factors

Strategic fit and business needs: High alignment

The Theme Implementation of Designated Site Management Plans appears to align well with the Strategic fit and business needs CSF, along with the Sustainable Land Management Objectives and various aims under the Well-being of Future Generations (Wales) Act 2015. Evidence suggests that managing designated sites can result in improvements to biodiversity, supporting the conservation and enhancement of the countryside. The evidence, and recent examples from other nations, demonstrates that financial support provided through the Theme can be linked to the delivery of measurable economic and environmental actions.

Value for money: Medium alignment

The Theme Implementation of Designated Site Management Plans has potential for medium alignment with the Value for money CSF. Evidence suggests that schemes similar in focus to the Theme have encouraged changing farming practices resulting in meaningful environmental impacts. There are further indications that result-based payment systems are more efficient and deliver greater value, however the evidence reviewed suggested that more research is needed in this area.

Supply side capacity and capability: Low alignment

The evidence reviewed has not provided relevant insights to the alignment of the Theme Implementation of Designated Site Management Plans with the Supply side capacity and capability CSF.

⁶⁵⁰ Murphy et al., '[The Extent of Farmer Participation in the Rural Environment Protection Scheme – What Habitats Are Actually Being Protected?](#)'

Affordability: High alignment

There is potentially high alignment between the Theme Implementation of Designated Site Management Plans and the Affordability CSF. Evidence reviewed suggests that funding models for AES have traditionally provided farmers with capital funds and ongoing payments for actions, offsetting income foregone or opportunity cost. Results-based payment approaches may offer a different way to allow farmers to recoup some costs from actions taken while encouraging improved outcomes. The evidence does however note that such schemes are less appealing to more intensive farming systems due to opportunity cost.

Hedgerow Creation or Restoration

The objective of the Theme Hedgerow Creation or Restoration is to support the restoration of hedges, planting new hedges and enhanced management Themes. The on-farm practices that could be included in this Theme are:

- hedge laying using traditional methods
- hedge planting
- hedge coppicing

Due to overlaps in on-farm practices with other Themes additional evidence for this Theme can be found in:

- Enhanced Woodland Management
- Woodland and Agroforestry Creation
- Advanced Continuous Professional Development (CPD)
- Improved Water Quality, Water Usage and Flood Mitigation.

REA Exclusion / Inclusion Criteria

Inclusion: Studies on planting, managing of, and laying of hedgerows by farmers or on farms, studies on comparative benefits of different boundary features, studies on benefits of hedgerows, studies on rejuvenating/restoring hedgerows.

Exclusion: Studies on benefits of non-hedgerow boundary features, studies on benefits of agroforestry and woodland.

Evidence Base

Using Scopus, 32 studies were identified as in scope of the evidence assessment according to quality and relevance criteria outlined in the methodology. An additional 12 studies were sourced using Google Scholar and websites identified in Annex B. In total 40 articles were analysed with 4 Welsh-based, and 26 UK-based. The evidence base focussed particularly

on the potential impacts of creating and managing hedgerows for carbon, biodiversity and pollinators.

Design of the Intervention (21 studies)

Evidence across the different environmental, social and economic impacts of hedgerow restoration and planting highlighted the importance of;

- targeting interventions
- identifying the correct solution for the objective
- identifying the correct solution for the landscape
- identifying the correct solution for the farming system [footnote ⁶⁵¹].

Albrecht et al., (2020) suggested that the effect on biodiversity of adding a hedgerow was independent of landscape context [footnote ⁶⁵²]. However, evidence suggested that the effectiveness of planting new hedgerows was increased when contributing to the established hedgerow network [footnote ⁶⁵³]. A review by Staley et al. (2023) identified evidence supporting increasing hedgerow extent in the UK to an average 10km/km² to

⁶⁵¹ Black et al., '[Biomass Carbon Stocks and Stock Changes in Managed Hedgerows](#)', Science of the Total Environment 871 (2023);

Image, E. Gardner, and T.D. Breeze, '[Co-Benefits from Tree Planting in a Typical English Agricultural Landscape: Comparing the Relative Effectiveness of Hedgerows, Agroforestry and Woodland Creation for Improving Crop Pollination Services](#)', Land Use Policy 125 (2023);

Gardner et al., '[Field Boundary Features Can Stabilise Bee Populations and the Pollination of Mass-Flowering Crops in Rotational Systems](#)', Journal of Applied Ecology 58, no;

Boinot et al., '[Hedgerows Are More Multifunctional in Preserved Bocage Landscapes](#)', Ecological Indicators 154 (2023);

Staley et al., '[Long-Term Effects of Hedgerow Management Policies on Resource Provision for Wildlife](#)', Biological Conservation 145, no. 1 (2012): 24–29;

Biffi et al., '[Soil Carbon Sequestration Potential of Planting Hedgerows in Agricultural Landscapes](#)', Journal of Environmental Management 307 (2022);

Staley et al., '[Re-Structuring Hedges: Rejuvenation Management Can Improve the Long Term Quality of Hedgerow Habitats for Wildlife in the UK](#)', Biological Conservation 186 (2015): 187–96;

Alison et al., '[Woodland, Cropland and Hedgerows Promote Pollinator Abundance in Intensive Grassland Landscapes, with Saturating Benefits of Flower Cover](#)'.

⁶⁵² Albrecht et al., '[The Effectiveness of Flower Strips and Hedgerows on Pest Control, Pollination Services and Crop Yield: A Quantitative Synthesis](#)', Ecology Letters 23, no.

⁶⁵³ Image, Gardner, and Breeze, '[Co-Benefits from Tree Planting in a Typical English Agricultural Landscape: Comparing the Relative Effectiveness of Hedgerows, Agroforestry and Woodland Creation for Improving Crop Pollination Services](#)', 2023;

Boinot et al., '[Hedgerows Are More Multifunctional in Preserved Bocage Landscapes](#)'.

optimise benefits for farmland biodiversity e.g., increasing foraging habitat provision and connectivity [footnote ⁶⁵⁴]. Outside of the existing hedgerow network, the evidence suggested that the next most beneficial location for the planting of new hedgerows is in intensively farmed landscapes of intermediate complexity [footnote ⁶⁵⁵]. While these general principles hold, the evidence indicates that aligning the characteristics of the landscape and farm type with hedgerow type, placement, and intended outcomes can help to maximise benefits from an intervention, for example the creation of green lanes to enhance biodiversity benefits [footnote ⁶⁵⁶].

Staley et al. (2015) in a study in England focussed on different methods of hedge laying and coppicing and identified different costs and benefits depending on the aims of the intervention and motivations of the farmer [footnote ⁶⁵⁷]. The authors identified different styles in different parts of the UK, Germany and the Netherlands with the most widespread style in the UK known as “midland” style hedge laying. In an experiment the authors measured the effectiveness of 3 types of laying – traditional, conservation and wildlife, and coppicing and found that each style was associated with different benefits and costs. However, the authors also identified risk factors such as age with older hedgerows less likely to survive coppicing.

The objective of the intervention is likely to affect its design with those focussed on biodiversity likely to benefit more from the use of broadleaf species [footnote ⁶⁵⁸], cutting in February and March [footnote ⁶⁵⁹], and hedgerow management restricted to the prevention of an emerging treeline [footnote ⁶⁶⁰]. Those focussed on pollination services may want to focus on reducing field size and targeting coverage where existing flower coverage is low

⁶⁵⁴ Staley, R. Wolton, and L.R. Norton, [‘Improving and Expanding Hedgerows—Recommendations for a Semi-Natural Habitat in Agricultural Landscapes’](#), *Ecological Solutions and Evidence* 4, no. 1 (2023).

⁶⁵⁵ Batáry et al., [‘The Role of Agri-environment Schemes in Conservation and Environmental Management’](#); Albrecht et al., [‘The Effectiveness of Flower Strips and Hedgerows on Pest Control, Pollination Services and Crop Yield: A Quantitative Synthesis’](#).

⁶⁵⁶ Croxton et al., [‘Linear Hotspots? The Floral and Butterfly Diversity of Green Lanes’](#), *Biological Conservation* 121, no.

⁶⁵⁷ Staley et al., [‘Re-Structuring Hedges: Rejuvenation Management Can Improve the Long Term Quality of Hedgerow Habitats for Wildlife in the UK’](#).

⁶⁵⁸ Black et al., [‘Biomass Carbon Stocks and Stock Changes in Managed Hedgerows’](#).

⁶⁵⁹ Dunn et al., [‘Can Hedgerow Management Mitigate the Impacts of Predation on Songbird Nest Survival?’](#), *Journal of Environmental Management* 184 (2016): 535–44,

⁶⁶⁰ Amy et al., [‘Hedgerow Rejuvenation Management Affects Invertebrate Communities through Changes to Habitat Structure’](#), *Basic and Applied Ecology* 16, no.

[footnote ⁶⁶¹]. For carbon, interventions can focus on increasing the width of hedgerows, planting new and plugging existing hedgerows. Planting on former hedgerow sites may see more limited increases in soil carbon as the soil may already store more carbon than the adjacent area which did not have hedgerows [footnote ⁶⁶²]. Ford et al. (2021), in a Welsh study warned that consideration of soil types and seasonal weather extremes is important as they suggested that during drought conditions "hedgerow-associated soil CO₂ efflux increased markedly, effectively, pausing the effect of hedgerow cover as carbon storage" due to the sudden change in soil temperature and moisture dynamics [footnote ⁶⁶³].

Across the evidence base it was suggested that the benefits of interventions for the creation of hedgerows had to take a longer view with soil organic carbon sequestration continuing to increase for at least 40 to 70 years [footnote ⁶⁶⁴], the economic benefits of coppicing occurring over a 15 to 20 year timescale for biofuels [footnote ⁶⁶⁵], and hedgerow management benefiting from a 40 year cycle to maximise benefits such as species richness [footnote ⁶⁶⁶].

Uptake of the Practice (8 studies)

The 2025 Glastir Evaluation found a 4% (2,200km) increase in new and restored hedgerows in Wales, of which 1,370km could be attributed to the Glastir scheme, as well as a 9% increase in both width and height since in 2021 with 50% of hedgerows in favourable condition [footnote ⁶⁶⁷]. An Irish study suggested that hedgerows were the most abundant

⁶⁶¹ Gardner et al., '[Field Boundary Features Can Stabilise Bee Populations and the Pollination of Mass-Flowering Crops in Rotational Systems](#)'.

⁶⁶² Ford et al., '[How Do Hedgerows Influence Soil Organic Carbon Stock in Livestock-Grazed Pasture?](#)', Soil Use and Management 35, no.

⁶⁶³ Ford et al., '[Hedgerow Effects on CO₂ Emissions Are Regulated by Soil Type and Season: Implications for Carbon Flux Dynamics in Livestock-Grazed Pasture](#)', Geoderma 382 (2021),

⁶⁶⁴ Black et al., '[Biomass Carbon Stocks and Stock Changes in Managed Hedgerows](#)'; Wenzel et al., '[Carbon Sequestration Potential and Fractionation in Soils after Conversion of Cultivated Land to Hedgerows](#)', Geoderma 435 (2023).

⁶⁶⁵ Biffi et al., '[Planting Hedgerows: Biomass Carbon Sequestration and Contribution towards Net-Zero Targets](#)', Science of the Total Environment 892 (2023).

⁶⁶⁶ Staley et al., '[Re-Structuring Hedges: Rejuvenation Management Can Improve the Long Term Quality of Hedgerow Habitats for Wildlife in the UK](#)'.

⁶⁶⁷ Emmett, B.A. & the ERAMMP team, '[ERAMMP Report-105: Wales National Trends and Glastir Evaluation](#).'

habitat on farms [footnote ⁶⁶⁸], although this has limited relevance to Wales. A UK study found that farmers were more willing to undertake management of field boundaries as opposed to cropped areas [footnote ⁶⁶⁹]. However, Albrecht et al. (2020) suggested that farmers are reluctant to adopt measures that are perceived to have negative effects on crop yield, due to reduction of land available for crops, including hedgerow management and creation [footnote ⁶⁷⁰].

Staley et al. (2016) found that the most adopted agri-environment scheme option for hedgerow management in the UK, cutting every 2 years in autumn, was the least beneficial for Lepidopteran indicating a widespread reluctance to adopt more ambitious schemes related to hedgerows [footnote ⁶⁷¹]. However, the Glastir Evaluation noted that hedgerow management options, which included a 3 year cutting regime (cutting once every 3 years), among other activities, contributed towards greater abundance of grassland guild bird species [footnote ⁶⁷²]. Staley et al. (2015) report evidence that between 2005 and 2014 under English Agri-Environment Schemes, just 1,268km of hedgerow was laid or coppiced, accounting for 0.32% of the total hedgerow length in 2007. Additionally, the 2007 Countryside Survey found that only 2% of hedgerows had been coppiced or laid in the previous 3 to 5 years. Considered in a 40-year rotation this would be the equivalent of 16 to 27% of hedgerows rejuvenated [footnote ⁶⁷³].

When considering the scale of hedgerow planting to contribute towards climate change mitigation, Biffi et al., (2023) suggested scheme-supported planting in the UK was 4 times lower than the required rate to meet Climate Change Committee recommendations [footnote ⁶⁷⁴]. However, the authors presented evidence that planting is taking place outside

⁶⁶⁸ Larkin et al., '[Semi-Natural Habitats and Ecological Focus Areas on Cereal, Beef and Dairy Farms in Ireland](#)', Land Use Policy 88 (2019);

Biffi et al., '[Planting Hedgerows: Biomass Carbon Sequestration and Contribution towards Net-Zero Targets](#)'.

⁶⁶⁹ Siriwardena, I.R. Cooke, and W.J. Sutherland, '[Landscape, Cropping and Field Boundary Influences on Bird Abundance](#)', Ecography 35, no. 2 (2012): 162–73,.

⁶⁷⁰ Albrecht et al., '[The Effectiveness of Flower Strips and Hedgerows on Pest Control, Pollination Services and Crop Yield: A Quantitative Synthesis](#)'.

⁶⁷¹ Staley et al., '[Little and Late: How Reduced Hedgerow Cutting Can Benefit Lepidoptera](#)', Agriculture, Ecosystems and Environment 224 (2016): 22–28.

⁶⁷² Emmett, B.A. & the ERAMMP team, '[ERAMMP Report-105: Wales National Trends and Glastir Evaluation](#)'.

⁶⁷³ Staley et al., '[Re-Structuring Hedges: Rejuvenation Management Can Improve the Long Term Quality of Hedgerow Habitats for Wildlife in the UK](#)'.

⁶⁷⁴ Biffi et al., '[Planting Hedgerows: Biomass Carbon Sequestration and Contribution towards Net-Zero Targets](#)'.

of schemes, self-funded, or through private sector schemes [footnote ⁶⁷⁵]. However, unlike woodland creation, the Glastir Evaluation found that the programme was responsible for over half of new hedgerows (1,370km out of 2,200km) in Wales [footnote ⁶⁷⁶].

Therefore, while the evidence reviewed in this section suggests that hedgerows are more abundant than other habitats on farms, there was little evidence identified that willingness to actively manage or create hedgerows is widespread.

Economic Impacts (5 studies)

The evidence reviewed suggested the following potential direct economic impacts of Hedgerow Creation or Restoration:

- potential cost savings in pest management through fewer pesticide applications and in increased yields through improving pollinator populations [footnote ⁶⁷⁷]
- if used for the production of woodchips, these can be sold with potential profits over a 60-year period, or used on farm to reduce costs on heating oil [footnote ⁶⁷⁸]
- employment opportunities for farm labourers in the quieter winter months related to optimum cutting times in February [footnote ⁶⁷⁹].

Environmental Impacts (30 studies)

The evidence identified suggested that planting or restoring hedgerows could contribute benefits to biodiversity, carbon sequestration, climate change mitigation, pollination and pest control, and soil health. These included:

⁶⁷⁵ Biffi et al. [Planting Hedgerows: Biomass Carbon Sequestration and Contribution towards Net-Zero Targets](#)

⁶⁷⁶ Emmett, B.A. & the ERAMMP team, '[ERAMMP Report-105: Wales National Trends and Glastir Evaluation.](#)'

⁶⁷⁷ Morandin, Long, and Kremen, '[Hedgerows Enhance Beneficial Insects on Adjacent Tomato Fields in an Intensive Agricultural Landscape](#)', Agriculture, Ecosystems and Environment 189 (2014): 164–70,;

Boinot et al., '[Hedgerows Are More Multifunctional in Preserved Bocage Landscapes](#)';

Gardner et al., '[Field Boundary Features Can Stabilise Bee Populations and the Pollination of Mass-Flowering Crops in Rotational Systems](#)'.

⁶⁷⁸ Smith et al., '[Making Hedgerows Pay Their Way: The Economics of Harvesting Field Boundary Hedges for Bioenergy](#)', Agroforestry Systems 97, no. 3 (2023): 291–303,.

⁶⁷⁹ Ibid.

- Biodiversity: provision of key habitats for a wide range of species including birds [footnote ⁶⁸⁰], mammals [footnote ⁶⁸¹], invertebrates [footnote ⁶⁸²] and fungi [footnote ⁶⁸³], provision of shelter, nesting and feed resources, supporting species richness (when hedgerows are structurally complex), supporting connectivity between habitat patches, and generally increasing overall farmland biodiversity [footnote ⁶⁸⁴]
- Carbon: when the intervention is designed effectively hedgerows act as carbon sinks with above-ground biomass and below-ground biomass, particularly older hedgerows. Soil organic carbon is significantly higher beneath hedgerows when compared to cropland and grassland. Increasing hedgerow cover by 20% by 2035

⁶⁸⁰ Siriwardena, Cooke, and Sutherland, '[Landscape, Cropping and Field Boundary Influences on Bird Abundance](#)';

Dunn et al., '[Can Hedgerow Management Mitigate the Impacts of Predation on Songbird Nest Survival?](#)';

Dadam, D, and G M Siriwardena. '[Agri-Environment Effects on Birds in Wales: Tir Gofal Benefited Woodland and Hedgerow Species](#)';

Sage, S. Wilson, and T. Powell, '[Using Fledged Brood Counts of Hedgerow Birds to Assess the Effect of Summer Agri-Environment Scheme Options](#)', Ecological Indicators 57 (2015): 376–83;

Aebischer et al., '[Twenty Years of Local Farmland Bird Conservation: The Effects of Management on Avian Abundance at Two UK Demonstration Sites](#)', Bird Study 63, no. 1 (2016): 10–30.

⁶⁸¹ Broughton et al., '[Agri-Environment Scheme Enhances Small Mammal Diversity and Abundance at the Farm-Scale](#)', Agriculture, Ecosystems and Environment 192 (2014): 122–29,;

Dondina et al., '[How to Manage Hedgerows as Effective Ecological Corridors for Mammals: A Two-Species Approach](#)', Agriculture, Ecosystems and Environment 231 (2016): 283–90;

Fuentes-Montemayor et al., '[Small Mammal Responses to Long-Term Large-Scale Woodland Creation: The Influence of Local and Landscape-Level Attributes](#)';

Sellers et al., '[Impact of Field-Edge Habitat on Mammalian Wildlife Abundance, Distribution, and Vectored Foodborne Pathogens in Adjacent Crops](#)', Crop Protection 108 (2018): 1–11,;

Tattersall et al., '[Is Habitat Linearity Important for Small Mammal Communities on Farmland?](#)', Journal of Applied Ecology 39, no. 4 (2002): 643–52,;

Froidevaux et al., '[Managing Hedgerows for Nocturnal Wildlife: Do Bats and Their Insect Prey Benefit from Targeted Agri-Environment Schemes?](#)', Journal of Applied Ecology 56, no. 7 (2019): 1610–23.

⁶⁸² Alison et al., '[Spatial Targeting of Habitat Creation Has the Potential to Improve Agri-Environment Scheme Outcomes for Macro-Moths](#)', Journal of Applied Ecology 53, no. 6 (2016): 1814–22;

Fuentes-Montemayor, D. Goulson, and K.J. Park, '[The Effectiveness of Agri-Environment Schemes for the Conservation of Farmland Moths: Assessing the Importance of a Landscape-Scale Management Approach](#)', Journal of Applied Ecology 48, no. 3 (2011): 532–42.

⁶⁸³ Boinot et al., '[Hedgerows Are More Multifunctional in Preserved Bocage Landscapes](#)';

Staley, R. Wolton, and L.R. Norton, '[Improving and Expanding Hedgerows—Recommendations for a Semi-Natural Habitat in Agricultural Landscapes](#)', Ecological Solutions and Evidence 4, no. 1 (2023),.

⁶⁸⁴ Amy et al., '[Hedgerow Rejuvenation Management Affects Invertebrate Communities through Changes to Habitat Structure](#)'.

could provide contributions to climate change mitigation potentially offsetting up to 6.2% of annual agricultural CO₂ emissions [footnote ⁶⁸⁵]

- Pollination and pest control: hedgerows were found to support a range of bee species with increased hedgerow cover improving pollination services, particularly for mass-flowering crops, hedgerows were found to support natural pest control by harbouring predatory insects such as hoverflies [footnote ⁶⁸⁶]
- Soil health and water management: Hedgerows were found to reduce soil erosion, particularly on sloped landscapes, with evidence indicating that they enhance soil structure and fertility, can act as flood control by enhancing soil filtration, and help buffer extreme temperatures in adjacent soils [footnote ⁶⁸⁷].

Social Impacts (1 study)

One article highlighted the potential for increased employment opportunities during quieter winter months [footnote ⁶⁸⁸].

⁶⁸⁵ Drexler and Don, '[Carbon Sequestration Potential in Hedgerow Soils: Results from 23 Sites in Germany](#)', *Geoderma* 445 (2024),;

Biffi et al., '[Planting Hedgerows: Biomass Carbon Sequestration and Contribution towards Net-Zero Targets](#)';

Wenzel et al., '[Carbon Sequestration Potential and Fractionation in Soils after Conversion of Cultivated Land to Hedgerows](#)';

Ford et al., '[How Do Hedgerows Influence Soil Organic Carbon Stock in Livestock-Grazed Pasture?](#)';

Biffi et al., '[Soil Carbon Sequestration Potential of Planting Hedgerows in Agricultural Landscapes](#)';

Black et al., '[Biomass Carbon Stocks and Stock Changes in Managed Hedgerows](#)'.

⁶⁸⁶ Gardner et al., '[Field Boundary Features Can Stabilise Bee Populations and the Pollination of Mass-Flowering Crops in Rotational Systems](#)';

Albrecht et al., '[The Effectiveness of Flower Strips and Hedgerows on Pest Control, Pollination Services and Crop Yield: A Quantitative Synthesis](#)';

Alison et al., '[Woodland, Cropland and Hedgerows Promote Pollinator Abundance in Intensive Grassland Landscapes, with Saturating Benefits of Flower Cover](#)';

Holland et al., '[Semi-Natural Habitats Support Biological Control, Pollination and Soil Conservation in Europe. A Review](#)', *Agronomy for Sustainable Development* 37, no. 4 (2017),;

Garratt et al., '[The Benefits of Hedgerows for Pollinators and Natural Enemies Depends on Hedge Quality and Landscape Context](#)', *Agriculture, Ecosystems and Environment* 247 (2017): 363–70;

Božek et al., '[Non-Forest Woody Vegetation: A Critical Resource for Pollinators in Agricultural Landscapes—A Review](#)'.

⁶⁸⁷ Drexler and Don, '[Carbon Sequestration Potential in Hedgerow Soils: Results from 23 Sites in Germany](#)'; Wenzel et al., '[Carbon Sequestration Potential and Fractionation in Soils after Conversion of Cultivated Land to Hedgerows](#)'.

⁶⁸⁸ Smith et al., '[Making Hedgerows Pay Their Way: The Economics of Harvesting Field Boundary Hedges for Bioenergy](#)'.

Barriers (8 studies)

A range of potential barriers were identified in the evidence considered these are:

- a concern that planting hedgerows may impact land productivity and yields [footnote ⁶⁸⁹] was commonly reported when considering barriers, however, a recent study suggested that this is not the case [footnote ⁶⁹⁰]
- the financial costs of planting hedgerows [footnote ⁶⁹¹]
- difficulty calculating the impacts of hedgerows on profitability
- farmer perceptions of hedgerow appearance with a preference for “neat” or “tidy” hedgerows [footnote ⁶⁹²]
- that targeted agri-environment schemes are relatively expensive because the positive impacts are restricted to a small number of priority species [footnote ⁶⁹³]
- that hedgerows are not considered within National Inventory Reports for carbon calculations which may result in them not being prioritised when compared to other actions such as woodland creation [footnote ⁶⁹⁴]
- lack of supply of hedgerow plant saplings from UK nurseries [footnote ⁶⁹⁵].

⁶⁸⁹ Morandin, Long, and Kremen, '[Hedgerows Enhance Beneficial Insects on Adjacent Tomato Fields in an Intensive Agricultural Landscape](#)';

Staley, Wolton, and Norton, '[Improving and Expanding Hedgerows—Recommendations for a Semi-Natural Habitat in Agricultural Landscapes](#)';

Staley et al., '[Long-Term Effects of Hedgerow Management Policies on Resource Provision for Wildlife](#)';

Biffi et al., '[Planting Hedgerows: Biomass Carbon Sequestration and Contribution towards Net-Zero Targets](#)';

Albrecht et al., '[The Effectiveness of Flower Strips and Hedgerows on Pest Control, Pollination Services and Crop Yield: A Quantitative Synthesis](#)'.

⁶⁹⁰ Biffi et al., '[Planting Hedgerows: Biomass Carbon Sequestration and Contribution towards Net-Zero Targets](#)'.

⁶⁹¹ Ibid.

⁶⁹² Staley, Wolton, and Norton, '[Improving and Expanding Hedgerows—Recommendations for a Semi-Natural Habitat in Agricultural Landscapes](#)'.

⁶⁹³ Froidevaux et al., '[Managing Hedgerows for Nocturnal Wildlife: Do Bats and Their Insect Prey Benefit from Targeted Agri-Environment Schemes?](#)', *Journal of Applied Ecology* 56, no. 7 (2019): 1610–23,.

⁶⁹⁴ Black et al., '[Biomass Carbon Stocks and Stock Changes in Managed Hedgerows](#)'.

⁶⁹⁵ Biffi et al., '[Planting Hedgerows: Biomass Carbon Sequestration and Contribution towards Net-Zero Targets](#)'.

Evidence Gaps (6 studies)

Studies identified the following gaps:

- how to measure and report the impact of hedgerows in climate regulation and carbon sequestration [footnote ⁶⁹⁶]
- the human well-being impacts of hedgerows [footnote ⁶⁹⁷]
- the cultural ecosystem service provision of hedgerows [footnote ⁶⁹⁸]
- the potential for hedges to facilitate range expansion of insects, mammals and bird populations to mitigate the impacts of climate change [footnote ⁶⁹⁹]
- longer term studies, rather than one to 3 year studies, to understand the effectiveness of hedgerows in delivering ecosystem services and the impact of farming practices on hedgerow ecosystem service provision [footnote ⁷⁰⁰]
- economic evaluations of the cost and benefits of supporting semi-natural habitats, including hedgerows [footnote ⁷⁰¹].

Cost-effectiveness Evidence (4 studies)

One study described that the planting of trees within hedgerows can add to costs as it impedes mechanical trimming and increases shading on adjacent crops. Boughey et al.

⁶⁹⁶ Dadam, D, and G M Siriwardena. '[Agri-Environment Effects on Birds in Wales: Tir Gofal Benefited Woodland and Hedgerow Species](#)';

Wenzel et al., '[Carbon Sequestration Potential and Fractionation in Soils after Conversion of Cultivated Land to Hedgerows](#)';

Black et al., '[Biomass Carbon Stocks and Stock Changes in Managed Hedgerows](#)'.

⁶⁹⁷ Castle et al., '[Evidence for the Impacts of Agroforestry on Ecosystem Services and Human Well-Being in High-Income Countries: A Systematic Map](#)'.

⁶⁹⁸ Ibid.

⁶⁹⁹ Staley, Wolton, and Norton, '[Improving and Expanding Hedgerows—Recommendations for a Semi-Natural Habitat in Agricultural Landscapes](#)'.

⁷⁰⁰ Holland et al., '[Semi-Natural Habitats Support Biological Control, Pollination and Soil Conservation in Europe. A Review](#)'.

⁷⁰¹ Ibid.

(2011) identified that while flail cutting is widespread due to its low cost, it is associated with declining hedge quality and reduced biodiversity value [footnote ⁷⁰²].

A study that focussed on the potential for hedgerow planting for biofuel suggested that hedgerows could feasibly contribute to on-farm heating which could result in cost savings of £21.00 to £34.80 per metre cubed [footnote ⁷⁰³]. The authors also calculated the potential for successful revenue generation through sale of woodchips. However, the authors emphasised that this approach may conflict with other intervention aims such as increasing biodiversity.

The study that identified different approaches to hedge laying and suggested that alternatives to traditional hedge laying provide many of the same environmental benefits but at a lower cost with the following [footnote ⁷⁰⁴]:

- traditional hedge laying (e.g., Midland's style hedge-laying) can be expensive due to labour intensity and skill requirements but provides strong long-term structural and aesthetic benefits
- wildlife hedging (chainsaw used to make basal cuts on every stem, and hedge pushed over along its length with not woody stem or branches removed) can be significantly cheaper (one-third of the cost) while still delivering many of the biodiversity and habitat benefits of traditional hedge laying
- conservation hedging (remaining stems and branches laid along line of the hedge rather than to one side, fewer branches removed, stakes used sparingly and binders omitted) can be half the cost of traditional hedge laying and offers similar benefits in regrowth and berry provision

⁷⁰² Boughey et al., '[Improving the Biodiversity Benefits of Hedgerows: How Physical Characteristics and the Proximity of Foraging Habitat Affect the Use of Linear Features by Bats](#)', *Biological Conservation* 144, no. 6 (2011): 1790–98.

⁷⁰³ Smith et al., '[Making Hedgerows Pay Their Way: The Economics of Harvesting Field Boundary Hedges for Bioenergy](#)'.

⁷⁰⁴ Staley et al., '[Re-Structuring Hedges: Rejuvenation Management Can Improve the Long Term Quality of Hedgerow Habitats for Wildlife in the UK](#)' *Biological Conservation* 186 (2015): 187–96,

- coppicing (stems cut close to ground level with chainsaw) is an effective rejuvenation method, however, in areas with high deer browsing fencing is required which may make it less economically viable in areas.

Finally, one study highlighted that planting and restoring hedgerows may be an economically more advantageous in songbird conservation when compared to other interventions such as direct control of corvids [footnote ⁷⁰⁵].

Critical Success Factors

Strategic fit and business needs: High alignment

The evidence reviewed indicates that hedgerow restoration and creation can deliver a wide range of environmental benefits, including biodiversity enhancement, carbon sequestration, support for pollinators and pest control, and improved soil health. These outcomes directly support the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023. The Theme may also align with broader policy ambitions around climate change and nature recovery. While the evidence does not confirm widespread adoption by farmers, the abundance of hedgerows across the Welsh landscape suggests a strong baseline for uptake. Based on this, the Theme Hedgerow Creation or Restoration is assessed as having high alignment, though its success would still depend on engagement and support mechanisms.

Value for money: High alignment

The reviewed evidence suggests that hedgerow creation and restoration have the potential to deliver significant value for money. These practices are generally accessible to most farms, and can support a wide range of environmental outcomes, particularly around climate resilience and pollinator services. While few studies directly quantify economic return, some indicate cost savings through reduced pesticide use and energy savings via biofuel use. Additionally, the relatively low capital investment required for certain approaches makes the Theme broadly viable. The presence of multiple delivery models (e.g. traditional laying, coppicing, or planting) allows for a tailored approach depending on farm type and

⁷⁰⁵ Dunn et al., '[Can Hedgerow Management Mitigate the Impacts of Predation on Songbird Nest Survival?](#)'

landscape. Based on this, the Theme Hedgerow Creation or Restoration is assessed as having high alignment with the Value for money CSF.

Supply side capacity and capability: Low alignment

While the evidence highlights the environmental value of hedgerows, it also points to limited farmer willingness to actively manage or plant them, particularly when such actions are perceived as reducing productivity. The literature does not show strong evidence of advisory support, peer learning networks, or collaborative infrastructure to encourage uptake. Additionally, some practices, such as traditional hedge laying, require specialist skills that are not widely held. Although the Theme encourages more sustainable practices, current supply-side readiness appears limited. For these reasons, the Theme Hedgerow Creation or Restoration is assessed as having low alignment with this CSF based on the reviewed evidence.

Affordability: Medium alignment

The evidence reviewed indicates that the cost of implementing hedgerow-related actions can vary significantly depending on the method used. While some approaches, such as wildlife or conservation-style hedge laying are lower cost, traditional laying and maintenance practices can be more expensive and labour intensive. Economic benefits, such as biofuel use or pest control may offset these costs over time, but this is not guaranteed. The evidence also notes that hedgerows are currently excluded from carbon accounting frameworks, which could reduce their appeal for climate-based funding. However, some evidence points to the possibility of private investment interest. On balance, the Theme Hedgerow Creation or Restoration is assessed as having medium alignment with Affordability, with outcomes dependent on implementation costs and access to support.

Advanced Continuous Professional Development (CPD)

The objectives of the Theme Advanced Continuous Professional Development (CPD) are to build on Universal Action 4: Continuous Personal Development by providing more complex or higher level CPD. The Theme is intended to support the other OTs and is likely to include group based learning potentially on-farm.

REA Exclusion / Inclusion Criteria

Inclusion: Studies on continuous professional development in agriculture, studies on on-farm training, and peer to peer learning.

Exclusion: Studies on agricultural education in a formal institutional setting such as a college or university

Due to overlaps in on-farm practices with other Themes, additional evidence for this Theme can be found in:

- Enhanced Woodland Management
- Woodland and Agroforestry Creation
- Enhanced Biosecurity Enhanced Habitat Management
- Improved Soil Health and Multispecies Crop Cover
- Organic Farming (Support and Conversion)
- Improved Water Quality, Water Usage and Flood Mitigation.
- Improved Air Quality and Lowering Ammonia Emissions
- Collaborative Innovation, Research and Development.

Evidence Base

Using Scopus 55 studies were identified as in scope of the evidence assessment. An additional 12 studies were sourced using Google Scholar and websites identified in Annex B. Using quality and relevance criteria 54 articles were analysed. Of these, 22 were based in the United Kingdom, with one in Wales.

The evidence base discussed the following options for potential on-farm training:

- Demonstration Farm: Farmer who has adopted a particular practice and hosts on-farm training (15 studies)
- Monitor Farm: Farm that is supported to implement an innovation with researchers hosts farm visits (3 studies)
- Discussion Group: Group of farmers who meet regularly to discuss topics of interest (8 studies).

Design of the Intervention (43 studies)

Demonstration Farm

Studies highlighted important factors that may determine the success of a Demonstration Farm intervention including:

- Relevance: the evidence analysed suggested that effective interventions matched farmers' interests and accounted for prior knowledge, ensuring that farmers were able to engage with the topic [footnote ⁷⁰⁶]. Studies identified a number of ways that demonstration topics may be chosen, including; the funding instrument, expert opinion on pressing issues and priorities for the sector, practical issues deemed important by individual farmers and determined by policy makers. Effectively designing an intervention to meet policy goals was found to depend on aligning these approaches, allowing for a flexible approach to programme design,

⁷⁰⁶ Alexopoulos et al., [Relevant Factors for Effective on Farm Demonstration: The Crucial Role of Relevance for Participants and Structural Set Up](#), Journal of Agricultural Education and Extension 27, no. 5 (2021): 657–76;

Adamsone-Fiskovica et al., [Disentangling Critical Success Factors and Principles of On-Farm Agricultural Demonstration Events](#), Journal of Agricultural Education and Extension 27, no. 5 (2021): 639–56;

Frick et al., [Agricultural Demonstration Events: What Matters](#), Agrarforschung Schweiz 10, no. 9 (2019): 330–37;

Sutherland and F. Marchand, [On-Farm Demonstration: Enabling Peer-to-Peer Learning](#), Journal of Agricultural Education and Extension 27, no. 5 (2021): 573–90.

and supporting farmers to develop approaches that they feel are relevant [footnote ⁷⁰⁷]

- Structure: the layout of the day (including breaks for farmers to network) structured to ensure a mixture of practical learning, question and answer, facilitated discussion. A review of 36 demonstration events across Europe found that for optimal effectiveness training should not have more than 20 farmers [footnote ⁷⁰⁸]. Facilitation was found to maximise the effectiveness of learning consistently across studies [footnote ⁷⁰⁹]
- Venue: in their literature review Adamsone-Fiskovia et al., highlight the importance of an appropriate venue for demonstration. Issues that studies raised included; the accessibility of the venue, if training is to be held across different farms they should be evenly distributed [footnote ⁷¹⁰], and the appropriateness of the venue. The evidence identified consistently demonstrated farmers' preference for demonstration sites to take place on commercial farms as opposed to research farms which are a part of a research institution [footnote ⁷¹¹]

⁷⁰⁷ Nettle et al., [‘Selecting Methods of Agricultural Extension to Support Diverse Adoption Pathways: A Review and Case Studies’](#), ed. Callum Eastwood, *Animal Production Science* 64, no. 1 (23 December 2022); Adamsone-Fiskovica et al., [‘Disentangling Critical Success Factors and Principles of On-Farm Agricultural Demonstration Events’](#); Sutherland and F. Marchand, [‘On-Farm Demonstration: Enabling Peer-to-Peer Learning’](#).

⁷⁰⁸ Marchand et al., [‘Effectiveness of On-Farm Demonstration Events in the EU: Role of Structural Characteristics’](#), *Journal of Agricultural Education and Extension* 27, no. 5 (2021): 677–97;

Adamsone-Fiskovica et al., [‘Disentangling Critical Success Factors and Principles of On-Farm Agricultural Demonstration Events’](#);

Knook et al., [‘Evaluation of Farmer Participatory Extension Programmes’](#), *Journal of Agricultural Education and Extension* 24, no. 4 (2018): 309–25;

Prager and Creaney, [‘Achieving On-Farm Practice Change through Facilitated Group Learning: Evaluating the Effectiveness of Monitor Farms and Discussion Groups’](#), *Journal of Rural Studies* 56 (2017): 1–11,.

⁷⁰⁹ Cooreman et al., [‘Power to the Facilitated Agricultural Dialogue: An Analysis of on-Farm Demonstrations as Transformative Learning Spaces’](#), *Journal of Agricultural Education and Extension* 27, no. 5 (2021): 699–719; Matthews, R.D. Fish, and J. Tzanopoulos, [‘Overcoming Barriers to Agri-Environmental Management at Landscape Scale: Balancing Farmer Coordination and Collaboration with the Aid of Facilitators and Pioneers’](#), *Journal of Environmental Management* 369 (2024).

⁷¹⁰ Adamsone-Fiskovica et al., [‘Disentangling Critical Success Factors and Principles of On-Farm Agricultural Demonstration Events’](#).

⁷¹¹ Mulkerrins et al., [‘Could the Influence of Monitor Farm Programmes on Practice Change Be BETTER? Lessons from Sheep Farmers and Advisors in Ireland’](#), *Journal of Agricultural Education and Extension* 29, no. 5 (2023): 653–78;

- People: evidence consistently found that the farmer leading the event, and/or the facilitator, if that is not the farmer, determined the intervention's success. As stated above, facilitation was seen as a key component for successfully translating the demonstration into learning for attendees. The identified literature suggested that training in facilitation for farmers who host a demonstration event is an effective approach. Finally, the literature suggested that the facilitator should have a number of qualities recognised by their industry such as expertise, experience and capability, and trustworthiness and openness (a willingness to share successes, failures and benchmarking information) [footnote ⁷¹²].

Monitor Farms

Monitor Farms as a sub-category of Demonstration Farms benefit from the above considerations, however the evidence provided additional specific findings. A key component of a Monitor Farm's success is the initial investment in a practice change or innovation which would be supported by the funder [footnote ⁷¹³]. This allows for the initial benchmark to be recorded at a stage when the farmer was operating more conventionally, and for visitors to observe the journey over a 3 or 4 year period. In addition, Monitor Farms can have an increased effectiveness due to the involvement of others, such as researchers, a management group, or a host of local farmers, which allows for sharing the learning more widely and shaping the direction of the discussions around the farm to maximise relevance.

Adamsone-Fiskovica et al., '[Disentangling Critical Success Factors and Principles of On-Farm Agricultural Demonstration Events](#)';

Sutherland and Marchand, '[On-Farm Demonstration: Enabling Peer-to-Peer Learning](#);

McWherter, Sherren, and Hunar, '[From Learner to Leader: Exploring Learning, Motivations, and Roles of Regenerative Grazing Mentors](#)', Agroecology and Sustainable Food Systems, 2025,.

⁷¹² Mulkerrins et al., '[Could the Influence of Monitor Farm Programmes on Practice Change Be BETTER?](#)'; Alexopoulos et al., '[Unraveling Relevant Factors for Effective on Farm Demonstration: The Crucial Role of Relevance for Participants and Structural Set Up](#)';

Marchand et al., '[Effectiveness of On-Farm Demonstration Events in the EU: Role of Structural Characteristics](#)';

Prager and Creaney, '[Achieving On-Farm Practice Change through Facilitated Group Learning: Evaluating the Effectiveness of Monitor Farms and Discussion Groups](#)';

Knook et al., '[Evaluation of Farmer Participatory Extension Programmes](#)';

Knook et al., '[The Evaluation of a Participatory Extension Programme Focused on Climate Friendly Farming](#)', Journal of Rural Studies 76 (May 2020): 40–48.

⁷¹³ Prager and Creaney, '[Achieving On-Farm Practice Change through Facilitated Group Learning: Evaluating the Effectiveness of Monitor Farms and Discussion Groups](#)';

Mulkerrins et al., '[Could the Influence of Monitor Farm Programmes on Practice Change Be BETTER?](#)'

Finally, the identified evidence found that Monitor Farm programmes tend to have consistent groups who will visit the farm over the course of the programme and observe the impacts of the change with the farmer [footnote ⁷¹⁴].

Discussion Groups

Discussion groups also benefit from similar considerations, specifically a consistent membership over long period of time to build trust and social learning within the group [footnote ⁷¹⁵]. Discussion groups require farmer collaboration to develop the programme to ensure that it is relevant to the members and that they are invested [footnote ⁷¹⁶]. Again, flexibility is required as the aim is to have long term productive groups that are built on trust, and that encourage sharing with group members. They are therefore likely to benefit from the presence of a facilitator to help shape the group, allow for critical discussion, and support new members to be added to the group where they would benefit [footnote ⁷¹⁷].

Whilst young farmers were found to be more involved in training than their older peers, the evidence identified did not suggest that differing demographics would impact the effectiveness of the activities. Nor did the evidence reviewed suggest that activities should be restricted based on farm type, although a small number of articles indicated that mixed farmer discussion groups were beneficial [footnote ⁷¹⁸]. Across the studies, those acting as mentors, hosts, or facilitators have been remunerated for their time, with some evidence

⁷¹⁴ Flanigan and Hardy, '[Learning and Change through Monitor Farms](#)' (Scotland: The James Hutton Institute, August 2021).

⁷¹⁵ Morgans et al., '[A Participatory, Farmer-Led Approach to Changing Practices around Antimicrobial Use on UK Farms](#)'.

⁷¹⁶ Morgans et al. '[A Participatory, Farmer-Led Approach to Changing Practices around Antimicrobial Use on UK Farms](#)';

Cawley et al., '[How Knowledge Transfer Impact Happens at the Farm Level: Insights from Advisers and Farmers in the Irish Agricultural Sector](#)', Sustainability (Switzerland) 15, no. 4 (2023).

⁷¹⁷ Dooley, '[Reorientating Social Learning: An Ethnographic Exploration of Metacognition and Critical Discourse in Farmer Discussion Groups](#)' (United Kingdom, University of Exeter, 2021);

O'Connor et al., '[Farmer Discussion Groups Create Space for Peer Learning about Safety and Health](#)', Journal of Agromedicine 26, no. 2 (3 April 2021): 120–31;

Alexopoulos et al., '[Unraveling Relevant Factors for Effective on Farm Demonstration: The Crucial Role of Relevance for Participants and Structural Set Up](#)';

Sutherland, L A, R J F Burton, C Adamsone-Fiskovica, C Hardy, B Elzen, L Debruyne, and S Flanigan. '[Full Article: Inclusivity of on-Farm Demonstration: Gender, Age, and Geographic Location](#)' 27, number 5 (2021): pages 591 to 613.

that this encourages participation [footnote ⁷¹⁹]. In addition, some participants reported that they pursued these opportunities to spread good practices, make the industry more sustainable, or their own career development, for example, becoming an advisor [footnote ⁷²⁰].

Uptake of the Practice (34 studies)

There was consensus across the identified literature that these interventions are effective mechanisms for encouraging farmers to adopt innovations and new practices [footnote ⁷²¹]. These findings are subject to the above considerations on designing interventions to maximise the potential for adoption. However, it is important to note that increased knowledge does not necessarily result in uptake of a practice. An intervention may result in a participant deciding not to adopt a practice as they learn that the practice is not appropriate for their farm [footnote ⁷²²]. This is an additional positive impact identified by the studies as it means less resource is spent pursuing inappropriate practices. Studies suggest that those who have engaged in an intervention on a consistent basis, rather than a one off, and those who have engaged in multiple forms of intervention, e.g., a discussion group centred around a Monitor Farm, are more likely to have adopted practices [footnote ⁷²³]. There is also evidence that advanced CPD may result in a spillover effect where other farmers in the participant's network or geographic vicinity may adopt practices when they have seen a success [footnote ⁷²⁴].

⁷¹⁹ Schaub et al., '[The Role of Behavioural Factors and Opportunity Costs in Farmers' Participation in Voluntary Agri-environmental Schemes: A Systematic Review](#);

Curry and Reid, '[Peer Group Mentors Contribute to Diversified, Sustainable and Innovative Farming Communities](#)' 5, no. 2.

⁷²⁰ Victor and Field, '[Farm Advisory Service Enhanced Monitoring and Evaluation : Prepared for Scottish Government](#)' (United Kingdom: Scottish Government, September 2019),.

⁷²¹ Ashfield, Mullan, and Jack, eds., '[Encouraging Farmer Participation in Agricultural Education and Training: A Northern Ireland Perspective](#)', International Journal of Agricultural Management, 2020.

⁷²² Marchand et al., '[Effectiveness of On-Farm Demonstration Events in the EU: Role of Structural Characteristics](#)'.

⁷²³ Mulkerrins et al., '[Could the Influence of Monitor Farm Programmes on Practice Change Be BETTER?](#)'; Prager and Creaney, '[Achieving On-Farm Practice Change through Facilitated Group Learning: Evaluating the Effectiveness of Monitor Farms and Discussion Groups](#)';

Sutherland and Marchand, '[On-Farm Demonstration: Enabling Peer-to-Peer Learning](#)'.

⁷²⁴ Wang, Möhring, and Finger, '[When My Neighbors Matter: Spillover Effects in the Adoption of Large-Scale Pesticide-Free Wheat Production](#)', Agricultural Economics (United Kingdom) 54, no. 2 (2023): 256–73; Teodoro, Baird, and Otung, '[Longitudinal Network Analysis on a Farmers' Community of Practice and Their](#)

Economic Impacts (13 studies)

Those studies which focussed on the economic impact of these interventions identified a range of successes, including;

- the Irish BETTER Farm Sheep Programme, a Monitor Farm programme, saw an average increase of overall gross margin of 31% across the participating farms with increases ranging from 24% to 75% [footnote ⁷²⁵]
- Danish Stable Schools, discussion groups, saw a “50% reduction in mastitis treatments on participating farms with no detriment to herd health, welfare, or production [footnote ⁷²⁶]
- Irish dairy discussion group members gained an average of £310 gross margin per hectare [footnote ⁷²⁷]
- a study in Wales identified a range of economic benefits from discussion groups and demonstration farmers, including improved business viability and profitability [footnote ⁷²⁸]
- an evaluation of monitor farms and discussion groups throughout Europe identified increased profitability through technology adoption rates [footnote ⁷²⁹].

It is important to note that the hosts of Monitor Farms and Demonstration Farms may experience benefits in addition to the potential benefits to visitors due to the support they receive to implement the practice change [footnote ⁷³⁰]. In addition, the remuneration for

[Changes in Agricultural Systems Management](#)’, Society and Natural Resources 36, no. 2 (2023): 90–107.; Fisher, [“A Gentleman’s Handshake”: The Role of Social Capital and Trust in Transforming Information into Usable Knowledge](#)’, Journal of Rural Studies 31 (2013): 13–22,

⁷²⁵ Mulkerrins et al., [‘Could the Influence of Monitor Farm Programmes on Practice Change Be BETTER?’](#)

⁷²⁶ Morgans et al., [‘A Participatory, Farmer-Led Approach to Changing Practices around Antimicrobial Use on UK Farms’](#).

⁷²⁷ Jack et al., [‘Investigating the Drivers of Farmers’ Engagement in a Participatory Extension Programme: The Case of Northern Ireland Business Development Groups’](#), Sustainability (Switzerland) 12, no. 11 (2020),.

⁷²⁸ Hill, Bradley, and Williams, [‘Evaluation of Knowledge Transfer: Conceptual and Practical Problems of Impact Assessment of Farming Connect in Wales’](#), Journal of Rural Studies 49 (2017): 41–49,.

⁷²⁹ Prager and Creaney, [‘Achieving On-Farm Practice Change through Facilitated Group Learning: Evaluating the Effectiveness of Monitor Farms and Discussion Groups’](#).

⁷³⁰ Leader, Kinsella, and O’Brien, [Engaging Commercial Dairy Demonstration Farmers in Farmland Biodiversity Management Communication](#)’, The Journal of Agricultural Education and Extension, October

providing these services is likely to increase the resilience of these farms as well as open diversification opportunities as an agricultural advisor.

Environmental Impacts (12 studies)

Studies identified a range of environmental impacts emerging from participation in discussion groups, demonstration or monitor farms, and on-farm training. These included:

- implementation of climate change mitigation practices [footnote ⁷³¹]
- agroforestry [footnote ⁷³²]
- adoption of integrated pest management [footnote ⁷³³]
- adoption of rotational grazing [footnote ⁷³⁴]
- regenerative agriculture [footnote ⁷³⁵]
- increased biodiversity [footnote ⁷³⁶]
- adoption of organic farming [footnote ⁷³⁷]
- better habitat management [footnote ⁷³⁸].

2024, 1–26;

Prager and Creaney, '[Achieving On-Farm Practice Change through Facilitated Group Learning: Evaluating the Effectiveness of Monitor Farms and Discussion Groups](#)'.

⁷³¹ Knook et al., '[The Evaluation of a Participatory Extension Programme Focused on Climate Friendly Farming](#)'.

⁷³² Felton et al., '[Farmers' Attitudes towards, and Intentions to Adopt, Agroforestry on Farms in Lowland South-East and East England](#)'.

⁷³³ Creissen et al., '[Identifying the Drivers and Constraints to Adoption of IPM among Arable Farmers in the UK and Ireland](#)', *Pest Management Science* 77, no. 9 (2021): 4148–58.

⁷³⁴ Jordon, Winter, and Petrokofsky, '[Advantages, Disadvantages, and Reasons for Non-Adoption of Rotational Grazing, Herbal Leys, Trees on Farms and Ley-Arable Rotations on English Livestock Farms](#)'.

⁷³⁵ McWherter, Sherren, and Hunar, '[From Learner to Leader: Exploring Learning, Motivations, and Roles of Regenerative Grazing Mentors](#)'.

⁷³⁶ Leader, Kinsella, and O'Brien, '[Engaging Commercial Dairy Demonstration Farmers in Farmland Biodiversity Management Communication](#)'.

⁷³⁷ Hinzpeter, '[Dissemination of Organic Farming Knowledge through Model Farmers: Exploring the BioRegio Betriebsnetz in Bavaria, Germany](#)', *Journal of Agricultural Education and Extension*, 2024.

⁷³⁸ Victor and Field, '[Farm Advisory Service Enhanced Monitoring and Evaluation : Prepared for Scottish Government](#)'.

Social Impacts (13 studies)

Studies identified that identified a social impact focussed on the benefits of peer learning with studies across the evidence analysed identifying farmers feeling more supported by peers and facilitators [footnote ⁷³⁹]. Other studies reported increased confidence, resilience an improved social life [footnote ⁷⁴⁰], improved health and well-being [footnote ⁷⁴¹], reductions in isolation, and increased job satisfaction [footnote ⁷⁴²]. This was particularly the case for mentors and facilitators, however evidence suggests they need sufficient support for these benefits to be realised [footnote ⁷⁴³]. A study in Wales found that networks established through discussion groups as a part of Farming Connect continued once support ended with farmers continuing to support one another informally [footnote ⁷⁴⁴].

Barriers (11 studies)

Barriers to the successful implementation of these interventions and their ability to encourage adoption effectively, beyond those mentioned in the design of the intervention section, included:

- farmers lacking the knowledge to fully engage – which can be mitigated by a facilitator [footnote ⁷⁴⁵]

⁷³⁹ Adamsone-Fiskovica et al., '[Disentangling Critical Success Factors and Principles of On-Farm Agricultural Demonstration Events](#)';

Morgans et al., '[A Participatory, Farmer-Led Approach to Changing Practices around Antimicrobial Use on UK Farms](#)'.

⁷⁴⁰ Ashfield, Mullan, and Jack, '[Encouraging Farmer Participation in Agricultural Education and Training](#)'.

⁷⁴¹ McWherter, Sherren, and Hunar, '[From Learner to Leader: Exploring Learning, Motivations, and Roles of Regenerative Grazing Mentors](#)'.

⁷⁴² McWherter, Sherren, and Hunar; '[From Learner to Leader: Exploring Learning, Motivations, and Roles of Regenerative Grazing Mentors](#)';

Knook et al., '[Resilience Building in Agricultural Extension Programmes: Application of a Resilience Framework and Development of a Farmer-Focused Assessment Tool](#)', The Journal of Agricultural Education and Extension 30, no. 5 (19 October 2024): 753–73.

⁷⁴³ Greenhalgh and Rawlinson, '[A Review of Mentoring in Agriculture: Another Learning Option for the next Generation of New Zealand Farmers?](#)', Extension Farming Systems Journal, 2013.

⁷⁴⁴ Hill, Bradley, and Williams, '[Evaluation of Knowledge Transfer: Conceptual and Practical Problems of Impact Assessment of Farming Connect in Wales](#)'.

⁷⁴⁵ Morgans et al., '[A Participatory, Farmer-Led Approach to Changing Practices around Antimicrobial Use on UK Farms](#)'.

- the length of time for benefits to be realised (3 years for Monitor Farms in some cases) [footnote ⁷⁴⁶]
- the costs of training
- availability of labour coverage when the farm is attending training
- age and attitude of farmers themselves which may affect whether they see the training as worthwhile
- the perception that the programme may push a certain point of view
- IT skills [footnote ⁷⁴⁷].

Evidence Gaps (4 studies)

The studies analysed suggested that evidence was needed to;

- improve the evaluation of activities
- to understand what specifically makes interventions effective
- identify areas of change activities are most effective for [footnote ⁷⁴⁸]
- to increase the validity of studies by undertaking studies with control groups to assess difference [footnote ⁷⁴⁹]

Cost-effectiveness Evidence (5 studies)

Prager and Creaney's (2017) review of Irish and Scottish programme evaluations found that programme cost can be affected by:

⁷⁴⁶ Flanigan and Hardy, '[Learning and Change through Monitor Farms](#)'.

⁷⁴⁷ Mulkerrins et al., '[Could the Influence of Monitor Farm Programmes on Practice Change Be BETTER? Lessons from Sheep Farmers and Advisors in Ireland](#)';

Ashfield, Mullan, and Jack, '[Encouraging Farmer Participation in Agricultural Education and Training](#)'; Cawley et al., '[How Knowledge Transfer Impact Happens at the Farm Level](#)'.

⁷⁴⁸ Knook et al., '[The Evaluation of a Participatory Extension Programme Focused on Climate Friendly Farming](#)'.

⁷⁴⁹ Prager and Creaney, '[Achieving On-Farm Practice Change through Facilitated Group Learning: Evaluating the Effectiveness of Monitor Farms and Discussion Groups](#)';

Mulkerrins et al., '[Could the Influence of Monitor Farm Programmes on Practice Change Be BETTER?](#)'

- farmers being paid to participate which they suggest can increase the number of participants, although an Irish study found that the majority of farmers would continue to attend their discussion groups without payment
- the farm type, with dairy farmers more likely to attend without payment than beef farmers
- payment to the host farmer - 53% of Scottish Monitor Farms supported host farmers receiving payment
- farmers paying to attend, which a Scottish evaluation suggested would improve attendance rates [footnote ⁷⁵⁰].

However, Jack et al., (2020) quoted evidence that farmers who received no payment to participate “significantly improved their farm performance in terms of gross margins yields compared to farmers who joined the group when payments were given” [footnote ⁷⁵¹]. As discussed earlier, a study in Wales provided evidence that establishing networks through discussion groups had a “self-sustaining legacy” which may suggest these are cost-effective methods in the longer-term [footnote ⁷⁵²].

Critical Success Factors

Strategic fit and business needs: High Alignment

The Theme Advanced Continuous Professional Development (CPD) aligns strongly with the strategic objectives set out in the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023. The evidence indicates that higher-level CPD, particularly when delivered through farmer-led formats like demonstration farms, Monitor Farms, and discussion groups, can enhance the capacity of farmers to adopt sustainable land management practices across a wide range of business models. These interventions were also shown to aid peer-to-peer learning, social cohesion, and economic resilience, all of which support the long-term viability of rural communities and farm businesses. As a facilitative Theme Advanced Continuous

⁷⁵⁰ Prager and Creaney, ‘[Achieving On-Farm Practice Change through Facilitated Group Learning: Evaluating the Effectiveness of Monitor Farms and Discussion Groups](#)’.

⁷⁵¹ Jack et al., ‘[Investigating the Drivers of Farmers’ Engagement in a Participatory Extension Programme: The Case of Northern Ireland Business Development Groups](#)’.

⁷⁵² Hill, Bradley, and Williams, ‘[Evaluation of Knowledge Transfer: Conceptual and Practical Problems of Impact Assessment of Farming Connect in Wales](#)’.

Professional Development (CPD) has the potential to amplify the outcomes of other Themes in the Scheme.

Value for money: High Alignment

There was strong evidence identified that Advanced Continuous Professional Development (CPD) can deliver value for money. Discussion groups and demonstration farms have been linked to improved farm business viability, profitability, and adoption of practices that reduce costs or increase efficiency. These outcomes are not limited to individual participants, studies also highlight spillover effects, where knowledge gained is shared among local farming networks, thereby extending the return on investment. Although delivery models vary, cost-effectiveness is enhanced where schemes build lasting farmer networks and engagement continues beyond formal support.

Supply side capacity and capability: High Alignment

The Theme Advanced Continuous Professional Development (CPD) appears to support Supply side capacity and capability by equipping farmers with the knowledge, skills, and peer support needed to assess and adopt sustainable practices. The evidence suggests that training formats, such as Monitor Farms and discussion groups, improve understanding of new practices, build confidence, and contribute to long-term behavioural change. These platforms may also provide opportunities for collaboration, reflection, and adaptive learning, suggesting strong alignment with this Critical Success Factor.

Affordability: Medium Alignment

The Theme Advanced Continuous Professional Development (CPD) demonstrates medium alignment with Affordability. While some CPD formats (e.g. discussion groups) are low-cost and can become self-sustaining, others (e.g., Monitor Farms) require upfront investment and ongoing facilitation to be effective. Remuneration of host farmers or facilitators was seen to encourage engagement and improve delivery. However, evidence suggests that many farmers value these opportunities intrinsically and continue to participate without payment, which supports the long-term affordability of the Theme when designed appropriately.

Improved Soil Health and Multispecies Crop Cover

In line with the Welsh Government Agricultural Soils Policy Statement [footnote ⁷⁵³], the overarching aim of this Theme is to:

- prevent soil loss
- improve beneficial soil microbiology, improve soil structure, and build Soil Organic Matter (SOM)

The evidence reviewed for this Theme focussed on the sowing of mixed cover crops.

Due to overlaps in on-farm practices with other Themes, additional evidence for this Theme can be found in:

- Advanced Continuous Professional Development (CPD)
- Organic Farming (Support and Conversion)
- Creation of Temporary and Permanent Habitats
- Improved Water Quality, Water Usage and Flood Mitigation.
- Collaborative Landscape Scale Activity.

REA Exclusion / Inclusion Criteria

Inclusion: Studies on multispecies cover crops.

Exclusion: Precision technologies with soil sensing. Studies that involve adoption of nutrient management plans / soil health plans more broadly. Studies that test soil or novel soil testing technologies. Studies that primarily focus on the benefits of single species cover crops.

Evidence Base

The search for multispecies cover crops returned 404 results. These underwent an initial scoping review for relevance and 139 studies were retained. In scope studies were

⁷⁵³ Welsh Government, '[Agricultural Soil Policy Statement 2025](#)', 2025.

prioritised based on quality and relevancy, resulting in 46 in scope for an evidence review plus 2 additional grey literature documents (48 total).

Design of the Intervention (5 studies)

5 studies discussed cover crop interventions. The studies identified did not distinguish between multispecies and single cover implementation. Evidence on effectiveness was mixed. One UK study found that farmers viewed the Ecological Focus Area (EFA) Guidelines from 2016 for cover crops to be too restrictive / prescriptive in how actions were to be implemented [footnote ⁷⁵⁴]. Another modelled cover crop uptake across EU countries under relevant CAP variations in each country and found that policy support was strongly associated with uptake [footnote ⁷⁵⁵]. Expert interviews from Germany indicated that farmers primarily selected to apply measures that they already implemented on their farms to qualify for schemes with catch crops, nitrogen fixing crops and fallow land being the most popular options [footnote ⁷⁵⁶].

Uptake of the Practice (1 study)

In a recent study of UK farm management practices 66% of respondents (n = 297) used cover crops following harvest in 2016. It found that of those respondents, single species cover crops accounted for 18% of cover while 2 to 3 and 4 + crop mixtures accounted for 51% and 31% of cover respectively.

Economic Impacts (14 studies)

Studies primarily considered whether a multispecies cover crop increases the yield of the subsequent cash crop. The approach to assessing economic impact was primarily to use yield improvements as the measure of economic benefit, and this was not regularly put in monetary terms.

⁷⁵⁴ Storr, Simmons, and Hannam, '[The Use of Cover Crops in the UK: A Survey](#)', December 2018.

⁷⁵⁵ Kathage et al., '[How Much Is Policy Driving the Adoption of Cover Crops? Evidence from Four EU Regions](#)', Land Use Policy 116 (1 May 2022): 106016.

⁷⁵⁶ Zinngrebe, Pe'er, Schueler, Schmitt, Schmidt, Lakner, '[The EU's ecological focus areas – How experts explain farmers' choices in Germany](#)', Land Use Policy, Volume 65, 2017, Pages 93-108.

Review studies: 5 studies considered economic benefits as part of a review. Overall, there was no strong or consistent evidence in these studies that cover crop mixtures outperformed single species cover crops for yield benefits. Legume cover crops or mixes that include legumes tended to provide the highest yield increases but a mix including legume did not consistently outperform single species in this respect [footnote ⁷⁵⁷]. Vegetable crops also tended to benefit more from a prior sown cover crop than grains [footnote ⁷⁵⁸]. However, performance is inconsistent, and effectiveness remains context-dependent, influenced by climate, cover crop establishment period and crop type [footnote ⁷⁵⁹]. In terms of timeframe, each review had a slightly different timeframe specified for assessing the benefits, but the most common assessment was for the subsequent cropping meaning evidence for longer term benefits are potentially overlooked.

Field trial single studies: One study found greater profit margins with cover crops in vegetable crops but not grain and oilseed crops indicating that cover crops effects on crop profitability are dependent on the production system [footnote ⁷⁶⁰]. Another found that cultivation of winter-persistent legumes alone or in a mixture with oilseed radish offers a promising tool for improving the yields of subsequent crops [footnote ⁷⁶¹].

Environmental Impacts (36 studies)

Review studies: 7 studies returned were systematic reviews and 3 reviews explicitly considering the benefits of mixtures over single species across a range of environmental performance metrics.

⁷⁵⁷ Allam et al., '[A Meta-Analysis Approach to Estimate the Effect of Cover Crops on the Grain Yield of Succeeding Cereal Crops within European Cropping Systems](#)', Agriculture 13, no. 9 (September 2023): 1714; Bourgeois et al., '[Interactive Effects between Cover Crop Management and the Environment Modulate Benefits to Cash Crop Yields: A Meta-Analysis](#)', ed. Brian Beres, Canadian Journal of Plant Science 102, no. 3 (1 June 2022): 656–78.

⁷⁵⁸ Adewale Osipitan et al., '[Cover Crop for Early Season Weed Suppression in Crops: Systematic Review and Meta-Analysis](#)', Agronomy Journal 110, no. 6 (2018): 2211–21.

⁷⁵⁹ Yousefi, Dray, Jaboury and Ghazoul, '[Assessing the Effectiveness of Cover Crops on Ecosystem Services: A Review of the Benefits, Challenges, and Trade-Offs](#)', International Journal of Agricultural Sustainability 22, no. 1 (31 December 2024): 2335106.

⁷⁶⁰ Chahal, I., Vyn, R.J., Mayers, D. et al. [Cumulative impact of cover crops on soil carbon sequestration and profitability in a temperate humid climate](#). *Sci Rep* 10, 13381 (2020).

⁷⁶¹ Hansen, Linn V. Meilvang, Jakob Magid, Kristian Thorup-Kristensen, Lars Stoumann Jensen, [Effect of soil fertility level on growth of cover crop mixtures and residual fertilizing value for spring barley](#), European Journal of Agronomy, Volume 145, 2023.

Review 1 looked at autumn-seeded mixtures and found that across the range of agroecosystem services studied mixtures had inconsistent effects in comparison to single species [footnote ⁷⁶²]. Legume based mixtures increase soil N and C contents, along with crop yield, whereas non-legume mixtures improve N recycling and weed suppression. Differences in functional groups within mixtures lead to trade-offs.

Review 2 evaluated whether mixtures are better than single species at improving soil physical health and found that mixtures did not enhance soil physical properties relative to monoculture cover crops in most cases [footnote ⁷⁶³]. However, the review notes that the soil benefits of mixtures should be evaluated on a site-specific basis as there are examples where their performance was superior.

Review 3 evaluated cover mixtures versus single species cover crops based on biomass, weed suppression, nitrogen, water retention, yield, and stability effects [footnote ⁷⁶⁴]. In 88% of these comparisons, the single species and mixture performed comparably. In 10% of the comparisons, the monoculture did better, and in 2% of comparisons the mixture performed better. Most of the cases where the monoculture performed better than the mixture was in the cover crop productivity category. The cases where the mixture performed significantly better than the monoculture fell in 4 categories: cover crop productivity, weed suppression, N retention, and crop yield promotion. All were situations the mixtures were of legumes with non-legumes and were planted at rates exceeding substitutive rates causing the effect of plant mixing to be confounded by the effects of seeding rate. Therefore, the authors note that the elevated performance of the cover crop mixtures in these 5 cases could be more a result of elevated seeding rate than the actual mixing of different cover crop species or it could also be partially due to the benefits of mixing legumes with non-legumes.

Field trial single studies: 23 of the studies covering environmental benefits were field or greenhouse trials where the benefits of multispecies crop cover were compared with the benefits of single stand mixes, some also included a none cover control. The reviewed field

⁷⁶² Lavergne et al., '[Using Fall-Seeded Cover Crop Mixtures to Enhance Agroecosystem Services: A Review](#)', *Agrosystems, Geosciences & Environment* 4, no. 2 (2021): e20161.

⁷⁶³ Blanco-Canqui, '[Do Cover Crop Mixtures Improve Soil Physical Health More than Monocultures?](#)', *Plant and Soil* 495, no. 1 (1 February 2024): 99–112.

⁷⁶⁴ Florence et al., '[Do diverse cover crop mixtures perform better than monocultures? A systematic review](#)' *Agronomy Journal*

trial studies examined various environmental benefits of multispecies cover crops, including weed suppression, nitrogen cycling, carbon sequestration, biomass production, soil health, and greenhouse gas emissions. Across these studies multispecies crop cover was not found to provide significantly better weed suppression than monocultures [footnote ⁷⁶⁵]. There was some indication that shoot biomass was accumulated more in mixtures [footnote ⁷⁶⁶] but the total biomass tended to be the same [footnote ⁷⁶⁷]. Mixtures with legumes provided nitrogen services, however this is the benefit of a single mixture component rather than the benefit of a mixture over single crop type [footnote ⁷⁶⁸]. This implies that similar benefits would have been derived from using legume only cover. Some mixtures did show reduced emissions of nitrous oxide following tillage of legume-grass cover mixtures compared to clover [footnote ⁷⁶⁹] and increased soil microbial diversity [footnote ⁷⁷⁰]. Overall, the benefits delivered from mixtures were site dependent, with benefits varying by location, soil conditions and species composition [footnote ⁷⁷¹]. Mixtures increased multifunctionality, meaning different objectives could be achieved with the same cover crop, for example weed suppression and fertilisation. But each objective might not necessarily be achieved at the highest levels for each function suggesting trade-offs. Competitive species within mixtures can dominate, reducing services from other species, particularly under high nitrogen conditions or when planting was early.

Social Impacts (0 studies)

None of the studies identified considered the social benefits of multispecies cover crops.

⁷⁶⁵ Smith, Warren, and Cordeau, '[Are Cover Crop Mixtures Better at Suppressing Weeds than Cover Crop Monocultures?](#)', Weed Science 68, no. 2 (March 2020): 186–94.

⁷⁶⁶ Elhakeem et al., '[Cover Crop Mixtures Result in a Positive Net Biodiversity Effect Irrespective of Seeding Configuration](#)', Agriculture, Ecosystems and Environment 285 (2019).

⁷⁶⁷ Elhakeem et al., '[Do Cover Crop Mixtures Give Higher and More Stable Yields than Pure Stands?](#)', Field Crops Research 270 (2021).

⁷⁶⁸ Reiss and Drinkwater, '[Ecosystem Service Delivery by Cover Crop Mixtures and Monocultures Is Context Dependent](#)', Agronomy Journal 112, no. 5 (2020): 4249–63.

⁷⁶⁹ Bressler and Blesh, '[Episodic N₂O Emissions Following Tillage of a Legume–Grass Cover Crop Mixture](#)', Biogeosciences 19, no. 13 (6 July 2022): 3169–84.

⁷⁷⁰ Drost et al., '[Decomposition of Mixtures of Cover Crop Residues Increases Microbial Functional Diversity](#)', Geoderma 361 (2020).

⁷⁷¹ Bressler and Blesh, '[Episodic N₂O Emissions Following Tillage of a Legume–Grass Cover Crop Mixture](#)', Biogeosciences 19, no. 13 (6 July 2022): 3169–84.

Barriers (4 studies)

The consistent theme relevant to temperate regions worldwide was challenges in terms of cover crop establishment [footnote ⁷⁷²]. Explicit evidence is needed on the economic viability of earlier cover crop sowing as well as strong technical and/or financial support for farmers during cover crop adoption in risky environmental conditions [footnote ⁷⁷³]. The latter is important to help farmers overcome site-specific complexities due to earlier cover crop sowing. None of the studies on barriers distinguish between barriers to multispecies establishment compared to single species establishment.

Evidence Gaps (1 study)

While the evidence on environmental and economic (yield) benefits of multispecies vs single species cover crops is extensive there was less evidence identified on uptake rates, barriers to uptake or interventions on multispecies cover versus single cover.

Cost-effectiveness Evidence (0 studies)

The evidence base identified did not include cost-benefit analysis. In those studies that conducted yield assessments the profitability was not well accounted for considering cost of the practice vs additional yield benefits.

Critical Success Factors

Strategic fit and business needs: Medium alignment

The evidence reviewed suggests that the Theme Improved Soil Health and Multispecies Crop Cover has the potential to support a range of environmental and economic outcomes, such as improved soil structure, nutrient cycling, carbon sequestration, and reduced fertiliser use. These outcomes are broadly aligned with the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023. However, much of the evidence related to cover cropping more generally, with limited distinction between single species and multispecies mixtures.

⁷⁷² Feng et al., '[Strategies to Improve Field Establishment of Cover Crops. A Review](#)', Agronomy for Sustainable Development 44, no. 5 (4 October 2024): 47.

⁷⁷³ Ibid.

While 82% of farmers surveyed in one UK study used 2 or more species in cover crops, the evidence did not clarify uptake in Wales or the feasibility of adoption across different farm types. As such, the Theme Improved Soil Health and Multispecies Crop Cover is assessed as having medium alignment, reflecting its potential to support strategic outcomes, but also the variability and site-specific nature of its effectiveness.

Value for money: Medium alignment

The reviewed studies present mixed findings regarding the economic benefits of multispecies cover crops. Some evidence suggests increased yields in vegetable systems or when legumes are used, but results were highly variable and often not expressed in monetary terms. The absence of cost-benefit analyses makes it difficult to assess value for money at farm scale. As outlined in the environmental benefits section, multispecies do not always outperform single species, however multispecies can deliver across multiple objectives, for example, nitrogen fixation and weed suppression as opposed to only delivering weed suppression. Therefore, support could deliver value for money where multiple soil improvement objectives are to be achieved. This could justify medium alignment, contingent on appropriate policy and financial support to increase uptake.

Supply side capacity and capability: Medium alignment

The evidence reviewed does not provide detailed insights into the availability of advisory services, training, or collaboration structures for these actions. While the relatively high rate of cover crop use in the UK suggests some baseline capacity, the literature does not examine whether farmers are equipped to assess the value of specific practices, particularly more complex multispecies mixes, or whether peer networks exist to support learning. . Given this, the Theme Improved Soil Health and Multispecies Crop Cover is assessed as having medium alignment with this CSF, based on the potential for capacity building but limited evidence of current support infrastructure.

Affordability: Low alignment

The evidence base highlights cost and economic viability as key barriers to uptake of both soil health and multispecies cover crop practices. Establishment challenges, yield variability, and site-specific performance contribute to financial risk for farmers, particularly in risky

environmental conditions. None of the reviewed studies on barriers distinguished between barriers to multispecies establishment compared to single species establishment.

Sustainable Production

The objectives of the Theme Sustainable Production are to build on Universal Action 3: Benchmarking, as well as other Themes which optimise business and environmental performance. Sustainable Production aims to encourage greater efficiency on farms which can improve productivity and reduce greenhouse gas emissions. Sustainable Production will initially include 3 sub-actions:

- Implementing graze and rest patterns
- Sustainably reducing the age at slaughter of prime beef animals
- beef sire registration.

Rotational Grazing, also known as mob or adaptive multi-paddock (AMP) grazing is a system which uses higher livestock concentration in smaller paddocks over a short period of time to allow for longer periods of rest for pastures to aid recovery and greater plant growth between grazing events [footnote ⁷⁷⁴]. The Theme will involve support through advice, guidance and capital investment to implement more sustainable grazing management such as graze and rest approaches.

Sire registration can allow farmers to make more informed breeding decisions based on the genetic potential of cattle.

Actions to reduce the age of slaughter involve reducing the age at which livestock is sent to slaughter, thereby reducing the time that livestock spend on farm, using the resources available to a farm, improving production and lowering GHG emissions.

REA Exclusion / Inclusion Criteria

Inclusion: Studies on rotational grazing, intensive rotational grazing, mob grazing, graze and rest, and adaptive multi-paddock (AMP) grazing. Studies on sire registration of cattle and schemes encouraging registration of calves. Studies on reducing the age of slaughter among cattle, and schemes encouraging a reduction in the age of slaughter of cattle.

⁷⁷⁴ Wagner, Waterton, and Norton, '[Mob Grazing: A Nature-Based Solution for British Farms Producing Pasture-Fed Livestock](#)', Nature-Based Solutions 3 (December 2023): 100054.

Exclusion: Studies concerned with non-comparable climates and farming systems.

Evidence Base

Due to the sub-actions under the Sustainable Production Theme, 3 different searches were conducted for each component.

Utilising the above search terms, rotational grazing returned 113 responses within the scope of the evidence assessment. Additional studies were sourced from Google Scholar and agreed grey literature websites. In total, 25 were taken forward for evidence review, with all others discarded due to not meeting thresholds for quality or relevance.

For reducing age of slaughter, Scopus returned 76 responses. In total, 8 were taken forward for further analysis, with further sources identified through Google Scholar and relevant websites, bringing the total to 14.

For sire registration, Scopus returned 26 responses. In total, 8 were taken forward for further analysis, with further sources identified through Google Scholar and relevant websites, bringing the total to 20.

Design of the Intervention (13 studies)

Rotational grazing

Little of the academic literature identified was concerned with the implementation of schemes to encourage the uptake of rotational grazing, concentrating instead on the details of different approaches to a graze and rest system. Similarly, a review of grey literature from the governments of UK nations and Ireland identified no published evidence of agricultural schemes with a specific focus on rotational grazing, other than some knowledge exchange programmes delivered by the Welsh Government [footnote ⁷⁷⁵].

Reducing the Age of Slaughter

None of the studies identified discussed the potential effectiveness of schemes to reduce the age of slaughter, however a relevant initiative has existed in Northern Ireland aimed at reducing the age of slaughter of cattle since January 2024. The Beef Carbon Reduction

⁷⁷⁵ [‘Rotational Grazing Improves Farm’s Grass Quality without Need to Reseed’](#), 26 October 2020.

Scheme (BCRS) is a four-year scheme that provides payment to farmers of £75 for each eligible animal slaughtered, with the threshold by year 4 of the scheme to reach 26 months at the age of slaughter [footnote ⁷⁷⁶].

An implication identified in some studies (explored in the Economic Benefits section below) is that the economic and environmental benefits of reducing the age of slaughter are greater in pasture-based systems with lower external inputs [footnote ⁷⁷⁷].

Sire registration

None of the academic studies identified discussed the design of interventions to register sires.

Uptake of the Practice (8 studies)

Rotational Grazing

Very few studies (2 out of 25) discussed the uptake of rotational grazing in detail beyond anecdotal discussion of the increased interest in the practice. The lack of consistent tracking of rotational grazing adoption across different agricultural systems makes it challenging to quantify its prevalence on a national or regional scale.

One study assessing how best to support rotational grazing in Wales identified a range of measures that could be taken, including improving flexibility in land rights and access to pasture to encourage longer-term investment, greater promotion of long-term tenancies, support for regenerative farming on common land, including granting temporary exclusive access to common land stipulating the principles of regenerative farming in the agreement, establishing pasture loans to help farmers set up rotational grazing, the use of transition payments, and the provision of training and support [footnote ⁷⁷⁸]. This study also notes the investment in regenerative farming from the private sector, with businesses such as Arla

⁷⁷⁶ [‘Beef Carbon Reduction Scheme – A Focus on Herd Management’](#), Department of Agriculture, Environment and Rural Affairs (blog), December 2024.

⁷⁷⁷ Murphy et al., [‘An Economic and Greenhouse Gas Emissions Evaluation of Pasture-Based Dairy Calf-to-Beef Production Systems’](#), *Agricultural Systems* 154 (June 2017): 124–32,.

⁷⁷⁸ Moore, [‘Supporting Farmers in Agro-Ecological Transition: A Systems Perspective of Regenerative Grazing in Wales’](#) (University of Hull, 2024),.

investing in a trial of regenerative practices and paying a premium for regeneratively farmed dairy products [footnote ⁷⁷⁹].

Reducing the Age of Slaughter

No studies were identified that discussed uptake of schemes to reduce the age of slaughter. The BCRS in Northern Ireland (NI) is in its early stages, however NI Government press releases have indicated that 8,000 businesses have opted into the scheme [footnote ⁷⁸⁰].

Sire Registration

Evidence from the Agriculture and Horticulture Development Board (AHDB) [footnote ⁷⁸¹] suggests that only 23% of sires are currently registered in the UK, with a significant proportion of animals still sold without recorded sire details, limiting the ability to fully capitalize on the benefits of genetic selection. The Beef Data and Genomics Programme (BDGP) in Ireland has demonstrated the value of genomic testing in improving the genetic merit of the national herd, with over 60% of cattle now genotyped annually under the scheme [footnote ⁷⁸²]. However, uptake of the BDGP remains uneven, with smaller farms or those with limited infrastructure facing challenges in adopting these practices. Scotland's Beef Efficiency Scheme, which asked farmers to submit tissue samples and other metrics saw only 30% of the national breeding herd take part [footnote ⁷⁸³].

Significantly, non-participating farms have also seen a positive impact from the BDGP, with these farms benefiting from the genetic gain seen in livestock across the sector. Described as a spill-over from the programme, non-participating farms have seen the mean value of

⁷⁷⁹ Moore, [Supporting Farmers in Agro-Ecological Transition: A Systems Perspective of Regenerative Grazing in Wales](#)

⁷⁸⁰ 'Successful First Year for the Beef Carbon Reduction Scheme', Department of Agriculture, Environment and Rural Affairs, 18 March 2025.

⁷⁸¹ 'AHDB', [Shout about the Sire](#) (blog), accessed 20 March 2025,.

⁷⁸² Cawley and Banks, '[Review of the Beef Data Genomics Programme 2015-2021](#)' (Economic and Planning Division, Department of Agriculture, Food and the Marine: Government of Ireland, December 2022).

⁷⁸³ Jenkins et al., '[Breeding for Reduced Methane Emissions in Livestock](#)' (Ricardo PLC, January 2025).

Replacement and Terminal Indices [footnote ⁷⁸⁴] increase, however not as much as for participating farms [footnote ⁷⁸⁵].

Economic Impacts (24 studies)

Rotational Grazing

Of the 25 studies, 10 discussed economic benefits, setting out strong support for the economic benefits of rotational grazing. These studies, however, like much of the literature on rotational grazing, were concerned with climates different to that of Wales, often on grasslands in North America, with the limited number of studies identified in the UK.

A key benefit noted in multiple academic studies and example case studies from Welsh farms is an improvement to grass yield [footnote ⁷⁸⁶]. Farmers can increase grass yield and reduce their dependence on purchased feed, which in turn lowers operational costs [footnote ⁷⁸⁷]. This was particularly evident in cases where farmers were able to extend their grazing season through improving grass growth over a longer period, thereby minimising their reliance on supplementary feed during colder months [footnote ⁷⁸⁸]. According to AHDB, an extended grazing period in the UK can save a business £1.25 per cow per day [footnote ⁷⁸⁹]. Rotational grazing has been linked to lower fertilizer expenses, as it allows for better nutrient distribution across fields due to concentrating animal waste in smaller areas, reducing the need for synthetic fertilizers.

⁷⁸⁴ The Terminal Index ranks breeding animals on the profitability of their resulting offspring in finishing systems, whereas the Replacement Index focuses on ranking breeding animals on the profitability and merits of their female offspring, becoming the next generation of suckler herds nationally

⁷⁸⁵ Cawley and Banks, '[Review of the Beef Data Genomics Programme 2015-2021](#)'.

⁷⁸⁶ Wagner, Waterton, and Norton, '[Mob Grazing: A Nature-Based Solution for British Farms Producing Pasture-Fed Livestock](#)';

Díaz De Otálora et al., '[Regenerative Rotational Grazing Management of Dairy Sheep Increases Springtime Grass Production and Topsoil Carbon Storage](#)', *Ecological Indicators* 125 (June 2021): 107484.

'[Rotational Grazing Improves Farm's Grass Quality without Need to Reseed](#)'.

⁷⁸⁷ '[Rotational Grazing Shown to Increase Soil Organic Matter on Welsh Farm](#)', 24 May 2021.

⁷⁸⁸ Wagner, Waterton, and Norton, '[Mob Grazing: A Nature-Based Solution for British Farms Producing Pasture-Fed Livestock](#)';

Brown, '[The Importance of How We Graze Our Cattle and Sheep - a Look at Mob Grazing](#)', *Star & Furrow*, no. 27 (June 2017): 16–19;

⁷⁸⁹ '[Rotational Grazing Systems for Cattle](#)', Knowledge Library (blog), 2025, Rotational Grazing Systems for Cattle.

Stocking rates can be higher in rotationally grazed systems, with evidence supporting that the increased grass yield allows for a higher carrying capacity for the land, in some studies up to 30% more than under conventional grazing approaches [footnote ⁷⁹⁰]. While rotational grazing is noted to increase productivity per acre, evidence suggests that weight gain rates under rotational grazing may be lower than under more conventional systems [footnote ⁷⁹¹]. In some studies, overall productivity was nonetheless higher due to higher stocking rates, mitigating lower rates of weight gain [footnote ⁷⁹²].

Additionally, rotational grazing contributes to long-term farm resilience by reducing soil degradation and maintaining pasture health, farmers employing these practices are better equipped to withstand environmental shocks such as droughts. Further evidence also suggests that rotational grazing systems can have lower instances of disease and parasite loads due to improved pasture management and less exposure to contaminated grazing areas [footnote ⁷⁹³].

Despite these advantages, the expenditure on infrastructure to establish rotational grazing systems, namely water and fencing infrastructure, can in the short term limit the economic impact of the system.

⁷⁹⁰ Rouquette, Sollenberger, and Vendramini, '[Grazing Management and Stocking Strategy Decisions for Pasture-Based Beef Systems: Experimental Confirmation vs. Testimonials and Perceptions](#)', *Translational Animal Science* 7, no. 1 (1 January 2023): txad069, Teague and Kreuter, '[Managing Grazing to Restore Soil Health, Ecosystem Function, and Ecosystem Services](#)', *Frontiers in Sustainable Food Systems* 4 (29 September 2020): 534187; Wagner, Waterton, and Norton, '[Mob Grazing: A Nature-Based Solution for British Farms Producing Pasture-Fed Livestock](#)'; Jacobo et al., '[Rotational Grazing Effects on Rangeland Vegetation at a Farm Scale](#)', *Rangeland Ecology & Management* 59, no. 3 (2006),.

⁷⁹¹ Rouquette, Sollenberger, and Vendramini, '[Grazing Management and Stocking Strategy Decisions for Pasture-Based Beef Systems: Experimental Confirmation vs. Testimonials and Perceptions](#)'; [Driving Your Landscape to Success: Managing a Grazing Business for Profit in the Agricultural Landscape](#), 24th-26th July 2012, [Joyes Hall, Charles Sturt University], Wagga Wagga : Proceedings of the 27th Annual Conference of The Grassland Society of NSW Inc (Orange, N.S.W.: Grassland Society of NSW, 2012).; David J. Augustine et al., '[Adaptive, Multi-Paddock, Rotational Grazing Management Alters Foraging Behavior and Spatial Grazing Distribution of Free-Ranging Cattle](#)', *Agriculture, Ecosystems & Environment* 352 (August 2023): 108521,.

⁷⁹² Badgery et al., '[Intensive Rotational Grazing Can Improve Profitability and Environmental Outcomes](#)', in *Proceedings of the 27th Annual Conference of the Grassland Society of NSW*, vol. 27, 2012.

⁷⁹³ Wagner, Waterton, and Norton, '[Mob Grazing: A Nature-Based Solution for British Farms Producing Pasture-Fed Livestock](#)'.

Some studies challenged the economic superiority of rotational grazing. A subset of the evidence suggested that the financial benefits may not always materialise, particularly for farms with limited infrastructure or those transitioning from continuous grazing systems, with some studies highlighting that the capital investment required for fencing, water systems, and labour can offset the savings on feed and fertilizer, particularly in the initial years of implementation [footnote ⁷⁹⁴].

Additionally, rotational grazing may require a steep learning curve for farmers unfamiliar with intensive grazing management, which could limit its feasibility in certain farm contexts. These findings indicate that while rotational grazing presents clear economic potential, its success is highly contingent on effective implementation and farm-specific conditions.

Reducing Age of Slaughter

Of the 14 studies and sources, 7 included a focus on the economic implications of reducing the age of slaughter. Reducing the age at slaughter has observed economic impacts on farm profitability, input costs, and market viability. The evidence base suggests that finishing cattle at a younger age improves feed conversion efficiency, as more of the intake is used for growth rather than maintenance [footnote ⁷⁹⁵]. Older cattle become less efficient in converting feed into muscle, leading to higher feed costs per kilogram of beef produced [footnote ⁷⁹⁶]. Earlier slaughter also reduces the duration cattle require housing, lowering costs related to bedding, manure management, and labour [footnote ⁷⁹⁷].

⁷⁹⁴ Badgery et al., '[Intensive Rotational Grazing Can Improve Profitability and Environmental Outcomes](#)', in *Proceedings of the 27th Annual Conference of the Grassland Society of NSW*, vol. 27, 2012.; Rouquette, Sollenberger, and Vendramini, '[Grazing Management and Stocking Strategy Decisions for Pasture-Based Beef Systems: Experimental Confirmation vs. Testimonials and Perceptions](#)', *Translational Animal Science* 7, no. 1 (1 January 2023): txad069,

⁷⁹⁵ Taylor et al., '[Bioeconomic and Greenhouse Gas Emissions Modelling of the Factors Influencing Technical Efficiency of Temperate Grassland-Based Suckler Calf-to-Beef Production Systems](#)', *Agricultural Systems* 183 (August 2020): 102860,.

⁷⁹⁶ McGee et al., '[Grass-Based Finishing of Early- and Late-Maturing Breed Bulls within Suckler Beef Systems: Performance, Profitability, Greenhouse Gas Emissions and Feed-Food Competition](#)', *Livestock Science* 279 (January 2024): 105392.

⁷⁹⁷ Murphy et al., '[An Economic and Greenhouse Gas Emissions Evaluation of Pasture-Based Dairy Calf-to-Beef Production Systems](#)'.

Studies indicate that earlier finishing increases net margins due to lower costs per kilogram of beef [footnote ⁷⁹⁸]. Pasture-based systems, particularly those with a 19-month finishing target, have been found to balance economic returns with emissions reductions, with pasture grazed systems being the most economically efficient option [footnote ⁷⁹⁹].

Farms adopting early finishing strategies may be better protected from feed price volatility, as reliance on supplementary feeding is reduced [footnote ⁸⁰⁰]. Managing pasture-based systems efficiently for early finishing also improves farm sustainability, reducing dependence on imported feeds and associated market risks.

Sire Registration

The evidence base supports the economic benefits of sire registration, particularly in terms of improved farm efficiency and reduced operational costs, with 9 of the 20 sources concerned with assessing its economic impacts. Sire registration is a key enabler of genomic testing, which builds on the foundation of registered lineages to allow for more precise selection of animals based on desirable traits. By selecting for genetically superior animals, farmers can significantly improve growth rates, feed efficiency, and carcass quality, leading to higher profitability. Evidence shows that genetic improvements resulting from sire registration and genomic testing contribute directly to greater farm output and lower feed costs per animal, as genetically improved cattle require less feed to reach slaughter weight [footnote ⁸⁰¹].

Shortening the time to slaughter is a major potential economic benefit of sire registration. By selecting for faster-finishing cattle, farmers can reduce the duration for which cattle require housing, bedding, and labour, lowering these operational costs. Sire registration, alongside genomic testing should farms opt for this further course of action, allows for better selection of traits like growth rate and feed efficiency, and can ultimately reduce the time cattle spend on the farm, directly translating into cost savings [footnote ⁸⁰²]. Evidence from Ireland's

⁷⁹⁸ Taylor et al., '[Bioeconomic and Greenhouse Gas Emissions Modelling of the Factors Influencing Technical Efficiency of Temperate Grassland-Based Suckler Calf-to-Beef Production Systems](#)'.

⁷⁹⁹ Murphy et al., '[An Economic and Greenhouse Gas Emissions Evaluation of Pasture-Based Dairy Calf-to-Beef Production Systems](#)'.

⁸⁰⁰ Ibid.

⁸⁰¹ Cawley and Banks, '[Review of the Beef Data Genomics Programme 2015-2021](#)'.

⁸⁰² Quinton et al., '[Prediction of Effects of Beef Selection Indexes on Greenhouse Gas Emissions](#)', *Animal* 12, no. 5 (2018): 889–97.

Genomics Programme indicates that participating report observed reductions in feed and maintenance costs, leading to higher profit margins [footnote ⁸⁰³].

Environmental Impacts (25 studies)

Rotational grazing

The evidence base indicates that rotational grazing can result in environmental impacts, with 16 out of 25 studies supporting its role in enhancing soil health, biodiversity, and carbon sequestration [footnote ⁸⁰⁴]. A key environmental benefit is its positive effect on soil structure and fertility [footnote ⁸⁰⁵]. Studies suggest that by allowing pastures to rest between grazing periods, rotational systems encourage greater root biomass development, leading to improved soil organic matter [footnote ⁸⁰⁶] and water infiltration capacity [footnote ⁸⁰⁷]. This, in turn, reduces the risk of soil erosion [footnote ⁸⁰⁸] and compaction, which are associated with continuous grazing systems. Furthermore, the ability of rotational grazing to enhance soil microbial diversity contributes to better nutrient cycling, [footnote ⁸⁰⁹] potentially lowering the need for synthetic fertilizers over time.

Another key environmental impact is its potential for increasing biodiversity. Rotational grazing has been linked to greater plant species richness, as it allows native grasses and forbs to recover between grazing cycles, [footnote ⁸¹⁰] and encourages herbivores not to select only the most nutritious grass species [footnote ⁸¹¹]. Positive impacts have been

⁸⁰³ Cawley and Banks, '[Review of the Beef Data Genomics Programme 2015-2021](#)'.

⁸⁰⁴ Harrison et al., '[Regenerative Agriculture Amplifies Productivity and Profitability While Negating Greenhouse Gas Emissions](#)' (In Review, 28 January 2025).

⁸⁰⁵ Wagner, Waterton, and Norton, '[Mob Grazing: A Nature-Based Solution for British Farms Producing Pasture-Fed Livestock](#)'.

⁸⁰⁶ Zaralis and Padel, '[Effects of High Stocking Grazing Density of Diverse Swards on Forage Production, Animal Performance and Soil Organic Matter: A Case Study](#)', in Innovative Approaches and Applications for Sustainable Rural Development, ed. Alexandros Theodoridis, Athanasios Ragkos, and Michail Salampasis, Springer Earth System Sciences (Cham: Springer International Publishing, 2019), 131–46.

⁸⁰⁷ Schmid et al., '[Adaptive Multipaddock \(AMP\) Pasture Management Increases Arthropod Community Guild Diversity Without Increasing Pests](#)', Rangeland Ecology & Management 94 (May 2024): 141–48.

⁸⁰⁸ Teague and Kreuter, '[Managing Grazing to Restore Soil Health, Ecosystem Function, and Ecosystem Services](#)'.

⁸⁰⁹ Ibid.

⁸¹⁰ Schmid et al., '[Adaptive Multipaddock \(AMP\) Pasture Management Increases Arthropod Community Guild Diversity Without Increasing Pests](#)'.

⁸¹¹ Teague and Kreuter, '[Managing Grazing to Restore Soil Health, Ecosystem Function, and Ecosystem Services](#)'.

identified for pollinators [footnote ⁸¹²] and soil invertebrates, which play a crucial role in maintaining ecosystem resilience, [footnote ⁸¹³] and some indication of positive impacts for mammal and bird species habitats [footnote ⁸¹⁴]. Improved weed management of undesirable species was also noted in the literature, resulting in a reduced need for non-nature-based herbicide applications [footnote ⁸¹⁵].

In terms of climate change mitigation, rotational grazing has been cited as an effective practice for enhancing carbon sequestration [footnote ⁸¹⁶]. One study suggested that increased root growth and organic matter accumulation in rotationally grazed pastures contributed to higher carbon storage in soils, helping to offset greenhouse gas emissions from livestock farming [footnote ⁸¹⁷]. However, this finding was site specific, was dependent on existing soil carbon levels, and identified increased soil carbon storage in comparison to conventional stocking.

However, some studies caution that the environmental benefits of rotational grazing may be contingent on proper management practices. While rotational grazing can lead to reduced nitrogen leaching and improved water retention, its success depends on appropriate stocking densities and rest periods between grazing cycles [footnote ⁸¹⁸]. Overuse of

⁸¹² Ravetto Enri et al., '[A Biodiversity-Friendly Rotational Grazing System Enhancing Flower-Visiting Insect Assemblages While Maintaining Animal and Grassland Productivity](#)', Agriculture, Ecosystems & Environment 241 (April 2017): 1–10.

⁸¹³ Schmid et al., '[Adaptive Multipaddock \(AMP\) Pasture Management Increases Arthropod Community Guild Diversity Without Increasing Pests](#)'.

⁸¹⁴ Ravetto Enri et al., '[A Biodiversity-Friendly Rotational Grazing System Enhancing Flower-Visiting Insect Assemblages While Maintaining Animal and Grassland Productivity](#)'.

⁸¹⁵ Wagner, Waterton, and Norton, '[Mob Grazing: A Nature-Based Solution for British Farms Producing Pasture-Fed Livestock](#)'.

⁸¹⁶ Harrison et al., '[Regenerative Agriculture Amplifies Productivity and Profitability While Negating Greenhouse Gas Emissions](#)'.

Zaralis and Padel, '[Effects of High Stocking Grazing Density of Diverse Swards on Forage Production, Animal Performance and Soil Organic Matter: A Case Study](#)', in Innovative Approaches and Applications for Sustainable Rural Development, ed. Alexandros Theodoridis, Athanasios Ragkos, and Michail Salampasis, Springer Earth System Sciences (Cham: Springer International Publishing, 2019), 131–46;

Khatri-Chhetri et al., '[Adaptive Multi-Paddock Grazing Increases Mineral Associated Soil Carbon in Northern Grasslands](#)', Agriculture, Ecosystems & Environment 369 (August 2024): 109000,;

Díaz De Otálora et al., '[Regenerative Rotational Grazing Management of Dairy Sheep Increases Springtime Grass Production and Topsoil Carbon Storage](#)', Ecological Indicators 125 (June 2021): 107484.; '[Rotational Grazing Shown to Increase Soil Organic Matter on Welsh Farm](#)', 24 May 2021.

⁸¹⁷ Harrison et al., '[Regenerative Agriculture Amplifies Productivity and Profitability While Negating Greenhouse Gas Emissions](#)'.

⁸¹⁸ Oates et al., '[Management-Intensive Rotational Grazing Enhances Forage Production and Quality of Subhumid Cool-Season Pastures](#)', Crop Science 51, number 2 (March 2011): pages 892 to 901.

pasture areas, even within a rotational system, can still lead to soil degradation and potential negative water quality impacts [footnote ⁸¹⁹]. Additionally, the environmental gains observed in some case studies may not always be replicable across different climatic regions, with some evidence indicating for drier climates (e.g., rangelands in the northern US states) that conventional stocking rates have better ecological outcomes, [footnote ⁸²⁰] suggesting that site-specific factors such as rainfall patterns and soil composition play a critical role in determining outcomes.

Furthermore, by allowing increased stocking densities, rotational grazing may increase GHG emissions in other ways through encouraging holdings to increase in size.

Reducing Age of Slaughter

7 studies discussed the environmental benefits of reducing the age of slaughter in detail. Reducing slaughter age has been widely shown to decrease GHG emissions per kilogram of beef, with studies estimating reductions of 1.6% to 3.2% per month [footnote ⁸²¹]. However, the environmental impact of reducing slaughter age is more complex when considering potential protein inputs required for growth and the trade-offs between different grazing or feed approaches.

While younger slaughter ages improve feed efficiency and lower methane emissions per unit of product, achieving optimal weight gain in a shorter time can require higher protein inputs, particularly through concentrate feeds [footnote ⁸²²]. Studies indicate that high-concentrate diets reduce methane emissions but increase embodied emissions from feed production, particularly if these feeds include imported cereals or soy-based proteins with

⁸¹⁹ De Otálora et al., '[Regenerative Rotational Grazing Management of Dairy Sheep Increases Springtime Grass Production and Topsoil Carbon Storage](#)', June 2021.

⁸²⁰ Rouquette, Sollenberger, and Vendramini, '[Grazing Management and Stocking Strategy Decisions for Pasture-Based Beef Systems: Experimental Confirmation vs. Testimonials and Perceptions](#)'; Abagandura et al., '[Soil Carbon and Nitrogen after Eight Years of Rotational Grazing in the Nebraska Sandhills Meadows](#)', *Geoderma* 442 (February 2024): 116776,

⁸²¹ Kearney et al., '[Mitigation of Greenhouse Gas Emissions in Pasture-Based Dairy-Beef Production Systems](#)', *Agricultural Systems* 211 (October 2023): 103748;

Taylor et al., '[Bioeconomic and Greenhouse Gas Emissions Modelling of the Factors Influencing Technical Efficiency of Temperate Grassland-Based Suckler Calf-to-Beef Production Systems](#)'.

⁸²² Murphy et al., '[An Economic and Greenhouse Gas Emissions Evaluation of Pasture-Based Dairy Calf-to-Beef Production Systems](#)'.

associated land-use change impacts [footnote ⁸²³]. This means that while early finishing systems are beneficial in lowering methane from enteric fermentation their total carbon footprint depends on how feed ingredients are sourced and used.

Grazing strategies influence environmental outcomes. Pasture-based systems that rely on high-quality forage and managed grazing can reduce reliance on concentrates and maintain a lower overall carbon footprint [footnote ⁸²⁴]. However, cattle finished on extended pasture systems tend to have longer production cycles and subsequently higher methane emissions per animal [footnote ⁸²⁵]. Some studies suggest that combining strategic concentrate supplementation in pasture-based systems offers a compromise between reducing methane intensity while limiting external feed inputs, however the most desirable production system from an economic standpoint is one that uses high levels of grazed pasture, exploiting existing resources available on the farm [footnote ⁸²⁶].

Soil carbon sequestration is another factor that complicates the environmental assessment. A study from the US noted that pasture-based systems can contribute positively to carbon sequestration, mitigating some of the emissions from livestock production [footnote ⁸²⁷]. An Irish study noted the omission of soil carbon sequestration from its model of environmental impact from rotational grazing, however recognised that to omit sequestration may lead to an overestimation of total emissions from pasture-based beef systems compared to concentrate-fed alternatives [footnote ⁸²⁸]. The latter study did however note that previous

⁸²³ Foley et al., '[Whole-Farm Systems Modelling of Greenhouse Gas Emissions from Pastoral Suckler Beef Cow Production Systems](#)', Agriculture, Ecosystems & Environment 142, numbers 3 to 4 (August 2011): pages 222 to 230.

⁸²⁴ Herron et al., '[Life Cycle Assessment of Pasture-Based Suckler Steer Weanling-to-Beef Production Systems: Effect of Breed and Slaughter Age](#)'.

⁸²⁵ Murphy et al., '[An Economic and Greenhouse Gas Emissions Evaluation of Pasture-Based Dairy Calf-to-Beef Production Systems](#)'.

⁸²⁶ Murphy et al. [An Economic and Greenhouse Gas Emissions Evaluation of Pasture-Based Dairy Calf-to-Beef Production Systems](#);

Foley et al., '[Whole-Farm Systems Modelling of Greenhouse Gas Emissions from Pastoral Suckler Beef Cow Production Systems](#)'.

⁸²⁷ Pelletier, Pirog, and Rasmussen, '[Comparative Life Cycle Environmental Impacts of Three Beef Production Strategies in the Upper Midwestern United States](#)', Agricultural Systems 103, number 6 (July 2010): pages 380 to 389.

⁸²⁸ Murphy et al., '[An Economic and Greenhouse Gas Emissions Evaluation of Pasture-Based Dairy Calf-to-Beef Production Systems](#)'.

studies of pasture-based grazing systems found positive sequestration impacts (as opposed to only soil carbon equilibrium) but noted the need for further research.

Sire Registration

The evidence base indicates that sire registration can have significant environmental impacts if used to inform further activity within the farming system, with 12 out of the 20 sources identifying positive environmental benefits. Studies show that selecting for certain traits can directly reduce methane emissions from livestock by choosing traits related to feed efficiency and growth rates [footnote ⁸²⁹]. Such selection can help farmers select animals that require less feed to achieve the same growth rate, resulting in lower feed costs and reduced environmental burden from feed production. This has implications for land use, water consumption, and fertilizer use. Registering lineages, especially when coupled with genomic testing, can provide the levels of insight into traits needed to achieve improvements in environmental outcomes.

The BDGP in Ireland has led to a 1.05% reduction in gross emissions from participating farms up to 2021 as compared to 2015 levels [footnote ⁸³⁰]. This reduction is primarily driven by genetic improvements in the national herd, particularly in feed efficiency, fertility, and carcass quality, all of which contribute to more efficient production systems with lower emissions per unit of beef produced. The continued use of genomic tools in the BDGP is expected to lead to further reductions in emissions over time, with projections indicating that the scheme could help achieve a 9.5% reduction in emissions by 2045, aligning with Ireland's broader climate targets.

Social Impacts (0 studies)

While the identified literature included no evidence relating to social impacts from rotational grazing, reducing the age of slaughter, and sire registration, other literature may be available that does provide relevant evidence on social impacts.

⁸²⁹ Quinton et al., '[Prediction of Effects of Beef Selection Indexes on Greenhouse Gas Emissions](#)'.
Jenkins et al., '[Breeding for Reduced Methane Emissions in Livestock](#)'.

⁸³⁰ Cawley and Banks, '[Review of the Beef Data Genomics Programme 2015-2021](#)'.

Barriers (9 studies)

Rotational grazing

The evidence base identifies several barriers to both the adoption of rotational grazing and the realisation of its full benefits. Barriers include the initial capital investment required to establish rotational grazing systems and setting up infrastructure such as fencing, water points, and pasture divisions, the need for additional knowledge and management skills, labour and time constraints [footnote ⁸³¹].

Reducing age at slaughter

The key barrier to reducing the age of slaughter is that transitioning to earlier slaughter may require adjustments in feeding strategies and infrastructure, such as improved grazing systems or feed storage facilities [footnote ⁸³²]. However, a barrier to achieving the desired reduction in GHG emissions is the potential for the use of protein inputs to offset any environmental benefits. This requires consideration for the whole-system effect, and maximising the use of pasture-grazing to reduce the need for external inputs.

Sire registration

The BDGP in Ireland was intended to support farmers with small herd sizes to register their cattle, however participating holdings are larger than the national average herd size and have higher incomes [footnote ⁸³³]. The voluntary nature of sire registration schemes where they have been instigated (e.g., Ireland) means that while adoption is increasing, it is not yet universal. [footnote ⁸³⁴].

Evidence Gaps (10 studies)

The evidence base highlights several key gaps in research related to rotational grazing, which limit the ability to fully understand its long-term impacts and effectiveness across

⁸³¹ Moore, '[Supporting Farmers in Agro-Ecological Transition: A Systems Perspective of Regenerative Grazing in Wales](#)';

Jordon, Winter, and Petrokofsky, '[Advantages, Disadvantages, and Reasons for Non-Adoption of Rotational Grazing, Herbal Leys, Trees on Farms and Ley-Arable Rotations on English Livestock Farms](#)'.

⁸³² Murphy et al., '[An Economic and Greenhouse Gas Emissions Evaluation of Pasture-Based Dairy Calf-to-Beef Production Systems](#)'.

⁸³³ Cawley and Banks, '[Review of the Beef Data Genomics Programme 2015-2021](#)'.

⁸³⁴ Jenkins et al., '[Breeding for Reduced Methane Emissions in Livestock](#)'.

different contexts, including its effect on animal performance, herbage mass, and insect populations [footnote ⁸³⁵]. Importantly, much of the literature focuses on North American rangelands, which differs to the UK in climate and in farming systems.

For rotational grazing in the UK, major gaps identified by authors in the literature reviewed include the lack of long-term, large-scale studies assessing the environmental and economic impacts of rotational grazing over multiple years, and the comparative performance of rotational grazing versus continuous grazing across different farm sizes and livestock systems. However, in 2021, the Department for Environment, Food and Rural Affairs (DEFRA) commissioned a consortium to research the environmental and economic productivity benefits of mob grazing systems in the UK, with the project set to run for 3.5 years [footnote ⁸³⁶].

Additionally, the role of policy and financial encouragements in promoting rotational grazing adoption remains underexplored. While economic barriers to adoption are well-documented, there is limited research on how specific subsidy schemes, advisory services, and payments influence uptake.

Cost-effectiveness Evidence (5 studies)

Rotational grazing

While few of the identified studies provided evidenced cost benefits from rotational grazing, the majority of the research reviewed does indicate an increase in farm productivity among other environmental and animal health benefits. Extending the grazing season can save £1.25 per cow per day, [footnote ⁸³⁷] while increased stocking rates, up to 30% higher than conventional systems [footnote ⁸³⁸], boost productivity. Though weight gain per animal may be lower, [footnote ⁸³⁹] overall output can rise. Long-term benefits include improved soil health, drought resilience, and lower disease prevalence.

⁸³⁵ Ravetto Enri et al., '[A Biodiversity-Friendly Rotational Grazing System Enhancing Flower-Visiting Insect Assemblages While Maintaining Animal and Grassland Productivity](#)'.

⁸³⁶ AHDB, '[Mob Grazing – What's It All about?](#)', *Knowledge Library* (blog), 2025,.

⁸³⁷ '[Rotational Grazing Systems for Cattle](#)'.

⁸³⁸ Rouquette, Sollenberger, and Vendramini, '[Grazing Management and Stocking Strategy Decisions for Pasture-Based Beef Systems: Experimental Confirmation vs. Testimonials and Perceptions](#)'.

⁸³⁹ Ibid.

Reducing age of slaughter

The economic efficiency of early finishing systems has been highlighted, with studies finding that earlier slaughter increases profitability due to lower feed and housing costs [footnote ⁸⁴⁰].

Sire registration

No evidence was identified which relates only to the costs of sire registration alone, however the evaluation of Ireland's BDGP, which also includes genomic testing alongside sire registration, indicates positive return on investment. The evaluation of the programme estimates that the upward trend in value seen in the Replacement and Terminal Indices will generate economic gain to the amount of €606 million, or an average of €48 million per year up to 2030 [footnote ⁸⁴¹]. They note however that other schemes in Ireland will have contributed to this improvement, with the trend not entirely attributable to the BDGP. Up to 2022, €294 million had been spent on the programme, [footnote ⁸⁴²] providing a positive net gain.

Critical Success Factors

Strategic fit and business needs: High alignment

Sustainable Production appears to have high alignment with the Strategic fit and business needs CSF based on the evidence reviewed. Evidence suggests that all 3 sub-areas of focus under the Theme Sustainable Production can make a positive contribution to Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023, particularly the objective to improve the sustainable production of food and other goods. As farm businesses will be able to partake in all 3 actions under Sustainable Production, their economic and environmental benefits can combine to maximise their contribution to SLM objectives. Similarly, they align with the Well-being of Future Generations (Wales) Act 2015 through supporting greater economic resilience and contributing to reducing GHG emissions produced by the farming sector. However, if implemented poorly, for example leading to

⁸⁴⁰ Taylor et al., '[Bioeconomic and Greenhouse Gas Emissions Modelling of the Factors Influencing Technical Efficiency of Temperate Grassland-Based Suckler Calf-to-Beef Production Systems](#)'.

⁸⁴¹ Cawley and Banks, '[Review of the Beef Data Genomics Programme 2015-2021](#)'.

⁸⁴² Ibid.

increased stocking density, rotational grazing may result in negative environmental impacts such as increased GHG emissions.

Value for money: High alignment

Alignment with Value for money is potentially high, with evidence in particular for sire registration in other contexts demonstrating considerable value for money through improved productivity. Reducing the age of slaughter has similar evidenced economic benefits, while rotational grazing is likely to have considerable benefits for farm productivity, however more UK-specific studies are required to fully explore the scale of the benefits against costs.

Supply side capacity and capability: Medium alignment

Evidence suggests at least a medium level of alignment with the Supply side capacity and capability CSF. Initial infrastructure investment and training is required to adopt rotational grazing methods, and while the latter is delivered through Farming Connect, the former need may prove to be the more difficult to address. Evidence from other national contexts has shown that schemes to encourage calf registration can greatly increase farmer involvement in sire recording schemes. However, the scheme discussed above still had difficulties in engaging certain sections of the farming sector.

Affordability: Medium alignment

Evidence suggests a medium alignment with the Affordability CSF. Rotational grazing requires initial infrastructure investment, which is a potential barrier to affordability. There are fewer affordability barriers to reducing the age of slaughter and sire registration.

Organic Farming (Support and Conversion)

The objective of the Organic Farming (Support and Conversion) Theme is to support farms to convert to organic status and for farms to maintain existing organic land.

Due to overlaps in on-farm practices with other Themes additional evidence for this Theme can be found in:

- Advanced Continuous Professional Development (CPD)
- Improved Soil Health and Multispecies Crop Cover.

REA Exclusion / Inclusion Criteria

Inclusion: Studies that evaluate the benefits (environmental, social, economic) of organic farming.

Exclusion: Studies that look at the factors affecting the adoption of organic farming or the effectiveness of interventions to increase the uptake of organic farming.

Evidence Base

The search for organic farming returned 1040 results. These underwent an initial scoping review for relevance and 366 studies were retained. In scope studies were prioritised based on quality and relevancy resulting in 273 in scope for an evidence review. Following the evidence review a further 238 studies were excluded, and the evidence of the 35 studies of the highest quality and relevancy was summarised.

Design of the Intervention (4 studies)

4 papers addressed the impacts of payment schemes for farmers on organic agriculture. The impacts of these payment schemes were generally found to be favourable on the adoption of organic agriculture when present, however they were not always associated with higher productivity levels on organic farms.

Uptake of the Practice (5 studies)

3 papers addressed the factors required for a switch to organic farming to be feasible, these included easy access to supply chains, certification, education and other support services.

For example, one study [footnote ⁸⁴³] emphasised the effect of exposure to education about organic farming practices on the positive environmental and economic benefits of organic farming.

3 studies dealt with the reasoning behind a switch to organic farming. In these studies, based in the EU, farmers tended to proceed with organic farming if economic benefits were seen to be high, and costs low, as well as if they felt dissatisfaction with their current methods of farming.

Cultural factors were found to be important in 4 papers, as well as a history of organic farming in their families or communities. Some farmers saw farming sustainably as an important cultural value, and this assisted with an increased uptake of the practice.

Economic Impacts (17 studies)

Studies primarily considered the yield and profitability comparisons of organic agriculture. The economic impact was discussed in terms of yield and profitability improvements and was not generally put in monetary terms.

Ten papers dealt with the differences in yields of organic agriculture when compared to conventional agriculture. Though yields were generally found to be lower for organic agriculture, there was no consensus on whether the overall economic impact was lower. For example, the increased risks from intensive agriculture could bring with it a greater risk to productivity, with environmental degradation and high stocking rates of livestock having potential impacts on future yields. Some papers [footnote ⁸⁴⁴] also addressed the impact that resource availability may have on the productivity of farms, suggesting that when forage of high quality and quantity are available organic farming is more financially viable. One paper [footnote ⁸⁴⁵] based in Finland suggested that the productivity gap between organic and conventional farming has been shrinking in recent years.

⁸⁴³ Krajewski et al., '[Evaluating the Path to the European Commission's Organic Agriculture Goal: A Multivariate Analysis of Changes in EU Countries \(2004–2021\) and Socio-Economic Relationships](#)', Agriculture 14, no. 3

⁸⁴⁴ Bang et al., '[Conventional or Organic Cattle Farming? Trade-Offs between Crop Yield, Livestock Capacity, Organic Premiums, and Government Payments](#)', Agricultural Systems 218 (June 2024): 103991,

⁸⁴⁵ Kuosmanen et al., '[Productive Performance of Organic Crop Farms in Finland 2010–2017](#)', Organic Agriculture 11, no.3 September 2021): pages 379 to 392.

6 papers discussed the productivity and profitability of organic and conventional agriculture. While yields may be lower, organic farms in the EU and UK tend to outperform conventional farms in terms of profits. This change is usually accounted for due to the increased demand and premium price of organic outputs outstripping the lower quantity of goods sold. Organic farming also generally has lower costs associated, with one study [footnote ⁸⁴⁶] based in Germany having found costs per hectare for crop production were 8% lower in organic systems. This is generally due to lower inputs required and fewer on farm actions required around fertiliser and pesticide use. In addition to these lower costs, organic farming often has associated financial schemes which can provide additional payments to farmers.

The ecosystem services associated with organic agriculture was discussed in 5 papers. Organic agriculture was suggested to have better impacts on water provisioning and space for biodiversity compared to conventional farming due to the lower levels of chemical fertilisers and pesticides used. However, a meta-analysis [footnote ⁸⁴⁷] comparing environmental impacts of conventional and organic agriculture argued that the loss in ecosystem services due to the increased land under production in an organic farming system outstrips the benefits.

2 papers considered the effects of an increase in organic farming on land use change. Due to the lower yields of organic farms, additional land would need to be farmed to provide the same levels of food, unless consumer behaviours changed alongside this increase in organic farming. This land use change and associated activities could lead to increased greenhouse gas emissions, negating the positive effects of organic farming.

Environmental Impacts (16 studies)

The evidence base addressed the environmental benefits and associated ecosystem services from organic farming, including biodiversity conservation, maintaining ecosystems, disease protection, enhanced soil fertility and better water quality. Organic farming practices further enhance soil health through techniques like crop rotation and organic matter utilization, making soils more resilient to weed pressure. Generally, the studies found

⁸⁴⁶ Heinrichs et al., '[Economic Effects of Plot Sizes and Farm-Plot Distances in Organic and Conventional Farming Systems: A Farm-Level Analysis for Germany](#)', *Agricultural Systems* 187 (February 2021): 102992.

⁸⁴⁷ Mondelaers, Aertsens, and Van Huylenbroeck, '[A Meta-analysis of the Differences in Environmental Impacts between Organic and Conventional Farming](#)', ed. G. Van Huylenbroek, *British Food Journal* 111, no. 10 (26 September 2009): pages 1098 to 1119.

agreed that soil organic carbon was usually higher in organic agriculture. However, another study [footnote ⁸⁴⁸] argued that both conventional and organic farms have similar levels of soil organic carbon, and that other factors such as climate and tillage system have a greater impact.

The additional land required for food production under an increase in organic farming was addressed by 5 papers. Due to the increased amount of cropland required under organic farming, an intensification or expansion of farming practices in other sites may be required to match existing food demand, potentially leading to an increase in greenhouse gas emissions and other negative environmental effects. While biodiversity levels are generally higher on organic farms, one paper [footnote ⁸⁴⁹] argued global biodiversity may be higher under low-footprint, high intensity systems, due to the increased land available for restoration and natural sites.

2 papers discussed the decreased pesticide, herbicide, fungicide and fertiliser use under organic farming. This generally has a positive effect on biodiversity and can affect a wider area than just the farmland these substances are used on due to transboundary effects and drift of materials. Organic farms adjacent to, or on areas which have been under, intensive agriculture was found to have lower species richness than other areas.

One study [footnote ⁸⁵⁰] addressed how under organic farming, laying hens have a greater risk of infectious diseases, however due to this risk, tend to have slightly better immune systems.

⁸⁴⁸ Smith, Laurence G, Guy J D Kirk, Philip J Jones, and Adrian G Williams. '[The Greenhouse Gas Impacts of Converting Food Production in England and Wales to Organic Methods](#)'. Nature Communications volume 10, number 1 (22 October 2019)

⁸⁴⁹ Smith, Olivia M, Abigail L Cohen, Cassandra J Rieser, Alexandra G Davis, Joseph M Taylor, Adekunle W Adesanya, Matthew S Jones, and others. '[Organic Farming Provides Reliable Environmental Benefits but Increases Variability in Crop Yields: A Global Meta-Analysis](#)'. Frontiers in Sustainable Food Systems volume 3 (27 September 2019):

⁸⁵⁰ Bonnefous, Claire, Anne Collin, Laurence A Guilleoteau, Vanessa Guesdon, Christine Filliat, Sophie Réhault-Godbert, T Bas Rodenburg, and others. '[Welfare Issues and Potential Solutions for Laying Hens in Free Range and Organic Production Systems: A Review Based on Literature and Interviews](#)'. Frontiers in Veterinary Science volume 9 (5 August 2022),

Social Impacts (6 studies)

2 papers [footnote ⁸⁵¹] looked at the health impacts of consuming organic produce. Lower pesticide and fungicide use on organic farms lead to lower rates of ingestion in consumers, which can avoid negative health outcomes. Organic milk was also found to be healthier, containing more vitamins and fatty acids than conventional produce.

The values of farmers were looked at by 3 papers, with some organic farmers having found a more environmentally friendly style of farming important to them personally. This can bring satisfaction to farmers where they identify organic farming as an expression of their values.

2 studies looked to compare the health of organic and conventional farmers in Europe and found that organic farmers tended to have marginally better mental and physical health than conventional farmers.

Barriers (5 studies)

5 studies discussed how local farm factors played a role in the adoption and profitability of organic farming, including the climate, risk-factors, plot size, and how the availability of forage and other resources may impact the relative ease of farming organically. One study [footnote ⁸⁵²] also discussed that weed abundance in organic agriculture can be a hindrance and identified it as a cause slowing the adoption of organic farming.

Evidence Gaps (6 studies)

Though many studies reported on decreased yields and increased profits, an analysis directly comparing those differences in different farming systems was not found under the given search parameters.

⁸⁵¹ Zuba-Ciszewska, Maria, Aleksandra Kowalska, Aneta Brodziak, and Louise Manning. '[Organic Milk Production Sector in Poland: Driving the Potential to Meet Future Market, Societal and Environmental Challenges](#)'. Sustainability volume 15, number 13 (21 June 2023): article 9903;

Benbrook, Charles, Susan Kegley, and Brian Baker. '[Organic Farming Lessens Reliance on Pesticides and Promotes Public Health by Lowering Dietary Risks](#)'. Agronomy volume 11, number 7 (22 June 2021): article 1266.

⁸⁵² Mwangi, Obadiah, Monicah Mucheru-Muna, Michael Kinyua, Peter Bolo, and Job Kihara. '[Organic Farming Practices Increase Weed Density and Diversity over Conventional Practices: A Meta-Analysis](#)'. Heliyon volume 10, number 12 (June 2024): article e32761.

The social impacts of organic farming, particularly the health impacts on both consumers and farmers, was only briefly discussed in the evidence found.

Cost-effectiveness Evidence (4 studies)

Of these studies, 3 papers dealt with the cost savings available to organic farmers through the reduced use of purchased herbicides, fertilisers, pesticides etc due to the organic and mechanical systems available on organic farms, such as integrated weed management systems.

Dietary and behavioural changes, and their impacts on organic farming, was looked at by one study [footnote ⁸⁵³]. It was found that increased demand for organic produce played a large role in the profitability of the practice.

Critical Success Factors

Strategic fit and business needs: High alignment

The evidence reviewed indicates that the Theme of Organic Farming (Support and Conversion) has the potential to deliver multiple environmental and social outcomes, including biodiversity improvement, soil health, reduced chemical inputs, and climate change mitigation. These outcomes align with the objectives of the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023. The evidence identifies that organic farming is already well supported and established across Wales, suggesting that, with continued or enhanced support, it can contribute meaningfully to national policy aims. However, this alignment is based on the potential delivery of benefits, and depends on the scale, scope, and targeting of implementation under the SFS.

Value for money: Medium alignment

The evidence reviewed suggests that organic farming can deliver improved biodiversity and reduced external inputs. It also notes that the availability of support and advisory services is a key factor influencing uptake and success. Therefore, this Theme is assessed as having

⁸⁵³ Borghino, Noémie, Lou Wissinger, Karl-Heinz Erb, Chantal Le Mouél, and Thomas Nesme. '[Organic Farming Expansion and Food Security: A Review of Foresight Modeling Studies](#)'. Global Food Security volume 41 (June 2024): article 100765,

medium alignment with this CSF, based on potential contributions to ecosystem resilience and climate change mitigation, but acknowledging limited evidence of accessibility due to potential barriers to adoption.

Supply side capacity and capability: Medium alignment

There is limited evidence in the literature review related to the availability of advisory services and support, however, relevant Europe-wide studies discuss the feasibility of switching to organic farming highlighting easy access to supply chains, certification, education and other support services. This Theme is assessed as having medium alignment, with due to the established nature of organic farming but acknowledging the limited evidence in the literature.

Affordability: Medium alignment

The affordability of organic farming is described in the report as variable, depending on enterprise type and market access. Some producers may already find organic farming financially viable or profitable. For this reason, Organic Farming (Support and Conversion) is assessed as having medium alignment with this CSF.

Creation of Temporary and Permanent Habitats

The objective of the Theme Creation of Temporary and Permanent Habitats is to create new permanent and temporary habitats in order to expand the extent of habitats contributing to Global Biodiversity Framework targets including 30x30 [footnote ⁸⁵⁴]. Creating permanent habitats is favoured to achieve longer term benefits and outcomes, however, temporary habitats can also provide valuable benefits. The on-farm practices that are or could be available under this Theme include:

- establishment or restoration of grassland
- allow improved grassland to set seed
- late cut grasslands
- establishment or restoration of wet grassland
- fixed rough grass margins on arable land
- rotational rough grass margins on arable land
- establish a wildlife cover crop (margin) on improved land
- establishment of mixed leys on improved land (also referred to as multi-species or herbal leys)
- unsprayed, unfertilised and uncultivated buffer adjacent to existing habitat (including open water) on improved grassland
- uncut/ungrazed, unsprayed, unfertilised and uncultivated buffer on improved grassland adjacent to existing habitat (including open water) and adjacent to field boundaries
- establishment of ponds or scrapes.

Due to overlaps in on-farm practices with other Themes, additional evidence for this Theme can be found in:

⁸⁵⁴ [Global Biodiversity Framework, '2030 Targets \(with Guidance Notes\)', Convention on Biological Diversity.](#)

- Enhanced Habitat Management
- Improved Soil Health and Multispecies Crop Cover
- Collaborative Landscape Scale Activity

REA Exclusion / Inclusion Criteria

Inclusion: Studies about the creation or restoration of new permanent or temporary habitats included within the defined list.

Exclusion: Studies dealing with habitats not included within the defined list. Studies about managing habitats as opposed to the creation of them.

Evidence Base

Using Scopus 31 studies were identified as in scope of the evidence assessment. An additional 5 studies were sourced using Google Scholar and websites identified in Annex B. Using the quality and relevance criteria 36 articles were analysed

3 of the studies were conducted in Wales, 23 were conducted in the rest of the UK, one was conducted in the Republic of Ireland, 4 were conducted in Northern Europe and the remaining 5 articles did not use an experimental design.

Design of the Intervention (15 studies)

Establishment or restoration of grassland (1 study)

Successful establishment of species-rich grassland on ex-arable land is often constrained by high nutrient levels. One approach identified by the evidence is carbon (C) addition to reduce nitrogen availability, which can shift plant competition dynamics and promote species richness [footnote ⁸⁵⁵]. The addition of C has been shown to act faster and more cost-effectively than alternatives such as topsoil removal or repeated hay cutting. Combining this method with sowing diverse seed mixes or targeted cutting regimes can accelerate the transition to species-rich grassland communities.

⁸⁵⁵ Eschen, René, Simon R. Mortimer, Clare S. Lawson, Andrew R. Edwards, Alex J. Brook, José M. Igual, Katarina Hedlund, and Urs Schaffner. '[Carbon Addition Alters Vegetation Composition on Ex-Arable Fields](#)'. *Journal of Applied Ecology* 44, no. 1 (2007): 95–104.

This technique is particularly relevant where the goal is to transition from intensively managed or previously cropped fields to semi-natural habitat, helping to suppress early colonising competitive grasses and favouring target wildflower and invertebrate communities.

Allow improved grassland to set seed (1 study)

Natural regeneration on ex-arable land, when left undisturbed, can yield positive biodiversity outcomes over time. Studies show that orthopteran diversity and abundance were higher in grasslands at least 8 years post-cropping, likely due to the establishment of microhabitats such as ant hills, bare soil, and a mix of fine grasses [footnote ⁸⁵⁶]. Importantly, these fields were not intensively managed, and grazing was primarily provided by wild lagomorphs and deer, rather than livestock.

These findings support an ecological restoration approach, particularly on marginal or less productive land, where wild grazers can maintain the desired structural heterogeneity in vegetation without the need for regular livestock management.

Establishment or restoration of wet grassland (2 studies)

Designing effective wet grassland features for biodiversity and hydrological benefit requires targeted water management. Footdrains, when coupled with sluices or pumps, offer a flexible method to control water levels, creating surface flooding that supports foraging and nesting habitat for breeding waders [footnote ⁸⁵⁷]. Locating footdrains in lower-lying parts of the field allows the creation of small-scale wet features without significantly disrupting farming operations.

The effectiveness of these interventions is dependent on soil type, as clay soils limit lateral water movement, requiring direct surface flooding, whereas peat soils allow broader hydrological influence from raised ditch water levels [footnote ⁸⁵⁸]. The literature also highlights the importance of delivering these interventions beyond nature reserves, through

⁸⁵⁶ Gardiner, Tim, and Dorothy Casey. '[Orthoptera in the Early Stages of Post-Arable Rewilding in South-East England](#)'. *Journal of Orthoptera Research* 31, no. 2 (30 September 2022): 163–72.

⁸⁵⁷ Eglington, S.M., J.A. Gill, M. Bolton, M.A. Smart, W.J. Sutherland, and A.R. Watkinson. '[Restoration of Wet Features for Breeding Waders on Lowland Grassland](#)'. *Journal of Applied Ecology* 45, no. 1 (2008): 305–14.

⁸⁵⁸ Ibid.

agri-environment schemes, to avoid isolated habitat fragments and support wider countryside conservation [footnote ⁸⁵⁹].

However, potential conflicts between wetland restoration and water quality management (e.g. increased nitrate release) must be considered, especially in previously drained peat soils [footnote ⁸⁶⁰].

Margins on arable land (3 studies)

Habitat creation on arable margins can offer biodiversity and ecosystem service co-benefits. Evidence indicates that removing up to 8% of productive land for habitat creation can be compatible with, or even enhance, crop yields, particularly through increases in pollinator populations [footnote ⁸⁶¹]. Structurally and floristically diverse field margins, including sown wildflower strips, are especially effective for invertebrates and birds.

Spatial targeting of interventions is critical, placing created habitats close to existing semi-natural habitat improves colonisation success for priority species such as macro-moths [footnote ⁸⁶²]. Margins should be diverse in type and strategically distributed across the farm, and their integration should consider interactions with adjacent features like hedgerows or woodland strips [footnote ⁸⁶³].

Establishment of ponds or scrapes (3 studies)

The addition of ponds or scrapes as part of a broader habitat mosaic can enhance aquatic and terrestrial biodiversity. Ponds, especially when implemented as part of pondscapes, are

⁸⁵⁹ Eglington, S.M., J.A. Gill, M. Bolton, M.A. Smart, W.J. Sutherland, and A.R. Watkinson. '[Restoration of Wet Features for Breeding Waders on Lowland Grassland](#)'. *Journal of Applied Ecology* 45, no. 1 (2008): 305–14.

⁸⁶⁰ Niedermeier, A., and J.S. Robinson. '[Hydrological Controls on Soil Redox Dynamics in a Peat-Based, Restored Wetland](#)'. *Geoderma* 137, no. 3–4 (January 2007): 318–26.

⁸⁶¹ Pywell, R.F., M.S. Heard, B.A. Woodcock, S. Hinsley, L. Ridding, M. Nowakowski, and J.M. Bullock. '[Wildlife-Friendly Farming Increases Crop Yield: Evidence for Ecological Intensification](#)'. *Proceedings of the Royal Society B: Biological Sciences* 282, no. 1816 (2015).

⁸⁶² Alison, Jamie, Simon J. Duffield, Catharina G. E. van Noordwijk, Michael D. Morecroft, Rob H. Marrs, Ilik J. Saccheri, and Jenny A. Hodgson. '[Spatial Targeting of Habitat Creation Has the Potential to Improve Agri-Environment Scheme Outcomes for Macro-Moths](#)'. *Journal of Applied Ecology* 53, no. 6 (2016): 1814–22.

⁸⁶³ Vickery, Juliet A., Ruth E. Feber, and Robert J. Fuller. 'Arable Field Margins Managed for Biodiversity Conservation: [A Review of Food Resource Provision for Farmland Birds](#)'. *Agriculture, Ecosystems & Environment* 133, no. 1 (1 September 2009): 1–13.

increasingly recognised as nature-based solutions for addressing biodiversity loss, water quality, and flood resilience [footnote ⁸⁶⁴]. Key design considerations include:

- location near existing semi-natural habitat, as many aquatic invertebrates (e.g. Sciomyzidae) have short dispersal ranges (<25 m) [footnote ⁸⁶⁵]
- minimising artificial surfaces and maintaining a buffer of semi-natural wetland vegetation around ponds
- stakeholder engagement and cross-sectoral collaboration to navigate competing land-use priorities and sustain long-term maintenance [footnote ⁸⁶⁶].

Additionally, while ponds can support biodiversity, they also carry risks such as supporting mosquito populations, which may require proactive monitoring and management strategies to mitigate nuisance and disease risks [footnote ⁸⁶⁷].

General design insights

Studies suggest that a wide range of complementary habitat types around created habitats maximise the number of positive shifts in function of plant and invertebrate communities [footnote ⁸⁶⁸]. A variety of habitats in one area provides diverse resources and environmental conditions that supports a broad range of species. The proximity of varied habitat types therefore aids greater connectivity and species movement across the landscape, leading to positive functional shifts, such as increased pollination or greater

⁸⁶⁴ Cuenca-Cambronero, M., M. Blicharska, J.-A. Perrin, T. A. Davidson, B. Oertli, M. Lago, M. Beklioglu, et al. '[Challenges and Opportunities in the Use of Ponds and Pondscapes as Nature-Based Solutions](#)'. *Hydrobiologia* 850, no. 15 (1 September 2023): 3257–71.

⁸⁶⁵ Mulkeen, Collette J., Michael J. Gormally, William T. Swaney, Mark G. Healy, and Christopher David Williams. '[Sciomyzidae \(Diptera\) Assemblages in Constructed and Natural Wetlands: Implications for Constructed Wetland Design](#)'. *Wetlands* 44, no. 1 (8 December 2023): 5.

⁸⁶⁶ Cuenca-Cambronero, M., M. Blicharska, J.-A. Perrin, T. A. Davidson, B. Oertli, M. Lago, M. Beklioglu, et al. '[Challenges and Opportunities in the Use of Ponds and Pondscapes as Nature-Based Solutions](#)'. *Hydrobiologia* 850, no. 15 (1 September 2023): 3257–71.

⁸⁶⁷ Medlock, Jolyon M., and Alexander GC Vaux. '[Impacts of the Creation, Expansion and Management of English Wetlands on Mosquito Presence and Abundance – Developing Strategies for Future Disease Mitigation](#)'. *Parasites & Vectors* 8, no. 1 (3 March 2015): 142.

⁸⁶⁸ Eschen, H. Müller-Schärer, and U. Schaffner, '[Aboveground Environment Type, Soil Nutrient Content and Arbuscular Mycorrhizal Fungi Explain Establishment Success of Centaurea Jacea on Ex-Arable Land and in Late-Successional Grasslands](#)', *Plant and Soil* 322, no. 1 (2009): 115–23;

Emily J et al Guest, '[Soil Macroaggregation Drives Sequestration of Organic Carbon and Nitrogen with Three-Year Grass-Clover Leys in Arable Rotations](#)', 2022.

resilience to environmental stressors. Therefore, when designing or restoring habitats, integrating them into a heterogeneous landscape matrix maximises ecological benefits and supports long-term biodiversity and ecosystem function. However, expanding habitat creation from small projects to large-scale efforts is challenging, especially when figuring out the best ways to support it on working farms.

A need for better engagement and training of farmers for the delivery of these more demanding and complex wildlife habitats. One article [footnote ⁸⁶⁹] (UK) suggested that training of farmers is highly effective in improving the quality of wildlife habitat delivered on farms and this may translate to greater benefits to crop yield.

Action-based payment schemes are often criticised for lacking sensitivity to local conditions, which may hinder their environmental effectiveness [footnote ⁸⁷⁰].

Uptake of the Practice (30 studies)

The identified studies show a broad geographic interest of habitat creation across agricultural landscapes across Wales, the UK and Northern Europe. Studies have examined interventions such as seeding, wetland construction, natural regeneration, and grass margins to create permanent or temporary habitats at sites such as Henfaes Research Station at Bangor University (Wales) [footnote ⁸⁷¹], Black Bourn Valley in Suffolk (UK) [footnote ⁸⁷²] and Mayo in Galway (Republic of Ireland) [footnote ⁸⁷³]. These projects highlight the growing focus on integrating biodiversity conservation with land management.

⁸⁶⁹ Austen et al., '[Experimental Evaluation of Biological Regeneration of Arable Soil: The Effects of Grass-Clover Leys and Arbuscular Mycorrhizal Inoculants on Wheat Growth, Yield, and Shoot Pathology](#)', *Frontiers in Plant Science* 13 (24 August 2022).

⁸⁷⁰ Woodcock et al., '[Effects of Grazing Management on Beetle and Plant Assemblages during the Re-Creation of a Flood-Plain Meadow](#)', *Agriculture, Ecosystems & Environment* 116, no. 3–4 (September 2006): 225–34.

⁸⁷¹ Carswell, Alison, Antonio Rafael Sánchez-Rodríguez, Karen Saunders, Kate Le Cocq, Rory Shaw, Joseph Cotton, Yushu Zhang, et al. '[Combining Targeted Grass Traits with Red Clover Improves Grassland Performance and Reduces Need for Nitrogen Fertilisation](#)'. *European Journal of Agronomy* 133 (February 2022): 126433.

⁸⁷² Gardiner, Tim, and Dorothy Casey. '[Orthoptera in the Early Stages of Post-Arable Rewilding in South-East England](#)'. *Journal of Orthoptera Research* 31, no. 2 (30 September 2022): 163–72..

⁸⁷³ Mulkeen, Collette J., Michael J. Gormally, William T. Swaney, Mark G. Healy, and Christopher David Williams. '[Sciomyzidae \(Diptera\) Assemblages in Constructed and Natural Wetlands: Implications for Constructed Wetland Design](#)'. *Wetlands* 44, no. 1 (8 December 2023): 5.

However, the majority of articles reviewed were of experimental design, concentrating on the local impacts of habitat creation on biodiversity, crop yields, and ecosystem functions rather than assessing the actual or likely widespread adoption or uptake of the intervention. In many cases, interventions were tested on a single farm or within a controlled research setting, limiting insights into actual uptake. The exceptions were 2 research papers investigating the use of arable field margins as habitat creation under agri-environmental schemes [footnote ⁸⁷⁴]. Both surveyed multiple farms and areas in Wales and the rest of the UK, providing a clearer picture of the impacts on real-world agricultural systems. However, due to sample size limitations, they do not provide a definitive measure of overall uptake.

The 2024 report on England's Farming and Countryside Programme [footnote ⁸⁷⁵], a transition plan following the decision to leave the EU, provides a better insight into uptake of similar habitat actions in England. Establishing and maintaining herbal leys saw the highest uptake, with a total of £74.2 million paid to farmers at £382 per hectare per year, more than double the funding of any other option. This far exceeded support for actions like avoiding certain pesticides on crops (£21.4 million), creating flower-rich margins (£8.4 million), and implementing grass buffer strips (£2 million). This provides insight into potential uptake of proposed habitat creation methods.

The Wales National Trends and Glastir Evaluation [footnote ⁸⁷⁶] provides additional insight into the uptake of similar interventions in Wales, revealing that despite clear and targeted objectives, both the adoption and ecological impact of Glastir management practices have been limited. In all, 3,890 hectares, just 0.2% of Wales, were converted to new habitat through reversion or land use change, with the large majority of this being woodland, based on Rural Payments Wales (RPW) data. This figure sits well within the detection limits of satellite monitoring, highlighting the small scale of implementation. Furthermore, these changes predominantly reflect payment-supported transitions rather than improvements to

⁸⁷⁴ MacDonald, Michael A., Ruth Angell, Trevor D. Dines, Stephen Dodd, Karen A. Haysom, Russel Hobson, Ian G. Johnstone, et al. '[Have Welsh Agri-Environment Schemes Delivered for Focal Species? Results from a Comprehensive Monitoring Programme](#)'. *Journal of Applied Ecology* 56, no. 4 (2019): 812–23.; Critchley et al., '[Vegetation Development of Sown Grass Margins in Arable Fields under a Countrywide Agri-Environment Scheme](#)', *Biological Conservation* 132, no. 1 (September 2006): 1–11,

⁸⁷⁵ National Audit Office. '[The Farming and Countryside Programme](#)'. Department for Environment, Food & Rural Affairs, 2024.

⁸⁷⁶ Emmett, B.A. & the ERAMMP team. '[ERAMMP Report-105: Wales National Trends and Glastir Evaluation](#)'. Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP), 2025.

existing habitat conditions, which formed the bulk of Glastir's intended interventions. Nationally, there was no measurable change in the area of Semi-Natural Habitat or in overall habitat diversity, and while a marginal 1.2% increase in Semi-Natural Habitat was detected, it falls within the margin of error and cannot be deemed reliable for updating key ecosystem health indicators. A 3.5% increase in grassland connectivity was noted, yet no corresponding improvements were seen for heathland or wetland habitats. The persistence of these patterns over the past 11 years, despite Glastir's clear environmental goals, suggests that adoption of practices has been modest in scale and impact, with limited success in driving the intended landscape-scale change. One caveat to this finding is that small-scale changes, such as field margins, are likely under-reported by the Farm Practice Survey (FPS), which captures management changes at the whole-farm level. While actual uptake of these actions may be higher, the available data still suggest that their overall scale was limited.

Economic Impacts (9 studies)

Establishment or restoration of grassland

2 grassland seeding studies reported contrasting economic outcomes. The first [footnote ⁸⁷⁷] (UK) found that using low-cost seed mixtures to support pollinators led to cost savings compared to intensive, large-scale grassland restoration. In contrast, the second [footnote ⁸⁷⁸] (UK) reported that while sowing seed mixtures resulted in significant functional benefits, it was also the most costly and demanding approach due to the additional management requirements, such as annual cutting, needed to maintain diverse vegetation on fertile soils.

Margins on arable land

Grass margins sown on arable fields were shown by one study [footnote ⁸⁷⁹] (UK) to have resulted in no loss to the farmer in terms of monetary yield across a typical 5-year arable

⁸⁷⁷ Woodcock, B.A., J. Savage, J.M. Bullock, M. Nowakowski, R. Orr, J.R.B. Tallowin, and R.F. Pywell. '[Enhancing Floral Resources for Pollinators in Productive Agricultural Grasslands](#)'. Biological Conservation 171 (March 2014): 44–51.

⁸⁷⁸ Pywell, Richard F., William R. Meek, R.G. Loxton, Marek Nowakowski, Claire Carvell, and Ben A. Woodcock. '[Ecological Restoration on Farmland Can Drive Beneficial Functional Responses in Plant and Invertebrate Communities](#)'. Agriculture, Ecosystems & Environment 140, no. 1–2 (January 2011): 62–67.

⁸⁷⁹ Pywell, R.F., M.S. Heard, B.A. Woodcock, S. Hinsley, L. Ridding, M. Nowakowski, and J.M. Bullock. '[Wildlife-Friendly Farming Increases Crop Yield: Evidence for Ecological Intensification](#)'. Proceedings of the Royal Society B: Biological Sciences 282, no. 1816 (2015).

crop rotation. This suggests it is not only feasible to remove up to 8% of land from an intensively managed commercial farm for grass margins but that yield and profitability of some insect-pollinated crops may even be increased by this approach [footnote ⁸⁸⁰]. Woodland creation on arable fields was also found to enhance crop pollination by attracting bees, which significantly boosted the yields of oilseed rape and field beans, 2 of the most economically important mass-flowering crops in the UK [footnote ⁸⁸¹].

Establishment of mixed leys on improved land

Incorporating short-term leys into arable rotations has demonstrated economic and agronomic advantages. Crop yields, except for spring barley, were generally higher when leys were included, while the need for fertilisers and pesticides decreased, resulting in both financial and environmental benefits [footnote ⁸⁸²] (Sweden). Red clover was identified as economically important in low-input, stockless farming, where nitrogen supplementation is limited [footnote ⁸⁸³] (UK). These systems reduce the use of expensive fertilisers and contribute to improved soil organic carbon levels and water-holding capacity, leading to monetary savings [footnote ⁸⁸⁴].

Establishment of ponds or scrapes

An important economic impact to consider and manage is the increased risk of liver fluke in wet areas, a parasite that can infect livestock such as sheep and cattle. Wales National Trends and Glastir Evaluation 2025 noted that the percentage of ponds with invasive

⁸⁸⁰ Pywell, R.F., M.S. Heard, B.A. Woodcock, S. Hinsley, L. Ridding, M. Nowakowski, and J.M. Bullock. '[Wildlife-Friendly Farming Increases Crop Yield: Evidence for Ecological Intensification](#)'. Proceedings of the Royal Society B: Biological Sciences 282, no. 1816 (2015).

⁸⁸¹ Critchley et al., '[Vegetation Development of Sown Grass Margins in Arable Fields under a Countrywide Agri-Environment Scheme](#)'.

⁸⁸² El Khosht, Fatima F., Göran Bergkvist, A. Sigrun Dahlin, Christine A. Watson, Johannes Forkman, Johan Nilsson, and Ingrid Öborn. '[Rotational Grass-Legume Leys Increase Arable Crop Yields, Particularly at Low N Fertiliser Rates](#)'. Field Crops Research 326 (May 2025): 109835.

⁸⁸³ Moyo, H., W.P. Davies, N.D. Cannon, and J.S. Conway. '[Influences of One-Year Red Clover Ley Management on Subsequent Cereal Crops](#)'. Biological Agriculture & Horticulture 31, no. 3 (3 July 2015): 193–204.

⁸⁸⁴ Austen, Nichola, Stefanie Tille, Despina Berdeni, Leslie G. Firbank, Martin Lappage, Michaela Nelson, Thorunn Helgason, et al. '[Experimental Evaluation of Biological Regeneration of Arable Soil: The Effects of Grass-Clover Leys and Arbuscular Mycorrhizal Inoculants on Wheat Growth, Yield, and Shoot Pathology](#)'. Frontiers in Plant Science 13 (24 August 2022).

species had doubled to 19% [footnote ⁸⁸⁵]. Liver fluke infections are more common in areas with ponds or poor drainage because the parasite's life cycle requires a snail host that lives in these environments [footnote ⁸⁸⁶]. Liver fluke infection leads to substantial economic losses in the livestock industry due to reduced productivity, liver condemnation, and lower carcass value [footnote ⁸⁸⁷].

Environmental Impacts (32 studies)

Establishment or restoration of grassland

Wildflower meadows that are appropriately placed and managed in the long term are important to the conservation of threatened species [footnote ⁸⁸⁸].

One study [footnote ⁸⁸⁹] (UK) demonstrated that the abundance and species richness of pollinators was correlated with the increased availability of legume and non-legume forb flowers. While the flowering resources provided by legumes declined rapidly once sown, the inclusion of a forb component within seed mixtures was effective in increasing the long-term persistence of these resources.

Another study's [footnote ⁸⁹⁰] (UK) results suggest that utilising carbon addition in grassland creation helps reduce nitrogen availability on ex-arable land, mitigating the negative effects of excess nutrients that favour fast-growing, competitive species. This supports the establishment of late-seral plant species, enhancing biodiversity and promoting the recovery of species-rich grasslands.

⁸⁸⁵ Emmett, B.A. & the ERAMMP team. '[ERAMMP Report-105: Wales National Trends and Glastir Evaluation](#)'. Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP), 2025..

⁸⁸⁶ Olsen et al., '[Prevalence, Risk Factors and Spatial Analysis of Liver Fluke Infections in Danish Cattle Herds](#)', Parasites & Vectors 8, no. 1 (15 March 2015): 160;

Selemetas et al., '[The Effects of Farm Management Practices on Liver Fluke Prevalence and the Current Internal Parasite Control Measures Employed on Irish Dairy Farms](#)'.

⁸⁸⁷ Olsen et al., '[Prevalence, Risk Factors and Spatial Analysis of Liver Fluke Infections in Danish Cattle Herds](#)'.

⁸⁸⁸ Jarvis, David. '[Best Practice Guidance for Land Regeneration](#)', 2014.

⁸⁸⁹ Woodcock, B.A., J. Savage, J.M. Bullock, M. Nowakowski, R. Orr, J.R.B. Tallowin, and R.F. Pywell. '[Enhancing Floral Resources for Pollinators in Productive Agricultural Grasslands](#)'. Biological Conservation 171 (March 2014): 44–51.

⁸⁹⁰ Eschen, René, Simon R. Mortimer, Clare S. Lawson, Andrew R. Edwards, Alex J. Brook, José M. Igual, Katarina Hedlund, and Urs Schaffner. '[Carbon Addition Alters Vegetation Composition on Ex-Arable Fields](#)'. Journal of Applied Ecology 44, no. 1 (2007): 95–104.

Allow improved grassland to set seed

One study [footnote ⁸⁹¹] (UK) showed that ecologically restoring arable farmland by allowing natural regeneration with minimal livestock grazing can help reverse the decline of insects like grasshoppers and bush crickets.

Margins on arable land

Sowing a diverse mix of wildflowers in farmland margins significantly enhances biodiversity by supporting more pollinators, herbivores, and beneficial predators compared to simple tall grass mixes [footnote ⁸⁹²]. Habitat creation interventions on arable land such as grass or wildflower margins, or the introduction of trees, supports a higher abundance and diversity of crop pollinators [footnote ⁸⁹³]. Sown margins have more grass and fewer weeds than naturally regenerated sites, with greater species richness and more food plants for birds, butterfly larvae, and bumblebees [footnote ⁸⁹⁴] (UK). These interventions not only encourage biodiversity but provide evidence to explain the increased yields of insect-pollinated field crops.

Establishment of mixed leys on improved land

Short-term leys, such as red clover or grass-clover, improve soil fertility, reduce the need for synthetic fertilisers, enhance biodiversity, and aid carbon sequestration, all of which contribute to more sustainable agricultural practices and better crop yields with a lower environmental impact [footnote ⁸⁹⁵]. Red clover in particular has been shown to increase dry

⁸⁹¹ Gardiner, Tim, and Dorothy Casey. '[Orthoptera in the Early Stages of Post-Arable Rewilding in South-East England](#)'. *Journal of Orthoptera Research* 31, no. 2 (30 September 2022): 163–72.

⁸⁹² Pywell, Richard F., William R. Meek, R.G. Loxton, Marek Nowakowski, Claire Carvell, and Ben A. Woodcock. '[Ecological Restoration on Farmland Can Drive Beneficial Functional Responses in Plant and Invertebrate Communities](#)'. *Agriculture, Ecosystems & Environment* 140, no. 1–2 (January 2011): 62–67.

⁸⁹³ Alison et al., 'Spatial Targeting of Habitat Creation Has the Potential to Improve Agri-Environment Scheme Outcomes for Macro-Moths'; R.F. Pywell et al., '[Wildlife-Friendly Farming Increases Crop Yield: Evidence for Ecological Intensification](#)', *Proceedings of the Royal Society B: Biological Sciences* 282, no. 1816 (2015); Image, Gardner, and Breeze, '[Co-Benefits from Tree Planting in a Typical English Agricultural Landscape: Comparing the Relative Effectiveness of Hedgerows, Agroforestry and Woodland Creation for Improving Crop Pollination Services](#)', 1 February 2023.

⁸⁹⁴ Critchley, C. Nigel R., John A. Fowbert, Ann J. Sherwood, and Richard F. Pywell. '[Vegetation Development of Sown Grass Margins in Arable Fields under a Countrywide Agri-Environment Scheme](#)'. *Biological Conservation* 132, no. 1 (September 2006): 1–11.

⁸⁹⁵ Moyo et al., '[Influences of One-Year Red Clover Ley Management on Subsequent Cereal Crops](#)', *Biological Agriculture & Horticulture* 31, no. 3 (3 July 2015): 193–204;

matter yield and herbage-nitrogen content, making it a viable fertiliser-nitrogen replacement [footnote ⁸⁹⁶].

Establishment or restoration of wet grassland / Establishment of ponds or scrapes

Constructed wetlands support scarce and threatened species such as sciomyzidae [footnote ⁸⁹⁷] (Republic of Ireland) and lapwings [footnote ⁸⁹⁸] (UK) by providing critical habitats and increasing foraging opportunities, while also enabling sustainable land management practices. Similarly, restored ponds quickly support aquatic invertebrate communities, with diversity peaking around 5 years before stabilising [footnote ⁸⁹⁹] (UK). Over time, constructed pond biodiversity and environmental conditions resemble natural ponds [footnote ⁹⁰⁰], enhancing habitat connectivity [footnote ⁹⁰¹] and supporting predators like amphibians and birds [footnote ⁹⁰²].

Additionally, constructed wetland systems and ponds are used to remove excess phosphorus from agricultural runoff. By retaining more phosphorus than it releases, the

Austen et al., '[Experimental Evaluation of Biological Regeneration of Arable Soil: The Effects of Grass-Clover Leys and Arbuscular Mycorrhizal Inoculants on Wheat Growth, Yield, and Shoot Pathology](#)';

Guest, '[Soil Macroaggregation Drives Sequestration of Organic Carbon and Nitrogen with Three-Year Grass-Clover Leys in Arable Rotations](#)';

Zani et al., '[Effects of Integrating Grass-Clover Leys with Livestock into Arable Crop Rotations on Soil Carbon Stocks and Particulate and Mineral-Associated Soil Organic Matter Fractions in Conventional and Organic Systems](#)', Soil Use and Management 38, no. 1 (2022): 448–65;

El Khosht et al., '[Rotational Grass-Legume Leys Increase Arable Crop Yields, Particularly at Low N Fertiliser Rates](#)', Field Crops Research 326 (May 2025): 109835.

⁸⁹⁶ Carswell et al., '[Combining Targeted Grass Traits with Red Clover Improves Grassland Performance and Reduces Need for Nitrogen Fertilisation](#)', European Journal of Agronomy 133 (February 2022): 126433;

El Khosht et al., '[Rotational Grass-Legume Leys Increase Arable Crop Yields, Particularly at Low N Fertiliser Rates](#)'.

⁸⁹⁷ Mulkeen, Collette J., Michael J. Gormally, William T. Swaney, Mark G. Healy, and Christopher David Williams. '[Sciomyzidae \(Diptera\) Assemblages in Constructed and Natural Wetlands: Implications for Constructed Wetland Design](#)'. Wetlands 44, no. 1 (8 December 2023): 5.

⁸⁹⁸ Eglington, S.M., J.A. Gill, M. Bolton, M.A. Smart, W.J. Sutherland, and A.R. Watkinson. '[Restoration of Wet Features for Breeding Waders on Lowland Grassland](#)'. Journal of Applied Ecology 45, no. 1 (2008): 305–14..

⁸⁹⁹ Beadle, Jeannie M., Joseph Holden, and Lee E. Brown. '[Landscape-Scale Peatland Rewetting Benefits Aquatic Invertebrate Communities](#)'. Biological Conservation 283 (July 2023): 110116..

⁹⁰⁰ Ibid.

⁹⁰¹ Cuenca-Cambronero, M., M. Blicharska, J.-A. Perrin, T. A. Davidson, B. Oertli, M. Lago, M. Beklioglu, et al. '[Challenges and Opportunities in the Use of Ponds and Pondscapes as Nature-Based Solutions](#)'.

Hydrobiologia 850, no. 15 (1 September 2023): 3257–71

⁹⁰² Beadle, Jeannie M., Joseph Holden, and Lee E. Brown. '[Landscape-Scale Peatland Rewetting Benefits Aquatic Invertebrate Communities](#)'. Biological Conservation 283 (July 2023): 110116.

system helps prevent pollution in nearby water bodies, improving water quality [footnote ⁹⁰³] (UK).

Negative/lack of environmental impacts

Whilst most of the reviewed evidence suggested a positive environmental impact resulted from habitat creation, some found differing results. One study [footnote ⁹⁰⁴] (UK) found no significant difference in nitrous oxide emissions between intensively managed land and newly created semi-natural grassland. This suggests that reducing management intensity may take longer than 10 years to present a noticeable effect on nitrous oxide emissions.

Other studies point to the difficulty in creating habitats that match the quality of existing ones. One [footnote ⁹⁰⁵] UK study reported natural reversion fields had a significantly lower cover and species-richness compared to the existing acid grassland. Another similarly [footnote ⁹⁰⁶] highlighted that whilst some wetlands can develop within years, other habitats, like species-rich grasslands or woodlands, take much longer (anything from 50 to 500 years) and may not be easily replicated due to changes in soil conditions and species mobility. Yet one study from Switzerland [footnote ⁹⁰⁷] reported that seedlings had high survival rates at restoration sites compared to late-successional grasslands, challenging the assumption that late-successional species struggle to establish. This contradictory evidence suggests that the evidence presented should be treated with caution as impacts may be site specific.

⁹⁰³ O'Neill, A., R.H. Foy, and D.H. Phillips. '[Phosphorus Retention in a Constructed Wetland System Used to Treat Dairy Wastewater](#)'. *Bioresource Technology* 102, no. 8 (April 2011): 5024–31.

⁹⁰⁴ Horrocks, C.A., J.A.J. Dungait, K.V. Heal, and L.M. Cardenas. '[Comparing N₂O Fluxes from Recently Created Extensive Grasslands and Sites Remaining under Intensive Agricultural Management](#)'. *Agriculture, Ecosystems & Environment* 199 (January 2015): 77–84.

⁹⁰⁵ Ausden, M, and Kemp. '[Creating Acid Grassland by Sheep Grazing and Natural Reversion at Minsmere RSPB Reserve, Suffolk, England](#)'. *Conservation Evidence* 2 (2005): 18–20.

⁹⁰⁶ Morris, R.K.A., I. Alonso, R.G. Jefferson, and K.J. Kirby. '[The Creation of Compensatory Habitat—Can It Secure Sustainable Development?](#)' *Journal for Nature Conservation* 14, no. 2 (July 2006): 106–16.

⁹⁰⁷ Eschen, R., H. Müller-Schärer, and U. Schaffner. '[Aboveground Environment Type, Soil Nutrient Content and Arbuscular Mycorrhizal Fungi Explain Establishment Success of *Centaurea Jacea* on Ex-Arable Land and in Late-Successional Grasslands](#)'. *Plant and Soil* 322, no. 1 (2009): 115–23.

Social Impacts (10 studies)

The main social impact identified in these studies concerns the benefits to agroecosystems. These benefits include increased crop yield through tree planting on arable land benefiting food production [footnote ⁹⁰⁸] (UK) and constructed wetland benefiting flood control [footnote ⁹⁰⁹] and water quality management [footnote ⁹¹⁰] (UK). These benefits extend beyond the immediate area, reducing flood risk downstream and improving the quality of water used for drinking and recreation. Agroecosystems are fundamental to human well-being, providing essential ecosystem services such as food production, natural hazard regulation and environmental resilience.

Establishment or restoration of wet grassland

Constructed wetlands, though valuable for flood control and water quality, require careful management to mitigate potential social health risks, such as mosquito-borne diseases [footnote ⁹¹¹]. Raising awareness among policymakers about the role of diverse agroecosystems is crucial for promoting sustainable land management practices that benefit both people and the environment [footnote ⁹¹²].

⁹⁰⁸ Image, Mike, Emma Gardner, and Tom D. Breeze. '[Co-Benefits from Tree Planting in a Typical English Agricultural Landscape: Comparing the Relative Effectiveness of Hedgerows, Agroforestry and Woodland Creation for Improving Crop Pollination Services](#)'. *Land Use Policy* 125 (February 2023): 106497.

⁹⁰⁹ Medlock, Jolyon M., and Alexander GC Vaux. '[Impacts of the Creation, Expansion and Management of English Wetlands on Mosquito Presence and Abundance – Developing Strategies for Future Disease Mitigation](#)'. *Parasites & Vectors* 8, no. 1 (3 March 2015): 142.

⁹¹⁰ Forbes, E. G. A., R. H. Foy, M. V. Mulholland, and J. L. Brettell. '[Performance of a Constructed Wetland for Treating Farm-Yard Dirty Water](#)'. *Water Science and Technology: A Journal of the International Association on Water Pollution Research* 64, no. 1 (2011): 22–28.

⁹¹¹ Medlock, Jolyon M., and Alexander GC Vaux. '[Impacts of the Creation, Expansion and Management of English Wetlands on Mosquito Presence and Abundance – Developing Strategies for Future Disease Mitigation](#)'. *Parasites & Vectors* 8, no. 1 (3 March 2015): 142.

⁹¹² Morris, R.K.A., I. Alonso, R.G. Jefferson, and K.J. Kirby. '[The Creation of Compensatory Habitat—Can It Secure Sustainable Development?](#)' *Journal for Nature Conservation* 14, no. 2 (July 2006): 106–16.

Barriers (12 studies)

Grassland habitat creation

One study [footnote ⁹¹³] (UK) suggested that adding carbon to the soil to aid grassland creation on ex-arable fields can create openings in the vegetation, which may allow late-stage plant species to establish over time. Whether keeping these open spaces is beneficial or a barrier to habitat creation depends on which species move in and take root.

Another [footnote ⁹¹⁴] (Switzerland) showed that the belowground environment is crucial for the survival and growth of restored grasslands. This makes choosing land for grassland creation a challenge as not all will have the suitable biotic and abiotic characteristics necessary for intervention. Even in projects that seem successful, a short-term species survey may not accurately represent the community that can or should develop over time. Plant and animal populations naturally shift as habitats mature or in response to changes in land management and climate conditions [footnote ⁹¹⁵].

Wildflower meadows require annual maintenance which is time consuming and costly [footnote ⁹¹⁶].

Arable habitat creation

The inclusion of leys in crop rotations must be financially sustainable or economically favourable compared to continuous cropping with full rotations. Without sufficient financial returns from grazing leys, and without adequate government subsidies, it becomes difficult for farmers to justify the switch to leys, especially if they do not see a clear economic benefit over traditional cropping methods [footnote ⁹¹⁷].

⁹¹³ Eschen, René, Simon R. Mortimer, Clare S. Lawson, Andrew R. Edwards, Alex J. Brook, José M. Igual, Katarina Hedlund, and Urs Schaffner. '[Carbon Addition Alters Vegetation Composition on Ex-Arable Fields](#)'. *Journal of Applied Ecology* 44, no. 1 (2007): 95–104..

⁹¹⁴ Eschen, R., H. Müller-Schärer, and U. Schaffner. '[Aboveground Environment Type, Soil Nutrient Content and Arbuscular Mycorrhizal Fungi Explain Establishment Success of Centaurea Jacea on Ex-Arable Land and in Late-Successional Grasslands](#)'. *Plant and Soil* 322, no. 1 (2009): 115–23.

⁹¹⁵ Morris, R.K.A., I. Alonso, R.G. Jefferson, and K.J. Kirby. '[The Creation of Compensatory Habitat—Can It Secure Sustainable Development?](#)' *Journal for Nature Conservation* 14, no. 2 (July 2006): 106–16.

⁹¹⁶ Jarvis, David. '[Best Practice Guidance for Land Regeneration](#)', 2014.

⁹¹⁷ Guest, Emily J et al. '[Soil Macroaggregation Drives Sequestration of Organic Carbon and Nitrogen with Three-Year Grass-Clover Leys in Arable Rotations](#)', 2022.

Evidence Gaps (13 studies)

Studies identified gaps in the following research areas:

- land management practices to best support the benefits of using of short-term ley [footnote ⁹¹⁸].
- the difference and benefits of diverse herbal leys versus red clover leys [footnote ⁹¹⁹].

Cost-effectiveness Evidence (12 studies)

Although the studies reviewed did not complete extensive cost-benefit analyses, the potential costs and economic benefits of proposed interventions for habitat creation were considered by several.

Establishment or restoration of grassland

One UK study [footnote ⁹²⁰] conducted over 3 years across 2 sites in Switzerland and 2 in the UK, used an experimental design to investigate the use of carbon addition to support grassland creation on ex-arable fields. The study found that the rapid response and the low cost of carbon addition made it a useful alternative to other methods, such as topsoil removal and hay cutting, which are more expensive and have slower effects on nutrient availability.

Another [footnote ⁹²¹] UK study demonstrated that simple, low-cost seed mixtures sown into improved grasslands can support insect pollinators and enhance floristic diversity at a cost

⁹¹⁸ Guest, Emily J et al. '[Soil Macroaggregation Drives Sequestration of Organic Carbon and Nitrogen with Three-Year Grass-Clover Leys in Arable Rotations](#)', 2022.

⁹¹⁹ Austen, Nichola, Stefanie Tille, Despina Berdeni, Leslie G. Firbank, Martin Lappage, Michaela Nelson, Thorunn Helgason, et al. '[Experimental Evaluation of Biological Regeneration of Arable Soil: The Effects of Grass-Clover Leys and Arbuscular Mycorrhizal Inoculants on Wheat Growth, Yield, and Shoot Pathology](#)'. *Frontiers in Plant Science* 13 (24 August 2022).

⁹²⁰ Eschen, René, Simon R. Mortimer, Clare S. Lawson, Andrew R. Edwards, Alex J. Brook, José M. Igual, Katarina Hedlund, and Urs Schaffner. '[Carbon Addition Alters Vegetation Composition on Ex-Arable Fields](#)'. *Journal of Applied Ecology* 44, no. 1 (2007): 95–104.

⁹²¹ Woodcock, B.A., J. Savage, J.M. Bullock, M. Nowakowski, R. Orr, J.R.B. Tallowin, and R.F. Pywell. '[Enhancing Floral Resources for Pollinators in Productive Agricultural Grasslands](#)'. *Biological Conservation* 171 (March 2014): 44–51.

of around €190 per hectare, which is comparable to current agri-environment scheme options like arable field margin establishment [footnote ⁹²²].

Margins on arable land

One study [footnote ⁹²³] in the UK found that establishing tall, competitive grasses in arable field margins effectively suppressed weeds, provided habitat for small mammals and bumblebees, and acted as a barrier against pesticide and fertiliser drift, at a cost of just €91 per hectare. In contrast, sowing a diverse mix of perennial wildflowers significantly increased restoration costs to €1186 per hectare and required annual cutting, reducing cost efficiency dramatically. However, adjusting the ratio of forbs to grasses could lower costs to €266 per hectare while maintaining ecological benefits.

Establishment of mixed leys on improved land

One study [footnote ⁹²⁴] encompassing Wales and the UK investigated the use of leys in arable land options, suggesting that persistence of sown varieties is a crucial factor for farmers who require long-term leys (over 3 years). If the persistence of these varieties is not maintained, the benefits of using red clover may be outweighed by the additional costs associated with reseedling, making it less economically viable for farmers.

Establishment or restoration of wet grassland

The estimated costs and benefits of constructed wetlands varied across studies. 2 studies suggested that constructed wetlands offer a more cost-effective and labour efficient alternative to conventional wastewater treatment due to the low construction, maintenance,

⁹²² Woodcock, B.A., J. Savage, J.M. Bullock, M. Nowakowski, R. Orr, J.R.B. Tallwin, and R.F. Pywell. [‘Enhancing Floral Resources for Pollinators in Productive Agricultural Grasslands’](#). Biological Conservation 171 (March 2014): 44–51.

⁹²³ Pywell, Richard F., William R. Meek, R.G. Loxton, Marek Nowakowski, Claire Carvell, and Ben A. Woodcock. [‘Ecological Restoration on Farmland Can Drive Beneficial Functional Responses in Plant and Invertebrate Communities’](#). Agriculture, Ecosystems & Environment 140, no. 1–2 (January 2011): 62–67.

⁹²⁴ Carswell, Alison, Antonio Rafael Sánchez-Rodríguez, Karen Saunders, Kate Le Cocq, Rory Shaw, Joseph Cotton, Yushu Zhang, et al. [‘Combining Targeted Grass Traits with Red Clover Improves Grassland Performance and Reduces Need for Nitrogen Fertilisation’](#). European Journal of Agronomy 133 (February 2022): 126433.

and energy costs [footnote ⁹²⁵]. However, one article [footnote ⁹²⁶] argued otherwise, contending that the high initial and ongoing maintenance costs often outweigh the benefits for farmers, making external financial support, such as agri-environment schemes, essential for feasibility.

Several studies noted that although their proposed intervention showed promising economic value, further monitoring and research is required to weigh the benefits against the costs and practical challenges of establishing and maintaining these habitats [footnote ⁹²⁷]. Most acknowledged this further analysis is essential to encourage farmers to adopt such habitat creation interventions.

Critical Success Factors

Strategic fit and business needs: High alignment

The reviewed evidence suggests potential for environmental impact linked to the creation of the discussed habitats, such as supporting threatened species and reducing the use of synthetic fertilisers, aligning highly with the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management objectives of the Agriculture (Wales) Act 2023. There is evidence of farmers engaging with habitat creation actions under agri-environmental schemes, however, evidence of uptake outside AES is lacking, as well as

⁹²⁵ Mulkeen et al., '[Sciomyzidae \(Diptera\) Assemblages in Constructed and Natural Wetlands: Implications for Constructed Wetland Design](#)', *Wetlands* 44, no. 1 (8 December 2023): 5;

A. O'Neill, R.H. Foy, and D.H. Phillips, '[Phosphorus Retention in a Constructed Wetland System Used to Treat Dairy Wastewater](#)', *Bioresource Technology* 102, no. 8 (April 2011): 5024–31.

⁹²⁶ Cuenca-Cambronero, M., M. Blicharska, J.-A. Perrin, T. A. Davidson, B. Oertli, M. Lago, M. Beklioglu, et al. '[Challenges and Opportunities in the Use of Ponds and Pondsapes as Nature-Based Solutions](#)'. *Hydrobiologia* 850, no. 15 (1 September 2023): 3257–71.

⁹²⁷ Pywell et al., 'Wildlife-Friendly Farming Increases Crop Yield'; MacDonald, Michael A., Ruth Angell, Trevor D. Dines, Stephen Dodd, Karen A. Haysom, Russel Hobson, Ian G. Johnstone, et al. '[Have Welsh Agri-Environment Schemes Delivered for Focal Species? Results from a Comprehensive Monitoring Programme](#)'. *Journal of Applied Ecology* 56, no. 4 (2019): 812–23.';

Horrocks et al., '[Comparing N2O Fluxes from Recently Created Extensive Grasslands and Sites Remaining under Intensive Agricultural Management](#)', *Agriculture, Ecosystems & Environment* 199 (January 2015): 77–84;

Zani et al., '[Effects of Integrating Grass-Clover Leys with Livestock into Arable Crop Rotations on Soil Carbon Stocks and Particulate and Mineral-Associated Soil Organic Matter Fractions in Conventional and Organic Systems](#)'.

farmers' approval rating of such actions and, opinions on economic feasibility for their businesses.

Value for money: High alignment

The potential value for money of this Theme is promising with interventions such as the use of short-term leys, suggesting positive economic impact through improved crop yields. Evidence supports these sustainable practices which in theory benefits both the farmers' businesses and rural communities, while also adapting to and mitigating climate change. However, the direct economic impact requires further investigation, as many identified studies overlooked this aspect. Those that did examine it emphasise the role of government payments in encouraging adoption and covering initial costs.

Supply side capacity and capability: Low alignment

While some evidence acknowledges the value of involving farmers in sustainable farming decisions, this is not a central focus in the reviewed research, making it difficult to determine the extent to which such involvement is currently taking place. Access to advisory services was not discussed in the evidence.

Affordability: Low alignment

Some methods appear to be cost-effective due to their low upfront costs and minimal maintenance requirements, though affordability varies between interventions. Additionally, no evidence was identified to suggest that farmers can supplement SFS support with external funding beyond Welsh Government assistance, and the direct financial burden on farmers participating in the SFS was not considered in the available research.

Improved Public Access to the Countryside

The objectives of the Theme Improved Public Access to the Countryside are to:

- improve accessibility with an emphasis on least restrictive access
- encourage responsible recreation
- improve visitor experience.

These objectives are to be achieved through capital works such as:

- removing stiles and installing gates on public rights of way or open access land that follow 'least restrictive access' principles
- installing information boards e.g. countryside code reminders, points of interest, educational
- installing seats/benches at viewpoints.

Due to overlaps in on-farm practices with other Themes additional evidence for this Theme can be found in:

- Enhanced Woodland Management
- Collaborative Landscape Scale Activity

REA Exclusion / Inclusion Criteria

Inclusion: Studies on nature connection, access to nature, outdoor recreation and engagement. Specific focus on agricultural landscapes, public access to agricultural land, agricultural tourism and farmer engagement with local communities.

Exclusion: N/A

Evidence Base

The search strategy described in Annex A returned 257 results/articles from Scopus. These articles underwent a scoping review and 43 were considered within scope of the evidence assessment. Given the low number of studies found to be relevant, all were reviewed in

detail and 24 were identified as suitable for evidence extraction. 2 further studies were found by consulting grey literature resulting in an evidence review of 26 items.

Design of the Intervention (4 studies)

No studies explicitly assessed the effectiveness of schemes to support access improvements through gates or waymarking. However, all indicated that compensation of farmers / landowners was likely to be required to improve accessibility.

One study [footnote ⁹²⁸] highlighted a voluntary scheme on Improving Public Access (IPA) in Scotland which allocated funds to improvements of rural paths. Nature Scot, provided an evaluation of IPA though not an impact assessment [footnote ⁹²⁹]. It found that 181 contracts were issued with a total value of £12.2 million between 2015 and 2022. While funds were allocated for a range of public access activities beyond the scope of the Theme Improved Public Access to the Countryside, it did fund 663 directional signs, 488 seats, 298 self-closing gates and 292 information signs.

Separately and through a choice experiment, one study found that 21% of woodland landowners in an Irish sample were willing to participate in an access scheme where they were not compensated and the public were not charged a fee (providing there was no personal costs to them to enable the access) while 29% indicated that they would be willing to participate if given financial compensation [footnote ⁹³⁰].

Uptake of the Practice (6 studies)

Related to the evidence on interventions, funding in Scotland has been successful in encouraging landowners to improve access and wayfinding using gates and signs [footnote ⁹³¹]. Due to the costs and the perceived risks and private disbenefits of increasing access

⁹²⁸ MacKay and Prager, '[The Dilemma of Upland Footpaths – Understanding Private Landowner Engagement in the Provision of a Public Good](#)', Scottish Geographical Journal 137, no.

⁹²⁹ [NatureScot, 'Evaluation and Monitoring of the Agri-Environment and Climate Scheme' | NatureScot, NatureScot, 20 May 2025.](#)

⁹³⁰ Howley et al., '[Exploring Preferences towards the Provision of Farmland Walking Trails: A Supply and Demand Perspective](#)', Land Use Policy 29, no.

⁹³¹ [NatureScot, 'Evaluation and Monitoring of the Agri-Environment and Climate Scheme' | NatureScot, NatureScot, 20 May 2025.](#)

landowners are unlikely to take these Themes without compensation [footnote ⁹³²]. A study of tourism providers in Sweden found evidence that improving accessibility is something that tourism providers (who are also landowners) in rural areas are willing to pursue but they suggest that individual firms adopting accessibility improvements in an uncoordinated way is less beneficial than public organisations taking the lead in collaborative efforts [footnote ⁹³³]. Forest owners by contrast were much less likely to take action to improve access to their land [footnote ⁹³⁴].

Economic Impacts (6 studies)

6 studies considered the economic benefits of a variety of access actions across Wales. However, these were studies where improvements to access were part of broader suites of actions to develop trails. Activities involved were more extensive than capital works outlined above but these benefits are noted here as they are relevant to the overall objectives of the Theme [footnote ⁹³⁵].

The closest in scope regarding the works outlined in this Theme was one study from Ireland which conducted a choice experiment that investigated what the general public might be willing to pay for improved access. Willingness to pay (WTP) means the maximum amount a person would be prepared to spend on a product, service or benefit, derived from hypothetical scenarios. It is a technique for the inference of value of a non-marketed good or service. It does not indicate any value which should be applied to acquiring that good or service in practice. The study identified the economic benefit quantified in pounds that walkers might be willing to pay for improved farmland walking trails in Ireland [footnote ⁹³⁶]. It found walkers were willing to pay €12.38 for path improvements and signage or €5 for signage only compared to the reference point of no improvements / signage or no signage

⁹³² Forest Research, '[Evidence Review Summary: Land Managers and Public Access in England](#)', 2024.

⁹³³ Wall-Reinius, Kling, and Ioannides, '[Access to Nature for Persons with Disabilities: Perspectives and Practices of Swedish Tourism Providers](#)'. *Tourism Planning & Development* 20, number 3 (4 May 2023): pages 336 to 354

⁹³⁴ Johnsson and Beery, '[Outdoor Recreation and the Private Forest Owner: Place Attachment, Social Values, and Public Access](#)', *Frontiers in Conservation Science* 3 (2022),

⁹³⁵ Tempesta and Vecchiato, '[The Value of a Properly Maintained Hiking Trail Network and a Traditional Landscape for Mountain Recreation in the Dolomites](#)'. *Resources* 7, number 4 (December 2018): 86; Lukoseviciute, Pereira, and Panagopoulos, '[The Economic Impact of Recreational Trails: A Systematic Literature Review](#)'. *Journal of Ecotourism* 21, number 4 (2 October 2022): pages 366 to 393

⁹³⁶ Howley et al., '[Exploring Preferences towards the Provision of Farmland Walking Trails: A Supply and Demand Perspective](#)'.

be respectively. For landowners, it was estimated that the average cost for their participation (in terms of Willingness to Accept) would be €460 per kilometre of walkway to ensure their cooperation with the supply of walking trails.

Environmental Impacts (2 studies)

One study discussed the tension between environmental protection and increasing accessibility [footnote ⁹³⁷]. It outlined arguments for maintaining some areas as “wild” and intentionally inaccessible, to minimise human impact on habitats, biodiversity, and soil. However, it also noted a bias in how access is structured: facilities that support able-bodied visitors, such as informal or rugged footpaths, are often accepted as minimally intrusive, whereas features designed to improve accessibility for a broader range of users, such as wheelchair-accessible paths, are more likely to be perceived as disruptive. The study suggested that all forms of access involve physical structures, and thus all represent a degree of intrusion, even if some are normalised or overlooked [footnote ⁹³⁸]. A second study highlighted how landowners chose to improve accessibility of some paths which increased their use and thus discouraged use of others in areas which might be particularly sensitive – such as nesting sites [footnote ⁹³⁹].

Social Impacts (5 studies)

Evidence of social benefits included an increase in use or perceived ease of use / accessibility by the public accessing the natural environment or evidence of health and well-being benefits for the general public being able to better access the natural environment.

2 studies on urban / peri-urban parks found that the inclusion of a walking route distance on wayfinding signage was valued by visitors, enabling them to make capability decisions about distances to be walked. Frequent users positively received the wayfinding intervention and whilst the main values were seen for infrequent visitors, however, those familiar with the

⁹³⁷ Kling, '[Accessible Nature: Balancing Contradiction in Protected Areas](#)', Environment and Planning E: Nature and Space 7, no.

⁹³⁸ Ibid.

⁹³⁹ MacKay and Prager, '[The Dilemma of Upland Footpaths – Understanding Private Landowner Engagement in the Provision of a Public Good](#)'.

park also reported increased engagement with the greenspace due to the intervention [footnote ⁹⁴⁰].

A study of viewpoints (including bench provision) found that they were a convenient way to present a large part of a protected area to a wider range of people [footnote ⁹⁴¹]. This study found that viewpoints enhanced the quality of the nature experience and enabled people who cannot easily hike the trails to get a good grasp of what the area looks like and its important features [footnote ⁹⁴²]. Furniture provision increased users' aesthetic evaluation of sites using an established scenic beauty estimation scale which required participants to rate the visual appeal of photographs [footnote ⁹⁴³].

A study from the Republic of Ireland found that flat or valley-endowed trails, and those with infrastructure, including signage, amenities, and maps or leaflets were associated with greater demand [footnote ⁹⁴⁴]. However, it did not indicate whether trails with these features were accessed by a wider range of people.

One study from Sweden argued that, to generate social benefits, public organisations needed to take the lead in collaborative efforts to provide effective access as, while private tourism providers were willing to take action, the social benefits were only generated at a larger scale [footnote ⁹⁴⁵].

Barriers (9 studies)

One study found that Swedish forest owners did not value outdoor recreation when asked about the social value of their forests and 2 out of 3 groups identified in the study were reluctant to allow the public access to their land for recreation as they preferred the peace,

⁹⁴⁰ Ryan and Hill, '[Public Perceptions on the Role of Wayfinding in the Promotion of Recreational Walking Routes in Greenspace—Cross-Sectional Survey](#)'. *Wellbeing, Space and Society* 3 (1 January 2022): 100111; Hill, and Ryan, '[Finding Your Way: Exploring Urban Park Users' Engagement with a Wayfinding Intervention through Intercept Go-along Interviews](#)'. *Cities & Health* 8, number 6 (1 November 2024): pages 1003 to 1016.

⁹⁴¹ Kling, '[Accessible Nature: Balancing Contradiction in Protected Areas](#)'.

⁹⁴² Ibid.

⁹⁴³ Liang and Wu, '[The Role of Single Landscape Elements in Enhancing Landscape Aesthetics and the Sustainable Tourism Experience: A Case Study of Leisure Furniture](#)', *Sustainability* 16, no.

⁹⁴⁴ Kelley, van Rensburg, and Jeserich, '[Determinants of Demand for Recreational Walking Trails in Ireland](#)', *Tourism Management* 52 (1 February 2016): 173–86.

⁹⁴⁵ Wall-Reinius, Kling, and Ioannides, '[Access to Nature for Persons with Disabilities: Perspectives and Practices of Swedish Tourism Providers](#)'.

quiet and remoteness of the forest [footnote ⁹⁴⁶]. As described in the section on economic impact, some landowners in the Republic of Ireland would be willing to allow access given sufficient compensation [footnote ⁹⁴⁷]. As noted above in Design of Interventions, due to the costs and the perceived risks and private disbenefits of increasing access, landowners outside of the tourism sector are unlikely to take these actions without compensation [footnote ⁹⁴⁸]. The final barrier identified was not knowing what type of infrastructure would improve accessibility, leading to inaction, since the needs of users are very broad [footnote ⁹⁴⁹].

Evidence Gaps (0 studies)

The identified evidence base for this Theme was limited. For example, no studies were found on the direct social, environmental, or economic benefits of introducing accessible gate vs stiles or non-accessible gates. However, evidence of wider and coordinated accessibility activities could be drawn upon.

Cost-effectiveness Evidence (6 studies)

Of 2 studies that attempted to value social benefits of improving access, one study of accessibility interventions for Scottish woodland (which included signage amongst other actions) found that intervention costs were modest but there were no significant changes in quality of life of their participants on which to base cost-effectiveness [footnote ⁹⁵⁰]. On the other hand, a study of wayfinding in urban parks argued for the value of low-cost wayfinding interventions, which increased recreational walking activity and community health.

A study from the Republic of Ireland on walking trail investment highlighted the importance of selecting trails to improve according to where investment would have the most impact.

⁹⁴⁶ Johnsson and Beery, '[Outdoor Recreation and the Private Forest Owner: Place Attachment, Social Values, and Public Access](#)'.

⁹⁴⁷ Howley et al., '[Exploring Preferences towards the Provision of Farmland Walking Trails: A Supply and Demand Perspective](#)'.

⁹⁴⁸ Forest Research, '[Evidence Review Summary: Land Managers and Public Access in England](#)', 2024.

⁹⁴⁹ Breen et al., '[Whose Right to Roam? Contesting Access to England's Countryside](#)', *Journal of Transport History* 44, no. 2 (2023): 276–307;

Wall-Reinius, Kling, and Ioannides, '[Access to Nature for Persons with Disabilities: Perspectives and Practices of Swedish Tourism Providers](#)'.

⁹⁵⁰ Thompson et al., '[Enhancing Health through Access to Nature: How Effective Are Interventions in Woodlands in Deprived Urban Communities? A Quasi-Experimental Study in Scotland, UK](#)', *Sustainability (Switzerland)* 11, no. 12 (2019),.

This study suggested ways to identify the most potentially impactful trails highlighting trails that are flat or valley-endowed, and those with infrastructure such as signage and amenities [footnote ⁹⁵¹].

Critical Success Factors

Strategic fit and business needs: Medium alignment

The evidence reviewed suggests that Improved Public Access to the Countryside has the potential to deliver social and cultural benefits by increasing access to nature and supporting community engagement with the nature. These outcomes are aligned with the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023. The reviewed literature did not explore stakeholder perspectives in depth, nor did it identify clear economic or environmental benefits. As such Improved Public Access to the Countryside is assessed as having medium alignment, based on its potential to contribute to broader well-being and broader social benefits, but with limited evidence on other impacts.

Value for money: High alignment

The Theme is generally considered to be low cost, as the activities are quite narrow and well defined such as installing a gate or sign. Despite this, evidence was identified that cost of establishment and maintenance was a barrier to farmers and landowners acting without financial support. These costs were not just the direct costs of installation, but the costs associated with making their land more accessible. The evidence reviewed suggests that Improved Public Access to the Countryside in time, provide meaningful social outcomes, such as improved mental and physical health, community connection, and increased understanding of land and food systems. These benefits extend beyond individual farm businesses and may justify public investment from a well-being perspective. However, achieving these benefits requires people to take advantage of the access and the evidence for these benefits is strongest for activities being joined up to develop area or trails. Given the low cost and potentially wide-reaching impacts, Improved Public Access to the Countryside is assessed as having high alignment with the value for money CSF.

⁹⁵¹ Kelley, van Rensburg, and Jeserich, [‘Determinants of Demand for Recreational Walking Trails in Ireland’](#).

Supply side capacity and capability: Low alignment

The evidence reviewed did not include information on existing advisory services, peer networks, or support systems to help farmers implement access capital items. There is no indication from the literature identified that farmers are currently supported or equipped to deliver these activities at scale in Wales. For this reason, Improved Public Access to the Countryside is assessed as having low alignment with the Supply side capacity and capability CSF.

Affordability: Medium alignment

The reviewed evidence suggests that many of the actions under the Theme Improved Public Access to the Countryside can be implemented at relatively low cost, particularly where they build on existing infrastructure or involve temporary interventions. However, there may still be financial and time costs to farmers. The review of evidence did not identify supplementary funding streams beyond SFS support. As such, Improved Public Access to the Countryside is assessed as having medium alignment with the Affordability CSF.

Improved water quality, water usage and flood mitigation

The objectives of the Theme Improved Water Quality, Water Usage and Flood Mitigation include improving and addressing the following:

- improve water quality by reducing pollutants reaching watercourses
- manage water resources to reduce impacts of drought and flood.

Due to overlaps in on-farm practices with other Themes, additional evidence for this Theme can be found in:

- Enhanced Woodland Management
- Woodland and Agroforestry Creation
- Enhanced Biosecurity
- Enhanced Habitat Management
- Hedgerow Creation or Restoration
- Advanced Continuous Professional Development (CPD)
- Improved Soil Health and Multispecies Crop Cover
- Collaborative Landscape Scale Activity

REA Exclusion / Inclusion Criteria:

Inclusion: Studies on: riparian buffers; water quality schemes; natural flood management solutions (NFM); water flow and impact on sediments and pesticides; mapping and observation tools such as Geographic Information System (GIS), Light Detection and Ranging (LIDAR), and aerial recognition; studies on biodiversity on riparian environment.

Exclusion: Studies on agroforestry and woodland.

Evidence base

Using Scopus, 65 studies were identified as in scope of the evidence assessment. Using quality and relevance criteria, 44 articles were analysed.

Given the wide scope of the Theme Improved Water Quality, Water Usage and Flood Mitigation, the evidence base analysed covered a broad range of topics and solutions impacting on water quality. They included specific on-farm measures such as traditional and conservation tillage, leaky dams, and riparian buffers. They also covered measures such as agri-environmental schemes, payment for ecosystem services (PES), agricultural land management practices and advisory services. Many articles also proposed the use of management and analytical tools such as information recording and management, analytical tools such as Life Cycle Assessment (LCA), Bayesian network modelling and SHETRAN hydrological modelling. Some of the solutions outlined from the analysis of the evidence can be implemented at catchment or regional/national level, such as payment schemes. However, these solutions are relevant within the scope of the Theme as they will require application at farm level or farmers' direct intervention or collaboration for their implementation, and may result in farm level impacts.

The main issues addressed in the set of articles analysed span from combating soil degradation, including reducing impact of phosphorus, nitrogen, pesticides, nutrients, and sediments, to soil erosion and to flood management. Also included are studies on engagement of the farming community, such as adoption of support schemes, and use of monitoring and mapping solutions.

The geographical scope of the studies varied from plot-specific studies, to a few farm sites, up to catchment area wide experimentation and analysis. They cover both activities on farmland and adjacent sites such as riparian buffers.

Design of the intervention (10 studies)

10 out of 44 articles clearly discussed approaches related to the design of schemes and actions that can have a direct or indirect impact on water quality. Other articles also touched upon elements that are useful to the design of water related interventions.

The wide scope of Improved Water Quality, Water Usage and Flood Mitigation lends itself to the review and adoption of different techniques and methodologies for designing interventions. Several articles suggested the adoption of multiple solution or approaches to obtain maximum benefits, and they encourage the adaptation of measures to specific contexts.

A number of articles outlined how activities on data gathering and information management can contribute to the effective design and implementation of schemes related to water management and water quality. Some articles covered solutions related to the use of GIS [footnote ⁹⁵²], LIDAR and other spatial observation and mapping techniques that can help identifying catchment level issues, such as water flow or riverbank erosion. The information collected can support the design of better targeted water management schemes and contribute to the efficient use of resources, avoiding “the issues surrounding blanket management policies that can often lead to negative downstream effects” [footnote ⁹⁵³].

2 articles explored the implementation of LCA, that can support decision making based on overall analysis of the impact of the on-farm intervention strategies. LCA is a standardised methodology (ISO 14040) for the evaluation of the environmental impact of a product or service throughout its entire lifecycle. In one article [footnote ⁹⁵⁴], focused on water quality in Hertfordshire, the experiment firstly categorised farm types in the area and then integrated spatial information and LCA results to obtain a spatially-oriented assessment. The research demonstrated how combining spatial models with LCA tools can generate valuable information, for instance on the analysis of acidification potential and eutrophication potential. The information generated can be specific to the area assessed and therefore can support farmers and policymakers in the restoration of waterbodies through targeted actions. For instance, the study demonstrated that “managing farm-based machinery optimally can make notable differences (~10% improvement) to water quality”.

⁹⁵² Stieger and Mckenzie, '[Riparian Landscape Change: A Spatial Approach for Quantifying Change and Development of a River Network Restoration Model](#)', Environmental Management 74, no. 5 (2024): 853–69.

⁹⁵³ Hayes et al., '[High-Resolution Assessment of Riverbank Erosion and Stabilization Techniques with Associated Water Quality Implications](#)', International Journal of River Basin Management 22, no. 4 (2024): 611–25.

⁹⁵⁴ McAuliffe, G.A.; Zhang, Y.; Collins, A.L., '[Assessing catchment scale water quality of agri-food systems and the scope for reducing unintended consequences using spatial life cycle assessment \(LCA\)](#)' Journal of Environmental Management, (2022)

2 articles adopted a Bayesian Network model as a tool to combine data and knowledge to test and compare the results of conventional and conservation agricultural practices used to reduce nitrogen input in surface water bodies [footnote ⁹⁵⁵]. The article demonstrated how the BN can be a useful decision-making tool that can help farmers in adopting the most effective agricultural practice to reduce nitrate leaching. Moreover, this method can be scaled to catchment area level to design effective water protection schemes in complex scenarios, as it can help accounting for the different variables affecting nitrogen run off in specific areas.

One article [footnote ⁹⁵⁶] tested the adoption of a Water Quality Trading (WQT) scheme in the river Alde (UK) as a method to reduce nitrogen input in waterbodies. The WQT scheme is a market-based mechanism that allowed farmers to buy and sell credits for nitrogen pollution in the specific catchment area. The measure allowed farmers to adopt a range of conservation practices to reduce runoff of nitrate or to buy credits, if more cost-effective. The scheme was demonstrated to improve the water quality at catchment area level and also promoted innovation and fostered collaboration among farmers. The article highlighted how, market-based solutions such as the WQT scheme can provide a useful tool in dealing with complex set of stakeholders and diverse geographical variables.

One article [footnote ⁹⁵⁷] reviewed the impact of the application of EU and national regulatory frameworks to protect drinking water resources from agricultural pressure at local level. The study covered 10 European countries (including the UK) and 13 regions (including England and Northern Ireland), encompassing different types of geographies. The findings outlined how different policy interventions and legal instruments affect water management, and how their complexity and inconsistencies become more pronounced at local level negatively affecting the effectiveness of the measures implemented locally. The article recommended it is ensured there is coherence of legal and policy frameworks at various levels – from international, to regional and local. It suggested strengthening cross-

⁹⁵⁵ Radomyski and Ashauer, '[A Site-Specific Indicator of Nitrogen Loads into Surface Waters from Conventional and Conservation Agriculture Practices: Bayesian Network Model](#)', *Ecological Indicators* 145 (2022).

⁹⁵⁶ Gonzalez Zapata, Vangipuram, and Erfani, '[Harnessing Market Based Mechanisms to Improve Water Quality: Water Quality Trading Policies in the River Alde, UK](#)', *Journal of Environmental Management* 357 (2024).

⁹⁵⁷ Wuijts et al., '[Protection of Drinking Water Resources from Agricultural Pressures: Effectiveness of EU Regulations in the Context of Local Realities](#)', *Journal of Environmental Management* 287 (2021).

sectoral collaboration at catchment levels to improve the effectiveness of the measures adopted to protect water quality.

4 articles also pointed out that the effect of any intervention tends to be seen in the medium to long term [footnote ⁹⁵⁸], at least 3 to 5 years, indicating that an adequate timespan should be allowed before reviewing results and impact of interventions on water quality.

Uptake of the practice (12 studies)

12 articles provided insights on elements that may contribute to a positive uptake of practices that can help improve water quality. 7 of them focussed on actual measures that can facilitate the uptake of the intervention considered, the other 5 articles touched upon the uptake of the practice incidentally, i.e. it is not the main aim focus of the article, but it can reveal contributing factors.

The main elements emerging from the review that can foster a positive uptake of practice by farmers are information, advice, incentives, and collaboration. The following paragraphs detail the findings for each of these elements.

Data and information

The use and provision of clear information and information systems was deemed an important factor across the reviewed articles, to enable a positive uptake of interventions related to water quality. 2 articles recommended adopting comprehensive yet clear monitoring and recording systems to tackle uncertainty, which can hinder uptake [footnote ⁹⁵⁹] (see also the section on barriers). One of these 2 articles looked at the impact that livestock farming in Northern Ireland can have on the quality of a water body. The research created a model around an agri-environmental scheme to explore the willingness of farmers to cooperate to preserve water quality. It highlighted how the provision of clear data and information on the results of their actions can reduce uncertainty and improve collaboration among farmers.

⁹⁵⁸ Farrow et al., '[Charting Water Quality Improvements and Practice Reversion with Pesticide Interventions at Catchment Scale](#)', *Science of the Total Environment* 960 (2025).

⁹⁵⁹ Angioloni and Cerroni, '[Farmers' Cooperation to Improve Water Quality under Scientific Uncertainty: A Lab-in-the-Field Experiment](#)', *Journal of Agricultural Economics* 76, no. 1 (2025): 45–73.

The second article examined the motivations of New Zealand land managers to record and report land management actions that can have an impact on water quality. The results highlighted how standardized indicators and methodologies can improve record management; the findings were used to inform the development of a register for land management actions, enabling better support of activities impacting on water quality at farm level [footnote ⁹⁶⁰].

One article highlighted the need for accurate geographical data to support riparian restoration. It focused on the river Linth in Switzerland and developed a restoration priority model using mapping and GIS tools [footnote ⁹⁶¹]. The model provided a transferable tool for the management of natural features at large scale.

Another article reviewed the effectiveness of Payments for Ecosystem Services (PES) schemes to reduce water pollution from agricultural activities. It examined schemes in England and Northern Ireland using a multi-criteria analysis approach (MCA) coupled with mapping tools. It took into account supply and demand criteria for water quality. It subsequently created a granular characterisation model of intervention areas to map the spatial variation in the potential for PES to improve water quality. The article concluded that this approach, and these models, could be adapted to specific national and regional contexts to identify areas for high potential for adoption of PES schemes, however, they acknowledge this was the “first tier” to improving the effectiveness of PES schemes to improve water quality [footnote ⁹⁶²].

One article looked at the uptake of nature-based solutions (NBS) for natural flood management (NFM) such as installing woody debris, re-meandering and connecting flood plains. The research conducted interviews and panel discussions with 118 water and environmental management stakeholders in the UK. Results highlighted that better uptake of such practices can be achieved if stakeholders (such as farmers, environmental organisations, private sector entities, and the general public) are made aware of the actions and their results including co-benefits of NBS such as biodiversity and carbon sequestration

⁹⁶⁰ Doehring et al., ‘[A Missing Piece of the Puzzle of On-Farm Freshwater Restoration: What Motivates Land Managers to Record and Report Land Management Actions?](#)’, *Ecology and Society* 27, no. 4 (2022).

⁹⁶¹ Stieger and McKenzie, ‘[Riparian Landscape Change: A Spatial Approach for Quantifying Change and Development of a River Network Restoration Model](#)’.

⁹⁶² Roberts et al., ‘[Mapping the Potential for Payments for Ecosystem Services Schemes to Improve Water Quality in Agricultural Catchments: A Multi-Criteria Approach Based on the Supply and Demand Concept](#)’.

[footnote ⁹⁶³]. The article provided 2 examples, firstly, highlighting that wider societal support can be improved by demonstrating how NFM can bring co-benefits on biodiversity and carbon sequestrations. Secondly, how by clearly explaining the co-benefits of NBS can “increase the set of potential actors willing to pay for changes in landscape management”.

Advisory and training services

Advisory and training services are more comprehensive and tailored than the information gathering and provision element outlined above. Advisory services are deemed useful in terms of practice uptake [footnote ⁹⁶⁴]. One article examined 2 Severn Trent Water (STW) PES schemes implemented in the West Midlands (UK) to reduce metaldehyde leaching from farming activities. The 2 schemes were based on product reduction and product substitution (for ferric phosphate). The article highlighted that to ensure uptake and participation from farmers it is essential to provide advice that is based on good understanding of agricultural operations, and to clearly demonstrate to farmers the benefits of the product reduction and/or substitutions actions, both on the farm and for the wider environment. Another article reviewed effectiveness of the Catchment Sensitive Farming advisory service in England, which provides advice to farmers to improve water and air quality. The article [footnote ⁹⁶⁵] concluded that farmers would be unwilling to engage with the advisory service if it became a paid service; moreover, it found that “free provision of advice is likely to act as a catalyst” for the service.

Another article reviewed the same Catchment Sensitive Farming scheme focusing on sites in English rivers with long term monitoring records (18 years) and water pollution issues. It found that it normally takes around a year before the specific advice of a practice is taken up by a farmer; and in some cases, it can take up to 5 years. The article also highlighted that after delivering advice to the farmers and the practice being implemented, it can take around 2 or 3 years before the practice can have a detectable impact on water quality

⁹⁶³ Bark, Martin-Ortega, and Waylen, ‘[Stakeholders’ Views on Natural Flood Management: Implications for the Nature-Based Solutions Paradigm Shift?](#)’, Environmental Science and Policy 115 (2021): 91–98.

⁹⁶⁴ Cooke et al., ‘[Farming for Water: Catchment Management Initiatives for Reducing Pesticides](#)’, Water and Environment Journal 34, no. 4 (2020): 679–91.

⁹⁶⁵ Chivers and Collins, ‘[\(Un\)Willingness to Contribute Financially towards Advice Surrounding Diffuse Water Pollution: The Perspectives of Farmers and Advisors](#)’, Journal of Agricultural Education and Extension 29, no. 3 (2023): 327–50.

downstream [footnote ⁹⁶⁶]. One article explored the changes in practices of pesticide use through the implementation of the Land Incentive Scheme, a catchment-based management scheme in the Derg catchment, in the Republic of Ireland and Northern Ireland. The study identified that training farmers on the use of the pesticide MCPA (2-methyl-4-chlorophenoxyacetic acid) is essential to provide long term positive effects in land-use management practices [footnote ⁹⁶⁷].

Incentives

This type of measure in the evidence identified included a variety of paid support, ranging from financial rewards for measurable clean water outputs, to direct payments for swapping to less harmful pesticides. One article [footnote ⁹⁶⁸] analysed the effectiveness of payment schemes aimed at reducing pesticide (methaldehyde) in the West Midlands. It concluded that farmers took direct initiatives to reduce the pesticide where financial incentives were awarded and a lower decrease of pesticide use was measured in a similar scheme that encouraged swapping products instead. One article investigated the modelling of a Water Quality Trading scheme (WQT) in the catchment of the river Alde (UK) which is a Nitrate Vulnerable Zone (NVZ). It found that paying rewards in the form of pollution credits that can be traded can increase the number of farmers taking up water pollution reduction actions, whilst providing flexibility to which actions they can take and ultimately reducing the overall pollution from nitrates at catchment level [footnote ⁹⁶⁹].

Collaboration and cross-sectoral engagement

2 articles evidenced how actively engaging with farmers in the design and implementation of a voluntary agri-environmental scheme provides higher level of uptake [footnote ⁹⁷⁰] and consequently better environmental outcomes. In a study on the river Alde (UK) on the

⁹⁶⁶ Davey et al., '[Water Quality Benefits from an Advice-Led Approach to Reducing Water Pollution from Agriculture in England](#)', Agriculture, Ecosystems and Environment 296 (2020),.

⁹⁶⁷ Farrow et al., '[Charting Water Quality Improvements and Practice Reversion with Pesticide Interventions at Catchment Scale](#)'.

⁹⁶⁸ Cooke et al., '[Farming for Water; Catchment Management Initiatives for Reducing Pesticides](#)'.

⁹⁶⁹ Gonzalez Zapata, Vangipuram, and Erfani, '[Harnessing Market Based Mechanisms to Improve Water Quality: Water Quality Trading Policies in the River Alde, UK](#)'.

⁹⁷⁰ Livingstone et al., '[Reducing the Time-Dependent Climate Impact of Intensive Agriculture with Strategically Positioned Short Rotation Coppice Willow](#)'.

reduction of nitrate in the catchment area, [footnote ⁹⁷¹], the authors outlined how “[c]ollaboration between policymakers, agricultural communities, and environmental organisations is essential to strike a balance between agricultural productivity and environmental conservation within Nitrate Vulnerable Zones (NVZs), ensuring a harmonious co-existence between human activities and the natural environment.” This element is further strengthened in an article about the benefits to water quality of recording land management actions in New Zealand, it provided a specific recommendation to get “catchment champions involved” in order to motivate other actors within the community to record and report land management actions which ultimately can improve the water quality of the catchment area [footnote ⁹⁷²].

Environmental Impacts (9 studies)

The studies reviewed covered a wide range of interventions and solutions that impact water quality, water flow, reducing soil erosion and degradation, and riparian restoration. The majority of these studies provided clear evidence on how such solutions can have a positive impact on the environment and water quality in particular. The on-farm actions covered included riparian buffers, conventional and conservation tillage practices.

Although most of the solutions were tested at a range of scales from individual plots up to catchment, the majority of the results outline how these on-farm practices could be beneficial at larger spatial scale level if adapted to a wider geographical area. One article [footnote ⁹⁷³] conducted observations on 2 adjacent plots in Cumbria, between a hedgerow wild margin and a bordering pasture. The findings demonstrated how the hedgerow wild margin significantly reduced overland-flow, improved soil chemical properties and “contained considerably larger quantities of nitrogenous compounds and sediment on the ground surface compared to pastures”. However, because of the small scale of some of the interventions, this article suggested that further evidence on the specific solutions was needed (see also evidence gaps section).

⁹⁷¹ Gonzalez Zapata, Vangipuram, and Erfani, ‘[Harnessing Market Based Mechanisms to Improve Water Quality: Water Quality Trading Policies in the River Alde, UK](#)’.

⁹⁷² Doehring et al., ‘[A Missing Piece of the Puzzle of On-Farm Freshwater Restoration: What Motivates Land Managers to Record and Report Land Management Actions?](#)’.

⁹⁷³ Wallace et al., ‘[The Effect of Hedgerow Wild-Margins on Topsoil Hydraulic Properties, and Overland-Flow Incidence, Magnitude and Water-Quality](#)’, *Hydrological Processes* 35, no. 3 (2021),.

A number of studies looked at the implementation and impact of natural based solutions (NBS) such as riparian buffers, natural flood management solutions (NFM), and constructed wetlands and leaky barriers.

Riparian buffers

2 articles examined the composition and concentration of terrestrial invertebrates in rivers in the Netherlands [footnote ⁹⁷⁴], and in Romania [footnote ⁹⁷⁵]. They were part of Crosslink, a project that carried out field studies on riparian buffers across Europe. Both studies drew positive conclusions on how riparian buffers contribute to enhancing biodiversity, based on the count and concentration of large invertebrates in the rivers examined.

3 studies were carried out at the site of Rothamsted Research in North Wyke (Devon, UK) on 3 different types of riparian buffers: grass, willow, and woodland. The articles analysed the effect of the buffers on nitrogen leaching, soil methane fluxes, and soil carbon dioxide fluxes, respectively. The first 2 studies found that all the 3 types of riparian buffers reduce the transfer of nitrogen from farmland to freshwaters [footnote ⁹⁷⁶] and reduce soil methane emissions [footnote ⁹⁷⁷]. The third article found that the woodland riparian buffer had slightly higher CO₂ soil emission compared to the other 2 types due to relatively higher organic matter in the soil. It concluded suggesting that careful selection of the type of riparian buffer should be adopted in soil CO₂ mitigation strategies [footnote ⁹⁷⁸].

Natural flood management

One article looked at flood impact on 2 replicated plots in Cumbria, one with a hedgerow wild-margin and one with an agriculturally-improved permanent bordering pasture in a UK upland setting. The findings suggested that wild margins provide “flood mitigation benefits”

⁹⁷⁴ Forio et al., ‘[Small Patches of Riparian Woody Vegetation Enhance Biodiversity of Invertebrates](#)’, Water (Switzerland) 12, no. 11 (2020): 1–21.

⁹⁷⁵ Popescu et al., ‘[Article Riparian Vegetation Structure Influences Terrestrial Invertebrate Communities in an Agricultural Landscape](#)’, Water (Switzerland) 13, no. 2 (2021).

⁹⁷⁶ Dlamini et al., ‘[Riparian Buffer Strips Influence Nitrogen Losses as Nitrous Oxide and Leached N from Upslope Permanent Pasture](#)’, Agriculture, Ecosystems & Environment 336 (15 September 2022): 108031.

⁹⁷⁷ Dlamini et al., ‘[Soil Methane \(CH₄\) Fluxes in Cropland with Permanent Pasture and Riparian Buffer Strips with Different Vegetation](#)’, Journal of Plant Nutrition and Soil Science 185, no. 1 (2022): 132–44,.

⁹⁷⁸ Dlamini et al., ‘[Soil Carbon Dioxide \(CO₂\) Fluxes in Permanent Upslope Pasture and Downslope Riparian Buffers with Varying Vegetation](#)’, Journal of Plant Nutrition and Soil Science 186, no. 4 (2023): 406–16.

thanks to significantly higher topsoil permeability than the pastures. [footnote ⁹⁷⁹]. A study carried out on 2 farm catchments in the river Evenlode catchment (Oxfordshire), examined the effects of nature-based solutions for flood management. It highlighted the positive effects on the reduction of sediments flowing into the watercourse, thanks to constructed wetland and in-line ponds, which are also NFM solutions, and suggested that flood management with NBS should be part of the tools to achieve water quality goals [footnote ⁹⁸⁰].

One article [footnote ⁹⁸¹] examined the effect of conservation tillage (CT), in the river Wensum, in Norfolk, over 5 years. CT is an agricultural practice that reduces soil disturbance and leaves at least 30% of soil surface covered by crop residues after planting. The study did not find evidence of significant positive environmental impact of the practice, at least on its own, neither on pollution reduction nor as NFM, but clarified that this may be due to the specific morphology of the area studied, i.e., lowland intensive arable systems with shallow gradients.

Social Impacts (1 study)

The majority of the articles reviewed did not consider the social impact of the measures examined. Only one article touched upon the potential social impacts of water conservation practices. It considered social and environmental benefits of 5 agricultural diversification strategies: livestock inclusion and diversification, crop diversification, soil conservation, non-crop plantings, and water conservation. However, the article mentioned only generic non quantified benefits for water conservation strategies such as “human well-being, yields, food security” [footnote ⁹⁸²].

⁹⁷⁹ Wallace et al., ‘[The Effect of Hedgerow Wild-Margins on Topsoil Hydraulic Properties, and Overland-Flow Incidence, Magnitude and Water-Quality](#)’.

⁹⁸⁰ Robotham et al., ‘[Nature-Based Solutions Enhance Sediment and Nutrient Storage in an Agricultural Lowland Catchment](#)’, *Earth Surface Processes and Landforms* 48, no. 2 (2023): 243–58,

⁹⁸¹ Cooper et al., ‘[Conservation Tillage and Soil Health: Lessons from a 5-Year UK Farm Trial \(2013–2018\)](#)’, *Soil and Tillage Research* 202 (2020);

Ali, ‘[A Trade-off between Farm Production and Flood Alleviation Using Land Use Tillage Preferences as a Natural Flood Management \(NFM\) Strategy](#)’, *Smart Agricultural Technology* 6 (2023).

⁹⁸² Rasmussen et al., ‘[Joint Environmental and Social Benefits from Diversified Agriculture](#)’, *Science* 384, no. 6691 (2024): 87–93.

Economic Impacts (4 studies)

The articles reviewed did not provide evidence of economic impact arising directly from water quality practices.

One article touched upon the economic benefits of the conservation tillage practice, that can provide higher profit margins: “13% higher than conventional ploughing after 5 years of practice due to a combination of operational efficiency savings and improved yields” [footnote ⁹⁸³].

One article advocated the adoption of high-resolution assessment measures to combat soil erosion as they can reduce “financial wastage” [footnote ⁹⁸⁴] by focusing riverbank restoration activities where they are most needed.

2 articles about the adoption of short rotation coppice willow as riparian buffer, touched upon the economic impact of the use of the willow for energy production as biomass. In particular, the article looking at the LCA methodology provided an estimate on the cost comparison of equipment needed for harvesting and energy production [footnote ⁹⁸⁵].

Barriers (8 studies)

A range of potential barriers to the uptake of practices were identified in the evidence considered, these were about knowledge, motivation, uncertainty.

One article studied motivation for land managers in New Zealand to record and report land management actions impacting water quality, and tackled specific decision-making mechanisms related to the range of freshwater actions that land managers may have to undertake. These actions ranged from fencing off land adjacent to waterways, and exclusion of stock from those areas, to preparing and implementing riparian management plans, to planting riparian buffers, to construction of seepage wetland [footnote ⁹⁸⁶]. It

⁹⁸³ Cooper et al., '[Role of Forested Land for Natural Flood Management in the UK: A Review](#)'.

⁹⁸⁴ Hayes et al., '[High-Resolution Assessment of Riverbank Erosion and Stabilization Techniques with Associated Water Quality Implications](#)'.

⁹⁸⁵ Livingstone et al., '[Life Cycle Assessment of a Short-Rotation Coppice Willow Riparian Buffer Strip for Farm Nutrient Mitigation and Renewable Energy Production](#)'.

⁹⁸⁶ Doehring et al., '[A Missing Piece of the Puzzle of On-Farm Freshwater Restoration: What Motivates Land Managers to Record and Report Land Management Actions?](#)'.

provided a categorisation of the variables that motivated land management in taking (or not) actions. These included:

- knowledge at technical and strategic level, such as knowledge of environmental problems and their consequences, affecting water at landscape or catchment level
- commitment, a verbal or written expression to undertake positive environmental actions
- aptitude to change
- the perception that their actions can make a positive difference on water quality - on their farm and/or at wider level.

Although the article aimed at establishing methods to quantify the result of freshwater restoration, it is useful to understand the barriers that can prevent the uptake of such measures; the results of the article provided a theoretical framework of responsible environmental behaviour that can encourage land managers to take and record actions affecting water quality.

One article [footnote ⁹⁸⁷] examined the attitude of farmers in Northern Ireland to changing on-farm practices for the management of phosphorus. The study assessed farmer capacity and inclination for changes in phosphorus management practices, based on psychological and social levers, such as personal experience, attachment to the place, competition concerns, household, and risk attitudes. It identified the barriers to adopting changes to on-farm activities that reduce the use of phosphorous and ultimately impacts water quality. Among the main barriers identified there were practical aspects such as lack of facilities to deal with manure processing, and economic ones such as lack of market for new derived product from manure disposal. Lack of information and unknowns associated with future changes of farming schemes came up as an overarching barrier to adopting new practices. The conclusions of the research indicated that although there was no inclination to a radical change in the practices of managing phosphorus on farm, there was willingness to adapt

⁹⁸⁷ Martin-Ortega et al., '[Are Stakeholders Ready to Transform Phosphorus Use in Food Systems? A Transdisciplinary Study in a Livestock Intensive System](#)', Environmental Science and Policy 131 (2022): 177–87.

and modify some of the activities related to the management of phosphorus on the farm: “farmers seem to have relatively high levels of perceived adaptive capacity”.

A few articles indicated that the lack of knowledge and the uncertainty around some on farm schemes are barriers to practice uptake. For instance, one article [footnote ⁹⁸⁸] examined 2 PES schemes of Severn Trent Water (STW) implemented in the West Midlands (UK) to reduce metaldehyde leaching from farming activities. The article illustrated how a lack of external advice around reducing the use of pesticides can hinder the uptake of (new) practices, ultimately having a negative impact on water quality.

An important barrier mentioned in 2 articles was the lack of consistency across policy and regulatory frameworks as it can generate conflicting information and thus hinder farmers actions. For instance, an article analysed the impact of the international (EU) and national regulatory framework on drinking water. The conclusions highlighted that, “complexities and inconsistencies of European legislation become most explicit at local level where cross-sectoral measures had to be taken and effects monitored. There they hampered the achievement of water quality objectives” [footnote ⁹⁸⁹]. Another article explored stakeholders’ views on Natural Flood Management (NFM) and nature-based solutions (NBS) and concluded that information uncertainty about effectiveness of actions and lack of sufficient data was a barrier to farmers and other stakeholders for the delivery of NBS [footnote ⁹⁹⁰].

Evidence Gaps (3 studies)

In general, as the studies focussed on specific spatial areas (from farm to catchment) the majority of the conclusions advocated for extending testing timelines in those areas and/or expanding spatial scope to enable better assessment of impact and results of any solution adopted. One article looked at the impact of NBS on flood management and sediments in 2 farming catchments in the Upper Thames area [footnote ⁹⁹¹]. It concluded that positive

⁹⁸⁸ Cooke et al., ‘[Farming for Water: Catchment Management Initiatives for Reducing Pesticides](#)’.

⁹⁸⁹ Wuijts et al., ‘[Protection of Drinking Water Resources from Agricultural Pressures](#)’.

⁹⁹⁰ Bark, Martin-Ortega, and Waylen, ‘[Stakeholders’ Views on Natural Flood Management: Implications for the Nature-Based Solutions Paradigm Shift?](#)’.

⁹⁹¹ Robotham et al., ‘[Nature-Based Solutions Enhance Sediment and Nutrient Storage in an Agricultural Lowland Catchment](#)’.

effects can be evidenced in the short term (around 3 years) from on-farm practices such as leaky barriers [footnote ⁹⁹²].

One article examined the economic viability of short-rotation coppice willow practice on riparian buffers [footnote ⁹⁹³]. Although the LCA approach adopted showed that the practice can generate profits, the article proposed further investigation on the economic impacts and benefits of this type of initiatives. These further investigations would generate valuable information to assess economic viability of these practices at larger scale, as well as providing guidance to the selection of best practices in specific contexts.

Cost-effectiveness Evidence (3 studies)

From the literature reviewed, it is difficult to provide clear analysis of the costs of interventions and experiments carried out, from riparian buffers to tillage practices, to NBM such as leaky barriers. Moreover, costs and economic benefits was rarely a point of analysis in the literature identified and it requires a dedicated methodology to measure it in a meaningful manner.

However, 2 articles touched upon this, as they were directly concerned with financial schemes and other economic elements. With regards to payment for ecosystem services (PES), one article tried to define an approach to mapping the potential for PES schemes to improve water quality in agricultural catchments in England. It was based on multicriteria analysis (MCA) which had demand and supply of good water quality as the main criteria. The analysis was coupled with GIS information so that the results of the MCA were spatially relevant. The article highlighted how the cost of a catchment management scheme was usually lower than the costs of impact caused by poor water quality [footnote ⁹⁹⁴]. One article focused on the management of the river Linth in Switzerland. It aimed at producing a management tool based on historic analysis and GIS mapping to guide and provide a prioritised model for restoration actions of the river. It highlighted how interventions such as protection of watershed and riparian zones were less expensive than full river restoration,

⁹⁹² Wallace et al., '[The Effect of Hedgerow Wild-Margins on Topsoil Hydraulic Properties, and Overland-Flow Incidence, Magnitude and Water-Quality](#)', 20.

⁹⁹³ Livingstone et al., '[Life Cycle Assessment of a Short-Rotation Coppice Willow Riparian Buffer Strip for Farm Nutrient Mitigation and Renewable Energy Production](#)'.

⁹⁹⁴ Roberts et al., '[Mapping the Potential for Payments for Ecosystem Services Schemes to Improve Water Quality in Agricultural Catchments: A Multi-Criteria Approach Based on the Supply and Demand Concept](#)'.

and how the prioritisation model enabled sequencing of interventions focusing resources and activities where the benefits were greater. The conclusions suggested including in the prioritisation model ecological services of adjacent land cover and social benefits or restoration, not only economic and ecological ones [footnote ⁹⁹⁵].

Finally, it has to be noted that the articles that looked at monitoring and mapping areas with GIS, and other spatial methodologies provided some general indications that such solutions could contribute to a more efficient design and targeting of the various interventions, especially on erosion and NBS, without extending to actual review of costs to benefits of the solutions. For instance, a national scale high resolution mapping has been carried out in Northern Ireland, helping to identify Hydrologically Sensitive Areas (HSAs), which could prove a cost-effective strategy for tackling environmental issues linked with land pollution [footnote ⁹⁹⁶].

Critical Success Factors

Strategic fit and business needs: High alignment

Improved Water Quality, Water Usage and Flood Mitigation aligns closely with the strategic goals of the Welsh Government, particularly those outlined in the Well-being of Future Generations (Wales) Act 2015, and the Sustainable Land Management objectives of the Agriculture (Wales) Act 2023, by targeting improvements to water quality, water resource efficiency, and flood risk mitigation. Evidence from the reviewed literature suggests that riparian buffers and natural flood management interventions such as leaky dams can deliver multiple environmental benefits.

Value for money: Medium alignment

The evidence reviewed demonstrated clear benefits for maintaining and enhancing the resilience of ecosystems, and particularly the benefits they provide such as high water quality. While the evidence did not highlight how the full range of on-farm practices would provide benefits to farm businesses, it did identify positive benefits to flood mitigation and,

⁹⁹⁵ Stieger and McKenzie, '[Riparian Landscape Change: A Spatial Approach for Quantifying Change and Development of a River Network Restoration Model](#)'.

⁹⁹⁶ Service et al., '[A National-Scale High-Resolution Runoff Risk and Channel Network Mapping Workflow for Diffuse Pollution Management](#)', Journal of Environmental Management 368 (2024).

when using NFM approaches, potential benefits to addressing climate change. The evidence did, however, highlight that the costs of these more sustainable farm practices are less than the alternatives such as downstream water treatment and full river restoration suggesting that they may have wider societal benefits including for rural communities. Therefore, Improved Water Quality, Water Usage and Flood Mitigation is assessed as medium alignment for value for money.

Supply side capacity and capability: Medium alignment

The reviewed literature consistently identified a lack of advisory services, technical knowledge, and coordinated delivery as barriers to uptake, however, evidence specific to the Welsh context was limited. The evidence reviewed identified accessible on-farm practices that can and are implemented, therefore alignment with this Critical Success Factor is considered medium with potentially higher alignment dependent on enhanced support structures.

Affordability: Medium alignment

Several articles reviewed note that the adoption of water quality measures depends on incentives, advisory support, and scheme flexibility. While many practices under the Theme of Improved Water Quality, Water Usage and Flood Mitigation. (e.g., riparian buffers and leaky dams) can be low-cost in principle, their implementation may incur indirect costs or opportunity costs that deter uptake without financial compensation. The evidence also showed that many benefits emerge over the medium to long term, longer than 5 years, and initial investment or advisory support is often needed. Affordability is therefore assessed as medium alignment.

Improved Air Quality and Lowering Ammonia Emissions

The objective of the Theme Improved Air Quality and Lowering Ammonia Emissions is to:

- Improve air quality by reducing and intercepting airborne pollutants generated by farming.

To support this objective the Improved Air Quality and Lowering Ammonia Emissions Theme will support farms to invest in large infrastructure. Examples of the infrastructure identified by this review include:

- slurry stores and covers, which are structures to hold liquid manure with covers which can be placed on top
- variable rate application technology, which enables fertiliser to be applied at varying rates across fields based on site-specific conditions
- manure injection technology, which enables manure to be placed directly into the soil
- air scrubbers, which remove particulates, gases and odours from the air and are typically used for indoor pig and poultry farming.

While the Theme encompasses a broader range of potential infrastructure, the items of infrastructure listed here are those for which evidence was identified in the review, based on the Theme's on-farm infrastructure investment examples used as key search terms.

Due to overlaps in on-farm practices with other Themes, additional evidence can be found in:

- Enhanced Biosecurity
- Advanced Continuous Professional Development (CPD)
- Collaborative Landscape Scale Activity

REA Exclusion / Inclusion Criteria

Inclusion: Studies on uptake of capital investments related to air quality / ammonia emissions as outlined in the scoping document.

Exclusion: Studies that do not consider air quality or ammonia and are not capital items.

Evidence Base

The search returned 412 results, which after removing duplicates resulted in 272 records. These underwent an initial scoping review and 37 were identified as potentially in scope. In scope studies were prioritised based on quality and relevancy resulting in 24 studies being included in the evidence review.

Design of the Intervention (2 studies)

None of the studies identified as part of the evidence review evaluated the design of interventions related to the adoption of infrastructure investments for ammonia reduction / air quality improvement or variable rate nutrient application. One study [footnote ⁹⁹⁷] reflected on the barriers to variable rate application adoption. It emphasised the constraints arising from the high cost and the investments needed to adopt variable rate technology at farm level and noted that this was one of the main challenges to be solved through adequate policy instruments. Variable rate application involves applying fertiliser (or other inputs) to a field at different rates depending on need. Similar cost constraints were observed for injection technologies.

Uptake of the Practice (3 studies)

Only 2 studies mentioned the current rate of uptake of 2 technologies relevant to this Theme variable rate technology, and air scrubbers. Variable rate technologies are not considered to be widely adopted in the UK with an estimated uptake cited by one study at between 8% and 16% and uptake in Europe rarely exceeding 20% [footnote ⁹⁹⁸]. Use of these technologies is particularly low on small-scale farms in Europe relative to larger farms in the United States [footnote ⁹⁹⁹]. This study claims that lack of profitability on small fields and small farms is one of the main reasons for the low adoption rates - this is discussed further

⁹⁹⁷ Fabiani et al., '[Water Energy Food Nexus Approach for Sustainability Assessment at Farm Level: An Experience from an Intensive Agricultural Area in Central Italy](#)', ENVIRONMENTAL SCIENCE & POLICY 104 (February 2020): 1–12.

⁹⁹⁸ Masi et al., '[Precision Farming: Barriers of Variable Rate Technology Adoption in Italy](#)', Land (Multidisciplinary Digital Publishing Institute (MDPI), 2023).

⁹⁹⁹ Späti, Huber, and Finger, '[Benefits of Increasing Information Accuracy in Variable Rate Technologies](#)', *Ecological Economics* 185 (1 July 2021): 107047.

in economic impacts below. Low rates of adoption of air scrubbers in Europe were also mentioned, again one of the main reasons cited was the initial investment, but also the running costs - this is discussed further in economic impacts below [footnote ¹⁰⁰⁰].

Economic Impacts (13 studies)

Variable rate technologies (VRT) can save on fertiliser costs due to the reduced amount applied compared to a standardised rate. However, there was uncertainty in the literature identified as to whether this cost reduction is sufficient to make the practice profitable. Some argued that VRT is profitable when there is high spatial variability in soil fertility attributes e.g. particularly in field variability that affects yield [footnote ¹⁰⁰¹]. However, evidence on this was mixed. See evidence under cost-effectiveness in this section for more details.

Air scrubbers have high upfront costs but also high energy running costs [footnote ¹⁰⁰²]. Novel technologies are emerging where scrubbers can also act as heaters overall saving energy costs for the operation, though these are still in development [footnote ¹⁰⁰³].

Environmental Impacts (8 studies)

VRT benefits: Most of the studies recorded improved nitrogen use efficiency as their environmental benefit metrics. 2 studies also found ammonia volatilisation losses were significantly lower in field sections where fertiliser was applied at a variable rate compared to uniformly fertilised sections of the selected fields [footnote ¹⁰⁰⁴]. In this study variable rate fertilisation improved the nitrogen use efficiency and reduced the ammonia volatilisation in wild blueberry fields. Another study recorded evidence of a decrease in the use of nitrogen in the fields which was due to lower amounts of fertilisers being used. It also recorded a

¹⁰⁰⁰ Costantini et al., '[Improvement of Human Health and Environmental Costs in the European Union by Air Scrubbers in Intensive Pig Farming](#)', Journal of Cleaner Production (Elsevier Ltd, 2020).

¹⁰⁰¹ Zhao et al., '[Within-Field Spatial Variability and Potential for Profitability of Variable Rate Applications](#)', Precision Agriculture (Springer, 2023),.

¹⁰⁰² Moore Jr. et al., '[Development and Testing of the ARS Air Scrubber: A Device for Reducing Ammonia Emissions from Animal Rearing Facilities](#)', *FRONTIERS IN SUSTAINABLE FOOD SYSTEMS* 2 (15 June 2018).

¹⁰⁰³ Ibid.

¹⁰⁰⁴ Abbas et al., '[Effect of Split Variable Rate Fertilization on Wild Blueberry Plant Growth and Berry Yield](#)', American Society of Agricultural and Biological Engineers Annual International Meeting 2015 (American Society of Agricultural and Biological Engineers, 2015),.

better distribution of nitrogen according to the potential productivity of the field, causing improvements to groundwater quality as less nitrate loss by leaching [footnote ¹⁰⁰⁵].

Scrubbing: There was good evidence in the studies identified that scrubbers reduced ammonia [footnote ¹⁰⁰⁶]. Some types of scrubbers were more effective than others [footnote ¹⁰⁰⁷]. It should also be noted that while air scrubbers are effective at removing ammonia they can also be high energy to run so there needs to be a balance between air quality and overall GHG objectives.

Slurry tank covers: All slurry tank cover types substantially reduce ammonia emissions from slurry storage with impermeable covers having the best effect [footnote ¹⁰⁰⁸]. However, there may be trade-offs with other GHG emissions such as methane and nitrous oxide depending on the cover type and aerobic / anaerobic conditions [footnote ¹⁰⁰⁹]. These trade-offs occur because the cover can change the conditions within the tank and increase the rate of methane or nitrous oxide created within the tank. However, this depends on the cover type, slurry composition and other external factors.

Social Impacts (1 study)

One study tried to quantify the human health benefits of installing scrubbers to intensive livestock farming operations across Europe. It calculated that the annual impact on human health in Europe of disability-adjusted life years was significantly reduced when scrubber adoption was increased [footnote ¹⁰¹⁰]. A disability-adjusted life year is the equivalent of one lost year of a health life. The current scenario, combining emissions data from pig farms

¹⁰⁰⁵ Fabiani et al., '[Water Energy Food Nexus Approach for Sustainability Assessment at Farm Level: An Experience from an Intensive Agricultural Area in Central Italy](#)'.

¹⁰⁰⁶ Moore et al., '[Development and Testing of the ARS Air Scrubber: A Device for Reducing Ammonia Emissions from Animal Rearing Facilities](#)'.

¹⁰⁰⁷ De Vries and Melse, '[Comparing Environmental Impact of Air Scrubbers for Ammonia Abatement at Pig Houses: A Life Cycle Assessment](#)', Biosystems Engineering (Academic Press, 2017).

¹⁰⁰⁸ Kupper et al., '[A Novel Approach to Estimate the Abatement of Ammonia Emissions from Mitigation Techniques at Farm-Scale Slurry Stores Exemplified by a Semifloating Cover](#)', *Journal of Environmental Quality* 50, no. 5 (September 2021): 1074–83.

¹⁰⁰⁹ Van der Heyden et al., '[Continuous Measurements of Ammonia, Nitrous Oxide and Methane from Air Scrubbers at Pig Housing Facilities](#)', *Journal of Environmental Management* (Academic Press, 2016),; Vechi et al., '[Methane Emission Rates Averaged over a Year from Ten Farm-Scale Manure Storage Tanks](#)', *Science of the Total Environment* (Elsevier B.V., 2023).

¹⁰¹⁰ Costantini et al., '[Improvement of Human Health and Environmental Costs in the European Union by Air Scrubbers in Intensive Pig Farming](#)'.

with EU statistics, estimated a loss of just over 21,000 healthy years due to air pollution. However, if 35% of farms adopted scrubbers, they estimated this would drop by 15% or if 65% of farms adopted scrubbers this would drop by 40%.

Barriers (5 studies)

The main barrier identified to variable rate technology adoption was the initial cost of investment closely followed by limited evidence of longer-term pay off / profitability. A small-scale choice experiment in Austria found that technology costs, yield and environmental improvements were key drivers of variable rate technology adoption [footnote ¹⁰¹¹]. While another study [footnote ¹⁰¹²] argued that it is the lack of unanimous evidence about the profitability of variable rate technology that has kept adoption low. While few of the studies identified explored profitability in relation to adoption several did find inconsistent evidence about profitability of variable rate technologies. This is described under Economic Impacts.

Relatively high implementation and running costs currently represent the main obstacle to the widespread application of air scrubbing technology in pig farms in the EU [footnote ¹⁰¹³]. Certain types of scrubber are more appropriate to pig compared to poultry operations [footnote ¹⁰¹⁴]. Cost was also mentioned as a barrier to manure injection [footnote ¹⁰¹⁵].

Evidence Gaps (0 studies)

None of the studies identified on slurry storage and covers considered the economic benefits. Only the air scrubber studies covered social benefits. This was missing from evidence on scrubbers and variable rate application technology.

¹⁰¹¹ Blasch et al., '[Drivers and Barriers Influencing the Willingness to Adopt Technologies for Variable Rate Application of Fertiliser in Lower Austria](#)', Agronomy (MDPI, 2021).

¹⁰¹² Zhao et al., '[Within-Field Spatial Variability and Potential for Profitability of Variable Rate Applications](#)'.

¹⁰¹³ Costantini et al., '[Improvement of Human Health and Environmental Costs in the European Union by Air Scrubbers in Intensive Pig Farming](#)'.

¹⁰¹⁴ Moore et al., '[Development and Testing of the ARS Air Scrubber: A Device for Reducing Ammonia Emissions from Animal Rearing Facilities](#)'.

¹⁰¹⁵ Duncan et al., '[Coupling Dairy Manure Storage with Injection to Improve Nitrogen Management: Whole-Farm Simulation Using the Integrated Farm System Model](#)'.

Cost-effectiveness Evidence (2 studies)

Some variable rate technology studies did consider cost benefits and one study from Switzerland indicated that cost of using higher resolution tools should not exceed 4.5 CHF/ha to make the use of such tools profitable for farmers [footnote ¹⁰¹⁶]. A study from the US estimated the economic benefits of variable rate technology (VRT) at \$1.81 per acre per season, compared to an implementation cost of \$10 per acre per season [footnote ¹⁰¹⁷].

Critical Success Factors

Strategic fit and business needs: High alignment

The evidence reviewed indicates that actions to reduce ammonia emissions are closely aligned with the strategic aims of both the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management objectives of the Agriculture (Wales) Act 2023. Ammonia reduction contributes directly to improving air and water quality, and lowering greenhouse gas emissions, all key policy priorities. Although there was limited identified data on current farmer support or perceived feasibility, Improved Air Quality and Lowering Ammonia Emissions is assessed as having high alignment with this Critical Success Factor based on its strategic alignment.

Value for money: High alignment

Improved Air Quality and Lowering Ammonia Emissions is assessed as having high alignment with Value for money, based on evidence showing that ammonia reduction actions support climate change mitigation and encourage ecosystem resilience as it relates to air quality and nutrient management. Such actions support the achievement of statutory air quality targets, including UK ammonia emissions reduction targets, with associated benefits for public and environmental health. While there is relatively widespread availability of proven technologies these have significant costs, however, with support through SFS this can increase their accessibility to farmers.

¹⁰¹⁶ Späti, Robert Huber, and Robert Finger, '[Benefits of Increasing Information Accuracy in Variable Rate Technologies](#)', Ecological Economics (Elsevier B.V., 2021).

¹⁰¹⁷ Queiroz et al., '[An Expected Value of Sample Information \(EVSI\) Approach for Estimating the Payoff from a Variable Rate Technology](#)', Journal of Agricultural and Resource Economics (Colorado State University, 2023).

Supply side capacity and capability: Low alignment

The evidence reviewed does not provide indication of Supply side capacity and capability in Wales, including access to the advice, training, or collaborative support. The report identifies high costs and limited advisory support as key barriers to uptake. As such, Improved Air Quality and Lowering Ammonia Emissions is assessed as having low alignment with this CSF.

Affordability: Low alignment

Improved Air Quality and Lowering Ammonia Emissions is assessed as having low alignment with Affordability due to the high capital and maintenance costs associated with actions to reduce ammonia emissions, such as slurry storage infrastructure or low-emission spreading equipment.

Collaborative Innovation, Research and Development

The objective of the Theme Collaborative Innovation, Research and Development is to support farmers and wider agri-food supply chains:

- to participate in research and development including innovation challenges
- implement the results of Research and Development/test technologies and innovative practices in a real-world context
- the introduction (where appropriate) of findings into new SFS activity.

Due to overlaps in on-farm practices with other Themes additional evidence for this Theme can be found in:

- Collaborative Market and Supply Chain

REA Exclusion / Inclusion Criteria

It is important to note that whilst the Theme supports farmers and the wider agri-food supply chains the CSFs are farmer focussed. For this reason, the evidence gathered has focussed on on-farm practices and impacts.

Inclusion: Studies on innovation intervention, agricultural Collaborative Innovation, Research and Development programs including the private sector, research related to the adoption of new agricultural technologies and practices, and studies exploring the implementation of innovation and research and development findings in real-world agricultural settings

Exclusion: Studies on international agricultural innovations without clear applicability or relevance to the UK or Welsh context, research that is not specific to agriculture or does not explore innovations and technological developments in farming practices.

Evidence Base

Using Scopus 32 studies were identified as in scope of the evidence assessment. Of these, 11 were based in the United Kingdom, with 6 in Wales. The evidence base primarily focused on innovation and research in agricultural technologies, including precision farming,

digital tools, and Industry 4.0 technologies [footnote ¹⁰¹⁸], as well as their impact on farm productivity, sustainability, and social outcomes. Additionally, the evidence explored barriers to adoption, economic feasibility, and the role of government policies and subsidies in facilitating innovation uptake.

Strategic Context: Innovation Strategies, TRLs, and Welsh Research Landscape

In support of the objectives of the Theme Collaborative Innovation, Research and Development, it is important to situate agricultural innovation and research within the broader strategic, institutional, and readiness frameworks guiding technological development in Wales. This includes national innovation strategies, the concept of Technology Readiness Levels (TRLs), and the role of Welsh universities and innovation centres in advancing sector-wide transformation.

Technology Readiness Levels (TRLs)

TRLs offer a structured framework for assessing the maturity of a given innovation, ranging from basic principles observed (TRL 1) to full-scale deployment in an operational environment (TL 9). This framework is particularly relevant in the context of the Theme Collaborative Innovation, Research and Development, as it helps to clarify where different innovations sit in the research–development–deployment continuum. The evidence base reviewed largely concerns technologies in the mid to late TRL spectrum (TRLs 5–7), reflecting a focus on real-world piloting, testing, and early-stage commercialisation. These stages align well with the Theme’s emphasis on the implementation of innovation in practical agricultural settings.

National and Regional Innovation Strategies

The strategic direction for innovation in Wales is articulated through the Welsh Government’s Innovation Strategy: “Wales Innovates – Creating a Stronger, Fairer, Greener Wales” [footnote ¹⁰¹⁹]. This cross-sector strategy promotes mission-driven innovation and calls for stronger collaboration between government, academia, and industry to tackle

¹⁰¹⁸ Industry 4.0 technologies encompass the digital transformation of industrial processes, leveraging technologies like the Industrial Internet of Things (IIoT), automation, robotics, AI, and cloud computing to enhance efficiency, agility, and create new business models.

¹⁰¹⁹ Welsh Government, [‘Wales Innovates: Creating a Stronger, Fairer, Greener Wales’](#), 2023.

challenges in agriculture, climate, and rural development. Its Delivery Plan (2023–2028) outlines specific mechanisms—including regional R&D hubs, funding routes, and mission-aligned research calls—to support digital, environmental, and systems-level innovation [footnote ¹⁰²⁰]. In higher education, the Research Wales Innovation Fund (RWIF) promotes university-industry collaboration and knowledge exchange aligned with national priorities. This includes enhancing institutional capacity to deliver translational research in areas such as sustainable food systems and climate-smart land use [footnote ¹⁰²¹].

Beyond these high-level strategies, several complementary programmes strengthen Wales' innovation infrastructure:

- SMART Flexible Innovation Support (SMART FIS): Launched in 2023, this £30million initiative supports businesses and research institutions to develop robust R&D and innovation plans, offering financial assistance and technical advice to accelerate project readiness [footnote ¹⁰²²].
- The Helix Programme: A sector-specific initiative delivered by the 3 Food Centres in Wales and AberInnovation. The HELIX Programme helps food and drink businesses innovate, improve processing efficiency, and scale new products. At its original launch in 2016, it outlined ambitions to safeguard thousands of jobs and boost productivity through targeted knowledge transfer [footnote ¹⁰²³].
- Ambition North Wales – High Value Manufacturing Programme: As part of the North Wales Growth Deal, this regional strategy focuses on innovation in manufacturing and agri-food supply chains. It supports collaboration between businesses, universities, and research hubs to drive innovation-led economic growth [footnote ¹⁰²⁴].

Together, these strategies and programmes establish a strong foundation for the Theme Collaborative Innovation, Research and Development by reinforcing the need for co-

¹⁰²⁰ Welsh Government, '[Wales Innovates: Creating a Stronger, Fairer, Greener Wales](#)', 2023.

¹⁰²¹ Cardiff University, '[Research Wales Innovation Fund Strategy 2023/24 – 2027/28](#)', 29 September 2023.

¹⁰²² Welsh Government, '[New £30 million funds launched to boost innovation in Wales | GOV.WALES](#)', 8 June 2023.

¹⁰²³ '[£21m Food Innovation Project Set to Safeguard Thousands of Welsh Jobs | GOV.WALES](#)', 23 March 2017.

¹⁰²⁴ '[Ambition North Wales](#)', accessed 23 May 2025.

produced, applied innovation that spans the full supply chain, from farm to processor to market, and that draws on cross-sector expertise and infrastructure.

Welsh University R&D Contributions

Several Welsh universities are directly contributing to agri-innovation and R&D under the Themes relevant to the Theme Collaborative Innovation, Research and Development. For example:

- Aberystwyth University (IBERS) leads applied research in sustainable agriculture, plant genetics, and climate-smart land use through initiatives such as AberInnovation
- Bangor University's School of Natural Sciences undertakes research on agroecology, forestry, and ecosystem service optimisation
- Cardiff University's Sbarc|Spark Campus houses interdisciplinary research centres such as the Sustainable Places Research Institute, which focuses on sustainable food systems and urban-rural integration
- Swansea University's Circular Economy Research and Innovation Group (CERIG) develops industrial sustainability models with applications in food processing and waste reduction
- University of Wales Trinity Saint David (UWTSD) has recently opened the Innovation Matrix, a 2,200m² space supporting co-location between businesses and the university for collaborative innovation in digital technology and food innovation.

These universities provide the research, facilities, and partnerships needed to support the Theme Collaborative Innovation, Research and Development. They contribute to developing and testing technologies, engaging farmers and supply chains in co-design, and translating research into practice. Their infrastructure helps raise TRLs and supports adoption through advisory and innovation networks. These capabilities align directly with the objectives of the Theme Collaborative Innovation, Research and Development.

Food Innovation Infrastructure

Wales has also developed a specialised food innovation ecosystem under the Food Innovation Wales banner, supported by the Project HELIX programme:

- ZERO2FIVE Food Industry Centre (Cardiff Metropolitan University) provides compliance, NPD, and technical support to food SMEs.

- Food Technology Centre (Grŵp Llandrillo Menai) offers quality assurance and R&D services in North Wales.
- Food Centre Wales (Ceredigion County Council) delivers pilot processing, product scale-up, and analysis for SMEs in Mid and West Wales.

Together, these centres provide crucial infrastructure for innovation uptake across both upstream (technology and input suppliers) and downstream (processors, distributors, retailers) supply chains.

Design of the Intervention (28 studies)

The evidence base identified design factors that influence the effectiveness of agricultural innovation and research and development interventions. These included approaches to stakeholder engagement, system-level coordination, technology deployment, and advisory support. Findings are grouped thematically below.

Co-Creation and Inclusive Innovation

12 papers emphasised that effective innovation interventions are those that are co-designed with farmers, advisers, researchers, and other actors, rather than imposed top-down [footnote ¹⁰²⁵]. Co-production processes, such as participatory workshops and embedded

¹⁰²⁵ Beaudreault, Meinke, and Islam, '[From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems](#)', *Agricultural Systems* 221 (2024);

van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)', *World Archaeology* 42, no. 1 (March 2010): 1–12.;

de Laurentis, '[Renewable Energy Innovation and Governance in Wales: A Regional Innovation System Approach](#)', *European Planning Studies* 20, no. 12 (2012): 1975–96.;

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)', *International Journal of Production Economics* 253 (1 November 2022): 108582.;

Martens et al., '[Examining Proximity Factors in Public-Private Collaboration Models for Sustainable Agri-Food System Transformation: A Comparative Study of Two Rural Communities](#)', *Frontiers in Sustainable Food Systems* 7 (2023).;

Sikombe et al., '[Key Elements for Promoting Public-Private Partnerships in Research and Innovation](#)', *Cogent Business and Management* 11, no. 1 (2024).;

Isakhanyan et al., '[Business Strategies towards Climate-Smart Agriculture in Europe: A Literature Review](#)', *Business Strategy and the Environment* 33, no. 6 (2024): 5073–85.;

Ayre et al., '[Supporting and Practising Digital Innovation with Advisers in Smart Farming](#)', *NJAS - Wageningen Journal of Life Sciences* 90–91 (2019).;

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)'.;

researchers, were found to build trust, improve contextual fit, and support iterative improvement. One study noted that facilitation of structured learning environments supported the reframing of problems and improved buy-in from farmers [footnote ¹⁰²⁶].

Systems-Level and Ecosystem Approaches

11 papers discussed the importance of designing interventions at the systems level, positioning innovation within broader agri-food, policy, and knowledge ecosystems [footnote ¹⁰²⁷]. These studies recommended promoting digital innovation ecosystems, regional innovation systems, or innovation platforms that connect farmers, firms, researchers, and government. The Agri-Tech Catalyst programme in the UK was one such example,

Herrero et al., '[Innovation Can Accelerate the Transition towards a Sustainable Food System](#)', *Nature Food* 1, no. 5 (2020): 266–72.;

Campuzano et al., '[Barriers to the Adoption of Innovations for Sustainable Development in the Agricultural Sector—Systematic Literature Review \(SLR\)](#)', *Sustainability (Switzerland)* 15, no. 5 (2023).;

Pates, Duggett, and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.

¹⁰²⁶ Sikombe et al., '[Key Elements for Promoting Public-Private Partnerships in Research and Innovation](#)'.

¹⁰²⁷ Saoussane Srhir, Anicia Jaegler, and Jairo R. Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)', *Business Strategy and the Environment* 32, no. 7 (2023): 4143–4166.;

de Laurentis, '[Renewable Energy Innovation and Governance in Wales: A Regional Innovation System Approach](#)'.;

Sánchez-García et al., '[Finding Common Ground: Co-Producing National Soil Policy in Wales through Academic and Government Collaboration](#)', *Soil Security* 11 (2023).;

Giagnocavo et al., '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)', *Technology in Society* 81 (1 June 2025): 102763.;

Jonathan Ensor and Annemarieke de Bruin, '[The Role of Learning in Farmer-Led Innovation](#)', *Agricultural Systems* 197 (1 March 2022): 103356.;

Martens et al., '[Examining Proximity Factors in Public-Private Collaboration Models for Sustainable Agri-Food System Transformation: A Comparative Study of Two Rural Communities](#)'.;

Storm et al., '[Research Priorities to Leverage Smart Digital Technologies for Sustainable Crop Production](#)', *European Journal of Agronomy* 156 (1 May 2024): 127178.;

Isakhanyan et al., '[Business Strategies towards Climate-Smart Agriculture in Europe: A Literature Review](#)'.;

Eastwood, Klerkx, and Nettle, '[Dynamics and Distribution of Public and Private Research and Extension Roles for Technological Innovation and Diffusion: Case Studies of the Implementation and Adaptation of Precision Farming Technologies](#)', *Journal of Rural Studies* 49 (2017): 1–12.;

Campuzano et al., '[Barriers to the Adoption of Innovations for Sustainable Development in the Agricultural Sector—Systematic Literature Review \(SLR\)](#)'.;

Pates, Duggett, and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.

supporting innovation across multiple stages of readiness through industry-led, collaborative projects [footnote ¹⁰²⁸].

Advisory Services and Intermediary Roles

9 papers identified the crucial role of farm advisers, consultants, and other intermediaries in supporting the design and adoption of innovation [footnote ¹⁰²⁹]. Where interventions involved advisers in early design phases and equipped them with tools such as the Digital Value Assessment Tool (DVA) [footnote ¹⁰³⁰], they were more likely to lead to practical uptake [footnote ¹⁰³¹]. 2 studies raised concerns that over-reliance on private advisory services risks marginalising smaller or more traditional farms [footnote ¹⁰³²]. This is mainly because smaller farms may struggle to afford the high costs associated with private advisory services, which can create a barrier to access for those who might benefit the most from such support. Additionally, the business models of private advisors often prioritise larger, more commercially viable farms that are more likely to invest in technology. This situation may leave smaller, more traditional farms—often with limited financial resources or

¹⁰²⁸ Pates, Duggett, and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.

¹⁰²⁹ Feliciano, '[Factors Influencing the Adoption of Sustainable Agricultural Practices: The Case of Seven Horticultural Farms in the United Kingdom](#)', *Scottish Geographical Journal* 138, no. 3–4 (2022): 291–320.; Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)', *PLoS ONE* 19, no. 10 October (2024).;

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)';

Pellegrini et al., '[Exploring How EU Agri-Food SMEs Approach Technology driven Business Model Innovation](#)', *International Food and Agribusiness Management Review* 26, no. 3 (2023): 577–95.;

Sikombe et al., '[Key Elements for Promoting Public-Private Partnerships in Research and Innovation](#)';

Sloan, '[The Greater the Challenge, the More Diverse the Community Must Be to Solve It – the Case of the Agri-Food System](#)', *International Journal of Food Science and Technology* 59, no. 9 (2024): 6693–97.;

Herrero et al., '[Innovation Can Accelerate the Transition towards a Sustainable Food System](#)';

Campuzano et al., '[Barriers to the Adoption of Innovations for Sustainable Development in the Agricultural Sector—Systematic Literature Review \(SLR\)](#)';

Pates, Duggett, and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.

¹⁰³⁰ The Digital Value Assessment Tool (DVA) is a decision-support tool used by farm advisers to evaluate the potential impact and value of digital technologies on farm operations. It helps assess the economic, environmental, and operational benefits of adopting digital solutions, enabling more informed decision-making for farmers and facilitating the practical uptake of innovations.

¹⁰³¹ Herrero et al., '[Innovation Can Accelerate the Transition towards a Sustainable Food System](#)'.

¹⁰³² Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)';

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)'.

less familiarity with new technologies—without the guidance and support they need. As a result, there is a risk that these farms might miss out on the benefits of innovation, further exacerbating inequalities within the sector.

Policy and Institutional Alignment

Ten studies reported that interventions were more effective when aligned with broader policy frameworks and regulatory clarity [footnote ¹⁰³³]. These papers recommended policy instruments such as co-produced regulation, targeted public investment, and strategic use of R&D tax incentives to improve scalability and uptake. Embedded academic-policy collaboration, such as in the co-production of Wales' soil policy, was cited as a model of good practice [footnote ¹⁰³⁴].

Design of Technology and Interoperability

8 papers discussed how digital tools should be designed to support interoperability, scalability, and local adaptability, all of which were identified as essential for effective integration into farm systems [footnote ¹⁰³⁵]. Interoperability refers to the ability of digital

¹⁰³³ Srrhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)', *Business Strategy and the Environment* 32, no. 7 (2023): 4143–4166.;

de Laurentis, '[Renewable Energy Innovation and Governance in Wales: A Regional Innovation System Approach](#)', *European Planning Studies* 20, no. 12 (2012): 1975–96.; Sánchez-García et al.;

'[Finding Common Ground: Co-Producing National Soil Policy in Wales through Academic and Government Collaboration](#)'.

Giagnocavo et al., '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)', *Technology in Society* 81 (1 June 2025): 102763.;

Ensor and de Bruin, '[The Role of Learning in Farmer-Led Innovation](#)'.

Kumar et al., '[A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)', *Smart Agricultural Technology* 8 (2024).;

Isakhanyan et al., '[Business Strategies towards Climate-Smart Agriculture in Europe: A Literature Review](#)';

Campuzano et al., '[Barriers to the Adoption of Innovations for Sustainable Development in the Agricultural Sector—Systematic Literature Review \(SLR\)](#)'.

Pates, Duggett, and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.

¹⁰³⁴ de Laurentis, '[Renewable Energy Innovation and Governance in Wales: A Regional Innovation System Approach](#)'.

¹⁰³⁵ Zhao et al., '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)', 2023.;

Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)', *International Journal of Intelligent Networks* 3 (1 January 2022): 150–64.;

Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A](#)

systems and devices to exchange and make use of data across platforms, for example, linking soil sensors, machinery, and farm management software. Scalability relates to how well a technology can be expanded or adapted to different farm sizes or enterprises without loss of performance or increased cost. Local adaptability means the technology can be adjusted to suit specific farm conditions, such as crop type, soil quality, or climate.

Business Model and Financial Design

6 papers highlighted that innovation interventions are more likely to be effective if they are paired with business model innovation and financial strategy [footnote ¹⁰³⁶]. Small and medium enterprises (SMEs) benefited from support with market development, investor engagement, and commercialisation planning alongside the technical innovation process.

Reflexivity and Adaptive Learning

5 papers stressed the value of building flexibility and reflexivity into intervention design to allow adaptation over time [footnote ¹⁰³⁷]. These interventions used structured facilitation, action research, or Communities for Change models to test and adjust innovation

-
- [Systematic Literature Review](#)', Computers and Industrial Engineering 169 (2022).;
- Wolfert et al., '[Digital Innovation Ecosystems in Agri-Food: Design Principles and Organizational Framework](#)', Agricultural Systems 204 (2023).;
- Pedersen et al., '[Drivers and Barriers to Climate-Smart Agricultural Practices and Technologies Adoption: Insights from Stakeholders of Five European Food Supply Chains](#)', Smart Agricultural Technology 8 (1 August 2024): 100478.;
- Isakhanyan et al., '[Business Strategies towards Climate-Smart Agriculture in Europe: A Literature Review](#)'; Sloan, '[The Greater the Challenge, the More Diverse the Community Must Be to Solve It – the Case of the Agri-Food System](#)';;
- Herrero et al., '[Innovation Can Accelerate the Transition towards a Sustainable Food System](#)'.
- ¹⁰³⁶ Cuomo et al., '[Digital Strategic Collaborations in Agriculture: A Novel Asset for Local Identity Enhancement toward Agrifood 5.0](#)', British Food Journal 126, no. 11 (2024): 3922–52.;
- Giagnocavo et al., '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)';;
- Kumar et al., '[A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)';;
- Isakhanyan et al., '[Business Strategies towards Climate-Smart Agriculture in Europe: A Literature Review](#)';;
- Campuzano et al., '[Barriers to the Adoption of Innovations for Sustainable Development in the Agricultural Sector—Systematic Literature Review \(SLR\)](#)'.
- ¹⁰³⁷ Beaudreault, Meinke, and Islam, '[From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems](#)';;
- van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)';;
- Martens et al., '[Examining Proximity Factors in Public-Private Collaboration Models for Sustainable Agri-Food System Transformation: A Comparative Study of Two Rural Communities](#)';;
- Sikombe et al., '[Key Elements for Promoting Public-Private Partnerships in Research and Innovation](#)';;
- Herrero et al., '[Innovation Can Accelerate the Transition towards a Sustainable Food System](#)'.

approaches in real time. One paper noted that interventions which addressed not only cognitive learning (knowledge) but also normative (values) and relational (trust) learning were more successful in embedding change [footnote ¹⁰³⁸].

Uptake of the Practice (21 studies)

A small number of studies provided data specific to Wales; several UK-wide and international studies offered insight into the wider conditions affecting uptake.

Uptake in Wales and the UK

A review of innovation and research and development in Wales suggests that, while there is strong policy ambition and investment in agri-innovation, the translation of research into widespread on-farm practice remains limited. The Agri-Tech Catalyst programme, which funded over 100 UK-based projects involving more than 180 organisations, is the most substantial intervention relevant to Wales [footnote ¹⁰³⁹]. However, evaluation of the programme found that very few projects had reached commercial adoption by the time of reporting. Most remained in early or mid-development stages, with barriers including regulatory delay, weak investor interest, and insufficient follow-on funding.

One study examining innovation in the Welsh policy context highlighted the role of embedded researchers and co-produced governance in supporting uptake, particularly within land and natural resource management [footnote ¹⁰⁴⁰]. However, it also noted that uptake among land managers was uneven, often hindered by policy fatigue, low trust, and a lack of coordination across institutions [footnote ¹⁰⁴¹].

Evidence from UK-wide studies also indicates that uptake of smart and digital farming technologies, such as remote sensing, GPS-guided machinery, or data-driven input management, is relatively low among small and medium-sized farms, which make up the majority of Welsh holdings. Adoption is more common among larger commercial farms,

¹⁰³⁸ Sikombe et al., '[Key Elements for Promoting Public-Private Partnerships in Research and Innovation](#)'.

¹⁰³⁹ Pates, Duggett, and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.

¹⁰⁴⁰ de Laurentis, '[Renewable Energy Innovation and Governance in Wales: A Regional Innovation System Approach](#)'.

¹⁰⁴¹ Ibid, Sánchez-García et al., '[Finding Common Ground: Co-Producing National Soil Policy in Wales through Academic and Government Collaboration](#)'.

especially those with access to internal technical expertise [footnote ¹⁰⁴²]. Key barriers included limited broadband coverage, lack of platform compatibility, and a shortage of skilled digital advisers, all of which remain relevant to the Welsh context [footnote ¹⁰⁴³].

International Evidence on Uptake and Adoption Drivers

Beyond the UK, 12 studies identified consistent factors influencing uptake globally. The most frequently cited issue was economic viability, specifically, the high upfront costs of agri-tech, uncertain returns, and long investment payback periods, which acted as deterrents, particularly for smallholders and lower-income producers [footnote ¹⁰⁴⁴].

Knowledge, confidence, and training were key uptake factors in 10 studies, with digital literacy emerging as especially important for the adoption of smart farming tools. Where farmers lacked support from trusted advisers, or where advisers themselves were not confident in using or promoting technology, adoption suffered [footnote ¹⁰⁴⁵].

¹⁰⁴² Zhao et al., '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)' ;

Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)' ;

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)'.

¹⁰⁴³ Storm et al., '[Research Priorities to Leverage Smart Digital Technologies for Sustainable Crop Production](#)' ;

Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)' ;

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)'.

¹⁰⁴⁴ Bjerke and Johansson, '[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)', Food Policy 109 (2022).;

van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)' ;

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)' ;

Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)' ;

Isakhanyan et al., '[Business Strategies towards Climate-Smart Agriculture in Europe: A Literature Review](#)' ;

Kumar et al. '[A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)'.

¹⁰⁴⁵ Zhao et al., '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)' ;

Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)' ;

Cuomo et al., '[Digital Strategic Collaborations in Agriculture: A Novel Asset for Local Identity Enhancement toward Agrifood 5.0](#)' ;

Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)' ;

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)' ;

Pellegrini et al., '[Exploring How EU Agri-Food SMEs Approach Technology driven Business Model Innovation](#)' ;

Social trust and legitimacy were also found to influence uptake in 7 studies, particularly where innovations challenged traditional practices or professional identities. Participatory design processes and long-term relationships between farmers and innovation partners improved acceptance, [footnote ¹⁰⁴⁶] as did models that encouraged peer learning and on-farm experimentation [footnote ¹⁰⁴⁷].

Lastly, regulatory clarity and alignment with public policy were cited in 6 studies as critical to enabling uptake. Innovation was more likely to be adopted where public policy offered consistent encouragement or market signals, such as through subsidy reform, innovation grants, or sustainable procurement schemes [footnote ¹⁰⁴⁸].

Economic Impacts (16 studies)

The identified economic impacts of agricultural innovation and research and development on farmers include:

- Increased productivity: Several studies highlighted that precision agriculture and smart farming technologies lead to higher crop yields and improved resource

Martens et al., [‘Examining Proximity Factors in Public-Private Collaboration Models for Sustainable Agri-Food System Transformation: A Comparative Study of Two Rural Communities’](#);

Sloan, [‘The Greater the Challenge, the More Diverse the Community Must Be to Solve It – the Case of the Agri-Food System’](#);

Herrero et al., [‘Innovation Can Accelerate the Transition towards a Sustainable Food System’](#).

¹⁰⁴⁶ Ayre et al., [‘Supporting and Practising Digital Innovation with Advisers in Smart Farming’](#);

Sikombe et al., [‘Key Elements for Promoting Public-Private Partnerships in Research and Innovation’](#);

Beaudreault, Meinke, and Islam, [‘From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems’](#);

van der Veen, [‘Agricultural Innovation: Invention and Adoption or Change and Adaptation?’](#).

¹⁰⁴⁷ Martens et al., [‘Examining Proximity Factors in Public-Private Collaboration Models for Sustainable Agri-Food System Transformation: A Comparative Study of Two Rural Communities’](#); Sikombe et al., [‘Key Elements for Promoting Public-Private Partnerships in Research and Innovation’](#); Herrero et al., [‘Innovation Can Accelerate the Transition towards a Sustainable Food System’](#).

¹⁰⁴⁸ Kumar et al., [‘A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies’](#);

Pedersen et al., [‘Drivers and Barriers to Climate-Smart Agricultural Practices and Technologies Adoption: Insights from Stakeholders of Five European Food Supply Chains’](#);

Giagnocavo et al., [‘A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems’](#);

Turner et al., [‘Triggering System Innovation in Agricultural Innovation Systems: Initial Insights from a Community for Change in New Zealand’](#), Outlook on Agriculture 46, no. 2 (2017): 125–30.;

Srhir, Jaegler, and Montoya-Torres, [‘Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review’](#).

efficiency, such as reduced water and fertiliser use [footnote ¹⁰⁴⁹]. These increases in productivity are expected to drive profitability in the long term

- Cost savings: Innovations like automation, data-driven decision-making, and improved operational efficiencies reduce labour costs, energy use, and input costs, such as fertilisers and pesticides [footnote ¹⁰⁵⁰]. These reductions directly lower operational costs and enhance profitability, especially for large-scale farms
- Market expansion and competitiveness: Several studies indicated that adoption of digital tools and precision farming increases market competitiveness. It enables farmers to access new markets, especially for sustainable products, and improve product traceability [footnote ¹⁰⁵¹]. Technologies like blockchain and digital certifications help farmers meet premium market requirements, such as organic or fair trade certifications
- Economic diversification: Agricultural innovation, particularly in agroecology, alternative proteins, and sustainable farming practices, creates new income streams for farmers. These innovations allow farmers to diversify their income sources, reducing their reliance on traditional crops [footnote ¹⁰⁵²]. Additionally, innovations in

¹⁰⁴⁹ Zhao et al., '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)';

Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)';

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';

Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)'.

¹⁰⁵⁰ Townsend, L. C. and Noble, C. '[Variable Rate Precision Farming and Advisory Services in Scotland: Supporting Responsible Digital Innovation?](#)' *Sociologia Ruralis* 62, number 2 (2022): 212-230.;

Giagnocavo et al., '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)';

Bjerke and Johansson, '[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)';

Cuomo et al., '[Digital Strategic Collaborations in Agriculture: A Novel Asset for Local Identity Enhancement toward Agrifood 5.0](#)'.

¹⁰⁵¹ van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)';

Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)';

Wolfert et al., '[Digital Innovation Ecosystems in Agri-Food: Design Principles and Organizational Framework](#)', Pates, Rebecca, Joe Duggett, and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.

¹⁰⁵² Kumar et al., '[A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)';

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A](#)

renewable energy and bio-based products contribute to local economic growth in rural areas [footnote ¹⁰⁵³]

- Government encouragement: Public funding and subsidies for the adoption of innovation, particularly climate-smart agriculture and agri-tech solutions, are crucial in reducing the initial financial barriers for farmers [footnote ¹⁰⁵⁴]. These payments help farmers implement new technologies without facing overwhelming financial risk.

Costs and Economic Challenges

The evidence reviewed also highlighted a range of costs associated with implementing agricultural innovations:

- High initial investment: The upfront costs of adopting new technologies, including smart irrigation, robotics, and digital platforms, were identified as significant barriers for smaller farms [footnote ¹⁰⁵⁵]. Although these technologies can lead to long-term savings, the initial investment is a major deterrent, especially in resource-limited settings
- Uncertain ROI: The uncertainty of return on investment (ROI) for long-term projects like smart farming or sustainable practices was noted as a barrier in several studies

[Literature Review and Research Agenda](#);

Cuomo et al., '[Digital Strategic Collaborations in Agriculture: A Novel Asset for Local Identity Enhancement toward Agrifood 5.0](#)';

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)'.

¹⁰⁵³ Townsend and Noble, '[Variable Rate Precision Farming and Advisory Services in Scotland: Supporting Responsible Digital Innovation?](#)';

Turner et al., '[Triggering System Innovation in Agricultural Innovation Systems: Initial Insights from a Community for Change in New Zealand](#)';

Kumar et al., '[A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)'.

¹⁰⁵⁴ Kumar et al., '[A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)'; Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)';

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';

Javid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)'.

¹⁰⁵⁵ Zhao et al., '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)';

van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)';

Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)';

Herrero et al., '[Innovation Can Accelerate the Transition towards a Sustainable Food System](#)'.

[footnote ¹⁰⁵⁶]. This uncertainty is compounded by long payback periods and the evolving market conditions for new agricultural products

- Investment and market risks: While innovations like renewable energy and biotechnology offer promising economic benefits, market volatility and regulatory changes pose significant risks. Farmers are hesitant to invest in these innovations without clear market signals or policies that support their long-term viability [footnote ¹⁰⁵⁷].

Environmental Impacts (26 studies)

Environmental impacts resulting from agricultural innovation and research and development interventions were consistently associated with the application of digital technologies, precision agriculture, and climate-smart practices, which were found to enhance resource efficiency and reduce the environmental footprint of farming operations.

Positive Environmental Impacts

Reduction in greenhouse gas emissions: 13 studies highlighted how innovation can reduce emissions from farming systems. These include reductions in methane and nitrous oxide through improved feed efficiency and fertiliser use, as well as lower fuel use through automation and optimised machinery operations [footnote ¹⁰⁵⁸].

¹⁰⁵⁶ Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)'; Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)'; Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)'; Pates, Rebecca, Joe Duggett, and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.

¹⁰⁵⁷ van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)'; Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)'; Giagnocavo et al., '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)'; Herrero et al., '[Innovation Can Accelerate the Transition towards a Sustainable Food System](#)'.

¹⁰⁵⁸ Zhao et al., '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)'; Bjerke and Johansson, '[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)'; Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)';

Improved soil health and reduced erosion: 12 studies reported that interventions such as precision fertiliser application, regenerative agriculture, and digital soil mapping contribute to better soil structure, reduced erosion, and increased organic matter [footnote ¹⁰⁵⁹].

Water conservation and improved water quality: 11 studies found that precision irrigation, rainwater harvesting, and reduced pesticide runoff lead to more sustainable water use and less contamination of water sources [footnote ¹⁰⁶⁰].

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';

Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)';

Townsend and Noble, '[Variable Rate Precision Farming and Advisory Services in Scotland: Supporting Responsible Digital Innovation?](#)';

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)';

Giagnocavo et al., '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)';

Wolfert et al., '[Digital Innovation Ecosystems in Agri-Food: Design Principles and Organizational Framework](#)';

Kumar et al., '[A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)';

Isakhanyan et al., '[Business Strategies towards Climate-Smart Agriculture in Europe: A Literature Review](#)';

Eastwood, Klerkx, and Nettle, '[Dynamics and Distribution of Public and Private Research and Extension Roles for Technological Innovation and Diffusion: Case Studies of the Implementation and Adaptation of Precision Farming Technologies](#)';

Pates, Rebecca, Joe Duggett, and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.

¹⁰⁵⁹ Eastwood, Klerkx, and Nettle, '[Dynamics and Distribution of Public and Private Research and Extension Roles for Technological Innovation and Diffusion: Case Studies of the Implementation and Adaptation of Precision Farming Technologies](#)';

Herrero et al., '[Innovation Can Accelerate the Transition towards a Sustainable Food System](#)';

Kumar et al., '[A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)';

Sikombe et al., '[Key Elements for Promoting Public-Private Partnerships in Research and Innovation](#)';

Pellegrini et al., '[Exploring How EU Agri-Food SMEs Approach Technology driven Business Model Innovation](#)';

J.A. Turner et al., '[Triggering System Innovation in Agricultural Innovation Systems: Initial Insights from a Community for Change in New Zealand](#)', Outlook on Agriculture 46, no. 2 (2017): 125–30;

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)';

Townsend and Noble, '[Variable Rate Precision Farming and Advisory Services in Scotland: Supporting Responsible Digital Innovation?](#)';

Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)';

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';

van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)';

Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)'.

¹⁰⁶⁰ Zhao et al., '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)';

Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)';

Reduced chemical inputs and pollution: 11 papers indicated that digital and precision farming technologies reduce fertiliser and pesticide overuse, thereby lowering environmental pollution and nutrient leaching into surrounding ecosystems [footnote ¹⁰⁶¹].

Biodiversity and habitat protection: 10 studies linked innovation to enhanced biodiversity, including the promotion of agroecological practices, hedgerow planting, reduced pesticide use, and integration of organic farming approaches [footnote ¹⁰⁶²].

-
- van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)';
- Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';
- Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)';
- Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)';
- Wolfert et al., '[Digital Innovation Ecosystems in Agri-Food: Design Principles and Organizational Framework](#)';
- Kumar et al., '[A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)';
- Isakhanyan et al., '[Business Strategies towards Climate-Smart Agriculture in Europe: A Literature Review](#)';
- Eastwood, Klerkx, and Nettle, '[Dynamics and Distribution of Public and Private Research and Extension Roles for Technological Innovation and Diffusion: Case Studies of the Implementation and Adaptation of Precision Farming Technologies](#)';
- Herrero et al., '[Innovation Can Accelerate the Transition towards a Sustainable Food System](#)'.
- ¹⁰⁶¹ Pates, Rebecca, Joe Duggett, and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.;
- Eastwood, Klerkx, and Nettle, '[Dynamics and Distribution of Public and Private Research and Extension Roles for Technological Innovation and Diffusion: Case Studies of the Implementation and Adaptation of Precision Farming Technologies](#)';
- Isakhanyan et al., '[Business Strategies towards Climate-Smart Agriculture in Europe: A Literature Review](#)';
- Kumar et al., '[A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)';
- Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)';
- Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';
- van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)';
- Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)';
- Zhao et al., '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)'.
- ¹⁰⁶² van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)';
- Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';
- Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)';
- Sánchez-García et al., '[Finding Common Ground: Co-Producing National Soil Policy in Wales through Academic and Government Collaboration](#)';
- Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)';
- Turner et al., '[Triggering System Innovation in Agricultural Innovation Systems: Initial Insights from a Community for Change in New Zealand](#)';
- Giagnocavo et al., '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic](#)

Reduced waste and improved circularity: 8 articles reported that innovations such as digital logistics, Internet of Things (IoT) based [footnote ¹⁰⁶³] food monitoring, and closed-loop supply chains contribute to less food waste, better recycling, and more sustainable input-output balances [footnote ¹⁰⁶⁴].

Climate resilience and sustainability: 7 papers noted that improved land management, such as precision agriculture and data-driven decision-making, alongside better forecasting, and innovations in protein production (e.g., alternative proteins), can enhance the resilience of farming systems to climate impacts [footnote ¹⁰⁶⁵].

[and Agroecological Farming Systems](#)’;

Kumar et al., [‘A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)’;

Ayre et al., [‘Supporting and Practising Digital Innovation with Advisers in Smart Farming](#)’;

Herrero et al., [‘Innovation Can Accelerate the Transition towards a Sustainable Food System](#)’.

¹⁰⁶³ "IoT-based" refers to Internet of Things-based technologies that enable devices and systems to collect, exchange, and analyse data over the internet for improved efficiency and decision-making.

¹⁰⁶⁴ Ayre et al., [‘Supporting and Practising Digital Innovation with Advisers in Smart Farming](#)’;

Pedersen et al., [‘Drivers and Barriers to Climate-Smart Agricultural Practices and Technologies Adoption: Insights from Stakeholders of Five European Food Supply Chains](#)’;

Wolfert et al., [‘Digital Innovation Ecosystems in Agri-Food: Design Principles and Organizational Framework](#)’;

Giagnocavo et al., [‘A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)’;

Feliciano, [‘Factors Influencing the Adoption of Sustainable Agricultural Practices: The Case of Seven Horticultural Farms in the United Kingdom](#)’;

Srhir, Jaegler, and Montoya-Torres, [‘Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)’;

Zhao et al., [‘Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)’;

Pates, Duggett, and BEIS Research. [‘Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)’, BEIS Research Paper Number 2020/023, July 2020.

¹⁰⁶⁵ van der Veen, [‘Agricultural Innovation: Invention and Adoption or Change and Adaptation?’](#);

Srhir, Jaegler, and Montoya-Torres, [‘Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)’;

Townsend and Noble, [‘Variable Rate Precision Farming and Advisory Services in Scotland: Supporting Responsible Digital Innovation?’](#);

Simonetto et al., [‘Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)’;

Kumar et al., [‘A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)’;

Eastwood, Klerkx, and Nettle, [‘Dynamics and Distribution of Public and Private Research and Extension Roles for Technological Innovation and Diffusion: Case Studies of the Implementation and Adaptation of Precision Farming Technologies](#)’;

Herrero et al., [‘Innovation Can Accelerate the Transition towards a Sustainable Food System](#)’.

Environmental Trade-offs and Limitations

While the majority of studies focused on positive environmental outcomes, 5 papers also identified potential trade-offs or challenges associated with innovation:

- Increased energy use and e-waste: 4 studies warned that the infrastructure required to support digital and automated systems, such as sensors, servers, and mobile devices, may increase energy demand and contribute to electronic waste [footnote ¹⁰⁶⁶]
- Uneven access to benefits: Some studies noted that the environmental benefits of precision technologies are not guaranteed and often depend on adoption rates, scale of implementation, and farmer capacity. Small farms may lack the resources to invest in tools that deliver environmental gains [footnote ¹⁰⁶⁷]
- Unintended ecological risks: One study raised concerns that poorly designed renewable energy interventions (e.g. hydro schemes) can negatively affect local ecosystems if not carefully managed [footnote ¹⁰⁶⁸].

Social Impacts (14 studies)

5 articles noted the importance of digital tools and automation in improving working conditions, reducing physical labour, and enhancing job satisfaction for farmers. These technologies are seen as reducing physical strain and allowing farmers to focus on more skilled, less physically demanding tasks [footnote ¹⁰⁶⁹].

¹⁰⁶⁶ Maltby, [‘Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming’](#); Zhao et al., [‘Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach’](#).

¹⁰⁶⁷ Javaid et al., [‘Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies’](#); Maltby, [‘Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming’](#); Simonetto et al., [‘Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda’](#).

¹⁰⁶⁸ Ensor and de Bruin, [‘The Role of Learning in Farmer-Led Innovation’](#).

¹⁰⁶⁹ Zhao et al., [‘Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach’](#);

Bjerke and Johansson, [‘Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms’](#);

Cuomo et al., [‘Digital Strategic Collaborations in Agriculture: A Novel Asset for Local Identity Enhancement toward Agrifood 5.0’](#);

Additionally, skills development is a key theme, with several studies noting how precision farming and digital tools provide opportunities for farmers and agricultural workers gain new competencies, thus helping to create a more skilled workforce and facilitating social development within farming communities [footnote ¹⁰⁷⁰]. In terms of inclusivity, many studies highlighted that innovations in agriculture enable smallholder farmers, women, and marginalised groups to access new markets, improve food security, and increase social equity. These innovations help strengthen rural communities, particularly in underserved regions [footnote ¹⁰⁷¹].

Furthermore, community engagement through participatory approaches and collaborative farming models enhances knowledge sharing, strengthens social bonds, and ensures that technologies are adapted to local needs [footnote ¹⁰⁷²].

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)';

Giagnocavo et al., '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)'.

¹⁰⁷⁰ Kumar et al., '[A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)';

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)';

Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)';

Cuomo et al., '[Digital Strategic Collaborations in Agriculture: A Novel Asset for Local Identity Enhancement toward Agrifood 5.0](#)'.

¹⁰⁷¹ van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)';

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';

Giagnocavo et al., '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)';

Eastwood, Klerkx, and Nettle, '[Dynamics and Distribution of Public and Private Research and Extension Roles for Technological Innovation and Diffusion: Case Studies of the Implementation and Adaptation of Precision Farming Technologies](#)';

Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)'.

¹⁰⁷² Bjerke and Johansson, '[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)';

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)'; Herrero et al., '[Innovation Can Accelerate the Transition towards a Sustainable Food System](#)'.

Some studies raised concerns about the digital divide and accessibility, as farmers in rural or remote areas face barriers to adopting digital tools due to lack of internet access or digital literacy [footnote ¹⁰⁷³].

Barriers (14 studies)

Barriers to the uptake of agricultural innovation and research and development practices include:

- High initial costs: 6 studies highlighted the high upfront investment required for adopting new agricultural technologies and practices, which can be a major obstacle for smallholder farmers and those in developing regions. These costs include investments in digital tools, precision farming, and sustainable agricultural practices [footnote ¹⁰⁷⁴]
- Lack of infrastructure: 5 studies pointed out the insufficient infrastructure in rural areas, particularly limited broadband access and poor internet connectivity, which hinder the adoption of digital technologies in agriculture [footnote ¹⁰⁷⁵]. This makes it difficult for farmers to fully benefit from innovations such as data-driven farming tools

¹⁰⁷³ Cuomo et al., '[Digital Strategic Collaborations in Agriculture: A Novel Asset for Local Identity Enhancement toward Agrifood 5.0](#)';

Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)';

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)';

Giagnocavo et al., '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)';

Pates, Duggett, and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.

¹⁰⁷⁴ Zhao et al., '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)';

Bjerke and Johansson, '[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)';

Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)';

Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)';

Feliciano, '[Factors Influencing the Adoption of Sustainable Agricultural Practices: The Case of Seven Horticultural Farms in the United Kingdom](#)';

Morris, Henley, and Dowell, '[Farm Diversification, Entrepreneurship and Technology Adoption: Analysis of Upland Farmers in Wales](#)', *Journal of Rural Studies* 53 (2017): 132–43.

¹⁰⁷⁵ de Laurentis, '[Renewable Energy Innovation and Governance in Wales: A Regional Innovation System Approach](#)';

- Technological complexity: The complexity of advanced agricultural technologies, such as Blockchain, IoT, and precision farming, was mentioned as a barrier in 5 articles. Farmers often require specialised training and technical support, which may not always be readily available, especially for small-scale farms [footnote ¹⁰⁷⁶]
- Cultural resistance: Resistance to adopting new technologies due to traditional farming practices and a reluctance to change longstanding methods was identified as a significant barrier in 5 studies. Some farmers are hesitant to shift from conventional practices to newer, technology-driven approaches [footnote ¹⁰⁷⁷]. This resistance is often tied to socio-cultural identity and perceptions about the efficacy of new methods
- Lack of training and support: Insufficient training and support services for farmers in the use of new technologies was identified as a critical barrier in 5 articles. Many farmers are not familiar with the necessary tools and lack confidence in utilising them, which limits the potential benefits of innovation [footnote ¹⁰⁷⁸]

Turner et al., '[Triggering System Innovation in Agricultural Innovation Systems: Initial Insights from a Community for Change in New Zealand](#)';

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)'; van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)';

Beaudreault, Meinke, and Islam, '[From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems](#)'.

¹⁰⁷⁶ Bjerke and Johansson, '[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)';

Beaudreault, Meinke, and Islam, '[From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems](#)';

Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)';

Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)';

Feliciano, '[Factors Influencing the Adoption of Sustainable Agricultural Practices: The Case of Seven Horticultural Farms in the United Kingdom](#)'.

¹⁰⁷⁷ Bjerke and Johansson, '[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)';

van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)';

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';

Feliciano, '[Factors Influencing the Adoption of Sustainable Agricultural Practices: The Case of Seven Horticultural Farms in the United Kingdom](#)';

Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)'.

¹⁰⁷⁸ Bjerke and Johansson, '[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)';

- Regulatory challenges: 5 studies highlighted regulatory hurdles that slow the adoption of agricultural innovations. This includes issues such as inconsistent policies, unclear regulations, and delays in regulatory approvals, which can prevent farmers from fully implementing new technologies [footnote ¹⁰⁷⁹]
- Economic uncertainty: Concerns over the economic viability of adopting new technologies were cited in 5 articles, especially in regions where the return on investment is uncertain. This includes concerns about the long-term payback period and market access for the products of innovative agricultural practices [footnote ¹⁰⁸⁰]
- Data privacy concerns: Data privacy and security concerns were identified as barriers in 4 articles, particularly with the use of digital tools that require sharing sensitive farm data. Farmers are often hesitant to adopt technologies that may expose their operational data to third parties [footnote ¹⁰⁸¹]

Javaid et al., [‘Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies’](#);

Yadav et al., [‘Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review’](#);

Cuomo et al., [‘Digital Strategic Collaborations in Agriculture: A Novel Asset for Local Identity Enhancement toward Agrifood 5.0’](#);

Feliciano, [‘Factors Influencing the Adoption of Sustainable Agricultural Practices: The Case of Seven Horticultural Farms in the United Kingdom’](#).

¹⁰⁷⁹ Bjerke and Johansson, [‘Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms’](#);

van der Veen, [‘Agricultural Innovation: Invention and Adoption or Change and Adaptation?’](#);

Yadav et al., [‘Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review’](#);

Morris, Henley, and Dowell, [‘Farm Diversification, Entrepreneurship and Technology Adoption: Analysis of Upland Farmers in Wales’](#);

Townsend and Noble, [‘Variable Rate Precision Farming and Advisory Services in Scotland: Supporting Responsible Digital Innovation?’](#).

¹⁰⁸⁰ Townsend and Noble, [‘Variable Rate Precision Farming and Advisory Services in Scotland: Supporting Responsible Digital Innovation?’](#);

Maltby, [‘Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming’](#);

Feliciano, [‘Factors Influencing the Adoption of Sustainable Agricultural Practices: The Case of Seven Horticultural Farms in the United Kingdom’](#);

van der Veen, [‘Agricultural Innovation: Invention and Adoption or Change and Adaptation?’](#);

Beaudreault, Meinke, and Islam, [‘From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems’](#).

¹⁰⁸¹ Javaid et al., [‘Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies’](#);

Yadav et al., [‘Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review’](#);

Feliciano, [‘Factors Influencing the Adoption of Sustainable Agricultural Practices: The Case of Seven](#)

- Limited market access: 4 studies highlighted that limited market access for products resulting from innovative practice, such as sustainable agricultural product, can dissuade farmers from adopting new technologies, as they may not see a clear economic benefit [footnote ¹⁰⁸²].

Evidence Gaps (16 studies)

Gaps in the evidence base regarding the practice of agricultural innovation and research and development identified include:

- The need for long-term impact studies to assess the sustainability and effectiveness of innovative agricultural practices over extended periods, especially in terms of their economic, social, and environmental outcomes [footnote ¹⁰⁸³]
- A comparative analysis of the effectiveness of different technological approaches within precision agriculture and Agriculture 4.0 to identify the most efficient and cost-effective solutions [footnote ¹⁰⁸⁴]

[Horticultural Farms in the United Kingdom](#)’;

Turner et al., ‘[Triggering System Innovation in Agricultural Innovation Systems: Initial Insights from a Community for Change in New Zealand](#)’.

¹⁰⁸² Beaudreault, Meinke, and Islam, ‘[From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems](#)’;

Bjerke and Johansson, ‘[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)’;

van der Veen, ‘[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)’;

Srhir, Jaegler, and Montoya-Torres, ‘[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)’.

¹⁰⁸³ Zhao et al., ‘[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)’;

Beaudreault, Meinke, and Islam, ‘[From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems](#)’;

Bjerke and Johansson, ‘[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)’;

Javaid et al., ‘[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)’;

van der Veen, ‘[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)’.

¹⁰⁸⁴ Cuomo et al., ‘[Digital Strategic Collaborations in Agriculture: A Novel Asset for Local Identity Enhancement toward Agrifood 5.0](#)’;

Srhir, Jaegler, and Montoya-Torres, ‘[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)’;

Yadav et al., ‘[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)’;

Bjerke and Johansson, ‘[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural](#)

- More research on the integration of new technologies with local and traditional farming practices, especially in regions where innovations need to be adapted to the local context to ensure broader acceptance and effectiveness [footnote ¹⁰⁸⁵]
- The need for quantitative data to measure the impact and effectiveness of innovations, particularly inclusive innovations that aim to improve access for marginalized groups, including women, smallholder farmers, and indigenous communities [footnote ¹⁰⁸⁶]
- Economic analyses that consider the full lifecycle costs of implementing agricultural innovations, including maintenance, operational costs, and potential financial risks, to determine the long-term economic viability [footnote ¹⁰⁸⁷]

[Firms](#)’;

Zhao et al., ‘[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)’.

¹⁰⁸⁵ Beaudreault, Meinke, and Islam, ‘[From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems](#)’;

Bjerke and Johansson, ‘[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)’;

Srhir, Jaegler, and Montoya-Torres, ‘[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)’;

Yadav et al., ‘[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)’;

Simonetto et al., ‘[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)’.

¹⁰⁸⁶ Morris, Henley, and Dowell, ‘[Farm Diversification, Entrepreneurship and Technology Adoption: Analysis of Upland Farmers in Wales](#)’;

Feliciano, ‘[Factors Influencing the Adoption of Sustainable Agricultural Practices: The Case of Seven Horticultural Farms in the United Kingdom](#)’;

Srhir, Jaegler, and Montoya-Torres, ‘[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)’;

van der Veen, ‘[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)’;

Beaudreault, Meinke, and Islam, ‘[From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems](#)’.

¹⁰⁸⁷ Zhao et al., ‘[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)’;

Beaudreault, Meinke, and Islam, ‘[From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems](#)’;

Bjerke and Johansson, ‘[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)’;

Javaid et al., ‘[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)’;

Yadav et al., ‘[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)’.

- More evidence on the scalability and adaptability of agricultural innovations across different geographical regions and climatic conditions, especially for small-scale farmers in resource-limited settings [footnote ¹⁰⁸⁸]
- A focus on policy frameworks to better support digital transformation in agriculture and ensure coherent regulatory approaches for emerging technologies such as Blockchain, IoT, and AI in farming systems [footnote ¹⁰⁸⁹]
- More research on the social implications of innovations, particularly consumer acceptance of new technologies, such as lab-grown meat, digital food tracing, and precision farming [footnote ¹⁰⁹⁰]
- A lack of evidence on the long-term sustainability impacts of agricultural innovations, including their effect on soil health, biodiversity, and ecosystem stability [footnote ¹⁰⁹¹].

¹⁰⁸⁸ Beaudreault, Meinke, and Islam, '[From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems](#)';

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';

Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)';

Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)'.

¹⁰⁸⁹ van der Veen, '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)';

Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)';

Maltby, '[Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)';

Townsend and Noble, '[Variable Rate Precision Farming and Advisory Services in Scotland: Supporting Responsible Digital Innovation?](#)'.

¹⁰⁹⁰ Sánchez-García et al., '[Finding Common Ground: Co-Producing National Soil Policy in Wales through Academic and Government Collaboration](#)';

Feliciano, '[Factors Influencing the Adoption of Sustainable Agricultural Practices: The Case of Seven Horticultural Farms in the United Kingdom](#)';

Bjerke and Johansson, '[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)';

Zhao et al., '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)'.

¹⁰⁹¹ Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';

Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)';

Morris, Henley, and Dowell, '[Farm Diversification, Entrepreneurship and Technology Adoption: Analysis of Upland Farmers in Wales](#)';

Cost-effectiveness Evidence (11 studies)

Several studies highlighted the long-term financial benefits that could be realised through digital technologies, despite the high upfront costs. These include:

- Reduction in operational costs: 4 studies pointed out that technologies like blockchain, IoT, and precision agriculture can reduce resource wastage, improve supply chain efficiency, and lower transaction costs. However, the financial feasibility depends on factors such as scale, investment readiness, and integration with existing farming practices [footnote ¹⁰⁹²]
- Cost-effective resource allocation: Industry 4.0 technologies can improve farm efficiency by optimising resource use, which may lead to long-term cost savings. 3 articles highlighted that these technologies, while initially costly, provide a good return on investment (ROI) over time, especially when integrated across multiple sectors [footnote ¹⁰⁹³]
- 2 studies assessed the economic potential of shared digital innovation models. These models, particularly in networks or cooperatives, help share the financial burden of technology adoption, making it more financially accessible for smallholder farmers. This approach can address cost issues by allowing farmers to benefit from

Sánchez-García et al., '[Finding Common Ground: Co-Producing National Soil Policy in Wales through Academic and Government Collaboration](#)'.

¹⁰⁹² Zhao et al., '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)';

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)';

Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)';

Simonetto et al., '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)'.

¹⁰⁹³ de Laurentis, '[Renewable Energy Innovation and Governance in Wales: A Regional Innovation System Approach](#)';

Yadav et al., '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)';

Srhir, Jaegler, and Montoya-Torres, '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)'.

economies of scale and collective investment in technological infrastructure [footnote ¹⁰⁹⁴]

- 4 studies noted the role of government subsidies in addressing barriers related to cost of agricultural innovations. The availability of grants and subsidies was found to significantly offset the high initial costs associated with adopting advanced technologies. Studies highlighted that these support mechanisms are crucial in enabling smaller farms to overcome financial barriers that could otherwise impede the adoption of these technologies, ensuring that innovations are more accessible to farmers who might otherwise struggle with upfront investment [footnote ¹⁰⁹⁵]
- One study highlighted the de-risking role of innovation funds, such as the Agri-Tech Catalyst, which helped leverage over £35.8 million in private sector funding. This model accelerated the adoption of new technologies but also raised concerns about the displacement of internal R&D budgets in firms, suggesting the need for balanced financial support strategies [footnote ¹⁰⁹⁶].

Critical Success Factors

Strategic fit and business needs: High alignment

The evidence base suggests that innovation and research and development in agriculture have the potential to align with several key Welsh policy frameworks aimed at promoting sustainable agricultural practices. These include the Well-being of Future Generations (Wales) Act 2015, which emphasises sustainability and long-term well-being, and the

¹⁰⁹⁴ Cuomo et al., '[Digital Strategic Collaborations in Agriculture: A Novel Asset for Local Identity Enhancement toward Agrifood 5.0](#)';

Giagnocavo et al., '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)'.

¹⁰⁹⁵ Giagnocavo et al., '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)';

Townsend and Noble, '[Variable Rate Precision Farming and Advisory Services in Scotland: Supporting Responsible Digital Innovation?](#)';

Cuomo et al., '[Digital Strategic Collaborations in Agriculture: A Novel Asset for Local Identity Enhancement toward Agrifood 5.0](#)';

Javaid et al., '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)'.

¹⁰⁹⁶ Pates, Duggett, and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.

Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023, which promotes sustainable, resilient farming practices. The adoption of Industry 4.0 technologies (e.g. IoT, blockchain, precision agriculture) is in line with global trends toward digital transformation in agriculture. These technologies offer substantial potential to optimise resource use, reduce waste, and increase yields. However, successful adoption will require the integration of these innovations with local farming practices and overcoming socio-cultural resistance to change. Financial support and capacity-building initiatives are critical to aligning this intervention with the needs of farmers, especially in rural and smallholder contexts. The evidence suggests that the Theme may be highly aligned with the Strategic fit and business needs CSF, dependent on how it is delivered.

Value for money: High alignment

The value for money of adopting innovative agricultural technologies appears strong, as indicated by multiple studies highlighting long-term cost reductions and improved efficiencies. Technologies like blockchain and precision farming can simplify supply chains, reduce resource wastage, and lower operational costs. Despite the high upfront investment, these technologies offer a good return on investment (ROI) over time. The financial feasibility of these technologies is further enhanced through government subsidies and shared digital innovation models. The evidence suggests that the Theme may be highly aligned with the Value for money CSF, dependent on how it is delivered, as these long-term financial benefits can outweigh the initial costs, especially when supported by public and private financial mechanisms.

Supply side capacity and capability: Low alignment

While there is strong awareness of the potential benefits of agricultural innovations, the Supply side capacity and capability remain a significant challenge. Barriers such as a lack of digital skills, insufficient infrastructure in rural areas, and the financial limitations of smaller farms are key hurdles. These barriers hinder the widespread uptake of digital technologies, especially among smallholder and rural farmers who may lack the technical expertise and resources to fully leverage such technologies. Additionally, of the evidence reviewed, there is limited evidence of widespread collaboration within agricultural supply chains that could encourage the scaling of these innovations. Low alignment with this Critical Success Factor

reflects the need for additional education, infrastructure, and capacity-building initiatives to improve the uptake of innovative agricultural practices.

Affordability: High alignment

The affordability of innovative agricultural technologies is highly contingent on overcoming financial barriers, particularly for small and medium-sized farms. The evidence indicates that the high initial costs of technology adoption are a significant barrier, but these can be mitigated by government subsidies and cost-sharing models. Several studies have highlighted that, with financial support, farmers are more likely to adopt technologies that lead to long-term financial benefits, such as reduced resource costs and increased efficiency. Therefore, the evidence suggests that this Theme aligns highly with the Affordability CSF, especially when financial mechanisms are in place to alleviate the upfront investment burden.

Collaborative Landscape Scale Activity

The objective of the Theme Collaborative Landscape Scale Activity is to support farmers and land managers and others to work together at a landscape, catchment or pan-Wales level to deliver outcomes at scale. This Theme does not focus on specific on-farm practices, but rather on facilitating collaboration between farmers to deliver outcomes at scale.

Due to overlaps in on-farm practices with other Themes, additional evidence for this Theme can be found in:

- Enhanced Woodland Management
- Woodland and Agroforestry Creation
- Enhanced Biosecurity
- Enhanced Habitat Management
- Implementation of Designated Site Management Plans
- Improved Soil Health and Multispecies Crop Cover
- Creation of Temporary and Permanent Habitats
- Improved Public Access to the Countryside Improved Water Quality, Water Usage and Flood Mitigation.
- Improved Air Quality and Lowering Ammonia Emissions.

REA Exclusion / Inclusion Criteria

Inclusion: Studies on landscape-level, collaborative actions between farmers and land managers/landowners, including national park authorities and management of designated sites.

Exclusion: Studies outside temperate zones and in significantly different farming contexts to those in Wales.

Evidence Base

Using Scopus 51 studies were identified as in scope of the evidence assessment. An additional 5 studies were sourced using Google Scholar and websites identified in Annex B. Using quality and relevance criteria 56 articles were analysed. Of these, 4 were based in Wales and a further 33 were from the rest of the UK. The evidence base focussed particularly on collaborative agri-environment schemes, landscape-scale environmental conservation and designated site management.

Design of the Intervention (40 studies)

Collaboration and participation

Several studies highlighted the importance of collaboration and participation in designing landscape-scale agri-environment schemes. This includes efforts to include all stakeholders, especially farmers, in the design and development phases of the scheme to ensure it aligns with the goals and values of local people [footnote ¹⁰⁹⁷] and ensures long-term participation [footnote ¹⁰⁹⁸]. This should follow a bottom-up approach, being led by stakeholders [footnote ¹⁰⁹⁹] who are involved from the start [footnote ¹¹⁰⁰]. The formation of groups or cooperatives of no more than 30 members was recommended to aid communication and trust building [footnote ¹¹⁰¹]. The group should seek to identify common

¹⁰⁹⁷ Jones, Kam, and Potter, '[Are landholders willing to collaborate under ELMs? Promoting collaborative conservation on a landscape scale in the UK](#)', Journal of Rural Studies 103 (2023).;

Baker et al., '[Aligning strategic and participatory approaches to agri-environment scheme design and implementation to enhance nature recovery outcomes](#)', People and Nature 7, no. 2 (2025): 329–345;

Limbach, '[What Role for Environmental Cooperatives in Collective Agri-Environmental Schemes?](#)', Journal of Environmental Planning and Management 67, no. 7 (2024): 1409–33.;

Emery and Franks, '[The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers' Concerns with Current Schemes?](#)', Journal of Rural Studies 28, number 3 (1 July 2012): 218–31.;

Laven, D N, J L Jewiss, and N J Mitchell. '[Toward Landscape-Scale Stewardship and Development: A Theoretical Framework of United States National Heritage Areas](#)'. Society and Natural Resources 26, number 7 (2013): 762-777.

¹⁰⁹⁸ Prager, '[Implementing Policy Interventions to Support Farmer Cooperation for Environmental Benefits](#)'. Land Use Policy 119 (2022).

¹⁰⁹⁹ Scott, A, and P Shannon. '[Local Landscape Designations in Scotland: Opportunity or Barrier to Effective Landscape Management?](#)' Landscape and Urban Planning volume 81, number 3 (2007): 269

¹¹⁰⁰ Toderi et al., '[Bottom-up design process of agri-environmental measures at a landscape scale: Evidence from case studies on biodiversity conservation and water protection](#)', Land Use Policy 68 (2017): 295-305.

¹¹⁰¹ Prager, '[Implementing Policy Interventions to Support Farmer Cooperation for Environmental Benefits](#)'

interests of its members and develop a mutually acceptable plan [footnote ¹¹⁰²]. 2 studies referred to the creation of constitutions [footnote ¹¹⁰³] or ‘conservation covenants’ [footnote ¹¹⁰⁴] as ways to formalise agreements among members and between members and outside organisations. Organising in-person meetings and on-farm visits was recommended in a UK study to aid communication and trust building [footnote ¹¹⁰⁵].

Collaborative efforts can build on existing relationships and bridging structures [footnote ¹¹⁰⁶]. For example, a UK study revealed that many upland farmers have existing, longstanding coordination mechanisms for shared grazing of common land, which they can build on to form collaborative schemes [footnote ¹¹⁰⁷] and which act as hubs for communication and learning [footnote ¹¹⁰⁸]. Another UK study suggested targeting local farmers/individuals with high social capital and influence to help build connections and aid recruitment [footnote ¹¹⁰⁹].

One EU study recommended that groups should build on or establish partnerships with local agri-food businesses to provide an avenue for economic benefit creation for farmers who join the scheme [footnote ¹¹¹⁰]. Engaging with the local community was recommended where schemes may impact them, this can also improve engagement and buy-in [footnote

¹¹⁰² Opdam et al., '[Does Information on Landscape Benefits Influence Collective Action in Landscape Governance?](#)', Current Opinion in Environmental Sustainability, Sustainability governance and transformation 2016: Informational governance and environmental sustainability, 18 (1 February 2016): 107–14.

¹¹⁰³ Franks, '[The Collective Provision of Environmental Goods: A Discussion of Contractual Issues](#)', Journal of Environmental Planning and Management 54, no. 5 (2011): 637–60.

¹¹⁰⁴ Barkley, CJ Short, a C.-A. Chivers, '[Exploring the Potential of Long-Term Agreements for Achieving Landscape-Scale Environmental Recovery](#)', Wiley Interdisciplinary Reviews: Energy and Environment 13, no. 1 (2024).

¹¹⁰⁵ Thomas, Riley, and Spees, '[Knowledge Flows: Farmers' Social Relations and Knowledge Sharing Practices in "Catchment Sensitive Farming"](#)'. Land Use Policy 90 (2020).

¹¹⁰⁶ Schöler et al., '[Initiating Agri-Environmental Collaboration at Landscape Scale Requires Bridging Structures, Regional Facilitators and Addressing the Expectations of Actors](#)', People and Nature 7, no. 2 (2025): 320–28.

¹¹⁰⁷ Franks, J R, S B Emery, M J Whittingham, and A J McKenzie. '[Options for Landscape Scale Collaboration under the UK's Environmental Stewardship Scheme](#)'.

¹¹⁰⁸ Limbach, '[What Role for Environmental Cooperatives in Collective Agri-Environmental Schemes?](#)'; Prager, '[Implementing Policy Interventions to Support Farmer Cooperation for Environmental Benefits](#)'; Byrne, McCarthy, and Ryan-Doyle, '[Leveraging the Potential of Co-operative Agri-advisory Services in the Transition to Sustainable and Landscape-Based Agriculture](#)', International Food and Agribusiness Management Review 27, no. 1 (2024): 117–45.

¹¹⁰⁹ Matthews, Fish, and Tzanopoulos, '[Overcoming Barriers to Agri-Environmental Management at Landscape Scale: Balancing Farmer Coordination and Collaboration with the Aid of Facilitators and Pioneers](#)

¹¹¹⁰ Amblard, Guiffant, and Bussière, '[The Drivers of Farmers' Participation in Collaborative Water Management: A French Perspective](#)', International Journal of the Commons 17, no. 1 (2023): 411–30.

¹¹¹¹]. One UK study recommended building on existing networks of protected areas and using landscape agreements with farmers to join them up [footnote ¹¹¹²].

Coordination

Several studies highlighted the role of an alternative scheme structure to collaboration, coordination, whereby farmers don't work together directly but work towards the same goals in isolation [footnote ¹¹¹³]. This design may provide a lower point of entry and better align with those farmers holding strong individualist identities [footnote ¹¹¹⁴]. Raymond *et al* (2016) recommend a balance between the 2 approaches depending on the needs and interests of the group [footnote ¹¹¹⁵]. A UK-based study suggested that this model is more common in lowland farming contexts, where coordinated landscape activities tend to be driven by external organisations [footnote ¹¹¹⁶].

Facilitators and advisors

In both collaborative and coordinative schemes, the role of facilitators and trusted advisors [footnote ¹¹¹⁷] is highlighted by multiple studies as important for scheme design and delivery. Facilitators play a role in bringing stakeholders together and organising collaborative

¹¹¹¹ Ellis et al., '[Landscape-Scale Conservation in Practice: Lessons from Northern England, UK](#)'. Journal of Insect Conservation 15, no. 1 (2011): 69-81.

¹¹¹² Smart et al., '[Synergies between Site Protection and Agri-Environment Schemes for the Conservation of Waders on Lowland Wet Grasslands](#)', Ibis 156, no. 3 (2014): 576–90.

¹¹¹³ Reichensperner, Barghusen, and Matzdorf, '[Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-operation in Dutch Agri-Environment Schemes](#)', Journal of Environmental Planning and Management 67, no. 8 (2024): 1830–51.

¹¹¹⁴ Ibid.

¹¹¹⁵ Raymond et al., '[Integrating Different Understandings of Landscape Stewardship into the Design of Agri-Environmental Schemes](#)', Environmental Conservation 43, no. 4 (2016): 350–58.

¹¹¹⁶ Franks et al., '[Options for Landscape Scale Collaboration under the UK's Environmental Stewardship Scheme](#)'

¹¹¹⁷ Sinner et al., '[Great Expectations for Collective Management](#)'.

agreements [footnote ¹¹¹⁸] to reduce the time and labour costs to participants [footnote ¹¹¹⁹] and improve knowledge flow within the group [footnote ¹¹²⁰]. Both EU [footnote ¹¹²¹] and UK [footnote ¹¹²²] studies recommend that facilitators have knowledge of the local area [footnote ¹¹²³] and ‘speak farmers language’ [footnote ¹¹²⁴]. A German study found that half of participants would prefer a government agency as a facilitator, and the other half preferred a conservation NGO [footnote ¹¹²⁵]. Baker et al (2025) recommended implementing mechanisms to aid collaboration and coordination across landscapes, such as digital

-
- ¹¹¹⁸ Jones, Kam, and Potter, [‘Are landholders willing to collaborate under ELMs? Promoting collaborative conservation on a landscape scale in the UK’](#), *Journal of Rural Studies* 103 (2023).;
- Franks and Emery, [‘Incentivising Collaborative Conservation: Lessons from Existing Environmental Stewardship Scheme Options’](#), *Land Use Policy* 30, no. 1 (2013): 847–62;
- Franks, [‘An Application of Boundary Organisation Theory to Develop Landscape-Scale Conservation in Formal Agri-Environment Schemes’](#), *Sociologia Ruralis* 56, no. 1 (2016): 48–73;
- Häfner and Piorr, [‘Farmers’ Perception of Co-Ordinating Institutions in Agri-Environmental Measures – The Example of Peatland Management for the Provision of Public Goods on a Landscape Scale’](#), *Land Use Policy* 107 (1 August 2021): 104947;
- Thomas, Riley, and Spees, [‘Knowledge Flows: Farmers’ Social Relations and Knowledge Sharing Practices in “Catchment Sensitive Farming”’](#);
- Raymond et al., [‘Integrating Different Understandings of Landscape Stewardship into the Design of Agri-Environmental Schemes’](#);
- Ellis et al., [‘Landscape-Scale Conservation in Practice: Lessons from Northern England, UK’](#).
- ¹¹¹⁹ Matthews, Fish, and Tzanopoulos, [‘Overcoming Barriers to Agri-Environmental Management at Landscape Scale’](#);
- Häfner and Piorr, [‘Farmers’ Perception of Co-Ordinating Institutions in Agri-Environmental Measures – The Example of Peatland Management for the Provision of Public Goods on a Landscape Scale’](#).
- ¹¹²⁰ Riley et al., [‘Will Farmers Work Together for Conservation? The Potential Limits of Farmers’ Cooperation in Agri-Environment Measures’](#), *Land Use Policy* 70 (2018): 635–46;
- Schüler et al., [‘Initiating Agri-Environmental Collaboration at Landscape Scale Requires Bridging Structures, Regional Facilitators and Addressing the Expectations of Actors’](#).
- ¹¹²¹ Reichenspurner, Barghusen, and Matzdorf, [‘Exploring Farmers’ Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes’](#).
- ¹¹²² Barkley, Short, and Chivers, [‘Exploring the Potential of Long-Term Agreements for Achieving Landscape-Scale Environmental Recovery’](#).
- ¹¹²³ Barkley, Short, and Chivers, [‘Exploring the Potential of Long-Term Agreements for Achieving Landscape-Scale Environmental Recovery’](#);
- Thomas, Riley, and Spees, [‘Knowledge Flows: Farmers’ Social Relations and Knowledge Sharing Practices in “Catchment Sensitive Farming”’](#).
- ¹¹²⁴ Reichenspurner, Barghusen, and Matzdorf, [‘Exploring Farmers’ Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes’](#).
- ¹¹²⁵ Häfner and Piorr, [‘Farmers’ Perception of Co-Ordinating Institutions in Agri-Environmental Measures – The Example of Peatland Management for the Provision of Public Goods on a Landscape Scale’](#).

resource platforms, methods of feeding back and sharing examples of on-the-ground success [footnote ¹¹²⁶].

Payments

3 studies recommended employing a results-based approach to linking payments for provision of environmental outcomes, as these provide flexibility for farmers in how they deliver the required outcome [footnote ¹¹²⁷] and allows them to apply their context-specific knowledge to actions on their farms [footnote ¹¹²⁸]. The evidence reviewed suggests that payments for participation should cover both potential loss of productivity from implementing actions, but also the additional costs of time and labour required for collaboration [footnote ¹¹²⁹]. These payments should shift in line with changing opportunity costs for land management [footnote ¹¹³⁰].

When designing contracts for collaborative schemes, one study suggested that individual contracts with farmers would improve uptake by bypassing administrative concerns of group contracts and maintaining independence for farmers [footnote ¹¹³¹]. However, another study suggested that group contracts, whereby payments are made to a single group and money

¹¹²⁶ Baker et al., '[Aligning strategic and participatory approaches to agri-environment scheme design and implementation to enhance nature recovery outcomes](#)'.

¹¹²⁷ Meier et al., '[Collaborative Approaches at the Landscape Scale Increase the Benefits of Agri-Environmental Measures for Farmland Biodiversity](#)', *Agriculture, Ecosystems & Environment* 367 (15 June 2024): 108948;

Kam, '[Opportunities for Achieving Landscape Scale Conservation in England](#)', *Journal of Rural Studies* 110 (1 August 2024): 103380;

Amblard, Guiffant, and Bussière, '[The Drivers of Farmers' Participation in Collaborative Water Management: A French Perspective](#)'.

¹¹²⁸ Limbach, '[What Role for Environmental Cooperatives in Collective Agri-Environmental Schemes?](#)', *Journal of Environmental Planning and Management* 67, no. 7 (2024): 1409–33;

Loos et al., '[Limited Effectiveness of EU Policies to Conserve an Endangered Species in High Nature Value Farmland in Romania](#)', *Ecology and Society* 26, no. 3 (2021);

Reichenspurner, Barghusen, and Matzdorf, '[Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes](#)'.

¹¹²⁹ Jones, Kam, and Potter, '[Are landholders willing to collaborate under ELMs? Promoting collaborative conservation on a landscape scale in the UK](#)', *Journal of Rural Studies* 103 (2023).

¹¹³⁰ Barkley, Short, and Chivers, '[Exploring the Potential of Long-Term Agreements for Achieving Landscape-Scale Environmental Recovery](#)'.

¹¹³¹ Reichenspurner, Barghusen, and Matzdorf, '[Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes](#)'.

then distributed between group members, led to more equitable divisions of payments [footnote ¹¹³²].

Knowledge sharing

Incorporating stakeholder local knowledge was cited as important for trust building and improving buy-in from farmers [footnote ¹¹³³]. Bringing farmer knowledge together in a collaborative context helps knowledge pooling which can contribute to more effective scheme design [footnote ¹¹³⁴], adapted to the local context [footnote ¹¹³⁵].

Education, training and capacity building were cited by several studies as important for promoting shared learning [footnote ¹¹³⁶], changing farmer attitudes towards environmental measures [footnote ¹¹³⁷] and improving their knowledge of natural resource management [footnote ¹¹³⁸].

Developing specific, measurable aims [footnote ¹¹³⁹] and continuously monitoring scheme outcomes allows stakeholders to better understand the impact of their actions and maintain

¹¹³² Jane et al., '[Organising Collective Action for Effective Environmental Management and Social Learning in Wales](#)', Journal of Agricultural Education and Extension 17, no. 1 (2011): 69–83.

¹¹³³ Jones, Kam, and Potter, '[Are landholders willing to collaborate under ELMs? Promoting collaborative conservation on a landscape scale in the UK](#)', Journal of Rural Studies 103 (2023).'; Reichensperner, Barghusen, and Matzdorf, '[Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes](#)';

Mckenzie et al., '[FORUM: Landscape-Scale Conservation: Collaborative Agri-Environment Schemes Could Benefit Both Biodiversity and Ecosystem Services, but Will Farmers Be Willing to Participate?](#)', Journal of Applied Ecology 50, no. 5 (2013): 1274–80;

Barkley, Short, and Chivers, '[Exploring the Potential of Long-Term Agreements for Achieving Landscape-Scale Environmental Recovery](#)'.

¹¹³⁴ Meier et al., '[Collaborative Approaches at the Landscape Scale Increase the Benefits of Agri-Environmental Measures for Farmland Biodiversity](#)'.

¹¹³⁵ Thomas, Riley, and Spees, '[Knowledge Flows: Farmers' Social Relations and Knowledge Sharing Practices in "Catchment Sensitive Farming"](#)';

Franks, '[An Application of Boundary Organisation Theory to Develop Landscape-Scale Conservation in Formal Agri-Environment Schemes](#)'.

¹¹³⁶ Westerink et al., '[Collaborative Governance Arrangements to Deliver Spatially Coordinated Agri-Environmental Management](#)', Land Use Policy 69 (2017): 176–92.

¹¹³⁷ Amblard, Guiffant, and Bussière, '[The Drivers of Farmers' Participation in Collaborative Water Management: A French Perspective](#)';

Staley et al., (2022). [Landscape-scale species monitoring of agri-environment schemes](#). UKCEH and BTO. Final report to Natural England, project LM0465.

¹¹³⁸ Mckenzie et al., '[FORUM: Landscape-Scale Conservation: Collaborative Agri-Environment Schemes Could Benefit Both Biodiversity and Ecosystem Services, but Will Farmers Be Willing to Participate?](#)'.

¹¹³⁹ Emery and Franks, '[The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers' Concerns with Current Schemes?](#)'.

motivation [footnote ¹¹⁴⁰]. Implementing an adaptive management framework, whereby monitoring is used to inform changes to improve scheme design, was recommended by several studies to ensure schemes remain relevant to the local context and changing conditions over time [footnote ¹¹⁴¹]. Pilot trials were cited by an EU study as a potential measure to encourage engagement from farmers [footnote ¹¹⁴²].

Uptake of the Practice (24 studies)

The evidence identified suggests that agri-environment schemes have traditionally focussed on individual farm scales [footnote ¹¹⁴³], and that efforts to coordinate management agreements between landowners at a landscape scale have remained less common in the UK [footnote ¹¹⁴⁴]. England has trialled schemes such as the Countryside Stewardship Scheme [footnote ¹¹⁴⁵] and Environmental Stewardship Scheme [footnote ¹¹⁴⁶], which included a ‘supplement for group action’; uptake and success of this model was found to be low.

¹¹⁴⁰ Baker et al., '[Aligning strategic and participatory approaches to agri-environment scheme design and implementation to enhance nature recovery outcomes](#)';

Franks and Emery, '[Incentivising Collaborative Conservation: Lessons from Existing Environmental Stewardship Scheme Options](#)';

Emery and Franks, '[The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers' Concerns with Current Schemes?](#)'.

¹¹⁴¹ Limbach, '[What Role for Environmental Cooperatives in Collective Agri-Environmental Schemes?](#)', Journal of Environmental Planning and Management 67, no. 7 (2024): 1409–33';

Gabriel et al., '[Scale Matters: The Impact of Organic Farming on Biodiversity at Different Spatial Scales](#)', Ecology Letters 13, no. 7 (2010): 858–69;

Mathevet et al., '[Protected Areas and Their Surrounding Territory: Socioecological Systems in the Context of Ecological Solidarity](#)', Ecological Applications 26, no. 1 (2016): 5–16;

Staley et al., '[Landscape-scale species monitoring of agri-environment schemes](#)'. UKCEH and BTO. Final report to Natural England, project LM0465..

¹¹⁴² Limbach, '[What Role for Environmental Cooperatives in Collective Agri-Environmental Schemes?](#)', Journal of Environmental Planning and Management 67, no. 7 (2024): 1409–33

¹¹⁴³ Kam, '[Opportunities for Achieving Landscape Scale Conservation in England](#)'.

¹¹⁴⁴ Franks and Emery, '[Incentivising Collaborative Conservation: Lessons from Existing Environmental Stewardship Scheme Options](#)';

Emery and Franks, '[The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers' Concerns with Current Schemes?](#)'.

¹¹⁴⁵ Jones, Kam, and Potter, '[Are landholders willing to collaborate under ELMs? Promoting collaborative conservation on a landscape scale in the UK](#)', Journal of Rural Studies 103 (2023).

¹¹⁴⁶ Franks and Emery, '[Incentivising Collaborative Conservation: Lessons from Existing Environmental Stewardship Scheme Options](#)'.

A UK study revealed that 81% of farmers interviewed were not against the idea of a collaborative, landscape-scale scheme, this was supported by 75% of survey respondents in the same study [footnote ¹¹⁴⁷]. Another UK-based study found that 72% of farmers had existing formal or informal cooperative agreements with their neighbours, for example for equipment sharing, which could be built on [footnote ¹¹⁴⁸].

Type of landowner

Type of landowner was cited as important in predicting uptake of collaborative agri-environment schemes. Those most likely to engage are larger farmers with more equipment and income, part-time farmers with no formal agricultural training, and absentee landowners or those who are less production-oriented [footnote ¹¹⁴⁹].

The evidence suggests that those farmers already engaging in knowledge sharing and collaborative working with other farmers are more likely to engage in formal collaborative schemes [footnote ¹¹⁵⁰]. This pattern is also seen in farmers already engaging in agri-environment schemes [footnote ¹¹⁵¹]. Additionally, an EU study found that farmers with diverse networks of affiliations with both farming unions and environmental organisations are more likely to engage in collaborative processes [footnote ¹¹⁵²].

The evidence suggests that social networks influence farmer participation in collaborative arrangements [footnote ¹¹⁵³]. Several studies highlighted the impact of social pressure and

¹¹⁴⁷ Mckenzie et al., '[FORUM: Landscape-Scale Conservation: Collaborative Agri-Environment Schemes Could Benefit Both Biodiversity and Ecosystem Services, but Will Farmers Be Willing to Participate?](#)'.

¹¹⁴⁸ Macfarlane, '[Implementing Agri-Environment Policy: A Landscape Ecology Perspective](#)', Journal of Environmental Planning and Management 41, no. 5 (1998): 575–96.

¹¹⁴⁹ Häfner and Piore, '[Farmers' Perception of Co-Ordinating Institutions in Agri-Environmental Measures – The Example of Peatland Management for the Provision of Public Goods on a Landscape Scale](#)'.

¹¹⁵⁰ Franks, '[The Collective Provision of Environmental Goods: A Discussion of Contractual Issues](#)'; Jane et al., '[Organising Collective Action for Effective Environmental Management and Social Learning in Wales](#)';

Franks, J.R.; Emery, S.B.; Whittingham, M.J. and McKenzie, A.J. '[Options for Landscape Scale Collaboration under the UK's Environmental Stewardship Scheme](#)'. (2011) Centre for Rural Economy, University of Newcastle Upon Tyne..

¹¹⁵¹ Emery and Franks, '[The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers' Concerns with Current Schemes?](#)'.

¹¹⁵² Amblard, Guiffant, and Bussière, '[The Drivers of Farmers' Participation in Collaborative Water Management: A French Perspective](#)'.

¹¹⁵³ Ibid.

identity on farmer uptake, with farmers concerned around how collaboration may impact their reputation [footnote ¹¹⁵⁴] and whether other farmers would also engage [footnote ¹¹⁵⁵].

Scheme design

Scheme design was an important factor in influencing farmer uptake of collaborative arrangements. Elements of scheme design that improve uptake are:

- coordinative approaches rather than collaborative [footnote ¹¹⁵⁶]
- flexibility: allowing farmers to allocate portions of their land rather than the whole farm [footnote ¹¹⁵⁷], and shorter contracts [footnote ¹¹⁵⁸] or those that are flexible to changes over time [footnote ¹¹⁵⁹]
- schemes that consider social norms and communicate non-financial benefits to participants [footnote ¹¹⁶⁰]

¹¹⁵⁴ Jones, Kam, and Potter, '[Are landholders willing to collaborate under ELMs? Promoting collaborative conservation on a landscape scale in the UK](#)', *Journal of Rural Studies* 103 (2023).';

Limbach, '[What Role for Environmental Cooperatives in Collective Agri-Environmental Schemes?](#)', *Journal of Environmental Planning and Management* 67, no. 7 (2024): 1409–33;

Riley et al., '[Will Farmers Work Together for Conservation? The Potential Limits of Farmers' Cooperation in Agri-Environment Measures](#)';

Schüler et al., '[Initiating Agri-Environmental Collaboration at Landscape Scale Requires Bridging Structures, Regional Facilitators and Addressing the Expectations of Actors](#)'.

¹¹⁵⁵ Baker et al., '[Aligning strategic and participatory approaches to agri-environment scheme design and implementation to enhance nature recovery outcomes](#)'.

¹¹⁵⁶ Prager, '[Implementing Policy Interventions to Support Farmer Cooperation for Environmental Benefits](#)'..

¹¹⁵⁷ Baker et al., '[Aligning strategic and participatory approaches to agri-environment scheme design and implementation to enhance nature recovery outcomes](#)';

Franks, '[An Assessment of the Landscape-Scale Dimensions of Land Based Environmental Management Schemes Offered to Farmers in England](#)';

Emery and Franks, '[The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers' Concerns with Current Schemes?](#)'; Toderi et al., '[Bottom-up design process of agri-environmental measures at a landscape scale: Evidence from case studies on biodiversity conservation and water protection](#)'.

¹¹⁵⁸ Yang et al., '[Spatial Analysis of Agri-Environmental Policy Uptake and Expenditure in Scotland](#)', *Journal of Environmental Management* 133 (2014): 104–15.

¹¹⁵⁹ Waygood, U. A. 2024. [Agri-Environment Evidence Annual Report 2023. A summary of recently published projects](#). Natural England Research Report, NERR138. Natural England;

Franks et al., '[Options for Landscape Scale Collaboration under the UK's Environmental Stewardship Scheme](#)'. (2011) Centre for Rural Economy, University of Newcastle Upon Tyne.

¹¹⁶⁰ Dutton et al., '[Ecological and Social Challenges to Biodiversity Conservation on Farmland: Reconnecting Habitats on a Landscape Scale](#)', *Mammal Review* 38, no. 2–3 (2008): 205–19,;

- farmer control over payment processes [footnote ¹¹⁶¹]
- schemes which take the least amount of land out of production or required the least change. For example, creating hedge networks was viewed positively by 77% of respondents of one UK study, whereas allowing land to revert to semi-natural habitat was viewed as positive by just 14% of respondents [footnote ¹¹⁶²]
- farmer participation in designing and managing schemes [footnote ¹¹⁶³]
- the presence of trusted facilitators to manage the scheme [footnote ¹¹⁶⁴].

Costs of involvement were important in influencing uptake, concerns about impacts on productivity and a requirement for costs to be covered were cited by multiple studies [footnote ¹¹⁶⁵]. Additionally, the development of markets to support sustainable farming practices was cited as a potential motivator in one EU study [footnote ¹¹⁶⁶].

Reichenspurner, Barghusen, and Matzdorf, '[Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes](#)';

Baker et al., '[Aligning strategic and participatory approaches to agri-environment scheme design and implementation to enhance nature recovery outcomes](#)'.

¹¹⁶¹ Limbach, '[What Role for Environmental Cooperatives in Collective Agri-Environmental Schemes?](#)', Journal of Environmental Planning and Management 67, no. 7 (2024): 1409–33

¹¹⁶² Emery and Franks, '[The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers' Concerns with Current Schemes?](#)'.

¹¹⁶³ Emery and Franks, '[The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers' Concerns with Current Schemes?](#)'

¹¹⁶⁴ Jones, Kam, and Potter, '[Are landholders willing to collaborate under ELMs? Promoting collaborative conservation on a landscape scale in the UK](#)', Journal of Rural Studies 103 (2023).

¹¹⁶⁵ Jones, Kam, and Potter, '[Are landholders willing to collaborate under ELMs? Promoting collaborative conservation on a landscape scale in the UK](#)', Journal of Rural Studies 103 (2023).;

Baker et al., '[Aligning strategic and participatory approaches to agri-environment scheme design and implementation to enhance nature recovery outcomes](#)';

Prager, '[Implementing Policy Interventions to Support Farmer Cooperation for Environmental Benefits](#)'.

Barkley, Short, and Chivers, '[Exploring the Potential of Long-Term Agreements for Achieving Landscape-Scale Environmental Recovery](#)';

Jane et al., '[Organising Collective Action for Effective Environmental Management and Social Learning in Wales](#)';

Ellis et al., '[Landscape-Scale Conservation in Practice: Lessons from Northern England, UK](#)'.

Dutton et al., '[Ecological and Social Challenges to Biodiversity Conservation on Farmland: Reconnecting Habitats on a Landscape Scale](#)'.

¹¹⁶⁶ Amblard, Guiffant, and Bussière, '[The Drivers of Farmers' Participation in Collaborative Water Management: A French Perspective](#)'.

The requirement to see tangible results of collaborative action was cited as important for engaging farmers [footnote ¹¹⁶⁷]. Farmers in one UK study were more likely to be involved if they felt the scheme would deliver biodiversity benefits [footnote ¹¹⁶⁸].

Economic Impacts (8 studies)

Positive

One study suggested that transaction costs for individual farmers may be lower when working through a group agreement [footnote ¹¹⁶⁹]. Ecosystem service delivery, such as pollination and water quality improvement, delivered by landscape-scale environmental management can contribute to improved yields for farmers [footnote ¹¹⁷⁰]. Byrne et al. (2024) suggested that collaborations provide space for on-farm experimentation in new and improved business and governance models for farmers [footnote ¹¹⁷¹]. Another advantage of large-scale collaboratives is the opportunity to deliver traditional, low-intensity management across a landscape in a way that might not be commercially viable for single farms. A UK case study of landscape-scale conservation suggested implementing collaborative restoration of woodlands which cross multiple farm boundaries to produce wood fuel, or cross-boundary livestock grazing across greater areas [footnote ¹¹⁷²].

Negative impacts

Negative economic impacts include opportunity costs, potential loss of income through undertaking environmental management, and operational costs of time and labour to

¹¹⁶⁷ Stockdale and Barker, '[Sustainability and the Multifunctional Landscape: An Assessment of Approaches to Planning and Management in the Cairngorms National Park](#)', *Land Use Policy* 26, no. 2 (2009): 479–92; Kam, '[Opportunities for Achieving Landscape Scale Conservation in England](#)'; Matthews, Fish, and Tzanopoulos, '[Overcoming Barriers to Agri-Environmental Management at Landscape Scale: Balancing Farmer Coordination and Collaboration with the Aid of Facilitators and Pioneers](#)'; Baker et al., '[Aligning strategic and participatory approaches to agri-environment scheme design and implementation to enhance nature recovery outcomes](#)'.

¹¹⁶⁸ Franks and Emery, '[Incentivising Collaborative Conservation: Lessons from Existing Environmental Stewardship Scheme Options](#)'.

¹¹⁶⁹ Ibid.

¹¹⁷⁰ McKenzie et al., '[FORUM: Landscape-Scale Conservation: Collaborative Agri-Environment Schemes Could Benefit Both Biodiversity and Ecosystem Services, but Will Farmers Be Willing to Participate?](#)'.

¹¹⁷¹ Byrne, McCarthy, and Ryan-Doyle, '[Leveraging the Potential of Co-Operative Agri-Advisory Services in the Transition to Sustainable and Landscape-Based Agriculture](#)'.

¹¹⁷² Ellis et al., '[Landscape-Scale Conservation in Practice: Lessons from Northern England, UK](#)'.

engage in collaboration [footnote ¹¹⁷³]. If schemes are to be flexible and tailored to local contexts this may also increase administrative costs for the facilitator. One study suggested that overall transaction costs are expected to be higher for group agreements compared to individual ones, though this may be mitigated by spreading the cost among multiple farmers [footnote ¹¹⁷⁴], though this may be mitigated by administrative cost savings in the long term for just one group agreement to be negotiated [footnote ¹¹⁷⁵]. A study of the National Landscapes scheme in the Netherlands found that farming practices under collaborative schemes tend to be less intensive and can constrain economic activity of farmers [footnote ¹¹⁷⁶].

Environmental Impacts (21 studies)

Landscape-scale environmental management has been shown to improve ecological connectivity, reduce habitat fragmentation and improve species dispersal [footnote ¹¹⁷⁷]. This improved landscape permeability allows species to move into new environments and

¹¹⁷³ Baker et al., '[Aligning strategic and participatory approaches to agri-environment scheme design and implementation to enhance nature recovery outcomes](#)';

Jane et al., '[Organising Collective Action for Effective Environmental Management and Social Learning in Wales](#)'.

¹¹⁷⁴ Barkely et al., '[Exploring the Potential of Long-Term Agreements for Achieving Landscape-Scale Environmental Recovery](#)'.

¹¹⁷⁵ Jane et al., '[Organising Collective Action for Effective Environmental Management and Social Learning in Wales](#)'.

¹¹⁷⁶ Janssen, '[Sustainable Development and Protected Landscapes: The Case of the Netherlands](#)', International Journal of Sustainable Development and World Ecology 16, no. 1 (2009): 37–47.

¹¹⁷⁷ Jones, Kam, and Potter, '[Are landholders willing to collaborate under ELMs? Promoting collaborative conservation on a landscape scale in the UK](#)', Journal of Rural Studies 103 (2023);

Franks and Emery, '[Incentivising Collaborative Conservation: Lessons from Existing Environmental Stewardship Scheme Options](#)';

Franks, '[An Assessment of the Landscape-Scale Dimensions of Land Based Environmental Management Schemes Offered to Farmers in England](#)';

Riley et al., '[Will Farmers Work Together for Conservation? The Potential Limits of Farmers' Cooperation in Agri-Environment Measures](#)';

Saraev et al., '[The Potential for Agroforestry to Reduce Net GHG Emissions in Scotland through the Woodland Carbon Code](#)';

Baker et al., '[Landscape-Scale Responses of Birds to Agri-Environment Management: A Test of the English Environmental Stewardship Scheme](#)', Journal of Applied Ecology 49, no. 4 (2012): 871–82;

Jane et al., '[Organising Collective Action for Effective Environmental Management and Social Learning in Wales](#)'.

adapt to climate change [footnote ¹¹⁷⁸] and improves population genetic diversity [footnote ¹¹⁷⁹].

These effects vary depending on the species, species with larger foraging ranges benefit from coordinated landscape management [footnote ¹¹⁸⁰]. A UK study found that 35% of typical farmland species have ranges which exceed the size of an average English farm [footnote ¹¹⁸¹] – examples include bats [footnote ¹¹⁸²], large mammals [footnote ¹¹⁸³], bumblebees [footnote ¹¹⁸⁴], butterflies [footnote ¹¹⁸⁵], hoverflies [footnote ¹¹⁸⁶], moths [footnote ¹¹⁸⁷] and birds [footnote ¹¹⁸⁸]. A UK study into birds found that farms surrounded by a greater proportion of land managed under agri-environmental schemes supported higher

¹¹⁷⁸ Franks and Emery, [‘Incentivising Collaborative Conservation: Lessons from Existing Environmental Stewardship Scheme Options’](#);

Riley et al., [‘Will Farmers Work Together for Conservation? The Potential Limits of Farmers’ Cooperation in Agri-Environment Measures’](#).

¹¹⁷⁹ Riley et al., [‘Will Farmers Work Together for Conservation? The Potential Limits of Farmers’ Cooperation in Agri-Environment Measures?’](#)

¹¹⁸⁰ Franks, [‘The Collective Provision of Environmental Goods: A Discussion of Contractual Issues’](#);

Gabriel et al., [‘Scale Matters: The Impact of Organic Farming on Biodiversity at Different Spatial Scales’](#).

¹¹⁸¹ Mckenzie et al., [‘FORUM: Landscape-Scale Conservation: Collaborative Agri-Environment Schemes Could Benefit Both Biodiversity and Ecosystem Services, but Will Farmers Be Willing to Participate?’](#).

¹¹⁸² Mckenzie et al., [‘FORUM: Landscape-Scale Conservation: Collaborative Agri-Environment Schemes Could Benefit Both Biodiversity and Ecosystem Services, but Will Farmers Be Willing to Participate?’](#); Staley et al., (2022). [Landscape-scale species monitoring of agri-environment schemes](#). UKCEH and BTO. Final report to Natural England, project LM0465.

¹¹⁸³ Ibid.

¹¹⁸⁴ Mckenzie et al., [‘FORUM: Landscape-Scale Conservation: Collaborative Agri-Environment Schemes Could Benefit Both Biodiversity and Ecosystem Services, but Will Farmers Be Willing to Participate?’](#);

Larkin and Stanley, [‘Impacts of Management at a Local and Landscape Scale on Pollinators in Semi-Natural Grasslands’](#), Journal of Applied Ecology 58, no. 11 (2021): 2505–14.

¹¹⁸⁵ Gabriel et al., [‘Scale Matters: The Impact of Organic Farming on Biodiversity at Different Spatial Scales’](#); Larkin and Stanley, [‘Impacts of Management at a Local and Landscape Scale on Pollinators in Semi-Natural Grasslands’](#);

Staley et al., (2022). [Landscape-scale species monitoring of agri-environment schemes](#). UKCEH and BTO. Final report to Natural England, project LM0465.

¹¹⁸⁶ Larkin and Stanley, [‘Impacts of Management at a Local and Landscape Scale on Pollinators in Semi-Natural Grasslands’](#);

Staley et al., (2022). [Landscape-scale species monitoring of agri-environment schemes](#). UKCEH and BTO. Final report to Natural England, project LM0465.

¹¹⁸⁷ Staley et al., (2022). [Landscape-scale species monitoring of agri-environment schemes](#). UKCEH and BTO. Final report to Natural England, project LM0465.

¹¹⁸⁸ Mckenzie et al., [‘FORUM: Landscape-Scale Conservation: Collaborative Agri-Environment Schemes Could Benefit Both Biodiversity and Ecosystem Services, but Will Farmers Be Willing to Participate?’](#);

Dallimer et al., [‘Field-Level Bird Abundances Are Enhanced by Landscape-Scale Agri-Environment Scheme Uptake’](#), Biology Letters 6, no. 5 (2010): 643–46.

abundances of upland specialists and species of conservation concern [footnote ¹¹⁸⁹]. A Swiss study found similar results for plant, butterfly and bird species richness [footnote ¹¹⁹⁰].

Landscape-scale environmental management improves the connectivity of habitats and so increases the overall area of 'good quality' habitat for species to use [footnote ¹¹⁹¹]. This increases species populations [footnote ¹¹⁹²] and improves their resilience to environmental change [footnote ¹¹⁹³]. The importance of linear features like hedgerows and buffer zones were cited by several studies [footnote ¹¹⁹⁴]. Combining landscape-level management with existing designated sites could support their ability to protect rare species [footnote ¹¹⁹⁵].

Ecosystem services tend to be spatially extensive, meaning delivery of ecosystem services can be improved by landscape-scale actions [footnote ¹¹⁹⁶]. Services include pollination, flood storage capacity [footnote ¹¹⁹⁷], water quality [footnote ¹¹⁹⁸], soil erosion and diffuse nutrient pollution [footnote ¹¹⁹⁹].

Social Impacts (14 studies)

The potential social impacts of farmers engaging in landscape-level Collaborative Theme include:

¹¹⁸⁹ Dallimer et al., '[Field-Level Bird Abundances Are Enhanced by Landscape-Scale Agri-Environment Scheme Uptake](#)'.

¹¹⁹⁰ Meier et al., '[Collaborative Approaches at the Landscape Scale Increase the Benefits of Agri-Environmental Measures for Farmland Biodiversity](#)'.

¹¹⁹¹ Gabriel et al., '[Scale Matters: The Impact of Organic Farming on Biodiversity at Different Spatial Scales](#)'; Franks, '[The Collective Provision of Environmental Goods: A Discussion of Contractual Issues](#)'.

¹¹⁹² Waygood, U. A. 2024. [Agri-Environment Evidence Annual Report 2023. A summary of recently published projects](#). Natural England Research Report, NERR138. Natural England.

¹¹⁹³ McKenzie et al., '[FORUM: Landscape-Scale Conservation: Collaborative Agri-Environment Schemes Could Benefit Both Biodiversity and Ecosystem Services, but Will Farmers Be Willing to Participate?](#)'.

¹¹⁹⁴ Franks, '[The Collective Provision of Environmental Goods: A Discussion of Contractual Issues](#)'; Ellis et al., '[Landscape-Scale Conservation in Practice: Lessons from Northern England, UK](#)'.

¹¹⁹⁵ Williams et al., '[Factors Affecting Wetland Ground Beetle \(Carabidae\) Assemblages: How Important Are Habitats, Conservation Designations and Management?](#)', *Insect Conservation and Diversity* 7, no. 3 (2014): 206–22.

¹¹⁹⁶ McKenzie et al., '[FORUM: Landscape-Scale Conservation: Collaborative Agri-Environment Schemes Could Benefit Both Biodiversity and Ecosystem Services, but Will Farmers Be Willing to Participate?](#)'.

¹¹⁹⁷ Jane et al., '[Organising Collective Action for Effective Environmental Management and Social Learning in Wales](#)'.

¹¹⁹⁸ Sinner et al., '[Great Expectations for Collective Management](#)'.

¹¹⁹⁹ Jane et al., '[Organising Collective Action for Effective Environmental Management and Social Learning in Wales](#)'.

- increased confidence to undertake management and engage with their neighbours [footnote ¹²⁰⁰]
- improved social learning and sharing of knowledge and skills [footnote ¹²⁰¹]
- improved communication between farmers, leading to relationship building [footnote ¹²⁰²], improved trust [footnote ¹²⁰³] and improved community networks [footnote ¹²⁰⁴]
- improved social capital for individual farmers [footnote ¹²⁰⁵]
- improved sense of purpose and identity [footnote ¹²⁰⁶]

¹²⁰⁰ Limbach, ['What Role for Environmental Cooperatives in Collective Agri-Environmental Schemes?'](#), Journal of Environmental Planning and Management 67, no. 7 (2024): 1409–33;

Wynne-Jones, S. ['Understanding Farmer Co-Operation: Exploring Practices of Social Relatedness and Emergent Affects'](#), Journal of Rural Studies 53 (1 July 2017): 259–68;

Reichensperner, Barghusen, and Matzdorf, ['Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes'](#);

Jane et al., ['Organising Collective Action for Effective Environmental Management and Social Learning in Wales'](#).

¹²⁰¹ Reichensperner, Barghusen, and Matzdorf, ['Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes'](#);

Prager, ['Implementing Policy Interventions to Support Farmer Cooperation for Environmental Benefits'](#);

de Loë, Murray, and Simpson, ['Farmer Perspectives on Collaborative Approaches to Governance for Water'](#), Journal of Rural Studies 42 (2015): 191–205 ;

Jane et al., ['Organising Collective Action for Effective Environmental Management and Social Learning in Wales'](#);

Janssen, ['Sustainable Development and Protected Landscapes: The Case of the Netherlands'](#).

¹²⁰² Reichensperner, Barghusen, and Matzdorf, ['Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes'](#);

de Loë, Murray, and Simpson, ['Farmer Perspectives on Collaborative Approaches to Governance for Water'](#).

¹²⁰³ Mathevet et al., ['Protected Areas and Their Surrounding Territory: Socioecological Systems in the Context of Ecological Solidarity'](#).

¹²⁰⁴ Opdam et al., ['Does Information on Landscape Benefits Influence Collective Action in Landscape Governance?'](#)

¹²⁰⁵ Prager, ['Implementing Policy Interventions to Support Farmer Cooperation for Environmental Benefits'](#);

Schüler et al., ['Initiating Agri-Environmental Collaboration at Landscape Scale Requires Bridging Structures, Regional Facilitators and Addressing the Expectations of Actors'](#);

Franks, ['The Collective Provision of Environmental Goods: A Discussion of Contractual Issues'](#);

Mathevet et al., ['Protected Areas and Their Surrounding Territory: Socioecological Systems in the Context of Ecological Solidarity'](#).

¹²⁰⁶ Scott and Shannon, ["Local Landscape Designations in Scotland: Opportunity or Barrier to Effective Landscape Management?"](#).

- greater cultural embeddedness of pro-environmental behaviours and techniques [footnote ¹²⁰⁷].

Barriers (26 studies)

Barriers to uptake of landscape-scale collaborative actions include:

- fears around increased transaction costs to farmers through increased time, labour and potential impacts on productivity [footnote ¹²⁰⁸]
- distrust of collaborative or agri-environment schemes due to previous bad experiences [footnote ¹²⁰⁹]

¹²⁰⁷ Reichenspurner, Barghusen, and Matzdorf, '[Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes](#)';

Prager, '[Implementing Policy Interventions to Support Farmer Cooperation for Environmental Benefits](#)';

de Loë, Murray, and Simpson, '[Farmer Perspectives on Collaborative Approaches to Governance for Water](#)';

Jane et al., '[Organising Collective Action for Effective Environmental Management and Social Learning in Wales](#)';

Janssen, '[Sustainable Development and Protected Landscapes: The Case of the Netherlands](#)'.

¹²⁰⁸ Amblard, Guiffant, and Bussière, '[The Drivers of Farmers' Participation in Collaborative Water Management: A French Perspective](#)';

Franks and Emery, '[Incentivising Collaborative Conservation: Lessons from Existing Environmental Stewardship Scheme Options](#)';

Franks, '[An Assessment of the Landscape-Scale Dimensions of Land Based Environmental Management Schemes Offered to Farmers in England](#)';

Häfner and Pierr, '[Farmers' Perception of Co-Ordinating Institutions in Agri-Environmental Measures – The Example of Peatland Management for the Provision of Public Goods on a Landscape Scale](#)';

Westerink et al., '[Collaborative Governance Arrangements to Deliver Spatially Coordinated Agri-Environmental Management](#)';

Schüler et al., '[Initiating Agri-Environmental Collaboration at Landscape Scale Requires Bridging Structures, Regional Facilitators and Addressing the Expectations of Actors](#)';

Dutton et al., '[Ecological and Social Challenges to Biodiversity Conservation on Farmland: Reconnecting Habitats on a Landscape Scale](#)'.

¹²⁰⁹ Jones, Kam, and Potter, '[Are landholders willing to collaborate under ELMs? Promoting collaborative conservation on a landscape scale in the UK](#)', *Journal of Rural Studies* 103 (2023).

- fears around scheme conditions restricting farmers control over their own land [footnote ¹²¹⁰] and inhibiting their flexibility for future management [footnote ¹²¹¹]
- lack of knowledge [footnote ¹²¹²] and access to advisory support [footnote ¹²¹³] for designing ecological networks
- problems for tenants such as permissions from landowners [footnote ¹²¹⁴] and short-term tenancies [footnote ¹²¹⁵]
- fears about the need for facilitators who may bring interests into the group which conflict with those of the original participants [footnote ¹²¹⁶]
- a lack of existing social connection and cooperation between farmers to build from [footnote ¹²¹⁷]

¹²¹⁰ Raymond et al., '[Integrating Different Understandings of Landscape Stewardship into the Design of Agri-Environmental Schemes](#)';

Wynne-Jones, S. '[Understanding Farmer Co-Operation: Exploring Practices of Social Relatedness and Emergent Affects](#)';

Schüler et al., '[Initiating Agri-Environmental Collaboration at Landscape Scale Requires Bridging Structures, Regional Facilitators and Addressing the Expectations of Actors](#)'.

¹²¹¹ Dutton et al., '[Ecological and Social Challenges to Biodiversity Conservation on Farmland: Reconnecting Habitats on a Landscape Scale](#)';

Barkley, Short, and Chivers, '[Exploring the Potential of Long-Term Agreements for Achieving Landscape-Scale Environmental Recovery](#)'.

¹²¹² Schüler et al., '[Initiating Agri-Environmental Collaboration at Landscape Scale Requires Bridging Structures, Regional Facilitators and Addressing the Expectations of Actors](#)';

Riley et al., '[Will Farmers Work Together for Conservation? The Potential Limits of Farmers' Cooperation in Agri-Environment Measures](#)';

Jones, Kam, and Potter, '[Are landholders willing to collaborate under ELMs? Promoting collaborative conservation on a landscape scale in the UK](#)', *Journal of Rural Studies* 103 (2023).

¹²¹³ Kam, '[Opportunities for Achieving Landscape Scale Conservation in England](#)'.

¹²¹⁴ Baker et al., '[Landscape-Scale Responses of Birds to Agri-Environment Management: A Test of the English Environmental Stewardship Scheme](#)';

Emery and Franks, '[The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers' Concerns with Current Schemes?](#)'.

¹²¹⁵ Franks and Emery, '[Incentivising Collaborative Conservation: Lessons from Existing Environmental Stewardship Scheme Options](#)'.

¹²¹⁶ Westerink et al., '[Collaborative Governance Arrangements to Deliver Spatially Coordinated Agri-Environmental Management](#)'.

¹²¹⁷ Baker et al., '[Landscape-Scale Responses of Birds to Agri-Environment Management: A Test of the English Environmental Stewardship Scheme](#)';

Emery and Franks, '[The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers' Concerns with Current Schemes?](#)';

Schüler et al., '[Initiating Agri-Environmental Collaboration at Landscape Scale Requires Bridging Structures, Regional Facilitators and Addressing the Expectations of Actors](#)'.

- low levels of existing engagement with outside organisations [footnote ¹²¹⁸]
- increasing proportions of landowners being non-farmers, leading to reduced trust within farming groups [footnote ¹²¹⁹]
- the perception that collaborative management is in conflict with individualist [footnote ¹²²⁰] and productivist identities of being a 'good farmer' [footnote ¹²²¹]
- fears that other participants will act as 'free riders' and not contribute to the group [footnote ¹²²²]
- concerns over signing up to a scheme which may impact future generations on the farm [footnote ¹²²³]

¹²¹⁸ Stockdale and Barker, '[Sustainability and the Multifunctional Landscape: An Assessment of Approaches to Planning and Management in the Cairngorms National Park](#)'.

¹²¹⁹ Kam, '[Opportunities for Achieving Landscape Scale Conservation in England](#)'.

¹²²⁰ Baker et al., '[Landscape-Scale Responses of Birds to Agri-Environment Management: A Test of the English Environmental Stewardship Scheme](#)';

Reichenspurner, Barghusen, and Matzdorf, '[Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes](#)';

Prager, '[Implementing Policy Interventions to Support Farmer Cooperation for Environmental Benefits](#)';

Emery and Franks, '[The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers' Concerns with Current Schemes?](#)'; de Loë, Murray, and

Simpson, '[Farmer Perspectives on Collaborative Approaches to Governance for Water](#)'; Wynne-Jones,

'[Understanding Farmer Co-Operation: Exploring Practices of Social Relatedness and Emergent Affects](#)';

Riley et al., '[Will Farmers Work Together for Conservation? The Potential Limits of Farmers' Cooperation in Agri-Environment Measures](#)'

¹²²¹ Baker et al., '[Landscape-Scale Responses of Birds to Agri-Environment Management: A Test of the English Environmental Stewardship Scheme](#)';

Reichenspurner, Barghusen, and Matzdorf, '[Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes](#)';

Riley et al., '[Will Farmers Work Together for Conservation? The Potential Limits of Farmers' Cooperation in Agri-Environment Measures](#)';

Byrne, McCarthy, and Ryan-Doyle, '[Leveraging the Potential of Co-Operative Agri-Advisory Services in the Transition to Sustainable and Landscape-Based Agriculture](#)'.

¹²²² Reichenspurner, Barghusen, and Matzdorf, '[Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes](#)';

Emery and Franks, '[The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers' Concerns with Current Schemes?](#)'.

¹²²³ Barkley, Short, and Chivers, '[Exploring the Potential of Long-Term Agreements for Achieving Landscape-Scale Environmental Recovery](#)'.

- existing conflict with other farmers [footnote ¹²²⁴]
- administrative and time burdens of engaging with and managing collaborative groups [footnote ¹²²⁵]
- lack of access to legal advice for managing contracts and allocating payments within groups [footnote ¹²²⁶]
- perceived unwillingness of government to decentralise decision making [footnote ¹²²⁷].

Evidence Gaps (15 studies)

Multiple studies highlighted a lack of research into farmer motivation to engage in collaborative landscape schemes [footnote ¹²²⁸], as well as few real-life examples of collaborative landscape schemes [footnote ¹²²⁹] and research into how they can best be

¹²²⁴ Matthews, Fish, and Tzanopoulos, '[Overcoming Barriers to Agri-Environmental Management at Landscape Scale: Balancing Farmer Coordination and Collaboration with the Aid of Facilitators and Pioneers](#)'; de Loë, Murray, and Simpson, '[Farmer Perspectives on Collaborative Approaches to Governance for Water](#)'; Riley et al., '[Will Farmers Work Together for Conservation? The Potential Limits of Farmers' Cooperation in Agri-Environment Measures](#)'

¹²²⁵ Matthews, Fish, and Tzanopoulos, '[Overcoming Barriers to Agri-Environmental Management at Landscape Scale: Balancing Farmer Coordination and Collaboration with the Aid of Facilitators and Pioneers](#)'; Schüller et al., '[Initiating Agri-Environmental Collaboration at Landscape Scale Requires Bridging Structures, Regional Facilitators and Addressing the Expectations of Actors](#)'; de Loë, Murray, and Simpson, '[Farmer Perspectives on Collaborative Approaches to Governance for Water](#)'; Ellis et al., '[Landscape-Scale Conservation in Practice: Lessons from Northern England, UK](#)'; Häfner and Piore, '[Farmers' Perception of Co-Ordinating Institutions in Agri-Environmental Measures – The Example of Peatland Management for the Provision of Public Goods on a Landscape Scale](#)'.

¹²²⁶ Jane et al., '[Organising Collective Action for Effective Environmental Management and Social Learning in Wales](#)';

Barton, '[From Parks to Partnerships: National Heritage Areas and the Path to Collaborative Participation in the National Park Service's First 100 Years](#)', *Natural Resources Journal* 56, no. 1 (2016): 23–54.

¹²²⁷ Franks, '[The Collective Provision of Environmental Goods: A Discussion of Contractual Issues](#)'.

¹²²⁸ Jones, Kam, and Potter, '[Are landholders willing to collaborate under ELMs? Promoting collaborative conservation on a landscape scale in the UK](#)', *Journal of Rural Studies* 103 (2023).;

Franks, '[An Application of Boundary Organisation Theory to Develop Landscape-Scale Conservation in Formal Agri-Environment Schemes](#)';

Matthews, Fish, and Tzanopoulos, '[Overcoming Barriers to Agri-Environmental Management at Landscape Scale: Balancing Farmer Coordination and Collaboration with the Aid of Facilitators and Pioneers](#)'.

¹²²⁹ Barkley, Short, and Chivers, '[Exploring the Potential of Long-Term Agreements for Achieving Landscape-Scale Environmental Recovery](#)'.

designed on the ground [footnote ¹²³⁰]. 2 studies highlighted that there is a lack of research into the difference between landscape-scale and farm scale agri-environmental schemes in terms of cost effectiveness [footnote ¹²³¹] and trade-offs [footnote ¹²³²]. Long-term datasets of species abundance and diversity at landscape scales are still lacking [footnote ¹²³³].

Cost-effectiveness Evidence (2 studies)

A study from Wales suggested that provision of advice to groups of farmers could produce 'economies of scale' whereby the advice travels further than if it was given to just one individual [footnote ¹²³⁴]. Additionally, reductions in administration for the group and/or administrator (such as the government) may arise when collaborative schemes employ single contracts/agreements with external organisations instead of individual agreements for each farmer [footnote ¹²³⁵].

Critical Success Factors

Strategic fit and business needs: High alignment

The evidence suggests that the Theme Collaborative Landscape Scale aligns strongly with Strategic fit and business needs Critical Success Factor, along with the objectives of the Well-being of Future Generations (Wales) Act 2015 and the Agriculture (Wales) Act 2023. It

¹²³⁰ Reichensperner, Barghusen, and Matzdorf, '[Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes](#)';

Prager, '[Implementing Policy Interventions to Support Farmer Cooperation for Environmental Benefits](#)'; Häfner and Piore, '[Farmers' Perception of Co-ordinating Institutions in Agri-Environmental Measures – The Example of Peatland Management for the Provision of Public Goods on a Landscape Scale](#)'.

¹²³¹ Prager, '[Implementing Policy Interventions to Support Farmer Cooperation for Environmental Benefits](#)'.

¹²³² Raymond et al., '[Integrating Different Understandings of Landscape Stewardship into the Design of Agri-Environmental Schemes](#)'.

¹²³³ Staley et al., (2022). [Landscape-scale species monitoring of agri-environment schemes](#). UKCEH and BTO. Final report to Natural England, project LM0465;

Waygood, U. A. 2024. [Agri-Environment Evidence Annual Report 2023. A summary of recently published projects](#). Natural England Research Report, NERR138. Natural England.

¹²³⁴ Jane et al., '[Organising Collective Action for Effective Environmental Management and Social Learning in Wales](#)'.

¹²³⁵ Jane et al.; Franks, '[The Collective Provision of Environmental Goods: A Discussion of Contractual Issues](#)';

Franks, '[An Assessment of the Landscape-Scale Dimensions of Land Based Environmental Management Schemes Offered to Farmers in England](#)'.

is supported, in theory, by farmers and can deliver positive economic, environmental and social outcomes, with appropriate support.

Value for money: High alignment

Evidence suggests that if properly supported, the Theme Collaborative Landscape Scale Activity has the potential for high alignment with the Value for money Critical Success Factor. If properly supported, this Theme can be accessible to farmers and contribute to mitigation and adaptation to climate change and improving ecosystem resilience and service delivery. This Theme may contribute to behaviour change and embedding sustainable farming practices in communities.

Supply side capacity and capability: Medium alignment

This Theme can support farmers in building support networks and improving the delivery of environmental outcomes across landscapes, however, building on existing networks and institutions is advised to improve uptake. Advisory services are also needed to mitigate barriers to collaboration. The reviewed evidence therefore suggests the Theme Collaborative Landscape Scale Activity has a medium alignment with Supply side capacity and capability.

Affordability: Medium alignment

This Theme, if properly supported, offers medium alignment with the Affordability CSF as certain collaborative activities can be delivered at low cost to farmers. There was no evidence identified that additional investment may be catalysed through this Theme.

Collaborative Market and Supply Chain

The objective of the Theme Collaborative Market and Supply Chain is to support activities which add value to produce, to access new markets, to provide opportunities for adding value to produce, to develop supply chain opportunities. On-farm and wider supply chain activities for this Theme will:

- provide a thorough understanding of the market in order to better align production with customer requirements
- support diversification to exploit niche opportunities
- use the public perception in and outside of Wales as a USP
- build networks and clusters of businesses and others to create strong, diversified supply chains which are market focussed and can share knowledge and expertise
- focus on technical improvement and new product development, as well as promoting innovation across the supply chain
- develop export markets and inward investment
- upskill and transfer knowledge
- support and encourage to participation in Local Food Partnerships to create local networks of food production and related activity – either directly through producing and supplying or by making land or other assets available for third parties.

Sections of this chapter have considered options around the development of timber as a commercial opportunity for farm businesses, however it should be noted that commercial timber is only one potential opportunity, with other non-timber produce also able to be harvested from woodlands. Therefore, as this review focused on commercial timber, it should be considered a limited assessment in this regard.

Due to overlaps in on-farm practices with other Themes, additional evidence for this Theme can be found in:

- Collaborative Innovation, Research and Development.

REA Exclusion / Inclusion Criteria

Inclusion: Studies relating to support for activities concentrating on added value, new markets and supply chain opportunities in agriculture and farming.

Exclusion: Studies relating solely to countries outside of Europe or without a practical focus (where possible).

Evidence Base

Using Scopus, 142 studies were identified as in scope of the evidence assessment. An additional 6 evaluation reports from UK devolved administrations were included. Using quality and relevance criteria 68 articles were analysed. There was a dearth of academic literature on practical applications or evidence-based examples, with the majority of the articles reviewed discussing the identification of issues or the development of frameworks to measure impacts.

Of the studies reviewed;

- 15 related to understanding a changing market for products
- 18 related to diversification and collaboration
- 16 related to supply chains and networking
- 14 covered technical improvements and new products
- 4 related to knowledge transfer and innovation.

None related specifically to public perceptions in and outside of Wales as a USP (although the Value of Welshness report commissioned by the Welsh Government Food and Drink Division [footnote ¹²³⁶] could provide insights). Encouragement to create local networks is covered in the supply chains category, as far as it was identified.

¹²³⁶ [The Value of Welshness](#)

Design of the Intervention (67 studies)

Changing market for Products (15 studies reviewed)

In terms of consumer pressures and influences on food choices, research [footnote ¹²³⁷] showed that consumers expressed rising concerns over food prices and associated food poverty and inequality, leading to choosing cheaper alternatives to branded products. However, 77% of those interviewed expressed concern about the over processing of food. In wider terms, 11 of the articles described changes in consumer markets which could present opportunities (or threats) to Welsh farming. Key to these was a general acknowledgement that red meat is likely to play a less significant part in the public diet [footnote ¹²³⁸], citing existing recommendations to reduce meat consumption for both environmental reasons, such as land use and greenhouse gas emissions, and health concerns, as evidence links red, particularly processed, meat consumption with increased colorectal cancer risk. In addition, with rising concerns over soil health and food security, the evidence shows that current production systems will be unable to meet the demand for protein whilst addressing climate change [footnote ¹²³⁹]. A study of UK farmers and landowners [footnote ¹²⁴⁰] found that farmers are more concerned about the vulnerability of the food chain, in the context of climate change, trade policies, competition for land and ecological collapse, than a comparator group of food system experts interviewed in similar research. Currently, research shows that Welsh consumers absorb only a small proportion of the main Welsh farm outputs. Just 5% of Welsh red meat output is consumed in Wales [footnote ¹²⁴¹].

Overall, food and drink exports in Wales increased in 2023, from £797 million to £813 million [footnote ¹²⁴²], broadly in line with overall sector growth from £6.2 billion to £7.0 billion. Contrary to the academic consensus, Welsh meat and meat products experienced a

¹²³⁷ Cotton, C., Gosschalk, K., & Konn, J. (2024). '[Consumer Insights Tracker Report \(July 2023 - March 2024\)](#)'. *FSA Research and Evidence*.

¹²³⁸ Spiro, A.; Hill, Z.; Stanner, S., '[Meat and the future of sustainable diets—Challenges and opportunities](#)'; Nutrition Bulletin, October 2024

¹²³⁹ Ibid.

¹²⁴⁰ Jones, A., S. Bridle, P. Falloon, J. Fredenburgh, and C. Reynolds. '[Results of a Survey of UK Farmers on Food System Vulnerability over the Short and Long Term](#)'. Sustainability (Switzerland) 16, no. 16 (2024).

¹²⁴¹ Bowman, Froud, Haslam, Johal, Morgan, and Williams. '[What can Welsh Government do to increase the number of grounded SME firms in food processing and distribution?](#)'. Foundational Economy Research. 2021.

¹²⁴² Food and Drink Wales; '[Annual Export Bulletin 2024](#)' Welsh Government 2024

significant increase in turnover of 19% in 2023, the bulk of which was in the UK market [footnote ¹²⁴³]. This level of increase was mirrored in other sectors of production.

Key exports were meat and meat products (£234 million) for which France remains the key market, cereals and cereal preparations (£130 million) and dairy products and eggs (£99 million). Despite the UK's Exit from the EU, the EU remains the main trading partner, accounting for more than 50% of all exports in each food and drink category. [footnote ¹²⁴⁴] Beyond the EU, Saudi Arabia was the largest market for Welsh goods (£25 million), for which cereals and cereal preparations were the largest category.

In terms of changes to farming practice to reflect changing consumer tastes, a UK study [footnote ¹²⁴⁵] proposed a widespread shift to growing legumes as a means of crop diversification, noting the historic presence of legumes in farming rotations prior to the post-war "green revolution". Evidence noted that there is no research base to consider the alignment of agriculture (and agricultural support) aligning to healthier diets, or the impact of production aligned to dietary change on pesticide impacts and nutrient leaching [footnote ¹²⁴⁶].

A Welsh study [footnote ¹²⁴⁷] looked at livestock farmers' perceptions of a transition to plant-based diets and suggested that in the short-term, uncertainty makes farmers unlikely to change practice, although a trigger event might occur once livestock farmers are certain that consumer trends and climate mitigation require change. Social norms and reluctance to change in the face of accepted practice and views of the community about what constitutes "good farming" were also found to play a part. The research reported that capacity for change might be enhanced by portraying plant crops as a revival of historic practices from

¹²⁴³ Food and Drink Wales; ['Economic Appraisal'](#) Welsh Government 2024

¹²⁴⁴ Ibid.

¹²⁴⁵ Cusworth, George, Tara Garnett, and Jamie Lorimer. ['Agroecological Break out: Legumes, Crop Diversification and the Regenerative Futures of UK Agriculture'](#), Journal of Rural Studies 88 (December 2021): 126–37.

¹²⁴⁶ Sharp, R., A. S. Bellamy, A. Clear, S. M. Finnigan, E. Furness, E. Meador, H. Metcalfe, et al. ['Implications and Impacts of Aligning Regional Agriculture with a Healthy Diet'](#), Journal of Cleaner Production 449 (5 March 2024): 141375.

¹²⁴⁷ Craft, R., and H. Pitt. ['More than Meat? Livestock Farmers' Views on Opportunities to Produce for Plant-Based Diets'](#). Agriculture and Human Values 41, no. 3 (2024): 975–88.

traditional farming landscapes to address this. It should be noted that the ability to move away from livestock farming will be limited by land type [footnote ¹²⁴⁸].

Diversification and Collaboration (18 studies reviewed)

Several of the studies that were reviewed dealt with different models for diversification. One categorised diversification into 3 paradigms [footnote ¹²⁴⁹]:

- pluriactivity within the (existing) agro-industrial model, that is, broadening the range of activities carried out, without changing the fundamental model of farming delivery
- “post productivism”, where land uses beyond primary production become central to the farm enterprise, and
- a wider role as part of a sustainable rural development model.

This example compared diversification on farms in Wales to those in Tuscany to illustrate these models.

In terms of diversification within a production model, a UK study developed spatial projections for the suitability of growing alternative crops in the face of climate change, at a regional level [footnote ¹²⁵⁰]. The research showed that the optimum siting for many existing crops will change (further north and west) and that opportunities for increasing cultivation of soy, chickpeas and grapes will increase. The research called for significant support to prepare farmers to accommodate these changes, if food security is to be assured.

Producing for niche markets was covered in several research studies. One study modelled the impact of a shift to 100% pasture-fed beef farming in the UK [footnote ¹²⁵¹]. This was predicated on perceptions that feed ingredients used in conventional systems, such as

¹²⁴⁸ Bowman et al., ‘[What can Welsh Government do to increase the number of grounded SME firms in food processing and distribution?](#)’. Foundational Economy Research. 2021.

¹²⁴⁹ Morgan, Selyf Lloyd, Terry Marsden, Mara Miele, and Adrian Morley. ‘[Agricultural Multifunctionality and Farmers’ Entrepreneurial Skills: A Study of Tuscan and Welsh Farmers](#)’. Journal of Rural Studies 26, no. 2 (1 April 2010): 116–29.

¹²⁵⁰ Redhead, J.W., M. Brown, J. Price, E. Robinson, R.J. Nicholls, R. Warren, and R.F. Pywell. ‘[National Horizon Scanning for Future Crops Under a Changing UK Climate](#)’. Climate Resilience and Sustainability 4, no. 1 (2025).

¹²⁵¹ Rowe, E., L. Norton, A. McVittie, C. Watson, M. Wagner, C. Waterton, and L. Smith. ‘[Using Fuzzy Cognitive Mapping to Assess the Sustainability Impacts of Transitioning to Pasture-Fed Production in the UK Beef Sector](#)’. Renewable Agriculture and Food Systems 40 (2025).

soybean, are imported and often implicated with deforestation and habitat destruction elsewhere in the world and that pasture fed systems can be used to build soil health and biodiversity. In another example, Scottish farmers grew organic canola (oilseed rape) as a high value, low yielding crop, opening up a new niche market and alternative income source. However, another study [footnote ¹²⁵²] pointed out that ‘climate and topography limit the scope for the highly desirable large-scale diversification of Welsh farmers into arable and horticulture.’

UK insect production as a source of protein was evidenced in other research [footnote ¹²⁵³]. Uptake of the activity was reported to be slow, with barriers such as consumer perceptions, ambiguous regulations and a lack of supply chain affecting adoption.

Studies looking at wider diversification beyond primary production covered a range of activities which might benefit from collaborative action. Farmers’ markets were identified as providing a useful means of finding alternative distribution mechanisms for some farmers and growers [footnote ¹²⁵⁴]. The research identified that social networks created through farmers’ markets provided the contacts for wider collaboration and innovation to develop. Another study reviewed farm shops as a diversification strategy [footnote ¹²⁵⁵], citing an opportunity for greater impact through co-operation and networking through supply relationships and collaborative marketing. Another questioned why farmer co-operation is comparatively rare in the UK compared with other nations [footnote ¹²⁵⁶]. The study examined practice in the Netherlands to understand how co-operation could be encouraged in the UK. The research concluded that support is needed to address scepticism amongst farmers about the co-operative model, and especially around governance, and that farming industry bodies currently see other priorities for their members. A further study [footnote ¹²⁵⁷]

¹²⁵² Bowman et al., ‘[What can Welsh Government do to increase the number of grounded SME firms in food processing and distribution?](#)’. Foundational Economy Research. 2021.

¹²⁵³ Tiwasing, P., and L. Pate. ‘[Exploring Edible Insects as Feed in the UK: Current Challenges and Future Prospects](#)’. Journal of Insects as Food and Feed 11, no. 1 (2025): 139–55.

¹²⁵⁴ ‘[Building Resilience through Post-Productivism : The Case of Farmers](#)’, Markets - CORE’. Accessed 3 April 2025.

¹²⁵⁵ Slocum, Susan, and Kynda Curtis. ‘[Farm Diversification through Farm Shop Entrepreneurship in the UK](#)’, 2017.

¹²⁵⁶ MacMillan, Tom, and George Cusworth. ‘[Farmer Co-Operation in the UK: Opportunities for the Industry](#)’. Report. Co-operatives UK and RAU, 10 October 2019.

¹²⁵⁷ Griffin, R.G., and M. Phillips. ‘[The Farm Shop as a Retroscaped Place of Experiential Consumption](#)’. Sociologia Ruralis 64, no. 4 (2024): 613–38.

noted the benefits of creating on-farm experiences as a means to engage consumers and build short supply chains.

This category also included development of care farms [footnote ¹²⁵⁸], which were found to have grown rapidly, despite some reported challenges in establishing the activity at farm level because of a lack of enabling systems and lack of trust from actors within the wider health and care sector. Farmers delivering care activities reported high levels of satisfaction once established.

A Northern Ireland study looked at drivers of agroforestry adoption in Ireland and the nations of the UK. England and Wales were found to historically have the lowest-paid schemes, with no establishment payment and the lowest annual maintenance payments [footnote ¹²⁵⁹].

A Welsh Government literature review identified several studies that have considered the role of tree plantations to produce timber products as an alternative diversification strategy for farmers. Government incentives and legislative changes were cited as important to support farmers in undertaking commercial forestry on their land [footnote ¹²⁶⁰].

Another area covered by the research identified was that of energy production and integration, such as growing biomass crops or agri-voltaics, and the combining of ground-mounted solar photovoltaic panels with horticulture, animal grazing or ecosystem services. A study of perennial biomass crops called for greater government measures to give confidence to the market and support the development of the supply chain [footnote ¹²⁶¹]. Another looked at anaerobic digestion of various biowastes to produce biogas for combined heat and power to meet the energy demands of a dairy farm, including electricity, heating, and cooling. The project also modelled a larger unit with carbon capture included, selling surplus electricity into the grid. Both models had payback periods of 11 to 12 years.

¹²⁵⁸ Leck, Chris, Nick Evans, and Dominic Upton. '[Agriculture – Who Cares? An Investigation of “Care Farming” in the UK](#)'. *Journal of Rural Studies* 34 (1 April 2014): 313–25.

¹²⁵⁹ Olave, R.J., J. Smith, and J.H. McAdam. '[Drivers of Agroforestry Adoption in Northern Ireland in the Context of British and Irish Policy](#)'. *Agroforestry Systems* 99, no. 3 (2025).

¹²⁶⁰ Welsh Government (2025). [Strategies and interventions to support the timber industry: literature review \(summary\)](#).

¹²⁶¹ Ingram, J., J. Mills, and H. Mackley-Ward. "[For All Kinds of Reasons, It Hasn't Happened”: A Novel Integrative Perspective for Analysing the Barriers to Biomass Crops for Bioenergy in the United Kingdom](#)". *Energy Research and Social Science* 120 (2025).

One German study [footnote ¹²⁶²] researched the potential ecosystem benefits through habitat enhancement in more than 50 large solar farms. The planting of trees, shrubs and pollinator flowers led to significant increases in pollinator activity, reduced sediments in run off and water retention.

An example of the wider role of diversification in placemaking and rural development looked at heritage craft entrepreneurship in Norway and the UK, featuring a tweed-based textile business working alongside other rural entrepreneurs in a heritage building [footnote ¹²⁶³]. The study highlights the importance of connecting, organising, and co-developing to build entrepreneurial networks in rural settings around a central place.

Supply Chains and Networking (16 studies reviewed)

Much of the identified research on agri-food supply chains deals with achieving resilience and efficiency through collaboration and technology. One study took a multi-disciplinary approach to building supply chain resilience, noting that complex global supply chains may have thousands of actors and risk factors attached to them [footnote ¹²⁶⁴]. The research noted a need for supply chain actors to work together to anticipate disruptions and adopt an adaptive approach to supply chain design and management. One study identified a lack of SMEs in Welsh food processing and distribution, which, combined with low financial margins in food processing, reduced demand for Welsh goods and increased reliance on imported foods [footnote ¹²⁶⁵]. The research also recommended engaging with supermarkets to recruit more Welsh SME suppliers. This was backed up to some extent in other research [footnote ¹²⁶⁶], which showed that although there had been an increase in

¹²⁶² Ludzuweit, A., J. Paterson, K. Wydra, C. Pump, K. Müller, and Y. Miller. '[Enhancing Ecosystem Services and Biodiversity in Agrivoltaics through Habitat-Enhancing Strategies](#)'. Renewable and Sustainable Energy Reviews 212 (2025).

¹²⁶³ Jevnaker, B.H., and I. Hill. '[Heritage Craft Entrepreneurship in 'the Wild': The Role of Entrepreneurial Placemaking for Rural Development](#)'. Contemporary Issues in Entrepreneurship Research 18B (2024): 213–26.

¹²⁶⁴ Stone, Jamie, and Shahin Rahimifard. '[Resilience in Agri-Food Supply Chains: A Critical Analysis of the Literature and Synthesis of a Novel Framework](#)'. Supply Chain Management: An International Journal 23, no. 3 (27 March 2018): 207–38.

¹²⁶⁵ Bowman et al., '[What can Welsh Government do to increase the number of grounded SME firms in food processing and distribution?](#)'. Foundational Economy Research. 2021.

¹²⁶⁶ Food and Drink Wales; '[Economic Appraisal](#)' Welsh Government 2024

food and drink businesses in Wales in 2023, the majority were micro businesses and there had been a reduction in the number of medium sized firms.

A UK Parliament review [footnote ¹²⁶⁷] noted that shifting towards shorter domestic food supply chains may be an opportunity to increase the profitability of UK farm businesses and may also provide resilience to the impacts of extreme climate events on food supply chains. Some research explored alternative models of working, including Community Supported Agriculture schemes (CSAs) [footnote ¹²⁶⁸]. CSAs use a subscription-based model to support farmers and growers in advance, with members taking a share of the produce (and distributing the risk). These are said to bring about a collaborative supply relationship with consumers, who can become part of production and improve perceptions of social and environmental benefits. However, the study contrasted the greater engagement with CSAs in Norway compared with that of the UK, possibly reflecting social conservatism in the UK. There is an opportunity to stimulate collaborative efforts to engage communities in growing (and to a lesser extent animal husbandry) to develop localised supply chains.

A UK study highlighted a lack of data on the drivers of food loss and waste [footnote ¹²⁶⁹]. The results estimated that 37% of fruit and vegetables are lost between production and retail – primarily at primary production stage. 4 crops (apples, onions, carrots and potatoes) accounted for more than 70% of the losses. The research called for the development of processing networks to use surplus produce, possibly linked to public procurement, along with action to improve quality and storability of produce. A wider study echoed this, [footnote ¹²⁷⁰] proposing a need for collaborative action amongst salient stakeholders in the supply chain to retail products which did not conform to aesthetic standards (such as wonky vegetables and fruit). A further study proposed reframing farm waste as a resource

¹²⁶⁷ Dillon, Alistair, and Jonathan Wentworth. '[Food Systems, Food Security and Supply Chains](#)', 21 November 2024.

¹²⁶⁸ Milford, A.-B., D. Keech, and S.W. Muiruri. '[Community Supported Agriculture's Perceived Positive Impacts on Mental Health and Vegetable Consumption in Norway and the UK](#)'. *Agricultural and Food Economics* 13, no. 1 (2025).

¹²⁶⁹ Gage, E., L.A. Terry, and N. Falagán. '[Biological Factors and Production Challenges Drive Significant UK Fruit and Vegetable Loss](#)'. *Journal of the Science of Food and Agriculture* 105, no. 4 (2025): 2109–17.

¹²⁷⁰ Surucu-Balci, Ebru, and Okan Tuna. '[The Role of Collaboration in Tackling Food Loss and Waste: Salient Stakeholder Perspective](#)'. *Journal of Cleaner Production* 367 (20 September 2022): 133126.

management problem, rather than a waste management issue, allowing other legitimate approaches to reuse and recycling to be considered before disposal [footnote ¹²⁷¹].

Further research aimed to identify key behaviours necessary to build sustainable agri-food supply chains, using a case study of the red meat supply chain in Italy as an example [footnote ¹²⁷²]. The study concluded that producers need to respond to increasing consumer awareness of sustainability in production. Farmers were found to typically experience limitations in business skills, aspirations and systems thinking; often largely concerned with their own operations rather than forming an integrated collaboration system.

Some of these issues were addressed in a case study evaluation of a Welsh farmer-led collaboration supported through having access to scientific and technical expertise [footnote ¹²⁷³]. The research found that with effective facilitation and governance, farmer-led groups can lead to implementation of more sustainable farming practices at a landscape-scale. A wider study [footnote ¹²⁷⁴] concurred that a collaborative supply chain structure is a necessary pre-requisite for innovation and can benefit all the stakeholders in the supply chain. It identified 10 key behavioural factors governing successful supply-chain collaborations: joint efforts, sharing activities, collaboration value, adaptation, trust, commitment, power, continuous improvement, coordination and stability.

The evidence suggested that development of clusters and industry conferences were useful vehicles for building supply chain co-operation. [footnote ¹²⁷⁵]. Project HELIX has delivered these in the wide food processing sector to good effect and this could be applied elsewhere in the food and drink supply chain.

Many of the papers reviewed referenced the need for supply chains to respond to changing consumer preferences, health and biotechnology concerns. A study from Northern Ireland

¹²⁷¹ Sawyerr, Emmanuel, Gabriel Yesuf, Ruth Wade, and Alp Yildirim. '[Understanding & Evaluating On-Farm Loss and Waste in the UK](#)'.

¹²⁷² Wike Agustin Prima Dania, Ke Xing, and Yousef Amer, '[Collaboration Behavioural Factors for Sustainable Agri-Food Supply Chains: A Systematic Review](#)', Journal of Cleaner Production 186 (10 June 2018): 851–64.

¹²⁷³ Morse, Aimee. '[Collaboration and Policy Implementation at the Local Level in Wales: A Case-Study Evaluation of a Farmer Group in North Wales](#)', 30 June 2021.

¹²⁷⁴ Krishnan, Ramesh, Phi Yen, Renu Agarwal, K. Arshinder, and Christopher Bajada. '[Collaborative Innovation and Sustainability in the Food Supply Chain- Evidence from Farmer Producer Organisations](#)'. Resources, Conservation and Recycling 168 (1 May 2021): 105253.

¹²⁷⁵ Sawyer, A, Jardine, M, Loyd, Professor D. '[Project HELIX Annual Report 2023-4](#)', Food Innovation Wales, 2024.

observed that supply chain integration, where processes and retailers control primary production and can consequently apply consistent standards in pig and poultry production had increased control over these issues, whereas an opportunity exists for producers (primarily red meat) outside of contracts to use collaboration and producer networks to build trust and quality assurance [footnote ¹²⁷⁶]. Another study looked at the buying strategies faced by retailers in terms of controlling social and environmental responsibility in extended supply chains. The paper [footnote ¹²⁷⁷] outlines 2 sourcing archetypes, one from producers with higher environmental and social standards (and associated improved shelf life) and the other with lower standards, but at lower cost. The research suggested a collaborative whole supply chain approach to encouraging quality sourcing and maximisation of food safety, whilst educating consumers to accept higher prices as a trade-off. The study acknowledged that some consumers would change their choice or retailer as a result.

Technology was a significant focus for academic studies relating to supply chains and might be considered as an area for support. One study [footnote ¹²⁷⁸] examined the possibilities for live streaming production processes to build engagement and achieve direct sales, along with use of blockchain to provide quality assurance and traceability. The study concluded that streaming without use of influencers was unlikely to be a profitable approach at present but was seen to broaden social awareness of farming and showcase new products effectively.

Other popular areas for research were machine learning and AI to drive quality and resilience in agri-food supply chains. One found, for example, that AI driven cold storage could lead to a 60% reduction in post-harvest losses for perishable items [footnote ¹²⁷⁹], whilst logistics optimised using machine learning reduced transport-related food waste by 20%. There is also significant scope for use of AI to reduce the need for pesticides, through more timely and accurate interventions.

¹²⁷⁶ Patton et al., '[Evolution of Agri-Food Supply Chains to Enhance Competitiveness: Literature Review](#)'. Agri-Food and Biosciences Institute (2018).

¹²⁷⁷ Liu, J., S. Du, and Q. He. '[Research on the Impact of Information Scenarios on Retailers' Strategies for Purchasing Fresh Agricultural Products](#)'. Polish Journal of Environmental Studies 34, no. 2 (2025): 1243–54.

¹²⁷⁸ Xu, X., X. Chen, J. Hou, T.C.E. Cheng, Y. Yu, and L. Zhou. '[Should Live Streaming Be Adopted for Agricultural Supply Chain Considering Platform's Quality Improvement and Blockchain Support?](#)'

Transportation Research Part E: Logistics and Transportation Review 195 (2025).

¹²⁷⁹ Olawale, R.A., M.A. Olawumi, and B.I. Oladapo. '[Sustainable Farming with Machine Learning Solutions for Minimizing Food Waste](#)'. Journal of Stored Products Research 112 (2025).

With regards to commercial timber production on farms, the evidence identified made several recommendations for supporting timber supply chains in Wales. These included investment in research to identify local supply chain opportunities for landowners to take up, legislation and changes to building codes to promote the use of timber in construction and therefore increase demand for home-grown timber, and certification for timber products to improve trust among buyers [footnote ¹²⁸⁰]. Additionally, utilising Natural Capital Accounting was suggested by one study to improve the perceived value of timber products by integrating the benefits delivered by timber plantations pre-harvesting, including carbon sequestration, biodiversity and ecosystem services [footnote ¹²⁸¹].

Finally, the research also identified that policy makers could get a better return from the focused effort already going into SME food business support and development with a series of connected foundational interventions across the food system:

- Engage the supermarket chains in conversation about greater effort to recruit Welsh SME suppliers and a move towards outcome measures
- Use public procurement indirectly and strategically on volume demand to get Welsh food service distributors to stock more Welsh product lines
- Maintain and consolidate hard and soft infrastructure support arrangements for Welsh food SMEs [footnote ¹²⁸²].

Technical Improvements and New Products (14 Studies Reviewed)

Research showed that this is a transformative time in agriculture, both in terms of technologies in use for increasing productivity (especially in arable and horticulture) and also for trialling new crops and means of production (such as vertical farming). A Spanish study [footnote ¹²⁸³] reviewed digital advances in climate change mitigation and adaptation

¹²⁸⁰ Welsh Government (2025). [Strategies and interventions to support the timber industry: literature review \(summary\)](#).

¹²⁸¹ Dauksta, A. (2025) [Opportunities for More, Higher-Value Timber from the National Forest](#). Woodknowledge Wales.

¹²⁸² Bowman et al., 'What can Welsh Government do to increase the number of grounded SME firms in food processing and distribution?'. Foundational Economy Research. 2021.

¹²⁸³ Parra-López, C., S. Ben Abdallah, G. Garcia-Garcia, A. Hassoun, P. Sánchez-Zamora, H. Trollman, S. Jagtap, and C. Carmona-Torres. 'Integrating Digital Technologies in Agriculture for Climate Change Adaptation and Mitigation: State of the Art and Future Perspectives'. Computers and Electronics in Agriculture 226 (2024).

in agriculture such as use of sensors for crop and livestock monitoring, machine learning and AI for predicting water shortages and pest outbreaks, nanotechnology for soil improvement, and robots or drones for targeted spraying, taking a resource efficiency approach to technology. A similar study from Sri Lanka [footnote ¹²⁸⁴] reviewed a wide range of technologies in use or in development including:

- precision-based farming: drones, sensor-based monitoring
- gene editing for drought resistance
- analytics for supply chain management
- general technology to build efficiency and address environmental damage.

Critically, both reviews noted the need for farmers to be technologically literate, to be able to benefit from technological advance. This was echoed by a Chinese study [footnote ¹²⁸⁵] which identified the need for connected machines in the agri-food supply chain, but which cited a lack of technology skills and long payback times on investment as barriers to adoption at present. These could be addressed to some extent through Collaboration action.

Project HELIX provides specialist associates to work in food businesses to embed new product development, technical expertise and marketing skills. This is scope to consider similar provision for farmers and growers in Wales [footnote ¹²⁸⁶].

The use of blockchain (a distributed, digital contract which cannot be amended or deleted) for traceability and machine learning for crop management was also reviewed in the evidence [footnote ¹²⁸⁷], noting its incremental rise amongst retail supply chains, but with a

¹²⁸⁴ Gamage, A., R. Gangahagedara, S. Subasinghe, J. Gamage, C. Guruge, S. Senaratne, T. Randika, et al. '[Advancing Sustainability: The Impact of Emerging Technologies in Agriculture](#)'. Current Plant Biology 40 (2024).

¹²⁸⁵ Zhao et al., '[Analysis of Barriers to Adopting Industry 4.0 to Achieve Agri-Food Supply Chain Sustainability: A Group-Based Fuzzy Analytic Hierarchy Process](#)', Business Strategy and the Environment 33, no. 8 (2024): 8559–86.

¹²⁸⁶ Sawyer, A, Jardine, M, Loyd, Professor D. '[Project HELIX Annual Report 2023-4](#)', Food Innovation Wales, 2024.

¹²⁸⁷ D.V.R.T. Amulothu et al., '[Machine Learning for Pest and Disease Detection in Crops](#)', in Agriculture 4.0: Smart Farming with IoT and Artificial Intelligence, 2024, 111–32;
Duan, Onyeaka, and Pang, '[Leveraging Blockchain to Tackle Food Fraud: Innovations and Obstacles](#)', Journal

number of technical and cultural challenges remaining as barriers to scaling the technology, including comprehensive changes in physical, digital, and legal infrastructure. Solutions include reshaping farmer mindsets and enhancing awareness of the benefits of technology [footnote ¹²⁸⁸].

A UK study focused on the spatial disconnection of many agri-environment schemes, allowing pockets of unconnected good practice to be developed [footnote ¹²⁸⁹]. The report called for contextual criteria such as socio-economic criteria and barriers to engagement to be included in scheme design to incorporate aligned collaborative actions across adjacent holdings and hence achieve scale.

Research included several projects targeting energy generation (some of which are covered in diversification above. An Irish research project [footnote ¹²⁹⁰] looked at the financial viability of using silage to produce energy through anaerobic digestion, compared with beef production on the same holding. Although the research concluded it was not viable at present, because of the relatively high input costs in relation to the outputs, it provided some insights into a potential role for government in supporting a low carbon livestock sector.

A research project in Ireland engaged with dairy farmers and farm veterinary practitioners to understand challenges with animal health diagnosis, and subsequently to explore the initial development of a rapid, on-farm animal health testing tool to address these challenges. It concluded that a co-design approach with farmers and veterinarians would be important to ensure that such tools are easy to use and avoid misdiagnoses [footnote ¹²⁹¹].

of Agriculture and Food Research 18 (2024);

Srivastava et al., '[Revolutionizing Agriculture with IoT and Artificial Intelligence](#)', in Agriculture 4.0: Smart Farming with IoT and Artificial Intelligence, 2024, 1–21;

Gamage et al., '[Advancing Sustainability: The Impact of Emerging Technologies in Agriculture](#)'. Current Plant Biology 40 (2024).

¹²⁸⁸ Limpamont, A., P. Kittipanya-ngam, N. Chindasombatcharoen, and H.J.M. Cavite. '[Towards Agri-Food Industry Sustainability: Addressing Agricultural Technology Adoption Challenges through Innovation](#)'. Business Strategy and the Environment 33, no. 7 (2024): 7352–67.

¹²⁸⁹ Baker et al., '[Aligning strategic and participatory approaches to agri-environment scheme design and implementation to enhance nature recovery outcomes](#)'.

¹²⁹⁰ Tisocco, S., J.J. Lenehan, X. Zhan, and P. Crosson. '[Financial Assessment of Integrating Anaerobic Digestion with Cattle Farming for Biomethane Production – Implications for Farm Economics and the Supply Chain](#)'. Biomass and Bioenergy 195 (2025).

¹²⁹¹ McGrath, K., Á. Regan, E. Kennedy, and T. Russell. '[Development of an Animal Health Testing Tool to Reduce Antimicrobial Use on Farms: Perceptions, Implications, and Needs of Irish Dairy Farmers and Farm Veterinarians](#)'. Irish Veterinary Journal 77, no. 1 (2024).

Knowledge Transfer and Innovation (4 Studies Reviewed)

Several examples of knowledge transfer have been covered in other sections of this document. However, some specific studies were reviewed which dealt with knowledge transfer in the agriculture sector. Several literature reviews of the topic [footnote ¹²⁹²] identified a dearth of knowledge transfer research in the context of agriculture. One noted a focus on technology to support knowledge creation, rather than the interpersonal processes involved in knowledge creation. Knowledge transfer schemes were found to focus on top-down dissemination through extension programmes, rather than acknowledgement of the value of bottom-up indigenous knowledge sharing.

Another study [footnote ¹²⁹³] on knowledge transfer in animal health noted the importance of transferring knowledge gained from scientific advances into farming practice but reported a divergence in the understanding of animal health issues, with a lack of consensus regarding responsibilities for animal health and the need for individual and contextual relevance in the way that knowledge transfer is delivered. In the food processing sector, it was reported that project HELIX embeds professional expertise into businesses to build capacity and streamline processes. [footnote ¹²⁹⁴]

One Irish study [footnote ¹²⁹⁵], however, reported that interaction with agricultural advisory services had a significant impact on productivity, especially in the dairy sector. The results showed that a combination of group-based and individual activities were key to achieving impact. Examples noted were focused on key management practices for grassland, breeding, and financial management. Positive outcomes were found to be dependent on a high degree of trust between the farmer and the organisation, between the farmer and the adviser, and between the farmer and their peers. Productivity and profitability gains were understood to be the primary motivators for engaging in knowledge transfer activities, as

¹²⁹² Tumwebaze, J.N. Walsh, and J. Lannon, '[Knowledge Management in the Agriculture Sector: A Systematic Literature Review](#)', Knowledge Management Research and Practice 23, no. 2 (2025): 131–48.;

Hoischen-Taubner, Bielecke, and Sundrum, '[Knowledge Transfer Regarding the Issue of Animal Health](#)', Organic Agriculture 8, no. 2 (2018): 105–20.

¹²⁹³ Hoischen-Taubner, Bielecke, and Sundrum, '[Knowledge Transfer Regarding the Issue of Animal Health](#)', Organic Agriculture 8, no. 2 (2018): 105–20.

¹²⁹⁴ Sawyer, A, Jardine, M, Loyd, Professor D. '[Project HELIX Annual Report 2023-4](#)', Food Innovation Wales, 2024.

¹²⁹⁵ Cawley et al., '[How Knowledge Transfer Impact Happens at the Farm Level: Insights from Advisers and Farmers in the Irish Agricultural Sector](#)', Sustainability (Switzerland) 15, no. 4 (2023).

opposed to environmental considerations *per se*. In terms of the shift from knowledge acquisition to changed practice, short-term impacts were seen to be important.

An evaluation of the Knowledge Transfer and Innovation Fund in Scotland [footnote ¹²⁹⁶] reported on 12 knowledge transfer projects and identified that hands-on and practical demonstrations were the most memorable and impactful delivery means for participants. Case studies included the over-wintering of beef cattle from the wetter land in the west to arable sites in the east of Scotland [footnote ¹²⁹⁷] and the identification of complementary “monitor” farms to provide peer to peer learning across a wide range of practices and landscape conditions [footnote ¹²⁹⁸].

One study on the timber industry in Wales highlighted the importance of knowledge sharing for promoting uptake of commercial forestry by farmers. It was suggested that communicating the potential benefits of commercial planting for farmers, including water regulation, livestock protection and the economic potential of woodland products, would improve uptake. Similarly, the report suggested that further education on the benefits of timber use in construction was key to improve the demand for timber in the development sector [footnote ¹²⁹⁹]. Additionally, sharing knowledge with landowners on how to undertake commercial forestry was highlighted as important; the National Forest for Wales programme provided training and knowledge sharing through events, and promoted collaboration between local landowners to share best practice examples [footnote ¹³⁰⁰].

Uptake of the Practice (7 studies)

Whilst the majority of the studies reviewed were more concerned with proposed developments in supply chain and added value, or with developing frameworks for better understanding of potential developments, there were some insights into uptake of practice.

¹²⁹⁶ APS Group Scotland for Scottish Government, '[Scottish Rural Development Programme 2014-20: Evaluation of the Knowledge Transfer and Innovation Fund](#)', Scottish Government (2025).

¹²⁹⁷ SAOS, [KTIF Final Report East/West Beef Grazing Collaboration Pilot](#). Scottish Government, (2021).

¹²⁹⁸ Flanigan, S and Hardy, C. [Learning and Change through Monitor Farms](#)', James Hutton Institute (2025).

¹²⁹⁹ Welsh Government (2025). [Strategies and interventions to support the timber industry: literature review \(summary\)](#).

¹³⁰⁰ Dauksta, A. (2025) [Opportunities for More, Higher-Value Timber from the National Forest](#). Woodknowledge Wales.

- Several studies viewed a change towards plant-based diets as an inevitable trend [footnote ¹³⁰¹], whilst low margins on legume production and cultural resistance to changing farming practice in response to this change was noted, as well as topographical unsuitability to changing land use. However, improved experience of cultivating crops such as soya in the UK was noted to have reduced barriers to growing
- Shorter supply chains were acknowledged as beneficial to food security and building environmental resilience [footnote ¹³⁰²], but these are still largely limited to local vegetable growing and distribution [footnote ¹³⁰³]. There was little evidence of research on public procurement or working with retailers to shorten currently complex supply and logistics arrangements, although one study pointed out the need to engage with retail as ‘the great majority of the food system lies in the hands of private retail and public procurement only has limited levers’ [footnote ¹³⁰⁴].
- The emergence of AI, machine learning and blockchain technology to boost productivity and resource efficiency were frequently mentioned – especially in Asian studies, but with an acknowledgement that barriers of cost, reliability and trust have prevented widespread adoption to date [footnote ¹³⁰⁵]
- Knowledge transfer was acknowledged to have delivered results, especially where it involved peer to peer or grassroots-led learning, as well as top-down dissemination

¹³⁰¹ Cusworth, Garnett, and Lorimer, ‘[Agroecological Break out: Legumes, Crop Diversification and the Regenerative Futures of UK Agriculture](#)’, *Journal of Rural Studies* 88 (December 2021): 126–37.; Sharp et al., ‘[Implications and Impacts of Aligning Regional Agriculture with a Healthy Diet](#)’, *Journal of Cleaner Production* 449 (5 March 2024): 141375.; Burke, D.T., P. Hynds, and A. Priyadarshini. ‘[Evaluating the GHG Emissions, Land Use, and Water Use Associated with Contemporary Dietary Patterns in the Republic of Ireland](#)’. *Environmental Research* 270 (2025).

¹³⁰² Gage, E., L.A. Terry, and N. Falagán. ‘[Biological Factors and Production Challenges Drive Significant UK Fruit and Vegetable Loss](#)’. *Journal of the Science of Food and Agriculture* 105, no. 4 (2025): 2109–17.

¹³⁰³ Krishnan, Ramesh, Phi Yen, Renu Agarwal, K. Arshinder, and Christopher Bajada. ‘[Collaborative Innovation and Sustainability in the Food Supply Chain- Evidence from Farmer Producer Organisations](#)’. *Resources, Conservation and Recycling* 168 (1 May 2021): 105253.

¹³⁰⁴ Bowman et al., ‘[What can Welsh Government do to increase the number of grounded SME firms in food processing and distribution?](#)’ *Foundational Economy Research* (2021).

¹³⁰⁵ Zhao et al., ‘[Analysis of Barriers to Adopting Industry 4.0 to Achieve Agri-Food Supply Chain Sustainability: A Group-Based Fuzzy Analytic Hierarchy Process](#)’, *Business Strategy and the Environment* 33, no. 8 (2024): 8559–86.

of scientific research [footnote ¹³⁰⁶]. Short-term gains were seen as important for farmers to change practice following knowledge transfer sessions.

- The evidence identified suggested that timber production in Wales is limited by negative perceptions towards commercial tree planting, especially among the farming community [footnote ¹³⁰⁷]. Wales is a net importer of wood and wood products, which represents an opportunity to upscale domestic production to meet demand [footnote ¹³⁰⁸]. Several government strategies, including the Woodland for Wales Strategy and the National Forest for Wales have promoted commercial forestry and supply chain development, especially within the agricultural sector, as beneficial for local economies and for meeting carbon reduction targets [footnote ¹³⁰⁹].

Economic Impacts (28 studies)

Studies in several areas suggested that uncertainty about a combination of the economic impacts of change [footnote ¹³¹⁰] (especially where current activities remain profitable in the short-term) and the costs of changed practices were limiting take-up of new technologies or diversification, for example. There may be scope for collaboration action to reduce risk and make such Themes more palatable in the short-term.

Co-location of agriculture and ground-mounted solar photovoltaic panels [footnote ¹³¹¹] was identified as being able to bring commercial and economic benefits, bringing diversified income streams whilst enhancing biodiversity.

Niche markets were seen to offer some scope for positive economic impact, trading yield against higher prices for a niche product in the case of Scottish canola and pasture-fed beef

¹³⁰⁶ Cawley et al., '[How Knowledge Transfer Impact Happens at the Farm Level: Insights from Advisers and Farmers in the Irish Agricultural Sector](#)', Sustainability (Switzerland) 15, no. 4 (2023).

¹³⁰⁷ Dauksta, A. (2025) '[Opportunities for More, Higher-Value Timber from the National Forest](#)'. Woodknowledge Wales.

¹³⁰⁸ Welsh Government (2018). '[Woodlands for Wales: The Welsh Government's Strategy for Woodlands and Trees](#)'.

¹³⁰⁹ Ibid.

¹³¹⁰ Proskynitopoulou, V., S. Lorentzou, R. Yaman, G. Blanch, B. Herbert, F.J. Rubio Rincon, N. Moradi, et al. '[Mobile Solution for Digestate Transformation to High Added-Value Products](#)'. Journal of Cleaner Production 477 (2024).

¹³¹¹ Ludzuweit, A., J. Paterson, K. Wydra, C. Pump, K. Müller, and Y. Miller. '[Enhancing Ecosystem Services and Biodiversity in Agrivoltaics through Habitat-Enhancing Strategies](#)'. Renewable and Sustainable Energy Reviews 212 (2025).

[footnote ¹³¹²] and circular and economic benefits to insect farmers, if supply chains could be established [footnote ¹³¹³]. However, one study of a shift to plant-based production in South Wales identified that it could improve environmental performance in terms of GHG emissions, but would reduce both the number of calories produced and the profits to farmers [footnote ¹³¹⁴]. The study noted that model used to determine this outcome likely underestimated potential yields in South Wales due to weather conditions and that ‘South Wales is dominated by livestock systems, particularly in upland areas where crop production is not practical’.

One study of farmer co-operatives in the Netherlands and UK showed them to be economically resilient and providing the scale to improve bargaining power [footnote ¹³¹⁵]. Other, predominately European studies of collaborative action on short supply chains [footnote ¹³¹⁶] showed that collaboration resulted in fair prices for farmers, and more control of the value chain. A comparative study of red meat farmers in Italy and Wales showed that supply chain collaboration could bring economic benefits through matching supply and demand [footnote ¹³¹⁷]. Action on food waste through supply chain integration and collaboration was highlighted as a significant economic benefit, especially for producers of potatoes, apples and carrots [footnote ¹³¹⁸].

Research into new technology such as soil-less farming systems highlighted increased crop yields through resource management efficiency. However, input costs were found to reduce

¹³¹² Rowe et al., ‘[Using Fuzzy Cognitive Mapping to Assess the Sustainability Impacts of Transitioning to Pasture-Fed Production in the UK Beef Sector](#)’, Renewable Agriculture and Food Systems 40 (2025).

¹³¹³ Tiwasing, P., and L. Pate. ‘[Exploring Edible Insects as Feed in the UK: Current Challenges and Future Prospects](#)’. Journal of Insects as Food and Feed 11, no. 1 (2025): 139–55.

¹³¹⁴ Sharp, R., A. S. Bellamy, A. Clear, S. M. Finnigan, E. Furness, E. Meador, H. Metcalfe, et al. ‘[Implications and Impacts of Aligning Regional Agriculture with a Healthy Diet](#)’. Journal of Cleaner Production 449 (5 March 2024): 141375.

¹³¹⁵ MacMillan, Tom, and George Cusworth. ‘[Farmer Co-Operation in the UK: Opportunities for the Industry](#)’. Report. Co-operatives UK and RAU, 10 October 2019.

¹³¹⁶ Stoeva, S., R. Van Gompel, L. Van den Bossche, E. Rogge, P. Slavova, M. Grivins, and I. Mileiko. ‘[Understanding Collaboration in Short Food Supply Chains: A Focus on Collaborative Relationships, Interaction Mechanisms and Relational Benefits](#)’. Agricultural and Food Economics 12, no. 1 (30 December 2024): 49.

¹³¹⁷ Roekel, Jan & Chain, Agri & Center, Competence & Kopicki, Ronald & Bank, World & Supply, Chain & Advisor, Carry & Broekmans, & Agri,. [Building Agri Supply Chains: Issues and Guidelines](#). World Bank, 2002.

¹³¹⁸ Gage, E., L.A. Terry, and N. Falagán. ‘[Biological Factors and Production Challenges Drive Significant UK Fruit and Vegetable Loss](#)’. Journal of the Science of Food and Agriculture 105, no. 4 (2025): 2109–17.

the overall economic impact of these [footnote ¹³¹⁹]. Experimental approaches to integrate anaerobic digestion with cattle farming for biomethane production showed a need for substantial subsidies to enable profitability, and a similar position was identified for growing perennial biomass crops from short rotation coppice willow and miscanthus [footnote ¹³²⁰]. However, a study of using digested biowaste in a combined heat and power (CHP) or carbon capture, heat and power (CCHP) [footnote ¹³²¹] trigeneration system to provide, heating, cooling and electricity export demonstrated payback in 10 to 12 years.

The use of machine learning for crop disease prediction and pest management was found to offer substantial economic benefits if deployed at scale [footnote ¹³²²].

Knowledge transfer activities generally delivered economic benefits where adoption on learned practice occurred [footnote ¹³²³].

A study looking at food processing [footnote ¹³²⁴] identified that the great majority of the food system lies in the hands of private retail and public procurement only has limited levers. Wales is heavily dependent on imports and there is a disconnect between consumer demand and Welsh food and drink supply. The margins in food processing and retailing are very small and this is limiting investment and building in vulnerability.

The potential to integrate commercial forestry onto farmland was suggested by 2 studies as potentially beneficial for local economies in providing saleable woodland products for

¹³¹⁹ Zhou, X., D. Asioli, and K. Jürkenbeck. '[Investigating Consumers' Views on Foods from Soilless Farming Systems: A Review of the Literature and Discussion of Implications and Recommendations](#)'. Food Quality and Preference 126 (2025).

¹³²⁰ Ingram, J., J. Mills, and H. Mackley-Ward. "[For All Kinds of Reasons, It Hasn't Happened": A Novel Integrative Perspective for Analysing the Barriers to Biomass Crops for Bioenergy in the United Kingdom](#)". Energy Research and Social Science 120 (2025).

¹²⁵⁰ Tang et al., '[Net-Zero Farming: Trigenation with Carbon Capture and Storage](#)', *Renewable Energy* 238 (2025).

¹³²² Ibid.

¹³²³ Cawley et al., '[How Knowledge Transfer Impact Happens at the Farm Level: Insights from Advisers and Farmers in the Irish Agricultural Sector](#)', Sustainability (Switzerland) 15, no. 4 (2023).

¹³²⁴ Bowman et al., '[What can Welsh Government do to increase the number of grounded SME firms in food processing and distribution?](#)'. Foundational Economy Research. 2021.

landowners to diversify, and in boosting jobs in the sector, such as in forestry, sawmilling and timber construction industries [footnote ¹³²⁵].

Environmental Impacts (26 studies)

In terms of changing customer preferences, research showed that the pattern of local agricultural production gives Welsh food processors a very narrow input base, with the added challenge that ruminant based farming is emissions-intensive even when grass based. In the long run, there is a risk of ‘stranded assets’ (that is the process of certain products or services becoming less desirable through shifts in consumer demand or other demand-side factors) for farming communities and processors, without a significant shift into new products [footnote ¹³²⁶]. It was further identified that plant-based production and consumption produces much lower GHG emissions on a per unit of protein basis than red meat or dairy [footnote ¹³²⁷] and can bring a range of benefits such as enhancing soil health, promoting biodiversity, improving water management and supporting nutrient cycling [footnote ¹³²⁸]. A further study found that ‘on average, meat-based meals had 14 times higher environmental impact, while vegetarian meals had 3 times higher environmental impact than vegan meals’ [footnote ¹³²⁹]. However, a study of pasture-fed beef production showed that management of pasture through such a system can improve soil structure and deliver a range of associated environmental benefits [footnote ¹³³⁰].

¹³²⁵ Dauksta, A. (2025) [Opportunities for More, Higher-Value Timber from the National Forest](#).

Woodknowledge Wales.;

Welsh Government (2025). [Strategies and interventions to support the timber industry: literature review. \(summary\)](#).

¹³²⁶ Bowman et al., ‘[What can Welsh Government do to increase the number of grounded SME firms in food processing and distribution?](#)’. Foundational Economy Research. 2021.

¹³²⁷ Merlo et al., ‘[A Comparison of Animal and Plant-Based Proteins from an Economic, Environmental, and Nutritional Perspective in the Republic of Ireland](#)’, *Agricultural Systems* 221 (2024);

Sharp et al., ‘[Implications and Impacts of Aligning Regional Agriculture with a Healthy Diet](#)’.

¹³²⁸ Amulothu, D.V.R.T., R.R. Rodge, W. Hasan, and S. Gupta. ‘[Machine Learning for Pest and Disease Detection in Crops](#)’. In *Agriculture 4.0: Smart Farming with IoT and Artificial Intelligence*, 111–32, 2024.

¹³²⁹ Berill Takacs, Julia A. Stegemann, Anastasia Z. Kalea, Aiduan Borrion, ‘[Comparison of environmental impacts of individual meals - Does it really make a difference to choose plant-based meals instead of meat-based ones?](#)’ *Journal of Cleaner Production*, Volume 379, Part 2, 2022.

¹³³⁰ Rowe, E., L. Norton, A. McVittie, C. Watson, M. Wagner, C. Waterton, and L. Smith. ‘[Using Fuzzy Cognitive Mapping to Assess the Sustainability Impacts of Transitioning to Pasture-Fed Production in the UK Beef Sector](#)’. *Renewable Agriculture and Food Systems* 40 (2025).

It was also noted that when producers made links with consumers through farmers' markets, CSAs or producer groups [footnote ¹³³¹], they tended to become more environmentally aware as a result and this could feed through into practice [footnote ¹³³²].

One study showed that food waste reduction through supply chain collaboration could have significant environmental benefits in Wales [footnote ¹³³³], whilst digital technologies also help mitigate climate change by optimising inputs such as water and fertiliser, thereby reducing greenhouse gas emissions and promoting carbon sequestration [footnote ¹³³⁴].

Creating energy from biowaste was found to deliver substantial carbon savings, especially if linked to carbon capture and storage [footnote ¹³³⁵].

The evidence reviewed indicated that boosting commercial forestry, including through integration with agricultural land, has the potential to deliver environmental benefits including the carbon sequestration potential from fast-growing softwood plantations and the mitigation of emissions through using timber in construction, in place of more polluting materials [footnote ¹³³⁶]. Additionally, woodland on farms can deliver ecosystem services such as water regulation, air purification and soil formation. However, one study indicated that consideration of the whole timber lifecycle was important when evaluating the environmental impact of timber, looking not only at production but sawmilling, manufacturing and use and the potential impacts of those activities [footnote ¹³³⁷].

¹³³¹ Milford, A.-B., D. Keech, and S.W. Muiruri. '[Community Supported Agriculture's Perceived Positive Impacts on Mental Health and Vegetable Consumption in Norway and the UK](#)'. *Agricultural and Food Economics* 13, no. 1 (2025).

¹³³² Griffin, R.G., and M. Phillips. '[The Farm Shop as a Retroscaped Place of Experiential Consumption](#)'. *Sociologia Ruralis* 64, no. 4 (2024): 613–38.

¹³³³ Gage, E., L.A. Terry, and N. Falagán. '[Biological Factors and Production Challenges Drive Significant UK Fruit and Vegetable Loss](#)'. *Journal of the Science of Food and Agriculture* 105, no. 4 (2025): 2109–17.

¹³³⁴ Parra-López, C., S. Ben Abdallah, G. Garcia-Garcia, A. Hassoun, P. Sánchez-Zamora, H. Trollman, S. Jagtap, and C. Carmona-Torres. '[Integrating Digital Technologies in Agriculture for Climate Change Adaptation and Mitigation: State of the Art and Future Perspectives](#)'. *Computers and Electronics in Agriculture* 226 (2024).

¹³³⁵ Redhead, J.W., M. Brown, J. Price, E. Robinson, R.J. Nicholls, R. Warren, and R.F. Pywell. '[National Horizon Scanning for Future Crops Under a Changing UK Climate](#)'. *Climate Resilience and Sustainability* 4, no. 1 (2025).

¹³³⁶ Welsh Government (2025). '[Strategies and interventions to support the timber industry: literature review. \(summary\)](#)'.

¹³³⁷ Henderson, T. (2025). '[The Ecosystem Services Impacts of Woodland Creation and Timber Products](#)'. Woodknowledge Wales.

Social Impacts (27 studies)

Several studies referred to changing consumer preferences for more plant-based diets with associated lower levels of red meat consumption. One pointed out that cereals and legumes offer the best nutritional performance from a land use perspective [footnote ¹³³⁸], whilst conversely a meat focused diet was associated with the highest per capita land use [footnote ¹³³⁹]. However, financial margins remain higher on milk and dairy or red meat, discouraging shifts in production at present. Another study contrastingly made the point that conservation agriculture without animals – i.e., with a plant-based focus – can provide a just and inclusive model of production [footnote ¹³⁴⁰]. One study reported that consumers taking part in research accepted the need to reduce meat consumption for environmental and health reasons [footnote ¹³⁴¹], but it was acknowledged by others that changes in diet and farming practice required education and communications to render them acceptable to producers and consumers alike [footnote ¹³⁴²]. One study suggested “levering occupational and place attachments by portraying plant crops as a revival of historic practices from traditional farming landscapes” [footnote ¹³⁴³].

In terms of diversification, one study discussed how niche markets can encourage partnerships and networks that enable knowledge transfer and identification of best practice, thereby reducing the barriers to a transition to sustainable production systems [footnote ¹³⁴⁴]. Developing connections between producers and consumers was discussed

¹³³⁸ Merlo et al., ‘[A Comparison of Animal and Plant-Based Proteins from an Economic, Environmental, and Nutritional Perspective in the Republic of Ireland](#)’, *Agricultural Systems* 221 (2024).

¹³³⁹ Burke, D.T., P. Hynds, and A. Priyadarshini. ‘[Evaluating the GHG Emissions, Land Use, and Water Use Associated with Contemporary Dietary Patterns in the Republic of Ireland](#)’. *Environmental Research* 270 (2025).

¹³⁴⁰ Kassam, A., and L. Kassam. ‘[Regenerative Farming without Farmed Animals](#)’. In *Regenerative Farming and Sustainable Diets: Human, Animal and Planetary Health*, 167–74, 2024.

¹³⁴¹ Spiro, Z. Hill, and S. Stanner, ‘[Meat and the Future of Sustainable Diets—Challenges and Opportunities](#)’, *Nutrition Bulletin* 49, no. 4 (2024): 572–98.

¹³⁴² Zhou, X., D. Asioli, and K. Jürkenbeck. ‘[Investigating Consumers’ Views on Foods from Soilless Farming Systems: A Review of the Literature and Discussion of Implications and Recommendations](#)’. *Food Quality and Preference* 126 (2025).

¹³⁴³ Proskynitopoulou, V., S. Lorentzou, R. Yaman, G. Blanch, B. Herbert, F.J. Rubio Rincon, N. Moradi, et al. ‘[Mobile Solution for Digestate Transformation to High Added-Value Products](#)’. *Journal of Cleaner Production* 477 (2024).

¹³⁴⁴ Olagunju, K.O., S. Angioloni, and M. Canavari. ‘[Niche Markets for Sustainable Agri-Food Systems: A Systematic Review](#)’. *Heliyon* 11, no. 3 (2025).

in a number of research studies, especially with regard to farm shops and CSAs [footnote 1345].

Diversification was also reported to provide a means to build retention of young people on farm, whereas they would not have stayed to work on a purely livestock-based enterprise [footnote 1346]. A research study of care farming showed that farmers developed social benefits themselves, as well as for their service users, through their care activities [footnote 1347].

Regarding timber production, several social benefits were highlighted by the reviewed literature, including the aesthetic, spiritual and recreational benefits potentially delivered by on-farm woodland and productive plantations [footnote 1348], and the potential use of these spaces for community activities and education [footnote 1349].

A study of knowledge transfer activities on-farm noted that participants gained social benefits from networking with their peers, as well as embedding practice through experiencing demonstrations in context [footnote 1350].

Barriers (9 studies)

A Welsh study of farmer collaboration found that group members were reluctant to allow additional members into the group, having invested time and expertise in setting it up. This also led to group members experiencing fatigue, through lack of resource to manage the group [footnote 1351].

¹³⁴⁵ Griffin, R.G., and M. Phillips. [‘The Farm Shop as a Retroscaped Place of Experiential Consumption’](#). *Sociologia Ruralis* 64, no. 4 (2024): 613–38.

¹³⁴⁶ Gittins, P., S. Apostolopoulos, E.E. Anastasopoulou, and N. Apostolopoulos. [‘Responding to Greece’s Constrained Agricultural Context: Farm Diversification Strategies Used by Family Farmers’](#). *Journal of Rural Studies* 113 (2025).

¹³⁴⁷ Leck, Chris, Nick Evans, and Dominic Upton. [‘Agriculture – Who Cares? An Investigation of “Care Farming” in the UK’](#). *Journal of Rural Studies* 34 (1 April 2014): 313–25.

¹³⁴⁸ Henderson, T. (2025). [The Ecosystem Services Impacts of Woodland Creation and Timber Products](#). Woodknowledge Wales.

¹³⁴⁹ Dauksta, A. (2025) [Opportunities for More, Higher-Value Timber from the National Forest](#). Woodknowledge Wales.

¹³⁵⁰ APS Group Scotland for Scottish Government, [‘Scottish Rural Development Programme 2014-20: Evaluation of the Knowledge Transfer and Innovation Fund’](#), Scottish Government (2025).

¹³⁵¹ Morse, Aimee. [‘Collaboration and Policy Implementation at the Local Level in Wales: A Case-Study Evaluation of a Farmer Group in North Wales’](#), 30 June 2021.

The evidence base showed that barriers to adoption of technology included the capital investment and long payback times, along with a lack of awareness of the opportunities offered and a reluctance to be a first mover in a new market [footnote ¹³⁵²]. Similar barriers were experienced in growing of perennial biomass crops for energy, with one study calling for greater government support to pump prime the market and supply chain [footnote ¹³⁵³]. Care farmers, who offer farming opportunities for the purpose of providing or promoting physical or mental healing and well-being, found the main barriers to be in attracting clients, especially in terms of relationship with public sector health and care teams because of perceptions of risk and value [footnote ¹³⁵⁴].

One study showed that Wales suffers a lack of SMEs in food processing and distribution to engage with primary producers [footnote ¹³⁵⁵]. In a similar vein, research in Poland concerning short supply chains noted that farmers selling direct or through farmers markets found it difficult to scale because of a lack of supply chain opportunities [footnote ¹³⁵⁶]. They also faced increased bureaucracy in terms of environment, natural resources and institutional support [footnote ¹³⁵⁷].

¹³⁵² Zhao et al., '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability](#)';

Parra-López, C., S. Ben Abdallah, G. Garcia-Garcia, A. Hassoun, P. Sánchez-Zamora, H. Trollman, S. Jagtap, and C. Carmona-Torres. '[Integrating Digital Technologies in Agriculture for Climate Change Adaptation and Mitigation: State of the Art and Future Perspectives](#)'. *Computers and Electronics in Agriculture* 226 (2024).; Zhou, X., D. Ascoli, and K. Jürkenbeck. '[Investigating Consumers' Views on Foods from Soilless Farming Systems: A Review of the Literature and Discussion of Implications and Recommendations](#)'. *Food Quality and Preference* 126 (2025).

¹³⁵³ Ingram, J., J. Mills, and H. Mackley-Ward. "[For All Kinds of Reasons, It Hasn't Happened": A Novel Integrative Perspective for Analysing the Barriers to Biomass Crops for Bioenergy in the United Kingdom](#)". *Energy Research and Social Science* 120 (2025).

¹³⁵⁴ Leck, Chris, Nick Evans, and Dominic Upton. '[Agriculture – Who Cares? An Investigation of "Care Farming" in the UK](#)'. *Journal of Rural Studies* 34 (1 April 2014): 313–25.

¹³⁵⁵ Dauksta, A. (2025) '[Opportunities for More, Higher-Value Timber from the National Forest](#)'. Woodknowledge Wales.

¹³⁵⁶ Drejerska, Nina, and Wioleta Sobczak-Malitka. '[Nurturing Sustainability and Health: Exploring the Role of Short Supply Chains in the Evolution of Food Systems—The Case of Poland](#)'. *Foods* 12, no. 22 (19 November 2023): 4171.

¹³⁵⁷ Gittins, P., S. Apostolopoulos, E.E. Anastasopoulou, and N. Apostolopoulos. '[Responding to Greece's Constrained Agricultural Context: Farm Diversification Strategies Used by Family Farmers](#)'. *Journal of Rural Studies* 113 (2025).

With respect to knowledge transfer activities, research found that there is a lack of acknowledgement of the knowledge base that farmers offer and how that could be shared and transferred to organisational stakeholders [footnote ¹³⁵⁸].

Regarding timber production, barriers were identified for processors including sawmills, with a lack of standardisation of timber from different sources, and potential supply chain irregularity. Additionally, a perception of timber as being insufficiently stable or of high enough quality was highlighted as a potential barrier to promoting timber use in construction [footnote ¹³⁵⁹].

Evidence Gaps (9 studies)

The main evidence gap identified was the general lack of research studies relating to practice, rather than theory. However, within the evidence base, a range of gaps was identified, including:

- A lack of evidence about the extent of food waste in primary production and storage, and options for improvements to quality and storability of produce [footnote ¹³⁶⁰]
- A need for policy makers to consider how agricultural and environmental policy can also deliver socio-economic and cultural benefits [footnote ¹³⁶¹]. Also, to explore barriers and non-financial drivers in relation to uptake of agroforestry schemes [footnote ¹³⁶²] and to promote the expansion of a range of niche markets through, for example, legal recognition of environmentally friendly products [footnote ¹³⁶³]

¹³⁵⁸ Tumwebaze, J.N. Walsh, and J. Lannon, '[Knowledge Management in the Agriculture Sector: A Systematic Literature Review](#)', Knowledge Management Research and Practice 23, no. 2 (2025): 131–48.

¹³⁵⁹ Dauksta, A. (2025) [Opportunities for More, Higher-Value Timber from the National Forest](#). Woodknowledge Wales.

¹³⁶⁰ Gage, E., L.A. Terry, and N. Falagán. '[Biological Factors and Production Challenges Drive Significant UK Fruit and Vegetable Loss](#)'. Journal of the Science of Food and Agriculture 105, no. 4 (2025): 2109–17.

¹³⁶¹ Morse, Aimee. '[Collaboration and Policy Implementation at the Local Level in Wales: A Case-Study Evaluation of a Farmer Group in North Wales](#)', 30 June 2021.

¹³⁶² Olave, R.J., J. Smith, and J.H. McAdam. '[Drivers of Agroforestry Adoption in Northern Ireland in the Context of British and Irish Policy](#)'. Agroforestry Systems 99, no. 3 (2025).

¹³⁶³ Olagunju, K.O., S. Angioloni, and M. Canavari. '[Niche Markets for Sustainable Agri-Food Systems: A Systematic Review](#)'. Heliyon 11, no. 3 (2025).

- Future research could further examine how CSAs can increase their positive impact on members' vegetable consumption and mental health, for instance in the nature of members' participation [footnote ¹³⁶⁴]
- Research is recommended to validate outcomes in agrivoltaics including specific microclimatic conditions [footnote ¹³⁶⁵]
- Research is said to be lacking into the potential market for novel approaches such as soil-less food production [footnote ¹³⁶⁶], insect-based foods, food safety regulations and public acceptance [footnote ¹³⁶⁷]
- Public sector support for rapid development and deployment of digital technology applications in farming [footnote ¹³⁶⁸].
- A literature review on the timber industry in Wales identified gaps in the evidence base into practical approaches to improving knowledge sharing around sustainable forestry management among landowners. Additionally, actions to promote timber use in construction, especially in the public sector, were described as being very new and so evidence of the impacts of such interventions was lacking [footnote ¹³⁶⁹].

¹³⁶⁴ Milford, A.-B., D. Keech, and S.W. Muiruri. '[Community Supported Agriculture's Perceived Positive Impacts on Mental Health and Vegetable Consumption in Norway and the UK](#)'. *Agricultural and Food Economics* 13, no. 1 (2025).

¹³⁶⁵ Ludzuweit, A., J. Paterson, K. Wydra, C. Pump, K. Müller, and Y. Miller. '[Enhancing Ecosystem Services and Biodiversity in Agrivoltaics through Habitat-Enhancing Strategies](#)'. *Renewable and Sustainable Energy Reviews* 212 (2025).

¹³⁶⁶ Zhou, X., D. Asoli, and K. Jürkenbeck. '[Investigating Consumers' Views on Foods from Soilless Farming Systems: A Review of the Literature and Discussion of Implications and Recommendations](#)'. *Food Quality and Preference* 126 (2025).

¹³⁶⁷ Tiwasing, P., and L. Pate. '[Exploring Edible Insects as Feed in the UK: Current Challenges and Future Prospects](#)'. *Journal of Insects as Food and Feed* 11, no. 1 (2025): 139–55.

¹³⁶⁸ Parra-López, C., S. Ben Abdallah, G. Garcia-Garcia, A. Hassoun, P. Sánchez-Zamora, H. Trollman, S. Jagtap, and C. Carmona-Torres. '[Integrating Digital Technologies in Agriculture for Climate Change Adaptation and Mitigation: State of the Art and Future Perspectives](#)'. *Computers and Electronics in Agriculture* 226 (2024).

¹³⁶⁹ Welsh Government (2025). '[Strategies and interventions to support the timber industry: literature review \(summary\)](#)'.

Cost-effectiveness Evidence (6 studies)

The research studies reviewed suggest several areas for economic benefit arising from collaborative actions such as:

- action on the adoption of new technology for crop and livestock management [footnote ¹³⁷⁰]
- action to reduce on-farm product loss and waste, through collaboration on processing or adding value to produce at risk of loss [footnote ¹³⁷¹]. Development of collaborative supply chains and predictive technology to address issues of supply and demand mismatch [footnote ¹³⁷²]
- pilot programme for a mobile solution for recovery of water and nutrients from slurry through selective electrodialysis [footnote ¹³⁷³]
- demonstration unit to produce biogas and carbon capture from biowaste on farm [footnote ¹³⁷⁴]
- knowledge transfer around live streaming of farm activities and available produce to build engagement and sales [footnote ¹³⁷⁵].

¹³⁷⁰ Srivastava et al., '[Revolutionizing Agriculture with IoT and Artificial Intelligence](#)', in Agriculture 4.0: Smart Farming with IoT and Artificial Intelligence, 2024, 1–21

¹³⁷¹ Gage, E., L.A. Terry, and N. Falagán. '[Biological Factors and Production Challenges Drive Significant UK Fruit and Vegetable Loss](#)'. Journal of the Science of Food and Agriculture 105, no. 4 (2025): 2109–17.

¹³⁷² Jan Roekel et al., '[Building Agri Supply Chains: Issues and Guidelines](#)', n.d.

¹³⁷³ Proskynitopoulou, V., S. Lorentzou, R. Yaman, G. Blanch, B. Herbert, F.J. Rubio Rincon, N. Moradi, et al. '[Mobile Solution for Digestate Transformation to High Added-Value Products](#)'. Journal of Cleaner Production 477 (2024).

¹³⁷⁴ Redhead, J.W., M. Brown, J. Price, E. Robinson, R.J. Nicholls, R. Warren, and R.F. Pywell. '[National Horizon Scanning for Future Crops Under a Changing UK Climate](#)'. Climate Resilience and Sustainability 4, no. 1 (2025).

¹³⁷⁵ Xu, X., X. Chen, J. Hou, T.C.E. Cheng, Y. Yu, and L. Zhou. '[Should Live Streaming Be Adopted for Agricultural Supply Chain Considering Platform's Quality Improvement and Blockchain Support?](#)' Transportation Research Part E: Logistics and Transportation Review 195 (2025).

Critical Success Factors

Strategic fit and business needs: High alignment

The evidence reviewed suggests that the Theme Collaborative Market and Supply Chain has the potential to deliver a range of social, economic and environmental benefits for farmers and the wider public. It also has the potential to support the delivery of the Well-being of Future Generations (Wales) Act 2015, and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023. The evidence identified ways in which the Theme could increase the resilience of farm activities through support for diversification and improved supply chains making these Themes feasible for farm businesses and driving more sustainable farming practices and consumer behaviour.

Value for money: Medium alignment

The evidence reviewed had a limited focus on examples of practice, however, there are several calls for payments and support linked to de-risking changed practice in line with sustainable land management. In addition, evidence suggests collaboration can be used to de-risk the financial outlays needed for implementation of technology.

Supply side capacity and capability: Medium alignment

The identified evidence base contains a number of references to the need to build Supply side capacity and capability to diversify, embrace new technology, deal with food waste, and respond to changing consumer tastes. The evidence reviewed suggests that supply side capacity and capability could be built through demonstration projects, knowledge sharing and facilitation for collaborative action across the supply chain, and identified a number of examples in Wales where this has happened successfully.

Affordability: Medium alignment

One study made it clear that skills are needed to benefit from technological opportunities and that affordability and accessibility need to be ensured to get the best from these technologies. Some of the peer-to-peer learning discussed in the evidence is highly affordable in financial terms, as it is based solely on making time to attend groups to share knowledge and best practice, similarly to the Theme Advanced Continuous Professional

Development (CPD). However, it is acknowledged that some farmers consider themselves time poor and this could be a barrier.

Although some of the Themes explored in the research require significant capital investment, one study pointed out that collaboration can allow participants to share risk, cut costs, increase resilience and gain more control over their supply chain.

Conclusion

This chapter concludes the report by summarising:

- findings from each Optional and Collaborative Theme (OT/CT) highlighting the potential economic, social and environmental impacts organised according to the Purposes of Support outlined in Chapter 2 of the Agriculture (Wales) Act 2023
- the cost-effectiveness evidence section for each OT/CT
- potential alignment of each Theme with the CSFs.

This conclusion is intended to provide an accessible summary of the findings of the report; it is not intended to suggest that the below impacts and alignments indicate the cumulative potential impacts of the SFS OT/CTs. There are many factors that would need to be considered to determine any potential combined impacts of the Themes. This conclusion only outlines the evidence identified around each Themes potential impacts in relation to the purposes of support, cost-effectiveness evidence section, and CSFs.

Limitations

As discussed in the method section, and throughout, the research has a number of limitations which should be considered when reading the conclusions. The project was limited by the timescale, the broad scope of a number of the Themes, and the number of on-farm practices within a number of the Themes. Based on these limitations any outcomes highlighted, or evidence presented, must be considered with care as lessons from similar interventions may not be directly applicable. A more comprehensive REA for any single Theme may have explored these issues further.

In some cases, policy development around each Theme has continued since the REAs were conducted and therefore there may not be complete alignment with the final Themes.

Contribution to Purposes of Support

The Agriculture (Wales) Act 2023 outlines 15 purposes for which Ministers are able to provide support. These are:

- (a) encouraging the production of food in an environmentally sustainable manner;

- (b) helping rural communities to thrive and strengthening links between agricultural businesses and their communities;
- (c) improving the resilience of agricultural businesses;
- (d) sustaining the Welsh language and promoting and facilitating its use;
- (e) reducing emissions of greenhouse gases;
- (f) maximising carbon sequestration and storage;
- (g) maintaining and enhancing the resilience of ecosystems;
- (h) conserving and enhancing landscapes and the historic environment;
- (i) improving air quality;
- (j) improving water quality;
- (k) maintaining and enhancing public access to and engagement with the countryside and the historic environment;
- (l) mitigating flood and drought risks;
- (m) achieving and promoting high standards of animal health and welfare;
- (n) maximising resource efficiency;
- (o) encouraging agricultural businesses to manage energy effectively (including by adopting energy efficiency and energy saving practices, and generating renewable energy on their land).

This section takes each purpose of support in turn and lists each Theme which may contribute to the purpose with a brief discussion of how the Theme may meet the purpose by summarising the relevant social, economic and environmental outcomes which the evidence suggested it may provide. Whether an Theme contributes towards a purpose of support is dependent on the implementation of the Theme including the on-farm practices being carried out correctly and in the correct location. Not all impacts will occur in every instance of an on-farm action as they are often highly dependent on context specific factors. Also, other impacts may stem from actions that are not covered here, and there may be evidence of impacts stemming from these Themes that was not identified during the REA. The information below should therefore not be seen as exhaustive. The below list offers a brief overview of which Themes may contribute to each purpose of support.

- a) encouraging the production of food in an environmentally sustainable manner
 - Enhanced Woodland Management

- Woodland and Agroforestry Creation
- Enhanced Biosecurity
- Enhanced Habitat Management
- Hedgerow Creation or Restoration
- Advanced Continuous Professional Development (CPD)
- Improved Soil Health and Multispecies Crop Cover
- Sustainable Production
- Organic Farming (Support and Conversion)
- Creation of Temporary and Permanent Habitats
- Improved Water Quality, Water Usage and Flood Mitigation
- Improved Air Quality and Lowering Ammonia Emissions
- Collaborative Innovation, Research and Development
- Collaborative Landscape Scale Activity
- Collaborative Market and Supply Chain

b) helping rural communities to thrive and strengthening links between agricultural businesses and their communities

- Enhanced Woodland Management
- Woodland and Agroforestry Creation
- Improved Public Access to the Countryside
- Collaborative Innovation, Research and Development
- Collaborative Landscape Scale Activity
- Collaborative Market and Supply Chain

c) improving the resilience of agricultural businesses

- Enhanced Woodland Management
- Woodland and Agroforestry Creation
- Enhanced Biosecurity
- Implementation of Designated Site Management Plans
- Hedgerow Creation or Restoration
- Advanced Continuous Professional Development (CPD)
- Improved Soil Health and Multispecies Crop Cover
- Sustainable Production
- Organic Farming (Support and Conversion)
- Creation of Temporary and Permanent Habitats
- Collaborative Innovation, Research and Development
- Collaborative Landscape Scale Activity
- Collaborative Market and Supply Chain

d) sustaining the Welsh language and promoting and facilitating its use

- While no searches returned evidence related to impacts on the Welsh language, this reflects the methodology of the REA and not the absence of impacts on the language. See further text below for more detail.

e) reducing emissions of greenhouse gases

- Woodland and Agroforestry Creation
- Sustainable Production
- Improved Air Quality and Lowering Ammonia Emissions

- Collaborative Innovation, Research and Development
 - Collaborative Market and Supply Chain
- f) maximizing carbon sequestration and storage
- Enhanced Woodland Management
 - Woodland and Agroforestry Creation
 - Hedgerow Creation or Restoration
 - Improved Soil Health and Multispecies Crop Cover
 - Sustainable Production
 - Creation of Temporary and Permanent Habitats
 - Collaborative Innovation, Research and Development
- g) maintaining and enhancing the resilience of ecosystems
- Enhanced Woodland Management
 - Woodland and Agroforestry Creation
 - Enhanced Habitat Management
 - Implementation of Designated Site Management Plans
 - Hedgerow Creation or Restoration
 - Advanced Continuous Professional Development (CPD)
 - Improved Soil Health and Multispecies Crop Cover
 - Sustainable Production
 - Organic Farming (Support and Conversion)
 - Creation of Temporary and Permanent Habitats
 - Improved Water Quality, Water Usage and Flood Mitigation

- Collaborative Innovation, Research and Development
 - Collaborative Landscape Scale Activity
- h) conserving and enhancing landscapes and the historic environment
- Enhanced Woodland Management
 - Woodland and Agroforestry Creation
 - Enhanced Habitat Management
 - Hedgerow Creation or Restoration
 - Organic Farming (Support and Conversion)
 - Creation of Temporary and Permanent Habitats
 - Improved Public Access to the Countryside
 - Collaborative Innovation, Research and Development
 - Collaborative Landscape Scale Activity
- i) improving air quality
- Woodland and Agroforestry Creation
 - Enhanced Biosecurity
 - Improved Water Quality, Water Usage and Flood Mitigation
 - Improved Air Quality and Lowering Ammonia Emissions
- j) improving water quality
- Enhanced Woodland Management
 - Woodland and Agroforestry Creation
 - Enhanced Biosecurity
 - Enhanced Habitat Management

- Implementation of Designated Site Management Plans
 - Hedgerow Creation or Restoration
 - Sustainable Production
 - Organic Farming (Support and Conversion)
 - Creation of Temporary and Permanent Habitats
 - Improved Water Quality, Water Usage and Flood Mitigation
 - Improved Air Quality and Lowering Ammonia Emissions
- k) maintaining and enhancing public access to and engagement with the countryside and the historic environment
- Improved Public Access to the Countryside
- l) mitigating flood and drought risks
- Enhanced Woodland Management
 - Woodland and Agroforestry Creation
 - Hedgerow Creation or Restoration
 - Sustainable Production
 - Creation of Temporary and Permanent Habitats
 - Improved Water Quality, Water Usage and Flood Mitigation
 - Collaborative Landscape Scale Activity
 - Collaborative Market and Supply Chain
- m) achieving and promoting high standards of animal health and welfare
- Woodland and Agroforestry Creation
 - Enhanced Biosecurity

- Enhanced Habitat Management
- Organic Farming (Support and Conversion)
- Collaborative Innovation, Research and Development

n) maximizing resource efficiency

- Woodland and Agroforestry Creation
- Enhanced Biosecurity
- Enhanced Habitat Management
- Improved Soil Health and Multispecies Crop Cover
- Sustainable Production
- Organic Farming (Support and Conversion)
- Creation of Temporary and Permanent Habitats
- Improved Water Quality, Water Usage and Flood Mitigation
- Improved Air Quality and Lowering Ammonia Emissions
- Collaborative Innovation, Research and Development

o) encouraging agricultural businesses to manage energy effectively (including by adopting energy efficiency and energy saving practices, and generating renewable energy on their land)

- Hedgerow Creation or Restoration
- Improved Water Quality, Water Usage and Flood Mitigation
- Collaborative Innovation, Research and Development

(a) encouraging the production of food in an environmentally sustainable manner

Searches in relation to 15 of the Themes found evidence that they could encourage the production of food in an environmentally sustainable manner. Impacts related to encouraging the production of food in an environmentally sustainable manner were found in:

- **Enhanced Woodland Management.** Evidence has shown that woodland can provide habitats for pollinators and improve soil fertility improving yields for adjacent crops. Woodlands also contribute to higher water quality by reducing nutrient leaching while absorbing runoff, protecting soils from erosion, and preventing wash-off. In addition, they can act as carbon sinks. These potential impacts could increase the environmental sustainability of existing farm practices
- **Woodland and Agroforestry Creation.** The evidence reviewed suggested that tree planting and integrating woodland onto farms can support more environmentally sustainable crop and livestock farming with the potential for increased yields due to increased pollination and the provision of shelter. In addition, the evidence confirmed that tree planting can contribute to higher air quality by absorbing ammonia as well as increased soil health
- **Enhanced Biosecurity.** The evidence reviewed reported that biosecurity measures such as slurry injection and UV water treatment can reduce ammonia emissions and toxic disinfection by-products, supporting better air and water quality. These improvements could encourage the production of food in an environmentally sustainable manner
- **Enhanced Habitat Management.** The evidence reviewed suggested that reducing the use of avermectins and improving wet grassland management for biodiversity may contribute to better soil and ecosystem health. These practices have been shown to enhance nutrient cycling and reduce chemical loads, promoting long-term sustainability
- **Hedgerow Creation or Restoration.** The evidence reviewed found that hedgerows can support farmers to produce food in an environmentally sustainable manner

through the prevention of soil erosion and enhanced soil fertility, and the potential for increased yields due to improved pollinator populations

- **Advanced Continuous Professional Development (CPD).** The evidence reviewed suggested that this Theme could support farmers to adopt more environmentally sustainable on-farm practices due to increased understanding and ability to make informed decisions. The evidence identified that similar actions have encouraged the adoption of integrated pest management, regenerative agriculture, and organic farming
- **Improved Soil Health and Multispecies Crop Cover.** The evidence reviewed confirmed that these practices can promote soil biodiversity, enhance nutrient cycling, and reduce compaction with reduced reliance on chemical fertilisers. In addition, multispecies cover crops were associated with increased carbon sequestration in soils, contributing to improved soil health and long-term carbon storage
- **Sustainable Production.** Rotational grazing can increase grass yield and lower operational cost and allow for a higher carrying capacity for the land as well as enhancing soil structure. Reducing the age of slaughter was found to reduce carbon emissions therefore encouraging farmers to produce food in a more environmentally sustainable manner, while sire registration may enable practices such as genomic testing to support selective breeding resulting in more sustainable food production
- **Organic Farming (Support and Conversion).** Studies demonstrated that organic systems often support higher soil biodiversity and species richness with reduced agrochemical inputs linked to healthier ecosystems, with higher biodiversity on organic farms
- **Creation of Temporary and Permanent Habitats.** Grass margins on arable land were found to attract pollinators. Grass margins and short term leys were found to improve yields
- **Improved Water Quality, Water Usage and Flood Mitigation.** The evidence reviewed reported that the use of vegetative buffers reduced surface runoff which could protect and improve soil structure and fertility over time

- Improved Air Quality and Lowering Ammonia Emissions. The evidence reviewed found that technologies such as variable rate application can reduce air pollution, including ammonia, improve nitrogen use efficiency, and protect groundwater
- Collaborative Innovation, Research and Development. The evidence reviewed confirmed that supporting farmers to adopt innovations such as precision fertiliser application and related innovations could improve soil organic matter and reduce degradation
- Collaborative Landscape Scale Activity. The evidence reviewed suggested that coordinated management across farms can enhance habitat connectivity and ecosystem service delivery. The evidence suggested that this landscape-scale approach helps ensure that food is produced in a way that benefits the environment at scale.
- Collaborative Market and Supply Chain. The evidence reviewed found that supply chain collaboration could reduce food waste making the production of food in Wales more sustainable. The integration of digital technologies can also improve the sustainability of farming through the optimisation of inputs such as water and fertiliser.

Searches for one of the Themes identified potential negative consequences for encouraging the production of food in an environmentally sustainable manner. Negative impacts related to encouraging the production of food in an environmentally sustainable manner were found in:

- Sustainable Production. If rotational grazing is poorly managed, including increased stocking rates and insufficient rest periods, this may increase GHG emissions and prevent the emergence of the environmental benefits of rotational grazing.

(b) helping rural communities to thrive and strengthening links between agricultural businesses and their communities;

Searches in relation to 6 of the Themes found evidence that they could help strengthen rural communities to thrive and strengthen links between agricultural businesses and their communities. Impacts related to this were found in:

- **Enhanced Woodland Management.** Evidence suggested that woodland management techniques such as coppicing and pollarding were practices with deep cultural roots in Wales, contributing to landscape character and cultural continuity. Although no single study focused on the topic, woodland sites were broadly identified as being important spaces for environmental learning and a space for engagement with land stewardship principles
- **Woodland and Agroforestry Creation.** Evidence identified trees as contributing significantly to the cultural value of rural landscapes, strengthening connections to place for both farmers and local communities. Moreover, woodland creation was found to improve the aesthetic value of farmland landscapes, in turn enhancing the visual appeal of rural areas and reinforcing a sense of place for agricultural businesses and their surrounding communities. Woodlands on farms were also identified as potentially strengthening links between agricultural businesses and their surrounding communities by offering valuable spaces for outdoor learning and environmental education, being spaces for both school groups and community based educational activities
- **Improved Public Access to the Countryside.** Improved public access to farms and green space was associated with enhanced well-being and mental health benefits for local communities. Sites with enhanced educational materials, such as maps, signage, and leaflets, were shown to support greater public engagement with farming and nature, strengthening the links between agricultural businesses and their wider communities
- **Collaborative Innovation, Research and Development.** The evidence reviewed found that participatory innovation could promote the inclusion of women, marginalised groups, and smallholder farmers, contributing to social equity and recognising diverse cultural identities within farming systems
- **Collaborative Landscape Scale Activity.** Evidence reviewed found that when farmers engage in landscape level collaboration, greater cultural embeddedness of pro-environmental behaviours can be achieved whilst also supporting shared values and a collective sense of stewardship. Furthermore, engagement in collaborative land management at the landscape level was associated with improved social learning,

peer-to-peer exchange, and community-level knowledge sharing among farmers and land managers

- Collaborative Market and Supply Chain. The evidence reviewed found that strengthening local supply chains and encouraging collaborative approaches can support income diversification through farm-based experiences such as care farming, community-supported agriculture (CSA), and agritourism, as well as new opportunities in local food branding and direct-to-consumer sales.

(c) improving the resilience of agricultural businesses

Searches in relation to 13 of the Themes found evidence that they could improve the resilience of agricultural businesses. Impacts related to the improved resilience of agricultural businesses were found in:

- Enhanced Woodland Management. The evidence reviewed found that the management of on-farm woodland was associated with improved soil fertility and enhanced pollination services, both of which can contribute to improved agricultural productivity and long-term food security. Woodland can provide shelter for livestock, resulting in improved animal welfare and productivity. Managing woodland can contribute to income diversification through the sale of woodland/coppice products including timber, fruit crops and livestock. There is potential for farmers to receive Payments for Ecosystem Services through woodland management which delivers environmental benefits
- Woodland and Agroforestry Creation. The evidence reviewed found that creating woodland on farms can increase the yield of crops and livestock through delivery of ecosystem services such as habitat pollination and direct sheltering of livestock and crops. Similarly, the integration of trees on farms can generate diversified on-farm revenue through sale of fruit crops and timber. Creating woodland on farms was suggested to promote recreation and nature-based tourism which could generate income for farmers. The presence of woodland on farms was cited as delivering physical and mental health benefits, as well as promoting community cohesion for those involved – including farmers. Woodland creation is highlighted as having long

lead times for economic benefits, such as the financial return from woodland products

- **Enhanced Biosecurity.** Improved biosecurity practices such as enhanced slurry management and pathogen control can reduce disease incidence, leading to healthier livestock, improved productivity, and increased income through reduced losses and higher marketable yields. The savings generated by the implementation of higher standard of farm biosecurity measures are however long-term rather than immediate. The prevention of disease in livestock and improved animal welfare were associated with a positive impact on farmer welfare, reducing emotional distress and improving confidence in farm management practices. Effective control of disease in livestock can reduce the risk of zoonotic diseases being passed to humans. Measures such as UV disinfection can reduce the negative potential health impacts of chemical sanitisation on farmers
- **Implementation of Designated Site Management Plans.** The evidence reviewed suggested that farmers managing designated environmental sites may experience improved wellbeing and pride in their role as stewards of protected landscapes, which may contribute towards improved mental health which has been identified as a concern in the farming community
- **Hedgerow Creation or Restoration.** The evidence reviewed indicates that hedgerow creation and restoration can contribute to improved agricultural yields through supporting pollinator populations. Hedgerows can be used to produce wood chips for sale, and provide employment opportunities for farm labourers to manage them
- **Advanced Continuous Professional Development (CPD).** Peer-to-peer learning approaches, such as discussion groups and monitor farms, were found to enhance farmer wellbeing and mental health by reducing isolation and building sustainable networks which continued to deliver support even when outside funding ended. Several studies highlighted productivity benefits to farmers engaged in discussion groups and monitor farms, driven by technology adoption and improved business viability

- Improved Soil Health and Multispecies Crop Cover. The evidence reviewed found that rotating cover crops with vegetable crops may improve yields. The use of multispecies cover crops was associated with increased carbon sequestration in soils, contributing to improved soil health which may have knock-on effects on productivity
- Sustainable Production. The studies reviewed found that rotational grazing can increase grass yield, leading to reduced dependence on purchased feed. Rotationally grazed systems allow for higher stocking rates, contributing to improved livestock yields. Rotational grazing can improve the resilience and health of the soil and pasture to environmental shocks such as droughts. The evidence reviewed found that rotationally grazed systems can have lower disease and parasite loads, reducing the risk to livestock and treatment costs. The benefits from improving productivity, efficiency and KPI performance must be balanced with the cost of implementing that Theme, therefore it may take a few years after implementation to realise net economic benefits
- Organic Farming (Support and Conversion). The evidence reviewed found that organic farming can deliver higher profits to farmers through premium pricing and reduced input costs. Studies suggest that organic farming can bring satisfaction to farmers where these practices align with their intrinsic values, which can contribute to improved mental health outcomes
- Creation of Temporary and Permanent Habitats. Grass margins on arable land attract pollinators which can improve yields of insect-pollinated crops. Incorporating short-term leys into arable rotations was found to improve crop yields through soil quality improvement, which can also reduce the volume and costs of fertiliser inputs. Constructed wetlands can improve flood control on agricultural land and in the wider community which may make agricultural businesses more resilient to the negative economic impacts of unmanaged flooding
- Collaborative Innovation, Research and Development. The evidence reviewed demonstrated that innovation in agricultural practices and technologies can open up new income streams for farmers, including value-added products, novel cropping systems, and participation in research trials or pilot schemes. Technological

improvements can deliver cost savings through improved operational efficiencies and increase market competitiveness. Agricultural innovation, particularly in the development and dissemination of new practices and technologies, can contribute to economic diversification and resilience of farming systems. Incorporating technology can improve working conditions and reduce labour inputs for farmers, as well as fostering skill development for marginalised groups of farmers. These can have knock-on impacts on the local community through knowledge sharing and social cohesion. However, evidence suggested that these benefits may have long payback times due to high upfront costs of implementing new technologies

- Collaborative Landscape Scale Activity. The evidence reviewed indicates that collaborative management between farmers can enhance ecosystem service delivery and improve agricultural yields. Working in groups can reduce overall costs for individuals and provide space for experimentation and development of new business models. Participation in landscape-level collaborative actions was linked to improvements in farmer confidence, social capital and sense of purpose. Community benefits include greater social cohesion, knowledge sharing and cultural embeddedness of pro-environmental behaviours
- Collaborative Market and Supply Chain. The evidence reviewed confirmed that activities which add value to produce and open up income streams can improve profits for farmers and facilitate economic diversification and resilience of the farming business. Engaging in niche markets can encourage collaboration between agricultural stakeholders, facilitating knowledge sharing and better connection between producers and consumers. Farm diversification can encourage young people to remain in farming. Evidence suggested that these benefits may have long payback times due to high upfront costs of implementing new technologies.

Searches for 7 of the Themes identified potential negative consequences for the resilience of agricultural businesses. Negative impacts related to the resilience of agricultural businesses were found in:

- Enhanced Woodland Management. Evidence suggests that effective woodland management can result in higher costs due to increased management and labour costs associated with agroforestry systems

- **Woodland and Agroforestry Creation.** Evidence found that the creation of woodland and agroforestry is associated with higher costs due to the cost of buying and planting trees, as well as long term management of woodland on farms
- **Enhanced Habitat Management.** Evidence reviewed found that habitat creation and enhancement, such as pond and scrape installation, can involve high upfront costs, high ongoing maintenance requirement and costs, and potential loss of productive land, which may deter uptake without sufficient financial support
- **Sustainable Production.** Evidence reviewed found that rotational grazing requires a substantial upfront capital investment which can strain on farm cash flow
- **Improved Air Quality and Lowering Ammonia Emissions.** Evidence suggests that air quality technology like air scrubbers have high upfront costs and also high energy running costs
- **Collaborative Innovation, Research and Development.** Research found that agricultural innovations can incur a range of substantial costs and risks, including high initial investments, uncertain ROI and market uncertainty
- **Collaborative Landscape Scale Activity.** Evidence suggests that collaborative landscape- scale activity can be costly in terms of both opportunity costs and operational costs.

(d) sustaining the Welsh language and promoting and facilitating its use;

No searches returned evidence related to impacts on the Welsh language. As discussed in relation to the limitations of the research in the methodology, conclusion, and throughout, this does not mean that these Themes will not sustain, promote, or facilitate the use of the Welsh Language. It means the research identified did not choose to focus on the effect these Themes, or on-farm practices, may or may not have on the use of the Welsh Language. In addition, the focus of each REA was on a specific Theme, not the cumulative impact of the SFS, the SFS Optional and Collaborative Themes, nor the agriculture sector, therefore it was anticipated that any returns in relation to the Welsh Language would be limited at best.

Research on how the Welsh Language may or may not be affected by, related to, and impacted by the agriculture sector can be found in a number of studies on the Welsh language and agriculture. Powell [footnote ¹³⁷⁶] noted that 43 % of agricultural workers speak Welsh, a much higher percentage than the average in the general population which sits at 28 % [footnote ¹³⁷⁷]. Lewis noted that socio-economic development can have a range of impacts upon minority languages [footnote ¹³⁷⁸]. The relevant findings here are that economic restructuring, particularly declines in manual employment in sectors such as agriculture, can result in out-migration towards areas where the language is not spoken every day, contributing towards its decline. They note that this may not always be counter-acted by economic initiatives that may encourage inward migration of non-Welsh speakers.

Finally, Roberts noted in the 'Review into the resilience of Welsh farming' that agriculture as a source of employment is disproportionately high in the counties with highest number of Welsh speakers [footnote ¹³⁷⁹]. The review highlighted that decisions made at farm level have impacts on businesses across the sector in the surrounding areas, and raised stakeholder concerns that economic disruption faced by farmers may impact the number of people speaking Welsh as a first language in upland areas.

As stated, this report does not consider the cumulative impact of the SFS Optional and Collaborative Themes, however, with the link between farm business resilience and the sustaining of the Welsh Language, those Themes which are found to potentially contribute towards the economic, social and environmental resilience of the agricultural sector may also contribute towards this purpose. However, as the evidence in REAs did not identify this specifically, this connection cannot be made explicitly.

(e) reducing emissions of greenhouse gases;

Searches in relation to 5 of the Themes found evidence that they could help reduce emissions of greenhouse gases. Impacts related to a reduction in greenhouse gas emissions were found in:

¹³⁷⁶ Dyfan Powell, '[Agriculture and the Welsh Language](#)' (Arsyllfa Cymru / Observatory Wales, October 2020).

¹³⁷⁷ Welsh Government, '[Welsh Language Data from the Annual Population Survey: October 2023 to September 2024](#)', 23 January 2025.

¹³⁷⁸ Huw Lewis, '[Looking beyond ARFOR: Economic Development Strategies and the Welsh Language](#)' (Aberystwyth University, 2025).

¹³⁷⁹ Kevin Roberts, '[Review into the Resilience of Welsh Farming](#)' (Welsh Government, 2014).

- **Woodland and Agroforestry Creation.** The evidence reviewed indicates that while the presence of additional trees can enhance the interception of ammonia and contribute to carbon sequestration, these processes do not directly reduce emissions at source. However, where tree planting and woodland creation results in land use change, this may result in the reduction of GHG emissions through, for example, lower stocking densities, or a reduction of inputs applied to the land.
- **Sustainable Production.** The evidence reviewed found that adopting graze and rest approaches, reducing the age of slaughter, and sire registration (coupled with future genomic testing to determine desirable traits) can reduce greenhouse gas emissions through improved productivity. Graze and rest approaches can reduce the need for inputs such as fertiliser and feed while increasing stocking density, thereby increasing efficiency and reducing inputs, while reducing the age of slaughter and selection for environmental traits can both reduce total lifetime emissions from livestock production
- **Improved Air Quality and Lowering Ammonia Emissions.** Various cover types and management practices have been shown to significantly reduce ammonia (NH₃) emissions from slurry storage, lowering the sector's contribution to atmospheric pollution
- **Collaborative Innovation, Research and Development.** Evidence reviewed found that improvements and innovations in feed efficiency, fertiliser use, and technology adoption have been found to be associated with reductions in methane and nitrous oxide emissions, both of which are key contributors to agricultural greenhouse gas emissions
- **Collaborative Market and Supply Chain.** Evidence reviewed found that increased uptake in digital technologies can optimise certain inputs like fertiliser and water, which in turn could lead to reductions in greenhouse gas emissions.

Searches for one of the Themes identified potential negative consequences for the reduction of greenhouse gas emissions. Negative impacts related to the reduction of greenhouse gas emissions were found in:

- Sustainable Production. If rotational grazing leads to increased stocking rates this may increase GHG emissions due to the increased size of holdings.

(f) maximising carbon sequestration and storage;

Searches in relation to 7 of the Themes found evidence that they could improve and maximise carbon sequestration and storage. Impacts related to carbon sequestration and storage were found in:

- Enhanced Woodland Management. The evidence highlighted that woodlands act as significant carbon sinks, and practices such as coppicing and thinning can stimulate new growth and increase carbon uptake while cycling carbon through harvested materials. Evidence suggested that the carbon sequestration benefit of woodland management is realised only over a long-term timescale
- Woodland and Agroforestry Creation. The evidence reviewed identified that the establishment of new tree cover on farms can increase carbon sequestration through additional biomass and soil carbon capture. Evidence found that woodland creation yields carbon-sequestration benefits over extended timescales (multidecadal)
- Hedgerow Creation or Restoration. Hedgerows were found to be effective carbon sinks, helping to offset emissions from agricultural activities through both above- and below-ground biomass. Evidence highlighted that the restoration or planting of new hedgerows yields carbon-sequestration benefits over extended timescales, with soil organic carbon sequestration continuing to increase for at least 40 to 70 years
- Improved Soil Health and Multispecies Crop Cover. The use of multispecies cover crops was associated with increased carbon sequestration in soils, contributing to improved soil health and long-term carbon storage. Evidence found that multispecies cover crops supports increased carbon sequestration over long term timescales
- Sustainable Production. Rotational grazing systems were repeatedly cited in the evidence base as supporting carbon sequestration by improving pasture productivity and soil organic matter. The benefits of rotational grazing on carbon sequestration were found to occur over a long-term period

- Creation of Temporary and Permanent Habitats. Short-term leys, such as red clover or grass-clover, and constructed habitats can aid carbon sequestration, particularly through improved soil structure and vegetative cover. The benefits of habitat creation for carbon sequestration occurs over a long-term period
- Collaborative Innovation, Research and Development. Innovations in feed efficiency, fertiliser use, and technology adoption were associated with reductions in methane and nitrous oxide emissions, key contributors to agricultural GHG output.

(g) maintaining and enhancing the resilience of ecosystems;

Searches in relation to 14 of the Themes found evidence that they could help maintain and enhance the resilience of ecosystems. Impacts related to the maintenance and enhancement of ecosystem resilience were found in:

- Enhanced Woodland Management. Woodland management practices can produce structurally complex, multifunctional ecosystems that provide habitats for a variety of species. These diverse woodlands support rich ecological communities and promote landscape resilience when connected to trees across a landscape. Tree cover can lead to improved water and soil quality, reduce erosion and moderate the local microclimate and shelter species through wind protection
- Woodland and Agroforestry Creation. Evidence identified that woodland creation increases biodiversity by creating habitats for woodland flora and fauna. Tree corridors and connected woodland patches provide corridors for species dispersal and act as buffers for wind, flooding and chemicals. Increased tree cover improves air and soil quality, water retention, nutrient cycling and microclimate regulation
- Enhanced Habitat Management. The evidence reviewed indicates that wet grassland and arable land management, such as fallow and margin interventions, improve habitats for invertebrates and associated foraging opportunities for wading birds. Field margins provide habitats for pollinators, and reduced pesticide use is associated with improvements to species abundance and biodiversity

- **Implementation of Designated Site Management Plans.** The evidence suggests that creating field margins and wildflower strips in designated sites, can enhance biodiversity, especially when measures are targeted for specific species or outcomes
- **Hedgerow Creation or Restoration.** The evidence reviewed indicates that creating hedgerows can provide habitat and wildlife corridors, and increase species abundance and richness on farmland. Hedgerows contribute to ecosystem service delivery by supporting pollinators and natural pest predators, reducing soil erosion and protecting against flooding
- **Advanced Continuous Professional Development (CPD).** Whilst indirect, improved farmer understanding and uptake of nature-based actions can support biodiversity through informed decision-making and changes to agricultural practices. These include practices to reduce pesticide use, protect soils through regenerative practices, increase biodiversity and manage habitats sensitively
- **Improved Soil Health and Multispecies Crop Cover.** The evidence reviewed found that implementing multispecies cover crops can improve soil quality through nitrogen cycling, carbon sequestration and increased microbial diversity
- **Sustainable Production.** The evidence reviewed found that rotational grazing can improve soil health by supporting soil structure and improving fertility. Rotational grazing can enhance organic matter deposition in the soil and support microbial diversity. Rotational systems can enhance the soil structure and prevent erosion and nutrient leaching. These systems can support increased plant species richness which has knock-on impacts for pollinators and soil microorganisms. Rotational systems can reduce the prevalence of weeds, reducing the impacts of invasive species and the need for chemical herbicide application
- **Organic Farming (Support and Conversion).** According to the evidence reviewed, organic systems often support higher soil biodiversity and fertility. Reduced agrochemical inputs were linked to increased species richness on organic farms
- **Creation of Temporary and Permanent Habitats.** The evidence reviewed indicates that grassland creation and restoration can increase plant and invertebrate species abundance and richness. Flower-rich margins can increase pollinator abundance and

diversity and provide habitats for birds and insects. Constructed wetlands have been shown to support threatened insect and bird species, enhance habitat connectivity and provide habitats for amphibians. Evidence suggests that the development of new permanent habitats such as grasslands and woodlands can take a long time to develop

- Improved Water Quality, Water Usage and Flood Mitigation. Methods to improve water quality, such as riparian buffers and natural flood management, have been shown to enhance biodiversity and improve nutrient regulation between soils and water
- Collaborative Innovation, Research and Development. The evidence reviewed found that the use of innovative agricultural methods and technologies can improve soil health, reduce erosion and water pollution, and protect and enhance habitats and species richness
- Collaborative Landscape Scale Activity. The evidence reviewed found that landscape-scale environmental management can improve habitat connectivity and species dispersal, allowing species to disperse and adapt to climate change. Species with larger ranges are supported by joined-up actions to improve and connect habitats. Co-ordinated actions can deliver greater benefits in terms of soil and water quality, erosion and nutrient cycling, improving the overall ecological function of a landscape.

Searches for 3 of the Themes identified potential negative consequences for the enhancement and resilience of ecosystems. Negative impacts related to the maintenance and enhancement of the resilience of ecosystems were found in:

- Enhanced Woodland Management. The evidence reviewed demonstrated that some species with a particular preference for open or farmland habitats (curlews) may be negatively impacted by woodland management
- Woodland and Agroforestry Creation. Evidence found the potential negative impact of woodland creation on farms with ground nesting birds (curlew), negatively affecting both their density and activity.

- **Sustainable Production.** The positive environmental impacts of rotational grazing are dependent on management practices including appropriate stocking densities and rest periods between grazing cycles. Poorly managed rotational grazing may have negative consequences for ecosystems.

(h) conserving and enhancing landscapes and the historic environment

Searches in relation to 9 of the Themes found evidence that they could help conserve and enhance landscapes and the historic environment. Impacts related to the conservation and enhancement of landscapes and the historic environment were found in:

- **Enhanced Woodland Management.** The evidence reviewed highlighted tree shelterbelts between woodland patches can enhance landscape connectivity and landscape heterogeneity, providing ecological corridors for species to move between habitats. The cultural value of woodland management techniques like pollarding and coppicing are highlighted as important for the historic environment due to connections to ancient management practices which produce unique woodland features
- **Woodland and Agroforestry Creation.** Evidence reviewed found that lines of trees and woodland patches can act as buffers for pollutants and pesticides from agricultural activity, conserving the landscape by preventing their spread. Evidence highlighted the importance of trees for their cultural value in the landscape, which facilitates connection to the historic environment for farmers and locals
- **Enhanced Habitat Management.** Evidence demonstrated that arable field margins complement hedgerows and uncropped patches to enhance overall landscape functionality. Evidence suggests avermectin impairs seed exchange between habitats and therefore reducing use of these chemicals can conserve and enhance landscapes in the long-term. Several wader management options such as diverting predatory or cultivating verges highlight the need for a comprehensive, landscape-scale approach to conserve habitats for waders
- **Hedgerow Creation or Restoration.** Evidence reviewed found that restoring or planting new hedgerows is most effective when it strengthens existing hedgerow networks, reinforcing the historic structure of farmed landscapes. Hedgerows may

further help conserve the landscape by acting as flood control and reducing soil erosion, particularly on sloped landscapes

- Organic Farming (Support and Conversion). Evidence reviewed suggested that organic farming generally supports greater biodiversity which benefits and conserves the wider landscape through reduced chemical drift
- Creation of Temporary and Permanent Habitats. Evidence found that the proximity of varied habitat types facilitates greater connectivity and species movement across landscapes, leading to positive functional shifts, such as increased pollination or greater resilience to environmental stressors. Constructed ponds contribute to the conservation of landscape by providing similar biodiversity and ecological functions of natural ponds, supporting traditional wildlife such as amphibians and birds, which are integral to the historic environment
- Improved Public Access to the Countryside. Some evidence highlighted that improving the accessibility of certain public farm paths increased their use, which in turn helped divert pressure away from ecologically or culturally sensitive sites, such as nesting areas, conserving these landscapes
- Collaborative Innovation, Research and Development. Evidence found that innovative land management, such as precision agriculture and data-driven decision-making, and innovations in protein production could enhance the resilience of farming systems to climate impacts, supporting the conservation of landscapes and historic environments
- Collaborative Landscape Scale Activity. Evidence reviewed found that landscape-scale environmental management improves ecological connectivity, reduces habitat fragmentation, and supports species movement and adaptation to climate change, thereby enhancing the resilience of natural and historic landscapes. Collaborative action among farmers at this scale may also promote the cultural embedding of pro-environmental practices, reinforcing the importance of historic environments.

(i) improving air quality;

Searches in relation to 4 of the Themes found evidence that they could improve air quality. Impacts related to the improvement of air quality were found in:

- Woodland and Agroforestry Creation. Evidence reviewed confirmed that tree planting and woodland creation can contribute to increased air purification by absorbing atmospheric pollutants including ammonia
- Enhanced Biosecurity. Evidence reviewed found that slurry injection techniques could reduce ammonia volatilisation, ultimately improving air quality
- Improved Water Quality, Water Usage and Flood Mitigation. Evidence reviewed suggested that riparian buffers can reduce soil methane emission, in turn improving air quality
- Improved Air Quality and Lowering Ammonia Emissions. Evidence reviewed demonstrated that air scrubbing technologies, as well as improved slurry management could lead to reductions in ammonia emissions, with potential benefits for human respiratory health and reduced environmental exposure.

(j) improving water quality

Searches in relation to 14 of the Themes found that evidence they could improve water quality. Impacts related to improved water quality were found in:

- Enhanced Woodland Management. Evidence found that the inclusion of trees and woodland on farmland may contribute to higher water quality primarily through absorbing nutrients from agricultural runoff
- Woodland and Agroforestry Creation. Evidence reviewed found that on-farm woodland improves water quality as tree roots stabilise the soil, preventing sediment deposition into watercourses
- Enhanced Biosecurity. The evidence reviewed highlighted that biosecurity measures such as slurry injections and UV water treatments can reduce ammonia emissions, improve water efficiency, and reduce chemical sanitisers, supporting sustainable and improved water quality

- **Enhanced Habitat Management.** The evidence reviewed found that reducing avermectin use and improving wet grassland management for biodiversity can enhance soil and ecosystem health, leading to better water quality through improved nutrient cycling and reduced chemical loads
- **Implementation of Designated Site Management Plans.** Evidence found that a focus on conservation and environmental management is shown to have long-term benefits in terms of ecosystem services, for example, through the protection of water quality, biodiversity, and soil health
- **Hedgerow Creation or Restoration.** The reviewed evidence found that hedgerows contribute to improved water quality by reducing soil erosion, enhancing soil structure and filtration, limiting run off and sediment flow into watercourses
- **Sustainable Production.** Evidence highlighted that rotational grazing encourages greater root biomass development, leading to improved soil organic matter, water infiltration capacity, and improved water quality
- **Organic Farming (Support and Conversion).** The evidence reviewed confirmed that organic agriculture has reduced negative impacts on water provisioning and water quality compared to conventional farming due to the lower levels of chemical fertilisers and pesticides used
- **Creation of Temporary and Permanent Habitats.** Reviewed evidence found that constructed wetland systems and ponds used to remove excess phosphorus from agricultural runoff can help prevent pollution in nearby water bodies, improving water quality
- **Improve Water Quality, Flow and Usage, to Include Flood Mitigation.** The studies reviewed cover a wide range of interventions and solutions that impact water quality, water flow, reducing soil erosion and degradation, and riparian restoration
- **Improved Air Quality and Lowering Ammonia Emissions.** Evidence reviewed found that variable rate fertilisation improves nitrogen use efficiency and reduces ammonia volatilisation, leading to reduced nitrogen pollution and improved groundwater quality

- Collaborative Innovation, Research and Development. Evidence highlighted that environmental innovations such as precision irrigation, rainwater harvesting, and reduced pesticide runoff lead to less water source contamination and improve overall water quality
- Collaborative Landscape Scale Activity. The reviewed evidence found that because ecosystem services are often spatially extensive, landscape-scale actions can enhance their delivery, including improvements in water quality, flood storage, and reductions in soil erosion

(k) maintaining and enhancing public access to and engagement with the countryside and the historic environment;

Searches in relation to one of the Themes found evidence that they could potentially maintain and enhance public access to and engagement with the countryside and the historic environment. Impacts related to the maintenance and enhancement of public access to and engagement with the countryside and the historic environment were found in:

- Improved Public Access to the Countryside. Evidence reviewed suggested that improved signage, access infrastructure, and site amenities were linked to more positive recreational experiences and greater visitor engagement with farmland and surrounding natural areas. Moreover, improvements in accessibility, including path upgrades and the provision of site furniture, were associated with increased aesthetic appreciation and more positive visitor experiences
- **(l) mitigating flood and drought risks**

Searches in relation to 8 of the searches found evidence that they could help mitigate flood and drought risk. Impacts related to the mitigation of flood and drought risks were found in:

- Enhanced Woodland Management. The evidence reviewed concluded that that maintaining on-farm woodland and trees can improve water retention in soils and slow the flow of surface water, reducing peak flows and mitigating flood events. Riparian tree buffers and shelterbelts help store excess water and reduce flood risk. Tree management techniques such as pollarding have been shown to protect older trees from drought stress

- **Woodland and Agroforestry Creation.** The evidence reviewed found that creation of on-farm woodland can contribute to flood mitigation by increasing water storage in soils and reducing peak flows of surface water
- **Hedgerow Creation or Restoration.** The evidence concluded that hedgerows can enhance water filtration into soils by reducing erosion and improving soil structure. This improves water storage and reduces surface water runoff, which can contribute to flooding
- **Sustainable Production.** The evidence reviewed indicates that rotational grazing systems can reduce soil erosion and improve pasture health, making these systems more resilient to drought
- **Creation of Temporary and Permanent Habitats.** The evidence reviewed highlighted that constructed wetlands, ponds and scrapes retain water and reduce downstream flood risk
- **Improved Water Quality, Water Usage and Flood Mitigation.** The evidence found that nature-based interventions such as riparian buffers and constructed wetlands enhance water storage, reduce peak flows and reduce flood risks across the catchment
- **Collaborative Landscape Scale Activity.** The evidence reviewed highlighted that landscape-scale actions to enhance habitats can improve the delivery of spatially extensive ecosystem services, including flood mitigation
- **Collaborative Market and Supply Chain.** The evidence reviewed suggests that farmers are increasingly testing new technologies for improving farm efficiency, including the use of gene editing to produce drought-resistant crop varieties.

(m) achieving and promoting high standards of animal health and welfare;

Searches in relation to 5 of the Themes found evidence that they could potentially achieve and promote high standards of animal health and welfare. Impacts related to high animal health and welfare were found in:

- Woodland and Agroforestry Creation. Evidence reviewed found that increased tree cover and agroforestry systems can improve livestock shelter and reduce environmental stress, which could potentially lower susceptibility to disease, while also enhancing overall farm hygiene and biosecurity through improved nutrient and water management
- Enhanced Biosecurity. Evidence reviewed concluded that slurry injections and placement equipment can reduce airborne spread of diseases such as TB, while wildlife-proof feeders and troughs, vermin proof buildings/ feed stores, and watercourse fencing can all lead to reduced direct and indirect contact and contamination between cattle and wildlife, reducing the opportunity for TB transmission leading to a higher standard of animal health. The use of UV disinfection may reduce the use of chemicals like chlorine which have adverse health effects on livestock, reducing the incidence of chemical related health issues
- Enhanced Habitat Management. Evidence reviewed found that using targeted parasite control (ivermectin) potentially reduces parasite numbers and maintains healthy sheep weight. This selective approach improves overall herd health and welfare, whilst also lowering treatment costs and being more sustainable than alternative options
- Organic Farming (Support and Conversion) Some evidence pointed to the improved immune systems and improved animal health of laying hens under organic farming
- Collaborative Innovation, Research and Development. Evidence reviewed found that advances in animal health technologies, precision livestock farming, and disease monitoring systems can support early detection and control of disease, reducing losses and improving overall herd and flock health.

(n) maximising resource efficiency

Searches in relation to 10 of the Themes found evidence that they could improve and maximise resource efficiency. Impacts related to maximising resource efficiency were found in:

- **Woodland and Agroforestry Creation.** The evidence reviewed indicates that creating woodland on farms can reduce input costs by providing fodder for livestock and reducing nutrient leaching from soils which means less fertiliser application may be required
- **Enhanced Biosecurity.** The evidence reviewed indicates that manure recycling can reduce the need for artificial fertiliser application. UV water sterilisation increases water reuse on farms and reduces the need for chemical sanitiser application. Exclusion measures to protect livestock feed and water from contamination can reduce the costs associated with disease treatment
- **Enhanced Habitat Management.** The evidence identified found that targeted parasite treatments rather than whole-herd treatments can effectively reduce parasite numbers while saving on treatment costs. The use of long-acting parasite medications can lead to reduced treatment frequency and labour input
- **Improved Soil Health and Multispecies Crop Cover.** The evidence reviewed concluded that implementing cover crops and multispecies swards can improve soil fertility and nutrient management, reducing the need for fertiliser and application and lowering input costs. Multispecies crops have been found to suppress weed growth, which could reduce the need for pesticide application
- **Sustainable Production.** The evidence reviewed indicates that rotational grazing improves grass yield over longer time periods, reducing dependence on purchased livestock feed and so lowering input costs. The system can increase resource efficiency by extending the grazing season through improved grass growth, which also supports higher stocking rates, improving the efficiency of production. Rotational grazing systems can have lower disease and pest loads, reducing the need for pesticide application. Reducing cattle slaughter age can improve feed conversion efficiency and reduce housing duration, both of which lead to reduced inputs. Similarly, sire registration is a key step to allowing farmers to choose genetically improved cattle with higher growth rates and feed efficiency which require lower resource inputs

- Organic Farming (Support and Conversion). The evidence reviewed indicates that organic farming systems require lower inputs of fertilisers and pesticides
- Creation of Temporary and Permanent Habitats. The evidence reviewed found that incorporating grass margins and mixed leys on farms can support pollinator abundance, reduce weed abundance and improve soil fertility, reducing the need for chemical fertiliser and pesticide inputs while maintaining crop yields
- Improved Water Quality, Water Usage and Flood Mitigation. The evidence identified highlighted that natural flood management and riparian buffers reduce nutrient runoff from soils, reducing the need for re-application of fertilisers and the associated costs
- Improved Air Quality and Lowering Ammonia Emissions. The evidence reviewed indicates that variable rate technologies improve nutrient use efficiency by reducing nitrogen losses during application, reducing the need for additional fertiliser inputs
- Collaborative Innovation, Research and Development. The identified evidence suggests that precision agricultural technologies improve resource efficiency by reducing water and fertiliser use and associated input and labour costs. Techniques like precision irrigation and rainwater harvesting improve water conservation and reduce nutrient runoff, thereby reducing fertiliser re-application costs.

**(o) encouraging agricultural businesses to manage energy effectively
(including by adopting energy efficiency and energy saving practices, and
generating renewable energy on their land)**

Searches for 3 of the Themes found that evidence they could encourage agricultural businesses to manage energy effectively. Impacts related to encouraging agricultural businesses to manage energy effectively were found in:

- Hedgerow Creation or Restoration. Evidence found that newly planted hedgerows can help agricultural businesses manage energy effectively as they can be used to produce woodchips, which can ultimately be used to reduce energy costs on farm. Evidence suggests that the benefits of using coppicing for biofuels for energy use may occur over a 15 to 20 year timescale

- Improved Water Quality, Water Usage and Flood Mitigation. Some evidence suggests that the adoption of coppice willow as a riparian buffer can potentially encourage agricultural businesses to manage energy effectively as they can be used as biomass. Evidence suggests that the benefits of using coppicing for biofuels for energy use may occur over a 15 to 20 year period
- Collaborative Innovation, Research and Development. Evidence found that certain innovations like automation, improved operational efficiencies and data-driven decision making can reduce energy use for agricultural businesses, with other innovations in renewable energy and bio-based products helping contribute to the local economy in rural areas.

Cost Effectiveness Evidence relating to SFS Optional and Collaborative Themes

This section summarises the evidence identified in relation to the cost effectiveness of each Optional and Collaborative Theme (OT/CT). Where possible, more detail can be found in the relevant OT/CT section, with this section providing only a summary. In addition to the limitations highlighted at the beginning of the conclusion, it is important to highlight that evidence on the cost effectiveness of different interventions across the OT/CTs was limited by both the broad scope of the research, and often the focus of the academic literature itself, which was often driven by attention to outcomes as opposed to the relative cost-benefits of different Themes. This section is therefore not an assessment of each Theme's cost-benefits but a summary of what evidence the literature reviewed has been able to provide in relation to cost-effectiveness or broader economic impacts where such information was available.

Enhanced Woodland Management

The evidence reviewed suggested that short-rotation coppicing on buffer strips or woodland patches could deliver economic benefits without loss of productivity. Improved woodland management could also have positive impacts on yield. Encouraging natural regeneration through thinning and cutting regimes was seen as cost effective for farmers.

Woodland and Agroforestry Creation

One study suggested that incorporating natural regeneration in woodland creation was a lower cost option to manual planting with the same environmental outcomes. The evidence suggested that planting on “marginal” land already excluded from production would constitute a net benefit with potential for economic benefits of increased pollination and agroforestry activities where agriculture is not viable.

When considering the wider social value, a UK study suggested that ecosystem service delivery of planting broadleaves was the equivalent of £89,900 per hectare and £130,100 per hectare for conifers.

Enhanced Biosecurity

The evidence on the cost effectiveness of slurry injection methods was mixed with it identified as one of the most expensive interventions of 9 ammonia emission mitigation strategies reviewed. Shallow disk injection was identified as the most cost-effective with the greatest benefits and minimal costs, however, this was a study in the USA.

UV treatments for disinfecting water, as opposed to chlorination, were broadly identified as “good value for money” with UV lamps in particular highlighted due to a small initial investment and minimal maintenance.

Actions to prevent feed contamination, such as vermin-proof buildings and feedstores, were identified as cost effective due to minimal reliance on external power.

Enhanced Habitat Management

With regards to anthelmintic use one study found that medium and large farms could achieve a net economic gain from reducing anthelmintic use due to reduced product and labour costs. However, cost-effectiveness considerations were not evidenced across the review generally due to the need to develop clear alternatives to the drugs usage.

With regards to Wet Grassland Management for Waders, predator controls and predator exclusion fencing were found to be costly with evidence of effectiveness mixed. Other strategies such as habitat management through increasing wetness or adding verges were found to be more financially viable although with slightly less effectiveness than full predator exclusion.

With regards to arable land management field margins were found to offer a more cost-effective approach to providing food resources for birds than whole-field options.

Implementation of Designated Site Management Plans

No direct cost-effectiveness analysis included in the literature reviewed, although 2 studies suggested that outcome-based payment models can improve efficiency and cost-effectiveness. The evidence reviewed identified differing payment levels required to attract farmers with those who may face higher opportunity costs such as dairy farms requiring a higher payment.

Hedgerow Creation or Restoration

One study suggested that managing hedgerows for biofuel could provide a cost-effective solution for farmers.

One study identified 3 approaches to hedge laying which may produce the same environmental benefits with differing costs suggesting the potential for improved cost-effectiveness either the farmer, or government depending on the funding source. These approaches were identified as 'traditional', 'conservation' and 'wildlife' ranging from most expensive to least expensive.

Advanced Continuous Professional Development (CPD)

Programme cost can be affected by:

- farmers being paid to participate which some evidence suggested can increase the number of participants, although an Irish study found that the majority of farmers would continue to attend their discussion groups without payment
- conversely, farmers paying to attend, which a Scottish evaluation suggested would improve attendance rates due to improved buy-in
- the farm type, with Irish and Scottish dairy farmers more likely to attend without payment than beef farmers
- payment to the host farmer, which 53% of Scottish Monitor Farms supported.

A study in Wales provided evidence that establishing networks through discussion groups had a "self-sustaining legacy" which may suggest these are cost-effective methods in the longer-term.

Improved Soil Health and Multispecies Crop Cover

The evidence base identified did not include cost-benefit analysis. In those studies that conducted yield assessments the profitability was not well accounted for considering cost of the practice vs additional yield benefits.

Sustainable Production

Rotational grazing was identified in the evidence base as effective in increasing livestock productivity by extending the grazing season and allowing higher stocking rates, leading to greater profits. Reducing slaughter age can deliver efficiency benefits to the farmer by reducing input costs.

Whilst a study into Ireland's Beef Data and Genomics Programme indicated that investment in the programme will be outweighed by the economic gains generated for the economy by 2030, the programme involved genomic testing alongside sire registration, which goes beyond what is required under this Optional Theme.

Organic Farming (Support and Conversion)

The evidence reviewed discussed the impact of local farm factors on the potential profitability of switching to organic farming, with some farms being better suited to making the change without impacting their income. It also highlighted benefits of switching to organic farming associated with reduced input costs and the increasing demand for organic produce, both of which suggest organic farming could be cost-effective for some farmers.

Creation of Temporary and Permanent Habitats

Although the studies reviewed did not complete extensive cost-benefit analyses, the potential cost-effectiveness of proposed interventions for habitat creation were considered by several. One study identified carbon addition and low-cost seed mixtures as low-cost, high-value interventions which deliver tangible benefits for grassland creation and pollinators. The evidence identified suggests that creating grass margins in arable fields is a cost-effective method to improve biodiversity, suppress weeds and prevent pesticide and fertiliser drift – all at a relatively low cost compared to wildflower margins. Maintaining long-term leys was identified as more cost-effective than short-term leys, which acquire additional costs of reseeded.

Establishing wet grasslands and constructed wetlands were identified as a more cost-effective and labour efficient alternative to conventional wastewater treatment due to the low construction, maintenance, and energy costs. However, one study suggested this cost-effective solution can only be realised with external financial support.

Improved Public Access to the Countryside

The evidence base reviewed focussing on the cost-effectiveness of increasing access to nature interventions was limited. One study indicated that low-cost wayfinding interventions can deliver tangible outcomes for recreation and community health. Another study suggested that sites for trail improvement should be carefully selected to ensure the interventions are delivered in a cost-effective manner.

Improved Water Quality, Water Usage and Flood Mitigation

Though the literature identified did not provide clear cost-effectiveness evaluation for specific practices, with regards to payment for ecosystem services, studies highlighted how the cost of a catchment management scheme is usually lower than the costs of impact. Studies that looked at monitoring and mapping areas for interventions suggested that targeting Hydrologically Sensitive Areas could prove a cost-effective strategy for tackling water pollution.

Improved Air Quality and Lowering Ammonia Emissions

The number of articles within the evidence reviewed which considered the cost-effectiveness of air quality interventions was small. Some variable rate technology studies did consider cost-benefits, providing information from a Swiss context on the point at which implementation costs make the activity unprofitable for farmers.

Collaborative Innovation, Research and Development

Several studies highlighted long-term financial benefits that could be realised through digital technologies, despite high upfront costs. These include reduced operational costs, resource efficiency improvements, cooperative models for sharing financial costs, and accessing government grants and subsidises.

Collaborative Landscape Scale Activity

A study from Wales suggested that the provision of advice to groups of farmers could produce 'economies of scale' whereby the advice travels further than if it was given to just one individual. Additionally, reductions in administration for the group and/or administrator (such as government) may arise when collaborative schemes employ single

contracts/agreements with external organisations instead of individual agreements for each farmer.

Collaborative Market and Supply Chain

Studies focussed on potential economic benefits rather than cost-effectiveness of interventions. The evidence reviewed suggested that benefits arose from the adoption of new technology for crop and livestock management and reductions in waste due to collaboration in the supply chain amongst other things.

Potential Alignment of SFS Themes with CSFs

Each Theme was assessed to determine the potential for alignment with the CSFs chosen by Welsh Government. These were:

Strategic fit and business needs (strategic case):

- aligns the Sustainable Land Management Objectives established in the Agriculture (Wales) Act 2023.
- aligns with the WG's objectives reflected in the Well-being of Future Generations (Wales) Act 2015 and the Environment (Wales) Act 2016, especially in relation to sustainable land management
- is approved of and supported by key stakeholders, in particular those directly impacted by the SFS (such as farmers and rural communities) and wider groups across Wales
- provision of financial support is linked to delivery of measurable economic, environmental, and social outcomes
- farmers see sustainable practices as economically feasible with SFS support.

Value for money (economic case):

- the SFS is accessible to all farms and farmers
- farmers receive clear, accessible information about the direct and wider benefits and requirements of the SFS
- farmers are incentivised to change their behaviour to adopt more sustainable farming practices to the benefit of [disadvantaged] rural or farming communities
- farmers are encouraged to act to adapt to and mitigate the effects of climate change

Supply side capacity and capability:

- farmers are equipped to undertake a holistic assessment/appraisal of the potential value of adopting [more] sustainable farming practices

- farmers have sufficient access to advisory services and support networks (including peer-to-peer learning and demonstration projects)
- farmers are encouraged to collaborate to improve the efficiency of agricultural (and food) supply chains.

Affordability:

- farmers' costs of participating in the SFS are minimised
- farmers are able to supplement SFS support by attracting additional funding from investors other than the Welsh Government.

Each of the Themes were assessed for potential alignment with CSFs based on the evidence reviewed with potential alignment given a high, medium or low designation using the below framework:

- high – the majority of identified evidence suggested that similar Themes have achieved the objectives
- medium – some of the applicable evidence suggested that similar Themes have achieved the objectives
- low – the applicable evidence suggests that similar Themes have not achieved the objectives, or there was not enough evidence to assess potential alignment.

Alignment was assessed based only on the evidence reviewed which considered similar actions often delivered outside of Wales. The alignment designation is only a potential alignment and the extent to which potential benefits are realised will be highly dependent on specific delivery mechanisms, location of uptake, and scale of uptake.

Strategic fit and business needs

Evidence related to potential impacts of Themes was particularly relevant to the Strategic fit and business needs CSF (strategic case) when assessing alignment with WG objective and the delivery of measurable outcomes. Evidence related to barriers, cost-effectiveness, and uptake of the practice was relevant for considering stakeholder approval and whether farmers see the practices as economically feasible with SFS support.

High Alignment Themes

The evidence reviewed suggested that several OT/CTs have high potential alignment with the CSF of Strategic fit and business needs, in that the majority of applicable evidence suggested that similar Themes have achieved outcomes that align with the Strategic fit and business needs CSF. The potential impacts of these OT/CT are aligned with the strategic objectives of the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives outlined in the Agriculture (Wales) Act 2023. They may contribute directly to positive environmental, social, and economic outcomes depending on their implementation and delivery.

Themes assessed to have high potential alignment include:

- Enhanced Woodland Management. Contributes to climate change mitigation, biodiversity, and soil health. The Theme may also support economic outcomes through improved yields
- Enhanced Biosecurity. The evidence reviewed suggests that this Theme may provide economic and public health benefits through disease prevention and mitigation on-farms, resulting in protection for yields
- Implementation of Designated Site Management Plans. This Theme may support biodiversity and conservation in protected landscapes
- Hedgerow Creation or Restoration. This Theme may improve biodiversity, supports pollinators, and contribute to carbon storage
- Advanced Continuous Professional Development (CPD). Strongly facilitative and widely supported, but assessed as medium to reflect the indirect nature of its alignment with land management objectives. The Theme is indirect in that it does not produce tangible benefits on its own; benefits only emerge if it is implemented effectively with the activities offered aligning strongly enough with SLM priorities
- Sustainable Production. This Theme may improve economic outcomes, resource use efficiency, and climate change mitigation
- Organic Farming (Support and Conversion). This Theme may result in positive environmental and economic outcomes

- Creation of Temporary and Permanent Habitats. This Theme may support biodiversity, pollinator populations, and soil regeneration. These outcomes align well with key Welsh environmental policy goals and broader SLM objectives
- Improved Water Quality, Water Usage and Flood Mitigation. This Theme may support targeted improvements in water quality, natural flood management, and resource efficiency
- Improved Air Quality and Lowering Ammonia Emissions. This Theme may improve air and water quality
- Collaborative Innovation, Research and Development. This Theme may support adaptive practices that align with the Well-being of Future Generations (Wales) Act 2015 and Sustainable Land Management objectives of the Agriculture (Wales) Act 2023 reducing waste, increasing yield and minimising resource use.
- Collaborative Landscape Scale Activity. This Theme encourages coordinated land management with the potential for positive economic, social and environmental outcomes
- Collaborative Market and Supply Chain. This Theme may contribute towards more sustainable food systems and supports rural resilience potentially aligning with the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023

These Themes were assessed as high alignment based on their potential to deliver multiple, measurable environmental and social benefits, and because they align closely with the policy direction and legislative frameworks guiding Welsh land management.

Medium Alignment Themes

Some SFS Themes demonstrate medium alignment with Strategic fit and business needs, in that some of the applicable evidence suggested that similar Themes have achieved outcomes that align with the Strategic fit and business needs CSF. While these Themes have potential to support the Welsh Government's strategic objectives, the evidence reviewed identified limitations in scale, relevance, or supporting data.

Themes assessed as having medium alignment include:

- Woodland and Agroforestry Creation. While the evidence reviewed suggests that this Theme may have positive environmental, cultural barriers, uncertainties around economic feasibility, and land-use trade-offs limit its alignment
- Enhanced Habitat Management. The evidence demonstrated potential environmental benefits, however, the evidence lacked detail on feasibility, economic fit, and uptake of these on-farm practices
- Improved Soil Health and Multispecies Crop Cover. Soil health benefits are well-evidenced, but variable results, adoption barriers, and the literature focussing more on cover cropping generally with limited distinction between single and multispecies mixtures reduce certainty
- Improved Public Access to the Countryside. Some of the evidence reviewed suggested that this Theme may contribute towards positive social outcomes but that it aligns less directly with environmental and economic outcomes.

Overall Potential Alignment with Strategic fit and business needs

The review indicates that the majority of SFS OT/CTs show strong potential to align with Strategic fit and business needs. Themes that support biodiversity, climate resilience, ecosystem improvement, and improved economic outcomes generally align well with the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023. However, the level of alignment is conditional on Scheme implementation. Where evidence was lacking or outcomes were highly variable, Themes were assessed more cautiously. Overall, the reviewed evidence supports a broadly positive assessment of alignment with this CSF.

Value for money

In line with the Welsh Government CSFs, evidence related to potential impacts of Themes as they relate to sustainable farming practices and adaptation to and mitigation of the effects of climate change was used to assess alignment with the Value for money CSF (economic case). Barriers, uptake of the practice and cost-effectiveness questions were also used to assess alignment.

High Alignment Themes

A number of SFS Themes demonstrate high potential alignment with the Value for money CSF, in that the majority of applicable evidence suggested that similar Themes have achieved the identified Welsh Government objectives. The evidence reviewed suggested that similar Themes were generally considered low cost, widely accessible, and capable of delivering measurable economic, environmental, or social benefits. These OT/CTs have the potential to encourage positive behaviour change and offer a favourable return on public investment.

Themes that may align highly include:

- **Enhanced Woodland Management.** Evidence suggested that similar Themes have delivered climate and biodiversity outcomes at relatively low cost to farmers
- **Hedgerow Creation or Restoration.** Evidence suggested that similar Themes have enhanced ecosystem services such as pollination, improved biodiversity and contributed to carbon sequestration
- **Advanced Continuous Professional Development (CPD).** There was strong evidence for long-term value for money through improved decision-making, productivity, and sustainable behaviour change
- **Sustainable Production.** The evidence suggested that this Theme may support long-term business viability through improved resource efficiency, and support climate change mitigation
- **Creation of Temporary and Permanent Habitats.** The evidence reviewed suggested that this Theme may contribute towards biodiversity improvements
- **Improved Public Access to the Countryside.** The evidence found that similar Themes were generally low-cost and delivered clear social benefits
- **Improved Air Quality and Lowering Ammonia Emissions.** The evidence reviewed found that this Theme may support climate change mitigation, and other environmental outcomes

- Collaborative Innovation, Research and Development. The evidence reviewed suggested that this Theme may support innovation with potential to deliver measurable economic and environmental benefits
- Collaborative Landscape Scale Activity. The evidence reviewed suggested that this Theme may contribute towards positive environmental outcomes including ecosystem resilience and climate change sequestration.

The evidence identified suggests that these Themes have the potential to deliver value for money, as defined in this report, through their potential to deliver a broad range of economic, social and environmental benefits, including those related to ecosystem resilience and climate change, at relatively low cost or through mechanisms that are already known to support effective farmer engagement and uptake.

Medium Alignment Themes

Several Themes are assessed as medium potential alignment due to either uncertain cost-effectiveness, high variability in outcomes, or a need for sustained financial support to deliver their potential benefits.

Themes with medium alignment include:

- Woodland and Agroforestry Creation. The evidence reviewed suggested that this Theme may offer environmental benefits, however, they highlighted high potential costs and suggested that uptake may be an issue influenced by social and economic factors
- Enhanced Biosecurity. Similar Themes were identified in the evidence as having clear environmental and economic benefits; however, they may require significant investment by farm businesses limiting uptake
- Enhanced Habitat Management. Evidence suggests these Themes may contribute to biodiversity and ecosystem services. The evidence highlighted that positive outcomes are dependent on Scheme targeting and farmer engagement
- Implementation of Designated Site Management Plans. Evidence reviewed suggested that this Theme may contribute towards ecosystem resilience with positive

environmental outcomes, however, the evidence identified suggested that more research was needed to determine if this approach is effective

- Improved Soil Health and Multispecies Crop Cover. The evidence reviewed suggested that the Theme may improve long-term productivity with positive economic outcomes and potential positive environmental outcomes, however, both economic and environmental outcomes were variable
- Organic Farming (Support and Conversion). The evidence reviewed suggested that the Theme may contribute towards ecosystem resilience and climate change through improved soil organic carbon, however there is evidence of comparable soil organic carbon in non-organic farming. Furthermore, organic production requires greater land area than conventional farming due to lower yield, impacting footprint. The evidence identified also suggested that the Theme may generate environmental and social value, but profitability and cost-effectiveness are mixed depending on market access acting as barriers
- Improved Water Quality, Water Usage and Flood Mitigation. Evidence suggested that riparian buffers, and natural flood measures offer cost-effective alternatives to downstream infrastructure, particularly related to climate change adaptation, however, the REA identified limited formal economic evidence
- Collaborative Market and Supply Chain. The evidence reviewed suggested that this Theme could support farmers to adopt more sustainable farming practices and increase their resilience, but delivery costs and impact vary.

These Themes may deliver value for money in the right contexts, particularly where well-supported by advice and payments, but they carry a degree of uncertainty or depend on longer-term behavioural and market shifts.

Overall Potential Alignment with Value for money

Evidence for the SFS Themes reviewed demonstrated a generally positive potential for alignment with Value for money, particularly those that are low-cost, deliver co-benefits, and encourage farmer engagement. However, the strength of this alignment varies depending on Theme type, implementation design, and the presence of supporting infrastructure.

Themes that provide environmental and social benefits at scale, especially where supported by existing farmer practice or market incentives, show the clearest value for money potential. Others depend more heavily on consistent public funding, targeted advisory support, or cultural change to reach their full potential.

Supply side capacity and capability

Alignment with Supply side capacity and capability was assessed in a more limited capacity as the sub-factors could not be directly linked to an evidence review. The assessment was made using evidence related to barriers, design of the intervention and uptake of practice, however, other factors outside the scope of this report should be considered.

High Alignment Themes

Only one Theme demonstrated high potential alignment with the Supply side capacity and capability CSF; that is, the REAs identified limited evidence suggesting that similar Themes have successfully achieved the intended objectives. High alignment in this category requires that farmers have the necessary skills, access to advisory services, and opportunities to work together, with this capacity either in place before the implementation of the SFS or provided as part of rollout. Based on the evidence reviewed, one Theme clearly meet these criteria:

- Advanced Continuous Professional Development (CPD). The evidence reviewed suggested that this Theme may directly support Supply side capacity and capability by equipping farmers with the knowledge, skills, and peer support needed to assess and adopt sustainable practices. Evidence highlighted that discussion groups, monitor farms, and facilitated learning improve decision-making, build confidence, and contribute to long-term behavioural change.

Medium Alignment Themes

A number of Themes are assessed as medium alignment, in that some of the applicable evidence suggested that similar farmers have the skills, support, and opportunities to deliver Themes. These typically show some existing support structures or potential for uptake, but lack consistent evidence of widespread capability, access to services, or collaborative delivery models.

- **Woodland and Agroforestry Creation.** The evidence reviewed suggested that UK farmers may be limited by lack of knowledge, skills and labour resources for woodland creation. Evidence also highlighted that grant processes were a barrier, as was access to expertise. Difficulty access expertise was a finding from international and UK studies and therefore may not be directly applicable to Wales.
- **Enhanced Woodland Management.** The evidence reviewed suggested that barriers to uptake such as woodland management skills and knowledge in Wales and beyond were relatively common. However, evidence showed that some support structures exist in Wales. Greater uptake could be enabled with targeted guidance.
- **Improved Soil Health and Multispecies Crop Cover.** UK evidence suggested that there was growing use of multi-species cover crops, indicating some baseline capacity.
- **Sustainable Production.** Existing advisory networks and infrastructure, such as Farming Connect, can support data-driven approaches in Wales, though uptake varies by enterprise type.
- **Organic Farming (Support and Conversion).** An established advisory ecosystem exists in Wales for organic farming, but coverage and access may be uneven.
- **Improved Water Quality, Water Usage and Flood Mitigation.** The evidence suggests that this Theme may require specialist advice on hydrology and catchment planning. However, UK level evidence suggested that current advisory capacity is limited.
- **Collaborative Landscape Scale Activity.** This Theme encourages farmer collaboration and can build regional capacity where structures are in place.
- **Collaborative Market and Supply Chain.** The evidence suggests that this Theme may facilitate strong farmer engagement through peer-to-peer learning, demonstration activities, and advisory support, which in turn can enhance supply chain efficiency. The Theme may support collaboration, innovation, and knowledge transfer, contributing to long-term capacity-building.

Low Alignment Themes

Most Themes reviewed fall into the low alignment category, in that the applicable evidence either suggests a lack of capacity and capability to deliver Theme objectives, or there is an absence of evidence within the limited literature reviewed to support a stronger level of alignment.

- **Enhanced Biosecurity.** The evidenced identified lacked detail of advisory networks or coordinated delivery.
- **Enhanced Habitat Management.** Evidence identified was limited to conservation impacts, with little support infrastructure mentioned.
- **Implementation of Designated Site Management Plans.** No advisory or training support identified in the literature reviewed.
- **Hedgerow Creation or Restoration.** Requires specialist knowledge; the evidence reviewed did not identify large-scale farmer training or support in Wales, however, this is likely to relate to the literature reviewed.
- **Creation of Temporary and Permanent Habitats.** Implementation appears isolated, with little evidence of collaborative support.
- **Improved Public Access to the Countryside.** Not directly applicable to this CSF, with no support structures referenced.
- **Improved Air Quality and Lowering Ammonia Emissions.** Literature identified the potential for high implementation cost and limited evidence of current advisory or peer support.
- **Collaborative Innovation, Research and Development.** Identified barriers include lack of digital infrastructure, skills, and financial accessibility.

Overall Potential Alignment with Supply side capacity and capability

Overall, the review indicates limited current alignment between OT/CTs and the Supply side capacity and capability needed for successful implementation. As discussed in the methodology the REA's assessment of Supply side capacity and capability was intended to be limited providing any evidence of farmer capability, the provision of advisory services and

support networks, and encouragement of farmers to collaborate where relevant. However, as with other sections, absence of evidence in the REA is not evidence that these components are absent. Evidence of advisory infrastructure, training, or collaborative structures that enable widespread uptake was limited for most Themes due to the nature of the evidence reviewed.

Affordability

Evidence related to barriers, design of the intervention and uptake of practice was used to assess alignment with Affordability. Only 2 factors of the Affordability CSF were identified as relevant to this research, these are:

- farmers' costs of participating in the SFS are minimised
- farmers are able to supplement SFS support by attracting additional funding from investors other than WG.

Alignment was assessed by considering evidence related to these 2 factors alone, however, as most of the evidence was related to impacts of interventions identified evidence was limited.

High Alignment Themes

A small number of Themes reviewed were assessed as having high alignment with the Affordability CSF. These Themes were found to either require low capital investment or to offer viable opportunities for additional income, making participation more financially accessible to farmers.

Themes with high Affordability alignment include:

- Enhanced Woodland Management. Evidence suggested that this Theme can be integrated into existing farm systems with limited cost; some financial support mechanisms already exist.
- Woodland and Agroforestry Creation. Evidence suggested that while initial costs may be high, potential income from outside investors may offer financial opportunities.

- Implementation of Designated Site Management Plans. The evidence identified that delivery costs may be offset by payment schemes, with some evidence of the improved cost effectiveness of outcome-based payment models.
- Collaborative Innovation, Research and Development. The evidence reviewed suggested that while initial costs may be high, support schemes and shared models (e.g. farmer clusters) may reduce barriers to entry.

Medium Alignment Themes

Several Themes were assessed as having medium alignment with Affordability. These Themes are generally accessible to some farm types and can be low-cost depending on implementation, but may also require up-front investment or ongoing support.

- Enhanced Habitat Management. Costs of similar Themes were found to vary depending on the type and scale of habitat intervention.
- Hedgerow Creation or Restoration. Costs were found to vary by method, however, there was evidence of potential for private investment.
- Advanced Continuous Professional Development (CPD). The evidence suggested that discussion groups and similar CPD formats are relatively low-cost and may become self-sustaining, however, more structured approaches such as monitor farms require upfront investment and ongoing facilitation. Some farmers continue to participate without payments, suggesting long-term affordability when schemes are well-designed.
- Sustainable Production. The evidence reviewed suggested that while some practices may be costly (e.g. rotational grazing infrastructure), others are low-cost and scalable.
- Organic Farming (Support and Conversion). The evidence suggested that profitability depends on farm system and market access with some farmers already operating successfully.
- Improved Public Access to the Countryside. Evidence suggested that this Theme is generally low-cost with flexible options depending on the farm context.

- Improved Water Quality, Water Usage and Flood Mitigation. The evidence reviewed suggested that practices are mixed between those that are low-cost, and those that involve high upfront or opportunity costs.
- Collaborative Landscape Scale Activity. The evidence reviewed suggested that this Theme can be cost-effective for farmers depending on implementation.
- Collaborative Market and Supply Chain. The evidence reviewed highlighted a range of investment levels, from peer learning (low-cost) to infrastructure upgrades (higher-cost).

Low Alignment Themes

A number of Themes were assessed as having low alignment with Affordability due to high up-front or maintenance costs, opportunity costs, or lack of evidence.

- Enhanced Biosecurity. The evidence reviewed highlighted significant implementation costs, with farmers needing to invest in infrastructure such as slurry injection equipment, UV water treatment, or fencing.
- Improved Soil Health and Multispecies Crop Cover. The evidence reviewed was limited with regards to economic feasibility, with cost and performance highly site-specific.
- Creation of Temporary and Permanent Habitats. The evidence reviewed suggested that affordability depends on design with limited evidence of external investment.
- Improved Air Quality and Lowering Ammonia Emissions. The evidence reviewed suggested that infrastructure and equipment costs are high.

These Themes could become more financially viable with targeted long-term support, public-private investment models, or improved integration with income-generating schemes.

Overall Potential Alignment with Affordability

The evidence reviewed suggests that Affordability, as it relates to farmer costs of participating and access to additional investment, may present a barrier to implementation for several SFS Themes. While the evidence suggest that some Themes are low-cost or

associated with accessible funding options, others may require substantial up-front or long-term investment that may be prohibitive.

Overall Summary of Potential Alignment with Critical Success Factors

The evidence reviewed suggests that many Optional and Collaborative Themes within the SFS show strong potential alignment with the Welsh Government's strategic objectives, particularly in relation to environmental sustainability, public well-being, and resilient rural communities. A number of Themes have the potential to contribute meaningfully to the Well-being of Future Generations (Wales) Act 2015 and the Sustainable Land Management Objectives of the Agriculture (Wales) Act 2023. However, this alignment is conditional on how Themes are implemented, including the provision of financial support, technical advice, and appropriate delivery mechanisms.

Potential alignment with Value for money, as described throughout this report, is also promising, especially for Themes that offer low-cost or multi-benefit outcomes. Many could encourage behaviour change to more sustainable farming and deliver climate change mitigation and adaptation benefits. However, Supply side capacity and capability presents a more limited picture. Similarly, evidence for Affordability was limited, however, findings suggest that costs may constrain uptake for several higher-cost Themes unless additional funding, co-investment opportunities, or alternative income streams are made available.

Overall, the findings suggest that each of the SFS Optional and Collaborative Themes have potential to align with the SFS CSFs, but realising this potential will depend on a number of factors. Implementation of the Themes will be important to ensure that on-farm practices are targeted at appropriate sites to maximise benefits and avoid unintended consequences, as will proper application of on-farm practices by farmers. The full impact of the Themes will depend upon the level of uptake, whilst those managing the Scheme must ensure that uptake for each Theme and on-farm practice is appropriate to balance potentially conflicting objectives. Targeting interventions to appropriate locations, farm types and sectors will be important to ensure the balance between objectives, and delivery of Value for money. Across each of the Themes the evidence identified repeatedly identified the need for advisory support to ensure correct application of on-farm practices, and encourage uptake through knowledge exchange including demonstrating the social, economic and environmental benefits of the Themes.

References

- Abagandura, G.O., Mamo, M., Schacht, W.H. Shropshire, A., and Volesky, J.D. '[Soil Carbon and Nitrogen after Eight Years of Rotational Grazing in the Nebraska Sandhills Meadows](#)'. *Geoderma* 442 (February 2024): 116776.
- Abbas, A., Zaman, Q., Schuman, A., Brewster, G., Farooque, A., Donald, R. and Jameel, M. '[Effect of Split Variable Rate Fertilization on Wild Blueberry Plant Growth and Berry Yield](#)'. American Society of Agricultural and Biological Engineers Annual International Meeting 2015. American Society of Agricultural and Biological Engineers, 2015.
- Adams, R., and Johnston, C. '[Evaluating the Impacts of SRC Willows on Phosphorus Export from a Temperate Grassland Micro-Catchment](#)'. *Nature-Based Solutions* 5 (2024).
- Adamson-Fiskovica, A., Grivins, M., Burton, R.J.F., Elzen, B., Flanigan, S., Frick, R. and Hardy, C. '[Disentangling Critical Success Factors and Principles of On-Farm Agricultural Demonstration Events](#)'. *Journal of Agricultural Education and Extension* 27, number 5 (2021): pages 639 to 656.
- Adhikari, A., Parraga Estrada, K. J., Chhetri, V. S., Janes, M., Fontenot, K., & Beaulieu, J. C. '[Evaluation of Ultraviolet \(UV-C\) Light Treatment for Microbial Inactivation in Agricultural Waters with Different Levels of Turbidity](#)', *Food Science & Nutrition* 8, no. 2 (2020): 1237–43
- Aebischer, N.J., Bailey, C.M., Gibbons, D.W., Morris, A.J., Peach, W.J. and Stoate, C. '[Twenty Years of Local Farmland Bird Conservation: The Effects of Management on Avian Abundance at Two UK Demonstration Sites](#)'. *Bird Study* 63, number 1 (2016): pages 10 to 30.
- AHDB. '[Shout about the sire](#)'. Accessed 20 March 2025.
- Alarcón, L.V., Alberto, A.A. and Mateu, E. '[Biosecurity in Pig Farms: A Review](#)' *Porc Health Manag* 7, 5 (2021).
- Albanito, F., Jordon, M., Abdalla, M., Mcbey, D., Kuhnert, M., Vetter, S., Oyesiku-Blakemore, J. and Smith, P. '[Agroecology – a Rapid Evidence Review](#)'. University of Aberdeen, 2022.
- Albihn, A. and Vinnerås, B. '[Biosecurity and Arable Use of Manure and Biowaste — Treatment Alternatives](#)', *Livestock Science, Recycling of Livestock Manure in a Whole-Farm Perspective*, 112, no. 3 (1 December 2007): 232–39.
- Albrecht, M., Kleijn, D., Williams, N.M., Tschumi, M., Blaauw, B.R., Bommarco, R., Campbell, A.J. and others. '[The Effectiveness of Flower Strips and Hedgerows on Pest Control, Pollination Services and Crop Yield: A Quantitative Synthesis](#)'. *Ecology Letters* 23, number 10 (2020): pages 1488 to 1498.
- Alder, D.C., Edwards, B., Poore, A., Norrey, J. and Marsden, S.J. '[Irregular Silviculture and Stand Structural Effects on the Plant Community in an Ancient Semi-Natural Woodland](#)'. *Forest Ecology and Management* 527 (2023).
- Alder, D.C., Fuller, R.J., and Marsden, S.J. '[Implications of Transformation to Irregular Silviculture for Woodland Birds: A Stand Wise Comparison in an English Broadleaf Woodland](#)'. *Forest Ecology and Management* 422 (2018): pages 69 to 78.
- Alder, D.C., Poore, A., Norrey, J., Newson, S.E. and Marsden S.J. '[Irregular Silviculture Positively Influences Multiple Bat Species in a Lowland Temperate Broadleaf Woodland](#)'. *Forest Ecology and Management* 483 (2021).
- Alexopoulos, Y., Pappa, E., Perifanos, I., Marchand, F., Cooreman, H., Debruyne, L., Chiswell, H., Ingram, J. and Koutsouris, A. '[Unraveling Relevant Factors for Effective](#)

- on Farm Demonstration: The Crucial Role of Relevance for Participants and Structural Set Up'. *Journal of Agricultural Education and Extension* 27, number 5 (2021): pages 657 to 676
- Ali, Q. '[A Trade-off between Farm Production and Flood Alleviation Using Land Use Tillage Preferences as a Natural Flood Management \(NFM\) Strategy](#)'. *Smart Agricultural Technology* 6 (2023).
- Alison, J., Botham, M., Maskell, L.C., Garbutt, A., Seaton, F.M., Skates, J., Smart, S.M. and others. '[Woodland, Cropland and Hedgerows Promote Pollinator Abundance in Intensive Grassland Landscapes, with Saturating Benefits of Flower Cover](#)'. *Journal of Applied Ecology* 59, number 1 (2022): pages 342 to 354.
- Alison, J., Thomas, A., Evans, C.D., Keith, A.M., Robinson, D.A., Thomson, A., Dickie, I. and others. '[Environment and Rural Affairs Monitoring & Modelling Programme \(ERAMMP\) - Technical Annex 3: Soil Carbon Management. Sustainable Farming Scheme Evidence Review](#)'. Publication - Report. Bangor: NERC/Centre for Ecology & Hydrology, 5 July 2019.
- Alison, J., Duffield, S.J., van Noordwijk, C.G.E., Morecroft, M.D., Marrs, R.H., Saccheri, I.J. and Hodgson, J.A. '[Spatial Targeting of Habitat Creation Has the Potential to Improve Agri-Environment Scheme Outcomes for Macro-Moths](#)'. *Journal of Applied Ecology* 53, number 6 (2016): pages 1814 to 1822.
- Allam, M., Radicetti, E., Hassine, M.B., Jamal, A., Abideen, Z. and Mancinelli, R. '[A Meta-Analysis Approach to Estimate the Effect of Cover Crops on the Grain Yield of Succeeding Cereal Crops within European Cropping Systems](#)'. *Agriculture* 13, number 9 (September 2023): 1714.
- Amblard, L., Guiffant, N. and Bussi re, C. '[The Drivers of Farmers' Participation in Collaborative Water Management: A French Perspective](#)'. *International Journal of the Commons* 17, number 1 (2023): pages 411 to 430.
- Ambrose-Oji, B., Goodenough, A., Urquhart, J., Hall, C. and Karlsd ttir, B. '["We'Re Farmers Not Foresters": Farmers' Decision-Making and Behaviours towards Managing Trees for Pests and Diseases](#)'. *Forests* 13, number 7 (2022).
- Amir, S. '[Silvopoultry: Three Birds, One Stone](#)'. Farming Connect. IBERS, Aberystwyth University, 2023.
- Amorim, H.C.S., Ashworth, A.J., O'Brien, P.L., Thomas, A.L., Runkle, B.R.K. and Philipp, D. '[Temperate Silvopastures Provide Greater Ecosystem Services than Conventional Pasture Systems](#)'. *Scientific Reports* 13, number 1 (2023).
- Amulothu, D.V.R.T., Rodge, R.R., Hasan, W and Gupta, S. '[Machine Learning for Pest and Disease Detection in Crops](#)'. In *Agriculture 4.0: Smart Farming with IoT and Artificial Intelligence*, pages 111 to 132, 2024
- Amy, S.R., Heard, M.S., Hartley, S.E., George, C.T., Pywell, R.F. and Staley, J.T. '[Hedgerow Rejuvenation Management Affects Invertebrate Communities through Changes to Habitat Structure](#)'. *Basic and Applied Ecology* 16, number 5 (2015): pages 443 to 451.
- Angioloni, S. and Cerroni, S. '[Farmers' Cooperation to Improve Water Quality under Scientific Uncertainty: A Lab-in-the-Field Experiment](#)'. *Journal of Agricultural Economics* 76, number 1 (2025): pages pages 45 to to 73.
- APS Group Scotland for Scottish Government, '[Scottish Rural Development Programme 2014-20: Evaluation of the Knowledge Transfer and Innovation Fund](#)', Scottish Government (2025).

- Ashfield, A., Mullan, C., and Jack, C. '[Encouraging Farmer Participation in Agricultural Education and Training: A Northern Ireland Perspective](#)'. International Journal of Agricultural Management, 2020.
- Astigarraga, J., Calatayud, J., Ruiz-Benito, P., Madrigal-González, J., Tijerín-Triviño, J., Zavala, M.A., Andivia, E. and Herrero, A. '[Forest Structural Diversity Modulates Tree Growth Synchrony in Response to Climate Change](#)'. Forest Ecology and Management 579 (2025).
- Augustine, D.J., Kearney, S.P., Raynor, E.J., Porensky, L.M. and Derner J.D. '[Adaptive, Multi-Paddock, Rotational Grazing Management Alters Foraging Behavior and Spatial Grazing Distribution of Free-Ranging Cattle](#)'. Agriculture, Ecosystems & Environment 352 (August 2023): 108521.
- Ausden, M. and Kemp, M. '[Creating Acid Grassland by Sheep Grazing and Natural Reversion at Minsmere RSPB Reserve, Suffolk, England](#)'. Conservation Evidence 2 (2005): 18–20.
- Austen, N., Tille, S., Berdeni, D., Firbank, L.G., Lappage, M., Nelson, M., Helgason, T and others. '[Experimental Evaluation of Biological Regeneration of Arable Soil: The Effects of Grass-Clover Leys and Arbuscular Mycorrhizal Inoculants on Wheat Growth, Yield, and Shoot Pathology](#)'. Frontiers in Plant Science 13 (24 August 2022).
- Austen, Z., Penic, M., Reffaelli, D.G. and White, P.C.L. '[Stakeholder Perceptions of the Effectiveness and Efficiency of Agri-Environment Schemes in Enhancing Pollinators on Farmland](#)'. Land Use Policy 47 (September 2015): 156–62.
- Ayre, M., McCollum, V., Waters, W., Samson, P., Curro, A., Nettle, R., Paschen, J.A., King, B. and Reichelt, N. '[Supporting and Practising Digital Innovation with Advisers in Smart Farming](#)'. NJAS - Wageningen Journal of Life Sciences 90 to 91 (2019).
- Badgery, W.B., Cranney, P., Millar, G. and Mitchell, D. '[Intensive Rotational Grazing Can Improve Profitability and Environmental Outcomes](#)'. In Proceedings of the 27th Annual Conference of the Grassland Society of NSW, volume 27, 2012.
- Baggio-Compagnucci, A., Ovando, P., Hewitt, R.J., Canullo, R. and Gimona, A. '[Barking up the Wrong Tree? Can Forest Expansion Help Meet Climate Goals?](#)' Environmental Science and Policy 136 (2022): pages 237 to 249.
- Baker, D.J., Freeman, S.N., Grice, P.V. and Siriwardena, G.M. '[Landscape-Scale Responses of Birds to Agri-Environment Management: A Test of the English Environmental Stewardship Scheme](#)'. Journal of Applied Ecology 49, number 4 (2012): pages 871 to 882.
- Baker, D.J., Nye, C., Wheeler, R., Masquelier, C., Binner, A., Gaston, K.J., Heard, M.S., Lobley, M., Smith, D. and Maclean I.M.D. '[Aligning Strategic and Participatory Approaches to Agri-Environment Scheme Design and Implementation to Enhance Nature Recovery Outcomes](#)'. People and Nature 7, number 2 (2025): pages 329 to 345.
- Baker, T.P., Marais, Z.E., Davidson, N.J., Worledge, D. and Mendham, D.S. '[The Role of Open Woodland in Mitigating Microclimatic Extremes in Agricultural Landscapes](#)'. Ecological Management and Restoration 22, number S2 (2021): pages 118 to 126.
- Banach, J.L., Hoffmans, Y., Appelman, W.A.J., van Bokhorst-van de Veen, H. and van Asselt, E.D. '[Application of Water Disinfection Technologies for Agricultural Waters](#)', Agricultural Water Management 244 (2021).
- Bang, R., Hansen, B.G., Guajardo, M., Sommerseth, J.K., Flaten, O. and Asheim, L.J. '[Conventional or Organic Cattle Farming? Trade-Offs between Crop Yield, Livestock](#)

- [Capacity, Organic Premiums, and Government Payments](#)'. *Agricultural Systems* 218 (June 2024): 103991.
- Barasona, J.A., VerCauteren, K.C., Saklou, N., Gortazar, C. and Vicente, J. '[Prioritization of Pig Farm Biosecurity for Control of Salmonella and Hepatitis E Virus Infections: Results of a European Expert Opinion Elicitation](#)', *Porcine Health Management* 9, no. 1 (2023).
- Bark, R.H., Martin-Ortega, J. and Waylen, K.A. '[Stakeholders' Views on Natural Flood Management: Implications for the Nature-Based Solutions Paradigm Shift?](#)' *Environmental Science and Policy* 115 (2021): pages 91 to 98.
- Barkley, L.V., Short, C.J. and Chivers, C.A. '[Exploring the Potential of Long-Term Agreements for Achieving Landscape-Scale Environmental Recovery](#)'. *Wiley Interdisciplinary Reviews: Energy and Environment* 13, number 1 (2024).
- Barton, A.W. '[From Parks to Partnerships: National Heritage Areas and the Path to Collaborative Participation in the National Park Service's First 100 Years](#)'. *Natural Resources Journal* 56, number 1 (2016): pages 23 to 54.
- Bassett, T.J., Landis, D.A. and Brudvig, L.A. '[Effects of Experimental Prescribed Fire and Tree Thinning on Oak Savanna Understory Plant Communities and Ecosystem Structure](#)'. *Forest Ecology and Management* 464 (2020).
- Batáry, P., Dicks, L.V. Kleijn, D. and Sutherland, W.J. '[The Role of Agri-Environment Schemes in Conservation and Environmental Management](#)'. *Conservation Biology* 29, number 4 (2015): 1006 to 1016.
- Beauchamp, K., Alison, J. Broome, A., Burton, V. Griffiths, R. Keith, A.M., Maskell, L.C., Siriwardena, G. and Smart, S. '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Report-33: National Forest in Wales - Evidence Review Annex-1: Biodiversity](#)'. Publication - Report. Bangor: UK Centre for Ecology & Hydrology, 28 August 2020.
- Beauchamp, K., O'Brien, L., Hall, C., Swetnam, R., Jenkins, T.A.R., Doick, K.J., Nisbet, T.R. and others. '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report-37: National Forest in Wales - Evidence Review Annex-5: Ecosystem Services](#)'. Publication - Report. Bangor: UK Centre for Ecology & Hydrology, 28 August 2020.
- Beaudreault, A.R., Meinke, H. and Islam, M.M. '[From Emerging Theories to Messy Realities: Inclusive Innovation in Agriculture and Food Systems](#)'. *Agricultural Systems* 221 (2024).
- Bellamy, P.E., Charman, E.C., Riddle, N., Kirby, W.B., Broome, A.C., Siriwardena, G.M., Grice, P.V., Peach, W.J. and Gregory, R.D. '[Impact of Woodland Agri-Environment Management on Woodland Structure and Target Bird Species](#)'. *Journal of Environmental Management* 316 (2022).
- Benbrook, C., Kegley, S. and Baker, B. '[Organic Farming Lessens Reliance on Pesticides and Promotes Public Health by Lowering Dietary Risks](#)'. *Agronomy* 11, number 7 (22 June 2021): 1266.
- Bengtsson, V., Wheeler, C.P., Read, H and Harris, R. 'Responses of Oak Pollards to Pruning'. *Arboricultural Journal* 43, number 3 (2021): pages 15670.
- Bentrop, G., Hopwood, J., Adamson, N.L. and Vaughan, M. '[Temperate Agroforestry Systems and Insect Pollinators: A Review](#)'. *Forests* 10, number 11 (2019).
- Bertsch-Hoermann, B., Egger, C., Gaube, V. and Gingrich, S. '[Agroforestry Trade-Offs between Biomass Provision and Aboveground Carbon Sequestration in the Alpine Eisenwurzen Region, Austria](#)'. *Regional Environmental Change*, September 2021.

- Bester, C., Käsbohrer, A., Wilkins, N., Carreira, G.C. and Marschik, T. '[Identification of Cost-Effective Biosecurity Measures to Reduce Salmonella along the Pork Production Chain](#)'. *Frontiers in Veterinary Science* 11 (March 18, 2024).
- Beynon, S A. '[Potential Environmental Consequences of Administration of Anthelmintics to Sheep](#)'. *Veterinary Parasitology* 189, number 1 (September 2012): pages 113 to 124.
- Beynon, S.A., Wainwright, W.A. and Christie, M. '[The Application of an Ecosystem Services Framework to Estimate the Economic Value of Dung Beetles to the U.K. Cattle Industry](#)'. *Ecological Entomology* 40, number S1 (2015): pages 124 to 135.
- Biffi, S., Chapman, P.J., Grayson, R.P. and Ziv, G. '[Planting Hedgerows: Biomass Carbon Sequestration and Contribution towards Net-Zero Targets](#)'. *Science of the Total Environment* 892 (2023).
- Biffi, S., Chapman, P.J., Grayson, R.P, Ziv, G. '[Soil Carbon Sequestration Potential of Planting Hedgerows in Agricultural Landscapes](#)'. *Journal of Environmental Management* 307 (2022).
- Bishop, H., Erkelens, J. and Van Winden, S. '[Indications of a Relationship between Buying-in Policy and Infectious Diseases on Dairy Farms in Wales](#)'. *Veterinary Record* 167, number 17 (2010): pages 644 to 647.
- Bjerke, L., and Johansson, S. '[Innovation in Agriculture an Analysis of Swedish Agriculture- and Non-Agricultural Firms](#)'. *Food Policy* 109 (2022).
- Black, K., Lanigan, G., Ward, M., Kavanagh, I., hUallacháin, D.Ó. and Sullivan, L.O. '[Biomass Carbon Stocks and Stock Changes in Managed Hedgerows](#)'. *Science of the Total Environment* 871 (2023).
- Blanco-Canqui, H. '[Do Cover Crop Mixtures Improve Soil Physical Health More than Monocultures?](#)' *Plant and Soil* 495, number 1 (1 February 2024): pages 99 to 112.
- Blasch, J., Vuolo, F., Essl, L. and van der Kroon, B. '[Drivers and Barriers Influencing the Willingness to Adopt Technologies for Variable Rate Application of Fertiliser in Lower Austria](#)'. *Agronomy*. MDPI, 2021.
- Boinot, S., Alignier, A., Pétilion, J., Ridet, A. and Aviron, S. '[Hedgerows Are More Multifunctional in Preserved Bocage Landscapes](#)'. *Ecological Indicators* 154 (2023).
- Bolton, M., Tyler, G., Smith, K. and Bamford, R. '[The Impact of Predator Control on Lapwing Vanellus Vanellus Breeding Success on Wet Grassland Nature Reserves](#)'. *Journal of Applied Ecology* 44, number 3 (2007): pages 534 to 544.
- Bonn, A., Reed, M.S., Evans, C.D., Joosten, H., Bain, C., Farmer, J., Emmer, I., Couwenberg, J., Moxey, A., Artz, R., Tanneberger, F., von Unger, M., Smyth, M-A. and Birnie, D. '[Investing in nature: Developing ecosystem service markets for peatland restoration](#)' (2014) *Ecosystem Services*, Elsevier, vol. 9(C), pages 54-65.
- Bonnefous, C., Collin, A., Guilloteau, L.A., Guesdon, V., Filliat, C., Réhault-Godbert, S., Rodenburg, T.B. and others. '[Welfare Issues and Potential Solutions for Laying Hens in Free Range and Organic Production Systems: A Review Based on Literature and Interviews](#)'. *Frontiers in Veterinary Science* 9 (5 August 2022): 952922.
- Borghino, N., Wissinger, L., Erb, K-H., Le Mouél, C. and Nesme, T. '[Organic Farming Expansion and Food Security: A Review of Foresight Modeling Studies](#)'. *Global Food Security* 41 (June 2024): 100765.
- Bosco, S., Perez-Soba, A.M., Chen, M., Montero, C.A., Schievano, A., Tamburini, G., Catarino, R. and others. '[Scientific Evidence on Farming Practices Improving Sustainable Water Management in Agriculture](#)'. Joint Research Centre (European Commission), 2024.
- Boughey, K.L., Lake, I.R., Haysom, K.A. and Dolman, P.M. '[Improving the Biodiversity Benefits of Hedgerows: How Physical Characteristics and the Proximity of Foraging](#)

- [Habitat Affect the Use of Linear Features by Bats](#)'. Biological Conservation 144, number 6 (2011): pages 1790 to 1798.
- Bourgeois, B., Charles, A., Van Eerd, L.L., Tremblay, N., Lynch, D., Bourgeois, G., Bastien, M., Bélanger, V., Landry, C. and Vanasse, A. '[Interactive Effects between Cover Crop Management and the Environment Modulate Benefits to Cash Crop Yields: A Meta-Analysis](#)'. Edited by Brian Beres. Canadian Journal of Plant Science 102, number 3 (1 June 2022): pages 656 to 678.
- Bowditch, E.A.D, McMorran, R. and Smith, M.A. '[Right Connection, Right Insight Engaging Private Estate Managers on Woodland Expansion Issues in Times of Uncertainty](#)'. Land Use Policy 124 (1 January 2023): 106437.
- Bowman, A., Froud, J., Haslam, C. Johal, S., Morgan, K. and Williams, K. '[What can Welsh Government do to increase the number of grounded SME firms in food processing and distribution?](#)'. Foundational Economy Research. 2021.
- Bożek, M., Denisow, B., Strzałkowska-Abramek, M., Chrzanowska, E. and Winiarczyk, K. '[Non-Forest Woody Vegetation: A Critical Resource for Pollinators in Agricultural Landscapes—A Review](#)'. Sustainability 15, number 11 (January 2023): 8751.
- Bradfer-Lawrence, T., Finch, T., Bradbury, R.B., Buchanan, G.M., Midgley, A. and Field, R.H. '[The Potential Contribution of Terrestrial Nature-Based Solutions to a National "Net Zero" Climate Target](#)'. Journal of Applied Ecology 58, number 11 (2021): pages 2349 to 2360.
- Breen, T., Flint, A., Hickman, C. and O'Hara, G. '[Whose Right to Roam? Contesting Access to England's Countryside](#)'. Journal of Transport History 44, number 2 (2023): pages 276 to 307.
- Breland, S., Turley, N.E., Gibbs, J., Isaacs, R. and Brudvig, L.A. '[Restoration Increases Bee Abundance and Richness but Not Pollination in Remnant and Post-Agricultural Woodlands](#)', Ecosphere 9, no. 9 (2018).
- Brennan, M.L., and Christley, R.M. '[Biosecurity on Cattle Farms: A Study in North-West England](#).' PLOS ONE 7, number 1 (January 3, 2012): e28139.
- Bressler, A. and Blesh, J. '[Episodic N₂O Emissions Following Tillage of a Legume–Grass Cover Crop Mixture](#)'. Biogeosciences 19, number 13 (6 July 2022): pages 3169 to 3184.
- Broughton, R.K., Shore, R.F., Heard, M.S., Amy, S.R., Meek, W.R., Redhead, J.W., Turk, A. and Pywell, R.F. '[Agri-Environment Scheme Enhances Small Mammal Diversity and Abundance at the Farm-Scale](#)'. Agriculture, Ecosystems and Environment 192 (2014): pages 122 to 129.
- Brown, I. '[Challenges in Delivering Climate Change Policy through Land Use Targets for Afforestation and Peatland Restoration](#)'. Environmental Science and Policy 107 (2020): pages 36 to 45.
- Brown, P. '[The Importance of How We Graze Our Cattle and Sheep - a Look at Mob Grazing](#)'. Star & Furrow, number 27 (June 2017): pages 16 to 19.
- Brzeziecki, B., Bielak, K., Bolibok, L., Drozdowski, S., Zajączkowski, J. and Żybura, H. '[Structural and Compositional Dynamics of Strictly Protected Woodland Communities with Silvicultural Implications, Using Białowieża Forest as an Example](#)'. Annals of Forest Science 75, number 3 (2018).
- Buckley, P. '[Coppice Restoration and Conservation: A European Perspective](#)'. Journal of Forest Research 25, number 3 (2020): pages 125 to 133.
- Bullock, J.M., McCracken, M.E., Bowes, M.J., Chapman, R.E., Graves, A.R., Hinsley, S.A., Hutchins, M.G., Nowakowski, M., Nicholls, D.J.E., Oakley, S., Old, G.H., Ostle, N.J.,

- Redhead, J.W., Woodcock, B.E., Bedwell, T., Mayes, S., Robinson, V.S. and Pywell, R.F. [‘Does Agri-Environmental Management Enhance Biodiversity and Multiple Ecosystem Services?: A Farm-Scale Experiment’](#). Agriculture, Ecosystems & Environment 320 (October 2021): 107582.
- Burgess, P.J., and Rosati, A. [‘Advances in European Agroforestry: Results from the AGFORWARD Project’](#). Agroforestry Systems 92, number 4 (1 August 2018): pages 801 to 810.
- Burke, D.T., Hynds, P. and Priyadarshini, A. [‘Evaluating the GHG Emissions, Land Use, and Water Use Associated with Contemporary Dietary Patterns in the Republic of Ireland’](#). Environmental Research 270 (2025).
- Burke, T., Rowland, C.S., Whyatt, J.D., Blackburn, G.A. and Abbatt, J. [‘Spatially Targeting National-Scale Afforestation for Multiple Ecosystem Services’](#). Applied Geography 159 (1 October 2023): 103064.
- Burton, V., Metzger, M.J., Brown, C. and Moseley, D. [‘Green Gold to Wild Woodlands: Understanding Stakeholder Visions for Woodland Expansion in Scotland’](#). Landscape Ecology 34, number 7 (1 July 2019): pages 1693 to 1713.
- Burton, V., Moseley, D., Brown, C., Metzger, M.J. and Bellamy, P. [‘Reviewing the Evidence Base for the Effects of Woodland Expansion on Biodiversity and Ecosystem Services in the United Kingdom’](#). Forest Ecology and Management 430 (15 December 2018): pages 366 to 379.
- Busin, V., Kenyon, F., Laing, M., Denwood, M.J., McBean, D., Sargison, N.D. and Ellis, K. [‘Addressing Sustainable Sheep Farming: Application of a Targeted Selective Treatment Approach for Anthelmintic Use on a Commercial Farm’](#). Small Ruminant Research 110, numbers 2 to 3 (March 2013): pages 100 to 103.
- Byg, A., Novo, P. and Kyle, C. [‘Caring for Cinderella—Perceptions and Experiences of Peatland Restoration in Scotland’](#). Edited by Barbara Muraca. People and Nature 5, number 2 (April 2023): pages 302 to 312.
- Byrne, N., McCarthy, O. and Ryan-Doyle, M. [‘Leveraging the Potential of Co-Operative Agri-Advisory Services in the Transition to Sustainable and Landscape-Based Agriculture’](#). International Food and Agribusiness Management Review 27, number 1 (2024): pages 117 to 145.
- Camarero, J.J., Valeriano, C. and Rubio-Cuadrado, A. [‘Old Oaks Show Increasing Growth Synchrony after Pollarding Cessation as Climate Becomes More Arid’](#). Forest Ecology and Management 569 (2024).
- Camarero, J.J., Valeriano, C., Sánchez-Sancho, J.A. and de Jaime Loren, C. [‘Pollarding May Relieve Drought Stress in Black Poplars’](#). Forests 15, number 11 (2024).
- Campuzano, L.R., Hincapié Llanos, G.A., Zartha Sossa, J.W., Orozco Mendoza, G.L., Palacio, J.C. and Herrera, M. [‘Barriers to the Adoption of Innovations for Sustainable Development in the Agricultural Sector—Systematic Literature Review \(SLR\)’](#). Sustainability (Switzerland) 15, number 5 (2023).
- Cardiff University. [‘Research Wales Innovation Fund Strategy 2023/24 – 2027/28’](#), 29 September 2023.
- Carr, A., Weatherall, A. and Jones, G. [‘The Effects of Thinning Management on Bats and Their Insect Prey in Temperate Broadleaved Woodland’](#). Forest Ecology and Management 457 (2020).
- Carswell, A., Sánchez-Rodríguez, A.R., Saunders, K., Le Cocq, K., Shaw, R., Cotton, J., Zhang, Y. and others. [‘Combining Targeted Grass Traits with Red Clover Improves Grassland Performance and Reduces Need for Nitrogen Fertilisation’](#). European Journal of Agronomy 133 (February 2022): 126433.

- Carvell, C., Meek, W.R., Pywell, R.F., Goulson, D. and Nowakowski, M. '[Comparing the Efficacy of Agri-Environment Schemes to Enhance Bumble Bee Abundance and Diversity on Arable Field Margins](#)'. *Journal of Applied Ecology* 44, no. 1 (2007): 29–40.
- Castle, S.E., Miller, D.C., Merten, N., Ordonez, P.J. and Baylis, K. '[Evidence for the Impacts of Agroforestry on Ecosystem Services and Human Well-Being in High-Income Countries: A Systematic Map](#)'. *Environmental Evidence* 11, number 1 (2022).
- Cawley, A., Heanue, K., Hilliard, R., O'Donoghue, C. and Sheehan, M. '[How Knowledge Transfer Impact Happens at the Farm Level: Insights from Advisers and Farmers in the Irish Agricultural Sector](#)'. *Sustainability (Switzerland)* 15, number 4 (2023).
- Cawley, A. and Banks, C. '[Review of the Beef Data Genomics Programme 2015-2021](#)'. Economic and Planning Division, Department of Agriculture, Food and the Marine: Government of Ireland, December 2022.
- Chahal, I., Vyn, R.J., Mayers, D. and Van Eerd, L.L. '[Cumulative Impact of Cover Crops on Soil Carbon Sequestration and Profitability in a Temperate Humid Climate](#)'. *Scientific Reports* 10, number 1 (7 August 2020): 13381.
- Chapman, M., Walker, W.S., Cook-Patton, S.C., Ellis, P.W., Farina, M., Griscom, B.W. and Baccini, A. '[Large Climate Mitigation Potential from Adding Trees to Agricultural Lands](#)'. *Global Change Biology* 26, number 8 (2020): pages 4357 to 4365.
- Chivers, C.A. and Collins, A.L. '[\(Un\)Willingness to Contribute Financially towards Advice Surrounding Diffuse Water Pollution: The Perspectives of Farmers and Advisors](#)'. *Journal of Agricultural Education and Extension* 29, number 3 (2023): pages 327 to 350.
- Chylinski, C., Athanasiadou, S., Thüer, S., Grovermann, C., Moakes, S., Hoste, H., Petkevicius, S., Verwer, C., Verkaik, J. and Werne, S. '[Reducing Anthelmintic Inputs in Organic Farming: Are Small Ruminant Farmers Integrating Alternative Strategies to Control Gastrointestinal Nematodes?](#)' *Veterinary Parasitology* 315 (1 March 2023): 109864.
- Colangelo, M., Valeriano, C., de Andrés, E.G., Pizarro, M., Murria, E. and Camarero, J.J. '[Lack of Management, Land-Use Changes, Poor Site Conditions and Drought Contribute to the Decline of Old Pollarded Oaks](#)'. *Dendrochronologia* 86 (2024).
- Cole, L. '[Outcome-Based Agri-Environment and Climate Schemes](#)'. Farm Advisory Service - Scottish Rural Development Programme (SRDP) (blog), 28 February 2024.
- Convention on Biological Diversity. '[2030 Targets \(with guidance notes\)](#)'. Accessed: 21 August 2025.
- Cook, P., Alder, D., Hordley, L., Newson, S.E. and Pengelly, D. '[Seeing the Wood for the Trees, Irregular Silviculture Supports Bat Populations in Conifer Plantations](#)'. *Forest Ecology and Management* 544 (2023).
- Cook, P., Hordley, L., Alder, D., Powell, K. and Pengelly, D. '[Moths Respond to Key Habitat Structures in Conifer Plantations Managed as Irregular High Forest](#)'. *Forest Ecology and Management* 569 (2024).
- Cooke, A., Rettino, J., Flower, L., Filby, K. and Freer, A. '[Farming for Water; Catchment Management Initiatives for Reducing Pesticides](#)'. *Water and Environment Journal* 34, number 4 (2020): pages 679 to 691.
- Cooke, A.S., Morgan, E.R. and Dungait, J.A.J. '[Modelling the Impact of Targeted Anthelmintic Treatment of Cattle on Dung Fauna](#)'. *Environmental Toxicology and Pharmacology* 55 (October 2017): pages 94 to 98.

- Cooke, A.S. '[Colonisation, Impacts in Conservation Woodland and Management of Reeves' Muntjac \(Muntiacus Reevesi\) in an English County](#)'. *European Journal of Wildlife Research* 67, number 3 (2021).
- Cooper, M.M.D., Patil, S.D., Nisbet, T.R., Thomas, H., Smith, A.R. and McDonald, M.A. '[Role of Forested Land for Natural Flood Management in the UK: A Review](#)'. *Wiley Interdisciplinary Reviews: Water* 8, number 5 (2021).
- Cooper, R.J., Hama-Aziz, Z.Q., Hiscock, K.M., Lovett, A.A., Vrain, E., Dugdale, S.J., Sünnerberg, G., Dockerty, T., Hovesen, P. and Noble, L. '[Conservation Tillage and Soil Health: Lessons from a 5-Year UK Farm Trial \(2013–2018\)](#)'. *Soil and Tillage Research* 202 (2020).
- Cooreman, H., Debruyne, L., Vandenabeele, J. and Marchand, F. '[Power to the Facilitated Agricultural Dialogue: An Analysis of on-Farm Demonstrations as Transformative Learning Spaces](#)'. *Journal of Agricultural Education and Extension* 27, number 5 (2021): pages 699 to 719.
- Costantini, M., Bacenetti, J., Coppola, G., Orsi, L., Ganzaroli, A. and Guarino, M. '[Improvement of Human Health and Environmental Costs in the European Union by Air Scrubbers in Intensive Pig Farming](#)'. *Journal of Cleaner Production*. Elsevier Ltd, 2020.
- Cotton, C., Gosschalk, K., & Konn, J. (2024). '[Consumer Insights Tracker Report \(July 2023 - March 2024\)](#)'. *FSA Research and Evidence*.
- Craft, R., and Pitt, H. '[More than Meat? Livestock Farmers' Views on Opportunities to Produce for Plant-Based Diets](#)'. *Agriculture and Human Values* 41, no. 3 (2024): 975–88.
- Creissen, H.E., Jones, P.J., Tranter, R.B., Girling, R.D., Jess, S., Burnett, F.J., Gaffney, M., Thorne, F.S. and Kildea, S. '[Identifying the Drivers and Constraints to Adoption of IPM among Arable Farmers in the UK and Ireland](#)'. *Pest Management Science* 77, number 9 (2021): pages 4148 to 4158.
- Critchley, C.N.R., Fowbert, J.A., Sherwood, A.J. and Pywell, R.F. '[Vegetation Development of Sown Grass Margins in Arable Fields under a Countrywide Agri-Environment Scheme](#)'. *Biological Conservation* 132, number 1 (September 2006): pages 1 to 11.
- Croft, S., Aegerter, J.N., Beatham, S., Coats, J. and Massei, G. '[A Spatially Explicit Population Model to Compare Management Using Culling and Fertility Control to Reduce Numbers of Grey Squirrels](#)'. *Ecological Modelling* 440 (2021).
- Crous-Duran, J., Graves, A.R., Paulo, J.A., Mirck, J., Oliveira, T.S., Kay, S., García de Jalón, S. and Palma, J.H.N. '[Modelling Tree Density Effects on Provisioning Ecosystem Services in Europe](#)'. *Agroforestry Systems* 93, number 5 (2019): pages 1985 to 2007.
- Croxton, P.J., Hann, J.P., Greatorex-Davies, J.N. and Sparks, T.H. '[Linear Hotspots? The Floral and Butterfly Diversity of Green Lanes](#)'. *Biological Conservation* 121, number 4 (2005): pages 579 to 584.
- Cuenca-Cambroner, M., Blicharska, M., Perrin, J.A., Davidson, T.A., Oertli, B., Lago, M., Beklioglu, M., Meerhoff, M., Arim, M., Teixeira, J., De Meester, L., Biggs, J., Robin, J., Martin, B., Greaves, H.M., Sayer, C.D., Lemmens, P., Boix, D., Mehner, T., Bartrons, M. and Brucet, S. '[Challenges and Opportunities in the Use of Ponds and Pondscapes as Nature-Based Solutions](#)'. *Hydrobiologia* 850, no. 15 (1 September 2023): 3257–71.
- Cullen, P. '[The Economics of Agri-Environment Schemes in Ireland: Essays on Design and Participation](#)'. Doctoral Thesis, University of Galway, 2021.

- Cuomo, M.T., Genovino, C., De Andreis, F., Fauceglia, G. and Papa, A. '[Digital Strategic Collaborations in Agriculture: A Novel Asset for Local Identity Enhancement toward Agrifood 5.0](#)'. *British Food Journal* 126, number 11 (2024): pages 3922 to 3952.
- Curry, D. and Reid, R. '[Peer Group Mentors Contribute to Diversified, Sustainable and Innovative Farming Communities](#)'. *Extension Farming Systems Journal* 5, number 2 (n.d.).
- Cusworth, G., Garnett, T. and Lorimer, J. '[Agroecological Break out: Legumes, Crop Diversification and the Regenerative Futures of UK Agriculture](#)'. *Journal of Rural Studies* 88 (December 2021): pages 126 to 137.
- Cutress, D. '[Agroforestry Options](#)'. Farming Connect. IBERS, Aberystwyth University, 30 January 2025.
- Dadam, D., and Siriwardena, G.M. '[Agri-Environment Effects on Birds in Wales: Tir Gofal Benefited Woodland and Hedgerow Species](#)'. *Agriculture, Ecosystems and Environment* 284 (2019).
- Dal Ferro, N., Fabbri, G., Gottardo, F. Mencaroni, M., Lazzaro, B. and Morari, F. '[Identifying NH3 Emission Mitigation Techniques from Farm to Field Using a Bayesian Network](#)', *Journal of Environmental Management* 373 (January 2025)
- Dallimer, M., Gaston, K.J., Skinner, A.M.J., Hanley, N., Acs, S. and Armsworth, P.R. '[Field-Level Bird Abundances Are Enhanced by Landscape-Scale Agri-Environment Scheme Uptake](#)'. *Biology Letters* 6, number 5 (2010): pages 643 to 646.
- Dania, W.A.P., King, K. and Amer, Y. '[Collaboration Behavioural Factors for Sustainable Agri-Food Supply Chains: A Systematic Review](#)', *Journal of Cleaner Production* 186 (10 June 2018): 851–64.
- Dauksta, A. '[Opportunities for More, Higher-Value Timber from the National Forest](#)'. Woodknowledge Wales (2025).
- Davey, A.J.H., Bailey, L., Bewes, V., Mubaiwa, A., Hall, J., Burgess, C., Dunbar, M.J., Smith, P.D. and Rambohul, J. '[Water Quality Benefits from an Advice-Led Approach to Reducing Water Pollution from Agriculture in England](#)'. *Agriculture, Ecosystems and Environment* 296 (2020).
- Davies M.G., Kettridge, N., Stoof, C.R., Gray, A., Marrs, R., Ascoli, D., Fernandes, P.M., Allen, K.A., Doerr, S.H., Clay, G.D., McMorro, J. and Vandvik, V. '[Informed debate on the use of fire for peatland management means acknowledging ecological complexity](#)'. *Nature Conservation* 16: 59-77.
- Davies, R.H. and Wales, A.D. '[Salmonella Contamination of Cereal Ingredients for Animal Feeds](#)', *Veterinary Microbiology* 166, no. 3–4 (October 2013): 543–49.
- De Laurentis, C. '[Renewable Energy Innovation and Governance in Wales: A Regional Innovation System Approach](#)'. *European Planning Studies* 20, number 12 (2012): pages 1975 to 1996.
- De Vries, J.W. and Melse, R.W. '[Comparing Environmental Impact of Air Scrubbers for Ammonia Abatement at Pig Houses: A Life Cycle Assessment](#)'. Biosystems Engineering. Academic Press, 2017.
- Department of Agriculture, Environment and Rural Affairs. '[Beef Carbon Reduction Scheme – A Focus on Herd Management](#)', December 2024.
- Department of Agriculture, Environment and Rural Affairs. '[Successful First Year for the Beef Carbon Reduction Scheme](#)'. 18 March 2025.
- Díaz De Otálora, X., Epelde, L., Arranz, J., Garbisu, C., Ruiz, R. and Mandaluniz, N. '[Regenerative Rotational Grazing Management of Dairy Sheep Increases Springtime](#)

- [Grass Production and Topsoil Carbon Storage](#)'. *Ecological Indicators* 125 (June 2021): 107484.
- Dillon, A. and Wentworth, J. ['Food systems, food security and supply chains'](#). (2024) Parliamentary Office of Science and Technology.
- Dlamini, J.C., Cardenas, L.M., Tesfamariam, E.H., Dunn, R.M., Loick, N., Charteris, A.F., Cocciaglia, L. and others. ['Riparian Buffer Strips Influence Nitrogen Losses as Nitrous Oxide and Leached N from Upslope Permanent Pasture'](#). *Agriculture, Ecosystems & Environment* 336 (15 September 2022): 108031.
- Dlamini, J.C., Cárdenas, L., Tesfamariam, E.H., Dunn, R., Hawkins, J., Blackwell, M., Evans, J. and Collins, A. ['Soil Methane \(CH₄\) Fluxes in Cropland with Permanent Pasture and Riparian Buffer Strips with Different Vegetation'](#). *Journal of Plant Nutrition and Soil Science* 185, number 1 (2022): pages 132 to 144.
- Dlamini, J.C., Tesfamariam, E.H., Dunn, R., Evans, J., Hawkins, J., Blackwell, M., Collins, A. and Cardenas, L. ['Soil Carbon Dioxide \(CO₂\) Fluxes in Permanent Upslope Pasture and Downslope Riparian Buffers with Varying Vegetation'](#). *Journal of Plant Nutrition and Soil Science* 186, number 4 (2023): pages 406 to 416.
- Doehring, K., Longnecker, N., Cole, C., Young, R.G. and Robb, C. ['A Missing Piece of the Puzzle of On-Farm Freshwater Restoration: What Motivates Land Managers to Record and Report Land Management Actions?'](#) *Ecology and Society* 27, number 4 (2022).
- Dondina, O., Kataoka, L., Orioli, V. and Bani, L. ['How to Manage Hedgerows as Effective Ecological Corridors for Mammals: A Two-Species Approach'](#). *Agriculture, Ecosystems and Environment* 231 (2016): pages 283 to 290.
- Dooley, E. ['Reorientating Social Learning: An Ethnographic Exploration of Metacognition and Critical Discourse in Farmer Discussion Groups'](#). University of Exeter, 2021.
- Drejerska, N. and Sobczak-Malitka, W. ['Nurturing Sustainability and Health: Exploring the Role of Short Supply Chains in the Evolution of Food Systems—The Case of Poland'](#). *Foods* 12, no. 22 (19 November 2023): 4171.
- Drexler, S., and Don, A. ['Carbon Sequestration Potential in Hedgerow Soils: Results from 23 Sites in Germany'](#). *Geoderma* 445 (2024).
- ['Driving Your Landscape to Success: Managing a Grazing Business for Profit in the Agricultural Landscape'](#), 24th to 26th July 2012, [Joyes Hall, Charles Sturt University], Wagga Wagga: Proceedings of the 27th Annual Conference of The Grassland Society of NSW Inc. Orange, NSW: Grassland Society of NSW, 2012.
- Drobyshev, I., Widerberg, M.K., Andersson, M., Wang, X. and Lindblad, M. ['Thinning around Old Oaks in Spruce Production Forests: Current Practices Show No Positive Effect on Oak Growth Rates and Need Fine Tuning'](#). *Scandinavian Journal of Forest Research* 34, number 2 (2019): pages 126 to 132.
- Drost, S.M., Rutgers, M., Wouterse, M., de Boer, W. and Bodelier, P.L.E. ['Decomposition of Mixtures of Cover Crop Residues Increases Microbial Functional Diversity'](#). *Geoderma* 361 (2020).
- Duan, K., Onyeaka, H. and Pang, G. ['Leveraging Blockchain to Tackle Food Fraud: Innovations and Obstacles'](#). *Journal of Agriculture and Food Research* 18 (2024).
- Duflot, R., Daniel, H., Aviron, S., Alignier, A., Beaujouan, V., Burel, F., Cochard, A., Ernoult, A., Pain, G. and Pithon, J.A. ['Adjacent Woodlands Rather than Habitat Connectivity Influence Grassland Plant, Carabid and Bird Assemblages in Farmland Landscapes'](#). *Biodiversity and Conservation* 27, number 8 (2018): pages 1925 to 1942.

- Dufour, L., Gosme, M., Le Bec, J. and Dupraz, C. '[Does Pollarding Trees Improve the Crop Yield in a Mature Alley-Cropping Agroforestry System?](#)' *Journal of Agronomy and Crop Science* 206, number 5 (2020): pages 640 to 649.
- Duncan, E.W., Kleinman, P.J.A., Beegle, D.B. and Rotz, C.A. '[Coupling Dairy Manure Storage with Injection to Improve Nitrogen Management: Whole-Farm Simulation Using the Integrated Farm System Model](#)'. *Agricultural & Environmental Letters* 2, number 1 (December 2017).
- Duncan, E.W., Dell, C.J., Kleinman, P.J.A. and Beegle, D.B. '[Nitrous Oxide and Ammonia Emissions from Injected and Broadcast-Applied Dairy Slurry](#)', *Journal of Environmental Quality* 46, no. 1 (2017): 36–44.
- Dunn, J.C., Gruar, D., Stoate, C., Szczur, J. and Peach, W.J. '[Can Hedgerow Management Mitigate the Impacts of Predation on Songbird Nest Survival?](#)' *Journal of Environmental Management* 184 (2016): pages 535 to 544.
- Dunn, M., Marzano, M., Forster, J. and Gill, R.M.A. '[Public Attitudes towards “Pest” Management: Perceptions on Squirrel Management Strategies in the UK](#)'. *Biological Conservation* 222 (2018): pages 52 to 63.
- Dutton, A., Edwards-Jones, G., Strachan, R. and Macdonald, D.W. '[Ecological and Social Challenges to Biodiversity Conservation on Farmland: Reconnecting Habitats on a Landscape Scale](#)'. *Mammal Review* 38, numbers 2 to 3 (2008): pages 205 to 219.
- Easton, S., Pinchbeck, G.L., Bartley, D.J., Hodgkinson, J.E. and Matthews, J.B. '[A Survey of Experiences of UK Cattle and Sheep Farmers with Anthelmintic Prescribers: Are Best Practice Principles Being Deployed at Farm Level?](#)' *Preventive Veterinary Medicine* 155 (July 2018): 27–37.
- Eastwood, C., Klerkx, L. and Nettle, R. '[Dynamics and Distribution of Public and Private Research and Extension Roles for Technological Innovation and Diffusion: Case Studies of the Implementation and Adaptation of Precision Farming Technologies](#)'. *Journal of Rural Studies* 49 (2017): pages 1 to 12.
- Edo, M., Entling, M.H., Herzog, F., Noe, K., Palma, J.H., Seithe, A., Simonson, W., Smith, J., Weiler, A. and Rösch, V. '[Agroforestry Systems Favor Bat Conservation but Only When Old and Grazed](#)'. *Global Ecology and Conservation* 57 (2025).
- Edo, M., Entling, M.H. and Rösch, V. '[Agroforestry Supports High Bird Diversity in European Farmland](#)'. *Agronomy for Sustainable Development* 44, number 1 (20 December 2023): 1.
- Eglington, S.M., Gill, J.A., Bolton, M., Smart, M.A., Sutherland, W.J. and Watkinson, A.R. '[Restoration of Wet Features for Breeding Waders on Lowland Grassland](#)'. *Journal of Applied Ecology* 45, number 1 (2008): pages 305 to 314.
- Eglington, S.M., Gill, J.A., Smart, M.A., Sutherland, W.J., Watkinson, A.R. and Bolton, M. '[Habitat Management and Patterns of Predation of Northern Lapwings on Wet Grasslands: The Influence of Linear Habitat Structures at Different Spatial Scales](#)'. *Biological Conservation* 142, number 2 (1 February 2009): pages 314 to 324.
- El Khosht, F.F., Bergkvist, G., Dahlin, A.S., Watson, C.A., Forkman, J., Nilsson, J. and Öborn, I. '[Rotational Grass-Legume Leys Increase Arable Crop Yields, Particularly at Low N Fertiliser Rates](#)'. *Field Crops Research* 326 (May 2025): 109835.
- Elalamy, Y., Doyen, L. and Mouysset, L. '[Contribution of the Land Use Allocation Model for Agroecosystems: The Case of Torrecchia Vecchia](#)'. *Journal of Environmental Management* 252 (2019).
- Elbakidze, M., Surová, D., Muñoz-Rojas, J., Persson, J.O., Dawson, L., Plieninger, T. and Pinto-Correia, T. '[Perceived Benefits from Agroforestry Landscapes across North-](#)

- [Eastern Europe: What Matters and for Whom?](#) Landscape and Urban Planning 209 (2021).
- Elhakeem, A., Bastiaans, L., Houben, S., Couwenberg, T., Makowski, D. and van der Werf, W. [‘Do Cover Crop Mixtures Give Higher and More Stable Yields than Pure Stands?’](#) Field Crops Research 270 (2021).
- Elhakeem, A., van der Werf, W., Ajal, J., Lucà, D., Claus, S., Vico, R.A. and Bastiaans, L. [‘Cover Crop Mixtures Result in a Positive Net Biodiversity Effect Irrespective of Seeding Configuration’](#). Agriculture, Ecosystems and Environment 285 (2019).
- Ellis, S., Wainwright, D., Berney, F., Bulman, C. and Bourn, N. [‘Landscape-Scale Conservation in Practice: Lessons from Northern England, UK’](#). Journal of Insect Conservation 15, number 1 (2011): pages 69 to 81.
- Ellis-Iversen, J., Smith, R.P., Van Winden, S., Paiba, G.A., Watson, E., Snow, L.C. and Cook, A.J.C. [‘Farm Practices to Control E. Coli O157 in Young Cattle - A Randomised Controlled Trial.’](#) Veterinary Research 39, number 1 (January 1, 2008): pages 1 to 12.
- Emery, S.B., and Franks, J.R. [‘The Potential for Collaborative Agri-Environment Schemes in England: Can a Well-Designed Collaborative Approach Address Farmers’ Concerns with Current Schemes?’](#) Journal of Rural Studies 28, number 3 (1 July 2012): pages 218 to 31.
- Emmett, B.A., and the ERAMMP team. [‘ERAMMP Report-105: Wales National Trends and Glastir Evaluation.’](#) Report to Welsh Government. (UKCEH 08435), 2025.
- English, C.J., Younger, S.E., Cannon, J.B., Brantley, S.T., Markewitz, D. and Dwivedi, P. [‘Forest Management for Water Yield: Assessing the Barriers and Impacts of Privately-Owned Open Pine Woodlands in the Southeastern United States’](#). Trees, Forests and People 17 (2024).
- Ensor, J. and de Bruin, A. [‘The Role of Learning in Farmer-Led Innovation’](#). Agricultural Systems 197 (1 March 2022): 103356.
- Eschen, R., Müller-Schärer, H. and Schaffner, U. [‘Aboveground Environment Type, Soil Nutrient Content and Arbuscular Mycorrhizal Fungi Explain Establishment Success of Centaurea Jacea on Ex-Arable Land and in Late-Successional Grasslands’](#). Plant and Soil 322, number 1 (2009): pages 115 to 123.
- Eschen, R., Mortimer, S.R., Lawson, C.S., Edwards, A.R., Brook, A.J., Igual, J.M., Hedlund, K. and Schaffner, U. [‘Carbon Addition Alters Vegetation Composition on Ex-Arable Fields’](#). Journal of Applied Ecology 44, no. 1 (2007): 95–104.
- Fabiani, S., Vanino, S., Napoli, R. and Nino, P. [‘Water Energy Food Nexus Approach for Sustainability Assessment at Farm Level: An Experience from an Intensive Agricultural Area in Central Italy’](#). ENVIRONMENTAL SCIENCE & POLICY 104 (February 2020): pages 1 to 12.
- Farrow, L., Glass, C., Morton, P.A., McRoberts, W.C., Floyd, S., Burgess, D., Jordan, P. and Cassidy, R. [‘Charting Water Quality Improvements and Practice Reversion with Pesticide Interventions at Catchment Scale’](#). Science of the Total Environment 960 (2025).
- Fatima, S., Abbas, S., Rebi, A. and Ying, Z. [‘Sustainable Forestry and Environmental Impacts: Assessing the Economic, Environmental, and Social Benefits of Adopting Sustainable Agricultural Practices’](#). Ecological Frontiers 44, number 6 (2024): pages 1119 to 1127.
- Fattorini, N., Lovari, S., Watson, P. and Putman, R. [‘The Scale-Dependent Effectiveness of Wildlife Management: A Case Study on British Deer’](#). Journal of Environmental Management 276 (2020).

- Feliciano, D. '[Factors Influencing the Adoption of Sustainable Agricultural Practices: The Case of Seven Horticultural Farms in the United Kingdom](#)'. Scottish Geographical Journal 138, numbers 3 to 4 (2022): pages 291 to 320.
- Felton, M., Jones, P., Tranter, R., Clark, J., Quaife, T. and Lukac, M. '[Farmers' Attitudes towards, and Intentions to Adopt, Agroforestry on Farms in Lowland South-East and East England](#)'. Land Use Policy 131 (2023).
- Feng, X., Alletto, L., Cong, W-F., Labreuche, J. and Lamichhane, J.R. '[Strategies to Improve Field Establishment of Cover Crops. A Review](#)'. Agronomy for Sustainable Development 44, number 5 (4 October 2024): article 47.
- Fielding, D. '[Unravelling the Terminology and Impacts of Rotational Grazing – What Evidence Is There for Environmental Benefits?](#)' James Hutton Institute, April 2022.
- Fisher, B., Bradbury, R.B., Andrews, J.E., Ausden, M., Benthams-Green, S., White, S.M. and Gill, J.A. '[Impacts of Species-Led Conservation on Ecosystem Services of Wetlands: Understanding Co-Benefits and Tradeoffs](#)'. Biodiversity and Conservation 20, number 11 (October 2011): pages 2461 to 2481.
- Fisher, R. '[“A Gentleman’s Handshake”: The Role of Social Capital and Trust in Transforming Information into Usable Knowledge](#)'. Journal of Rural Studies 31 (2013): pages 13 to 22.
- Flack, J., Lukac, M. and Todman, L. '[Woodland Planting on UK Pasture Land Is Not Economically Feasible, yet Is More Profitable than Some Traditional Farming Practices](#)'. Central European Forestry Journal 68, number 2 (2022): pages 61 to 71.
- Flanigan, S., and Hardy, C. '[Learning and Change through Monitor Farms](#)'. Scotland: The James Hutton Institute, August 2021.
- Fletcher, T.I., Scott, C.E., Hall, J. and Spracklen, D.V. '[The Carbon Sequestration Potential of Scottish Native Woodland](#)'. Environmental Research Communications 3, number 4 (April 2021): 041003.
- Florence, A.M. and McGuire, A.M. '[Do diverse cover crop mixtures perform better than monocultures? A systematic review](#)'. (2020) Agronomy Journal, 112(5), 3513–3534.
- Florence, A.M., Higley, L.G., Drijber, R.A., Francis, C.A. and Lindquist, J.L. '[Cover Crop Mixture Diversity, Biomass Productivity, Weed Suppression, and Stability](#)'. PLoS ONE 14, number 3 (2019).
- Foley, P.A., Crosson, P., Lovett, D.K., Boland, T.M., O'Mara, F.P. and Kenny, D.A. '[Whole-Farm Systems Modelling of Greenhouse Gas Emissions from Pastoral Suckler Beef Cow Production Systems](#)'. Agriculture, Ecosystems & Environment 142, numbers 3 to 4 (August 2011): pages 222 to 230.
- Follett, E., Davis, L., Wilson, C. and Cable, J. '[Working for the Environment: Farmer Attitudes towards Sustainable Farming Actions in Rural Wales, UK](#)'. Environment, Development and Sustainability, 2024.
- Food and Drink Wales. '[Annual Export Bulletin 2024](#)' Welsh Government 2024
- Food and Drink Wales. '[Economic Appraisal](#)' Welsh Government 2024
- Ford, H., Healey, J.R., Webb, B., Pagella, T.F. and Smith, A.R. '[Hedgerow Effects on CO2 Emissions Are Regulated by Soil Type and Season: Implications for Carbon Flux Dynamics in Livestock-Grazed Pasture](#)'. Geoderma 382 (2021).
- Ford, H., Healey, J.R., Webb, B., Pagella, T.F. and Smith, A.R. '[How Do Hedgerows Influence Soil Organic Carbon Stock in Livestock-Grazed Pasture?](#)' Soil Use and Management 35, number 4 (2019): pages 576 to 584.
- Ford, J.S., Bale, C.S.E. and Taylor, P.G. '[The Factors Determining Uptake of Energy Crop Cultivation and Woodland Creation in England: Insights from Farmers and Landowners](#)'. Biomass and Bioenergy 180 (1 January 2024): 107021

- Forest Research. '[Evidence Review Summary: Land Managers and Public Access in England](#)', 2024.
- Forest Research. '[Woodland for Water: Woodland measures for meeting Water Framework Directive objectives](#)'. (2011) Forest Research Monograph, 4, Forest Research, Surrey, 156pp.
- Forio, M.A.E., De Troyer, N., Lock, K., Witing, F., Baert, L., De Saeyer, N., Rîșnoveanu, G. and others. '[Small Patches of Riparian Woody Vegetation Enhance Biodiversity of Invertebrates](#)'. Water (Switzerland) 12, number 11 (2020): pages 1 to 21.
- Frampton, G.K. and Dorne, J.L.C.M. '[The Effects on Terrestrial Invertebrates of Reducing Pesticide Inputs in Arable Crop Edges: A Meta-Analysis](#)'. Journal of Applied Ecology 44, no. 2 (2007): 362–73.
- Franks, J.R., Emery, S.B., Whittingham, M.J. and McKenzie, A.J. '[Options for Landscape Scale Collaboration under the UK's Environmental Stewardship Scheme](#)'.
- Franks, J.R. '[An Application of Boundary Organisation Theory to Develop Landscape-Scale Conservation in Formal Agri-Environment Schemes](#)'. Sociologia Ruralis 56, number 1 (2016): pages 48 to 73.
- Franks, J.R., '[An Assessment of the Landscape-Scale Dimensions of Land Based Environmental Management Schemes Offered to Farmers in England](#)'. Land Use Policy 83 (2019): pages 147 to 159.
- Franks, J.R. '[The Collective Provision of Environmental Goods: A Discussion of Contractual Issues](#)'. Journal of Environmental Planning and Management 54, number 5 (2011): pages 637 to 660.
- Franks, J.R. and Emery, S.B. '[Incentivising Collaborative Conservation: Lessons from Existing Environmental Stewardship Scheme Options](#)'. Land Use Policy 30, number 1 (2013): pages 847 to 862.
- Franks, S.E., Roodbergen, M., Teunissen, W., Cotton, A.C. and Pearce-Higgins, J.W. '[Evaluating the Effectiveness of Conservation Measures for European Grassland-Breeding Waders](#)'. Ecology and Evolution 8, number 21 (2018): pages 10555 to 10568.
- Frick, R., Huber, K., Moschitz, H. and Alföldi, T. 'Agricultural Demonstration Events: What Matters'. Agrarforschung Schweiz 10, number 9 (2019): pages 330 to 337.
- Froidevaux, J.S.P., Boughey, K.L., Hawkins, C.L., Broyles, M. and Jones, G. '[Managing Hedgerows for Nocturnal Wildlife: Do Bats and Their Insect Prey Benefit from Targeted Agri-Environment Schemes?](#)' Journal of Applied Ecology 56, number 7 (2019): pages 1610 to 1623.
- Fuentes-Montemayor, E., Ferryman, M., Watts, K., Macgregor, N.A., Hambly, N., Brennan, S., Coxon, R., Langridge, H. and Park, K.J. '[Small Mammal Responses to Long-Term Large-Scale Woodland Creation: The Influence of Local and Landscape-Level Attributes](#)'. Ecological Applications 30, number 2 (2020).
- Fuentes-Montemayor, E., Goulson, D. and Park, K.J. '[The Effectiveness of Agri-Environment Schemes for the Conservation of Farmland Moths: Assessing the Importance of a Landscape-Scale Management Approach](#)'. Journal of Applied Ecology 48, number 3 (2011): pages 532 to 542.
- Fuentes-Montemayor, E., Park, K.J., Cordts, K. and Watts, K. '[The Long-Term Development of Temperate Woodland Creation Sites: From Tree Saplings to Mature Woodlands](#)'. Forestry 95, number 1 (2022): pages 28 to 37.

- Fuller, L., Fuentes-Montemayor, E., Watts, K., Macgregor, N.A., Bitenc, K. and Park, K.J. '[Local-Scale Attributes Determine the Suitability of Woodland Creation Sites for Diptera](#)'. *Journal of Applied Ecology* 55, number 3 (2018): pages 1173 to 1184.
- Gabriel, D., Sait, S.M., Hodgson, J.A., Schmutz, U., Kunin, W.E. and Benton, T.G. '[Scale Matters: The Impact of Organic Farming on Biodiversity at Different Spatial Scales](#)'. *Ecology Letters* 13, number 7 (2010): pages 858 to 869.
- Gage, E., Terry, L.A. and Falagán, N. '[Biological Factors and Production Challenges Drive Significant UK Fruit and Vegetable Loss](#)'. *Journal of the Science of Food and Agriculture* 105, no. 4 (2025): 2109–17.
- Galipó, E., Zoche-Golob, V., Sassu, E. L., Prigge, C., Sjölund, M., Tobias, T., Rzeżutka, A., Smith, R. P., & Burow, E. '[Prioritization of Pig Farm Biosecurity for Control of Salmonella and Hepatitis E Virus Infections: Results of a European Expert Opinion Elicitation](#)', *Porcine Health Management* 9, no. 1 (2023).
- Gamage, A., Gangahagedara, R., Subasinghe, S., Gamage, J., Guruge, C., Senaratne, S., Randika, T. and others. '[Advancing Sustainability: The Impact of Emerging Technologies in Agriculture](#)'. *Current Plant Biology* 40 (2024).
- García de Jalón, S., Graves, A., Palma, J.H.N., Williams, A., Upson, M. and Burgess, P.J. '[Modelling and Valuing the Environmental Impacts of Arable, Forestry and Agroforestry Systems: A Case Study](#)'. *Agroforestry Systems* 92, number 4 (2018): pages 1059 to 1073.
- Gardiner, T. and Casey, D. '[Orthoptera in the Early Stages of Post-Arable Rewilding in South-East England](#)'. *Journal of Orthoptera Research* 31, no. 2 (30 September 2022): 163–72.
- Gardner, E., Breeze, T.D., Clough, Y., Smith, H.G., Baldock, K.C.R., Campbell, A., Garratt, M.P.D. and others. '[Field Boundary Features Can Stabilise Bee Populations and the Pollination of Mass-Flowering Crops in Rotational Systems](#)'. *Journal of Applied Ecology* 58, number 10 (2021): pages 2287 to 2304.
- Garratt, M.P.D., Senapathi, D., Coston, D.J., Mortimer, S.R. and Potts, S.G. '[The Benefits of Hedgerows for Pollinators and Natural Enemies Depends on Hedge Quality and Landscape Context](#)'. *Agriculture, Ecosystems and Environment* 247 (2017): pages 363 to 370.
- Geoghegan, C., and O'Donoghue, C. '[A Spatial Analysis of the Economic Returns to Land-Use Change from Agriculture to Renewable Energy Production: Evidence from Ireland](#)'. *GCB Bioenergy* 16, number 9 (2024).
- Georgiev, M., Beauvais, W. and Guitian, J. '[Effect of Enhanced Biosecurity and Selected On-Farm Factors on Campylobacter Colonization of Chicken Broilers](#)'. *Epidemiology & Infection* 145, number 3 (February 2017): pages 553 to 567.
- Ghaffariyan, M.R. '[Silvopastoral Systems as a Strategy for Drought Resilience: A Short International Review](#)'. *Silva Balcanica* 26, number 1 (6 January 2025): pages 29 to 37.
- Giagnocavo, C., Duque-Acevedo, M., Terán-Yépez, E., Herforth-Rahmé, J., Defosse, E., Carlesi, S., Delalieux, S. and others. '[A Multi-Stakeholder Perspective on the Use of Digital Technologies in European Organic and Agroecological Farming Systems](#)'. *Technology in Society* 81 (1 June 2025): 102763.
- Giannitsopoulos, M.L., Graves, A.R., Burgess, P.J., Crous-Duran, J., Moreno, G., Herzog, F., Palma, J.H.N., Kay, S. and García de Jalón, S. '[Whole System Valuation of Arable, Agroforestry and Tree-Only Systems at Three Case Study Sites in Europe](#)'. *Journal of Cleaner Production* 269 (2020).

- Gittins, P., Apostolopoulos, S., Anastasopoulou, E.E. and Apostolopoulos, N. '[Responding to Greece's Constrained Agricultural Context: Farm Diversification Strategies Used by Family Farmers](#)'. *Journal of Rural Studies* 113 (2025).
- Glendinning, E.L. '[Building Resilience through Post-Productivism: The Case of Farmers' Markets](#)' (2012). PhD thesis, Cardiff University. Accessed: 3 April 2025.
- Golicz, K., Ghazaryan, G., Niether, W., Wartenberg, A.C., Breuer, L., Gattinger, A., Jacobs, S.R., Kleinebecker, T., Weckenbrock, P. and Große-Stoltenberg, A. '[The Role of Small Woody Landscape Features and Agroforestry Systems for National Carbon Budgeting in Germany](#)'. *Land* 10, number 10 (2021).
- Gonzalez Zapata, J., Vangipuram, B. and Erfani, T. '[Harnessing Market Based Mechanisms to Improve Water Quality: Water Quality Trading Policies in the River Alde, UK](#)'. *Journal of Environmental Management* 357 (2024).
- Gosling, R.J., Martelli, F., Wintrip, A., Sayers, A.R., Wheeler, K and Davies, R.H. '[Assessment of Producers' Response to Salmonella Biosecurity Issues and Uptake of Advice on Laying Hen Farms in England and Wales](#).' *British Poultry Science* 55, number 5 (September 3, 2014): pages 559 to 568.
- Götmark, F. '[Habitat Management Alternatives for Conservation Forests in the Temperate Zone: Review, Synthesis, and Implications](#)'. *Forest Ecology and Management* 306 (15 October 2013): pages 292 to 307.
- Graser, A., Kelling, M., Pabst, R., Schulz, M., Hölzel, N. and Kamp, J. '[Habitat Quality, Not Patch Isolation, Drives Distribution and Abundance of Two Light-Demanding Butterflies in Fragmented Coppice Landscapes](#)', *Journal of Insect Conservation* 27, no. 5 (2023): 743–58.
- Greenhalgh, J., and Rawlinson, P. '[A Review of Mentoring in Agriculture: Another Learning Option for the next Generation of New Zealand Farmers?](#)' *Extension Farming Systems Journal*, 2013.
- Griffin, R.G., and Phillips, M. '[The Farm Shop as a Retrosaped Place of Experiential Consumption](#)'. *Sociologia Ruralis* 64, no. 4 (2024): 613–38.
- Guerrero, I., Bielza Diaz-Caneja, M., Angileri, V., Assouline, M., Bosco, S., Catarino, R., Chen, M., Koeble, R., Lindner, S., Makowski, D., Montero Castaño, A., Perez-Soba Aguilar, M., Schievano, A., Tamburini, G., Terres, J. and Rega, C. '[Quantifying the Impact of Sustainable Farming Practices on Environment and Climate](#)'. Joint Research Centre (European Commission), 2024.
- Guest, E.J., Palfreeman, L.J., Holden, J., Chapman, P.J., Firbank, L.G., Lappage, M.G., Helgason, T. and Leake, J.R. '[Soil Macroaggregation Drives Sequestration of Organic Carbon and Nitrogen with Three-Year Grass-Clover Leys in Arable Rotations](#)'. *Science of The Total Environment* 852, number 158358 (2022).
- Gullett, P.R., Leslie, C., Mason, R., Ratcliffe, P., Sargent, I., Beck, A., Cameron, T. and others. '[Woodland Expansion in the Presence of Deer: 30 Years of Evidence from the Cairngorms Connect Landscape Restoration Partnership](#)'. *Journal of Applied Ecology* 60, number 11 (2023): pages 2298 to 2308.
- Häfner, K. and Piorr, A. '[Farmers' Perception of Co-Ordinating Institutions in Agri-Environmental Measures – The Example of Peatland Management for the Provision of Public Goods on a Landscape Scale](#)'. *Land Use Policy* 107 (1 August 2021): 104947.
- Haley, O. C., Zhao, Y., Hefley, T., Britton, L. L., Nwadike, L., Rivard, C., & Bhullar, M. '[Developing a Decision-Making Tool for Agricultural Surface Water Decontamination Using Ultraviolet-C Light](#)', *Journal of Food Protection* 86 (2023).

- Hall, C., O'Brien, L., Cook, M. & Ambrose-Oji, B. '[Environment and Rural Affairs Monitoring & Modelling Programme \(ERAMMP\) Report-54: National Forest in Wales Evidence Review, Technical Annex 8: Benefits to Society.](#)' Publication - Report. Bangor: NERC/Centre for Ecology & Hydrology, 29 October 2021.
- Hamřík, T., Košulič, O., Gallé, R., Gallé-Szpisjak, N. and Hédli, R. '[Opening the Canopy to Restore Spider Biodiversity in Protected Oakwoods](#)'. *Forest Ecology and Management* 541 (2023).
- Hansen, V., Meilvang, L.V., Magid, J., Thorup-Kristensen, K. and Jensen, L.S. '[Effect of Soil Fertility Level on Growth of Cover Crop Mixtures and Residual Fertilizing Value for Spring Barley](#)'. *European Journal of Agronomy* 145 (2023).
- Hardaker, A. '[Is Forestry Really More Profitable than Upland Farming? A Historic and Present Day Farm Level Economic Comparison of Upland Sheep Farming and Forestry in the UK](#)'. *Land Use Policy* 71 (2018): pages 98 to 120.
- Hardaker, A., Pagella, T. and Rayment, M. '[Integrated Assessment, Valuation and Mapping of Ecosystem Services and Dis-Services from Upland Land Use in Wales](#)'. *Ecosystem Services* 43 (2020).
- Hardaker, A., Bodner, T., and Dandy, N. '[Tree Planting for Climate Change: Coverage in the UK Farming Sector Press](#)'. *Journal of Rural Studies* 94 (1 August 2022): pages 140 to 49.
- Hardaker, A., Pagella, T. and Rayment, M. '[Ecosystem Service and Dis-Service Impacts of Increasing Tree Cover on Agricultural Land by Land-Sparing and Land-Sharing in the Welsh Uplands](#)'. *Ecosystem Services* 48 (1 April 2021): 101253.
- Hardman, C.J., Norris, K., Nevard, T.D., Hughes, B. and Potts, S.G. '[Delivery of Floral Resources and Pollination Services on Farmland under Three Different Wildlife-Friendly Schemes](#)'. *Agriculture, Ecosystems & Environment* 220 (March 2016): pages 142 to 151.
- Hardwicke, J., Hill, K.M. and Ryan, D.J. '[Finding Your Way: Exploring Urban Park Users' Engagement with a Wayfinding Intervention through Intercept Go-along Interviews](#)'. *Cities & Health* 8, number 6 (1 November 2024): pages 1003 to 1016.
- Hare, D., Daniels, M. and Blossey, B. '[Public Perceptions of Deer Management in Scotland](#)'. *Frontiers in Conservation Science* 2 (2021).
- Harrington, T.B. '[Long-Term Effects of Thinning and Woody Control on Longleaf Pine Plantation Development, Understory Abundance, and Tree Damage from an Ice Storm](#)'. *Forest Ecology and Management* 459 (2020).
- Harrison, M., Muleke, A., Christie-Whitehead, K., Cain, M., Burgess, P., Wiltshire, K., Liu, K. and Pexas, G. '[Regenerative Agriculture Amplifies Productivity and Profitability While Negating Greenhouse Gas Emissions](#)'. In Review, 28 January 2025.
- Hayes, E., Higgins, S., Mullan, D. and Geris, J. '[High-Resolution Assessment of Riverbank Erosion and Stabilization Techniques with Associated Water Quality Implications](#)'. *International Journal of River Basin Management* 22, number 4 (2024): pages 611 to 625.
- Heinrichs, J., Kuhn, T., Pahmeyer, C. and Britz, W. '[Economic Effects of Plot Sizes and Farm-Plot Distances in Organic and Conventional Farming Systems: A Farm-Level Analysis for Germany](#)'. *Agricultural Systems* 187 (February 2021): 102992.
- Henderson, T. '[The Ecosystem Services Impacts of Woodland Creation and Timber Products](#)'. *Woodknowledge Wales* (2025).
- Herrero, M., Thornton, P.K., Mason-D'Croz, D., Palmer, J., Benton, T.G., Bodirsky, B.L., Bogard, J.R. and others. '[Innovation Can Accelerate the Transition towards a Sustainable Food System](#)'. *Nature Food* 1, number 5 (2020): pages 266 to 272.

- Herron, J., Curran, T.P., Moloney, A.P., McGee, M., O’Riordan, E.G. and O’Brien, D. [‘Life Cycle Assessment of Pasture-Based Suckler Steer Weanling-to-Beef Production Systems: Effect of Breed and Slaughter Age’](#). *Animal* 15, number 7 (July 2021): 100247.
- Hill, B., Bradley, D. and Williams, E. [‘Evaluation of Knowledge Transfer: Conceptual and Practical Problems of Impact Assessment of Farming Connect in Wales’](#). *Journal of Rural Studies* 49 (2017): pages 41 to 49.
- Hinzpeter, K. [‘Dissemination of Organic Farming Knowledge through Model Farmers: Exploring the BioRegio Betriebsnetz in Bavaria, Germany’](#). *Journal of Agricultural Education and Extension*, 2024.
- Hodge, I., and Reader, M. [‘The Introduction of Entry Level Stewardship in England: Extension or Dilution in Agri-Environment Policy?’](#) *Land Use Policy* 27, number 2 (April 2010): pages 270 to 282.
- Hoischen-Taubner, S., Bielecke, A. and Sundrum, A. [‘Knowledge Transfer Regarding the Issue of Animal Health’](#). *Organic Agriculture* 8, number 2 (2018): pages 105 to 120.
- Hökkä, H., Repola, J., Moilanen, M. and Saarinen, M. [‘Seedling Establishment on Small Cutting Areas with or without Site Preparation in a Drained Spruce Mire - a Case Study in Northern Finland’](#). *Silva Fennica* 46, number 5 (2012): pages 695 to 705.
- Holland, J.M., Douma, J.C., Crowley, L., James, L., Kor, L., Stevenson, D.R.W. and Smith, B.M. [‘Semi-Natural Habitats Support Biological Control, Pollination and Soil Conservation in Europe. A Review’](#). *Agronomy for Sustainable Development* 37, number 4 (2017).
- Horrocks, C.A., Dungait, J.A.J., Heal, K.V. and Cardenas, L.M. [‘Comparing N2O Fluxes from Recently Created Extensive Grasslands and Sites Remaining under Intensive Agricultural Management’](#). *Agriculture, Ecosystems & Environment* 199 (January 2015): pages 77 to 84.
- Hosseini, P., Syndicus, I., Houghton, E., Alarcon, P., Fournie, G., Guitian, J., Paterson, A. and others. [‘Qualitative Studies on Farm Managers Perception of Risk from HPAIV and Implementation of Biosecurity Measures on UK Poultry Farms.’](#) *Preventive Veterinary Medicine* 239 (June 1, 2025): 106445
- Hough, R.L., Towers, W. and Aalders, I. [‘The Risk of Peat Erosion from Climate Change: Land Management Combinations—An Assessment with Bayesian Belief Networks’](#). *Human and Ecological Risk Assessment: An International Journal* 16, number 5 (7 October 2010): pages 962 to 976.
- Hounsom, B., Edwards, R.T. and Edwards-Jones, G. [‘A Note on the Effect of Farmer Mental Health on Adoption: The Case of Agri-Environment Schemes’](#). *Agricultural Systems* 91, number 3 (December 2006): pages 229 to 241.
- Howley, P., Doherty, E., Buckley, C., Hynes, S., van Rensburg, T. and Green, S. [‘Exploring Preferences towards the Provision of Farmland Walking Trails: A Supply and Demand Perspective’](#). *Land Use Policy* 29, number 1 (1 January 2012): pages 111 to 118.
- Hughes, S., Kunin, W., Watts, K. and Ziv, G. [‘New Woodlands Created Adjacent to Existing Woodlands Grow Faster, Taller and Have Higher Structural Diversity than Isolated Counterparts’](#). *Restoration Ecology* 31, number 4 (2023).
- Hughes, S., Kunin, W., Ziv, G. and Watts, K. [‘Spatial Targeting of Woodland Creation Can Reduce the Colonisation Credit of Woodland Plants’](#). *Ecological Solutions and Evidence* 4, number 3 (2023).
- Image, M., Gardner, E., and Breeze, T.D. [‘Co-Benefits from Tree Planting in a Typical English Agricultural Landscape: Comparing the Relative Effectiveness of Hedgerows,](#)

- [Agroforestry and Woodland Creation for Improving Crop Pollination Services](#)'. Land Use Policy 125 (2023).
- Image, M., Gardner, E., Clough, Y., Kunin, W.E., Potts, S.G., Smith, H.G., Stone, G.N., Westbury, D.B. and Breeze, T.D. [‘Which Interventions Contribute Most to the Net Effect of England’s Agri-Environment Schemes on Pollination Services?’](#) Landscape Ecology 38, no. 1 (1 January 2023): 271–91.
- Ingram, J., Mills, J., Mackley-Ward, H. [“For All Kinds of Reasons, It Hasn’t Happened”: A Novel Integrative Perspective for Analysing the Barriers to Biomass Crops for Bioenergy in the United Kingdom](#)'. Energy Research and Social Science 120 (2025).
- Irwin, R., Dhubháin, Á.N., and Short, I. [‘Irish Dairy and Drystock Farmers’ Attitudes and Perceptions to Planting Trees and Adopting Agroforestry Practices on Their Land](#)'. Environmental Challenges 9 (2022).
- Irwin, R., Short, I., Mohammadrezaei, M. and Dhubháin Á.N. [‘Increasing Tree Cover on Irish Dairy and Drystock Farms: The Main Attitudes, Influential Bodies and Barriers That Affect Agroforestry Uptake](#)'. Environmental Science and Policy 146 (2023): pages 76 to 89.
- Isakhanyan, G., Galgo, C.J., Gemtou, M. and Pedersen, S.M. [‘Business Strategies towards Climate-Smart Agriculture in Europe: A Literature Review](#)'. Business Strategy and the Environment 33, number 6 (2024): pages 5073 to 5085.
- Iversen, S.V., MacDonald, M.A., van der Velden, N., van Soesbergen, A., Convery, I., Mansfield, L. and Holt, C.D.S. [‘Using the Ecosystem Services Assessment Tool TESSA to Balance the Multiple Landscape Demands of Increasing Woodlands in a UK National Park](#)'. Ecosystem Services 68 (1 August 2024): 101644.
- Iversen, S.V., van der Velden, N., Convery, I., Mansfield, L. and Holt, C.D.S. [‘Why Understanding Stakeholder Perspectives and Emotions Is Important in Upland Woodland Creation – A Case Study from Cumbria, UK](#)'. Land Use Policy 114 (1 March 2022): 105929.
- Jack, C., Adenuga, A.H., Ashfield, A. and Wallace, M. [‘Investigating the Drivers of Farmers’ Engagement in a Participatory Extension Programme: The Case of Northern Ireland Business Development Groups](#)'. Sustainability (Switzerland) 12, number 11 (2020).
- Jack, C., Hotchkiss, E., Sargison, N.D., Toma, L., Milne, C. and Bartley, C.D. [‘A Quantitative Analysis of Attitudes and Behaviours Concerning Sustainable Parasite Control Practices from Scottish Sheep Farmers](#)'. Preventive Veterinary Medicine, SVEPM 2016 - Annual Conference of The Society for Veterinary Epidemiology and Preventive Medicine, 139 (1 April 2017): pages 134 to 145.
- Jacobo, E.J., Rodríguez, A.M., Bartoloni, N. and Society for Range Management. [‘Rotational Grazing Effects on Rangeland Vegetation at a Farm Scale](#)'. Rangeland Ecology & Management 59, number 3 (2006).
- Jane, M., Gibbon, D. Ingram, J., Reed, M., Short, C. and Dwyer, J. [‘Organising Collective Action for Effective Environmental Management and Social Learning in Wales](#)'. Journal of Agricultural Education and Extension 17, no. 1 (2011): pages 69 to 83.
- Janssen, J. [‘Sustainable Development and Protected Landscapes: The Case of the Netherlands](#)'. International Journal of Sustainable Development and World Ecology 16, number 1 (2009): pages 37 to 47.
- Jarvis, D. [‘Wildflower Meadow Creation and management in land regeneration](#)' in Best Practice Guidance for Land Regeneration, Forest Research (2014).

- Javaid, M., Haleem, A., Singh, R.P. and Suman, R. '[Enhancing Smart Farming through the Applications of Agriculture 4.0 Technologies](#)'. International Journal of Intelligent Networks 3 (1 January 2022): pages 150 to 164.
- Jebari, A., Pereyra-Goday, F., Kumar, A., Collins, A.L., Rivero, M.J. and McAuliffe, G.A. '[Feasibility of Mitigation Measures for Agricultural Greenhouse Gas Emissions in the UK. A Systematic Review](#)'. Agronomy for Sustainable Development 44, number 1 (2024).
- Jellesmark, S., Ausden, M., Blackburn, T.M., Hoffmann, M., McRae, L., Visconti, P. and Gregory, R.D. '[The Effect of Conservation Interventions on the Abundance of Breeding Waders within Nature Reserves in the United Kingdom](#)'. Ibis 165, number 1 (2023): pages 69 to 81.
- Jenkins, B., Herold, L., De Mendonça, M., Loughnan, H., Willcocks, J., David, T., Ginns, B., Rock, L., Wilshire, J. and Avis, K. '[Breeding for Reduced Methane Emissions in Livestock](#)'. Ricardo PLC, January 2025.
- Jevnaker, B.H. and Hill, I. '[Heritage Craft Entrepreneurship in 'the Wild': The Role of Entrepreneurial Placemaking for Rural Development](#)'. Contemporary Issues in Entrepreneurship Research 18B (2024): 213–26.
- Johnsson, F., and Beery, T. '[Outdoor Recreation and the Private Forest Owner: Place Attachment, Social Values, and Public Access](#)'. Frontiers in Conservation Science 3 (2022).
- Jones, A., Bridle, S., Falloon, P., Fredenburgh, J. and Reynolds, C. '[Results of a Survey of UK Farmers on Food System Vulnerability over the Short and Long Term](#)'. Sustainability (Switzerland) 16, no. 16 (2024).
- Jones, L., Bealey, B., Braban, C., Martineau, H., Williams, A. and Dragosits, U. '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 8: Improving Air Quality and Well-Being. Sustainable Farming Scheme. Evidence Review](#)'. Publication - Report. Bangor: NERC/Centre for Ecology & Hydrology, 4 July 2019.
- Jones, R.F., Kam, H. and Potter, C. '[Are Landholders Willing to Collaborate under ELMs? Promoting Collaborative Conservation on a Landscape Scale in the UK](#)'. Journal of Rural Studies 103 (2023).
- Jordon, M.W., Winter, D.M. and Petrokofsky, G. '[Advantages, Disadvantages, and Reasons for Non-Adoption of Rotational Grazing, Herbal Leys, Trees on Farms and Ley-Arable Rotations on English Livestock Farms](#)'. Agroecology and Sustainable Food Systems 47, number 3 (16 March 2023): pages 330 to 354.
- Jordon, M.W., Willis, K.J., Harvey, W.J., Petrokofsky, L. and Petrokofsky, G. '[Implications of Temperate Agroforestry on Sheep and Cattle Productivity, Environmental Impacts and Enterprise Economics. A Systematic Evidence Map](#)'. Forests 11, number 12 (2020): pages 1 to 29.
- Jouf, C., and Lawson, L.A. '[European Farmers' Responses to Higher Commodity Prices: Cropland Expansion or Forestlands Preservation?](#)' Ecological Economics 191 (2022).
- Judge, J., McDonald, R.A., Walker, N. and Delahay, R.J. '[Effectiveness of Biosecurity Measures in Preventing Badger Visits to Farm Buildings](#)', ed. Justin David Brown, PLoS ONE 6, no. 12 (29 December 2011): e28941,.
- Kaine, G., Edwards, P., Polyakov, M. and Stahlmann-Brown, P. '[Who Knew Afforestation Was Such a Challenge? Motivations and Impediments to Afforestation Policy in New Zealand](#)'. Forest Policy and Economics 154 (2023).
- Kam, H. '[Opportunities for Achieving Landscape Scale Conservation in England](#)'. Journal of Rural Studies 110 (1 August 2024): 103380.

- Kamp, J. '[Coppice Loss and Persistence in Germany](#)'. *Trees, Forests and People* 8 (2022).
- Kassam, A. and Kassam, L. '[Regenerative Farming without Farmed Animals](#)'. In *Regenerative Farming and Sustainable Diets: Human, Animal and Planetary Health*, 167–74, 2024.
- Kathage, J., Smit, B., Janssens, B., Haagsma, W. and Adrados, J.L. '[How Much Is Policy Driving the Adoption of Cover Crops? Evidence from Four EU Regions](#)'. *Land Use Policy* 116 (1 May 2022): 106016.
- Kay, S., Crous-Duran, J., Ferreira-Domínguez, N., García de Jalón, S., Graves, A., Moreno, G., Mosquera-Losada, M.R. and others. '[Spatial Similarities between European Agroforestry Systems and Ecosystem Services at the Landscape Scale](#)'. *Agroforestry Systems* 92, number 4 (2018): pages 1075 to 1089.
- Kearney, M., O'Riordan, E.G., Byrne, N., Breen, J. and Crosson, P. '[Mitigation of Greenhouse Gas Emissions in Pasture-Based Dairy-Beef Production Systems](#)'. *Agricultural Systems* 211 (October 2023): 103748.
- Keenleyside, C.B., Beaufoy, G., Alison, J., Gunn, I.D.M., Healey, J., Jenkins, T., Pagella, T. and Siriwardena, G.M. '[Environment and Rural Affairs Monitoring & Modelling Programme - ERAMMP Technical Annex 4: Building Ecosystem Resilience](#)'. Sustainable Farming Scheme Evidence Review. Bangor: Centre for Ecology & Hydrology, 2019.
- Keenleyside, C.B., and Old, G.H. '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP - Technical Annex 9: Flood Mitigation](#)'. Sustainable Farming Scheme Evidence Review. Bangor: Centre for Ecology & Hydrology, 2019.
- Kelley, H., van Rensburg, T.M. and Jeserich, N. '[Determinants of Demand for Recreational Walking Trails in Ireland](#)'. *Khatri-Chhetri, Upama, Karen A Thompson, Sylvie A Quideau, Mark S Boyce, Scott X Chang, Edward W Bork, and Cameron N Carlyle. 'Adaptive Multi-Paddock Grazing Increases Mineral Associated Soil Carbon in Northern Grasslands'*. *Agriculture, Ecosystems & Environment* 369 (August 2024): 109000.
- Kerr, C.L., Armstrong, D.R. and Anderson, A.J. '[Short Communication: A Practical Farm-Based Trial to Compare Ewe Nematode Control Strategies in Peri-Parturient Ewes](#)'. Edited by Arda Yildirim. *PLOS ONE* 15, no. 8 (13 August 2020): e0236143.
- Kerr, G. '[Environment and Rural Affairs Monitoring & Modelling Programme ERAMMP Report 34: National Forest in Wales - Evidence Review Annex-2: Managing Undermanaged Woodland](#)'. Publication – Report. Bangor: Centre for Ecology & Hydrology, 2020.
- Kirkland, H., Hare, D., Daniels, M., Krofel, M., Rao, S., Chapman, T. and Blossey, B. '[Successful Deer Management in Scotland Requires Less Conflict Not More](#)'. *Frontiers in Conservation Science* 2 (2021).
- Klaus, N.A., Rush, S.S., Weitzel, S.L. and Holdrege, M.C. '[Changes in Tree Canopy, Groundcover, and Avian Community Following Restoration of a Montane Longleaf Pine Woodland](#)'. *American Midland Naturalist* 184, number 2 (2020): pages 163 to 176.
- Kleijn, D., and Sutherland, W.J. '[How Effective Are European Agri-environment Schemes in Conserving and Promoting Biodiversity?](#)' *Journal of Applied Ecology* 40, number 6 (December 2003): pages 947 to 969.
- Kling, K.G. '[Accessible Nature: Balancing Contradiction in Protected Areas](#)'. *Environment and Planning E: Nature and Space* 7, number 5 (2024): pages 2036 to 2057.

- Knook, J., Eory, V., Brander, M. and Moran, D. '[Evaluation of Farmer Participatory Extension Programmes](#)'. Journal of Agricultural Education and Extension 24, number 4 (2018): pages 309 to 325.
- Knook, J., Eastwood, C., Beehre, L., Mitchelmore, K. and Barker, A. '[Resilience Building in Agricultural Extension Programmes: Application of a Resilience Framework and Development of a Farmer-Focused Assessment Tool](#)'. The Journal of Agricultural Education and Extension 30, number 5 (19 October 2024): pages 753 to 773.
- Knook, J., Eory, V., Brander, M. and Moran, D. '[The Evaluation of a Participatory Extension Programme Focused on Climate Friendly Farming](#)'. Journal of Rural Studies 76 (May 2020): pages 40 to 48.
- Knowledge Library. '[Mob Grazing – What's It All about?](#)', 2025.
- Knowledge Library. '[Rotational Grazing Systems for Cattle](#)', 2025.
- Košulič, O., Procházka, J., Tuf, I.H. and Michalko, R. '[Intensive Site Preparation for Reforestation Wastes Multi-Trophic Biodiversity Potential in Commercial Oak Woodlands](#)'. Journal of Environmental Management 300 (2021).
- Kozdasová, A., Batista, L.G., Hédl, R. and Szabó, P. '[Coppice Reintroduction in the Czech Republic: Extent, Motivation and Obstacles](#)'. European Journal of Forest Research 143, number 1 (1 February 2024): pages 305 to 317.
- Krajewski, S., Žukovskis, J., Gozdowski, D., Cieśliński, M. and Wójcik-Gront, E. '[Evaluating the Path to the European Commission's Organic Agriculture Goal: A Multivariate Analysis of Changes in EU Countries \(2004–2021\) and Socio-Economic Relationships](#)'. Agriculture 14, number 3 (15 March 2024): 477.
- Kreitzman, M., Chapman, M., Keeley, K.O. and Chan, K.M.A. '[Local Knowledge and Relational Values of Midwestern Woody Perennial Polyculture Farmers Can Inform Tree-Crop Policies](#)'. People and Nature 4, number 1 (2022): pages 180 to 200.
- Krishnan, R., Yen, P., Agarwal, R., Arshinder, K. and Bajada, C. '[Collaborative Innovation and Sustainability in the Food Supply Chain- Evidence from Farmer Producer Organisations](#)'. Resources, Conservation and Recycling 168 (1 May 2021): 105253.
- Krommweh, M.S., and Buescher, W. '[Heating Performance of a Laboratory Pilot-Plant Combining Heat Exchanger and Air Scrubber for Animal Houses](#)'. SCIENTIFIC REPORTS 11, number 1 (25 March 2021).
- Kumar, V., Sharma, K.V., Kadam, N., Patel, A., Kate, T.R. and Rathnayake, U. '[A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies](#)'. Smart Agricultural Technology 8 (2024).
- Kuosmanen, N., Yli-Heikkilä, M., Väre, M. and Kuosmanen, T. '[Productive Performance of Organic Crop Farms in Finland 2010–2017](#)'. Organic Agriculture 11, number 3 (September 2021): pages 379 to 392.
- Kupper, T., Eugster, R., Sintermann, J., Neftel, A. and Häni, C. '[A Novel Approach to Estimate the Abatement of Ammonia Emissions from Mitigation Techniques at Farm-Scale Slurry Stores Exemplified by a Semifloating Cover](#)'. Journal of Environmental Quality. John Wiley and Sons Inc, 2021.
- Laber, L., Eichberg, C., Zimmerbeutel, A., Düring, R.A. and Donath, T.W. '[Effects of Macrocyclic Lactone Anthelmintics on Seed Germination of Temperate Grassland Species](#)'. Plant Biology 25, number 7 (2023): pages 1046 to 1057.
- Laidlaw, R., Smart, J., Ewing, H., Franks, S., Belting, H., Donaldson, L., Hilton, G., Hiscock, N., Hoodless, A., Hughes, B., Jarrett, N., Kentie, R., Kleyheeg, E., Lee, R., Roodbergen, M., Scott, D., Short, M., Syroeschkovskiy, E., Teunissen, W. and Gill, J. '[Predator Management for Breeding Waders: A Review of Current Evidence and Priority Knowledge Gaps](#)'. Wader Study 128, no. 1 (15 April 2021).

- Laidlaw, R.A., Smart, J., Smart, M.A., Bodey, T.W., Coledale, T. and Gill, J.A. '[Foxes, Voles, and Waders: Drivers of Predator Activity in Wet Grassland Landscapes](#)'. *Avian Conservation and Ecology* 14, no. 2 (2019)
- Laidlaw, R.A., Smart, J., Smart, M.A. and Gill, J.A. '[Scenarios of Habitat Management Options to Reduce Predator Impacts on Nesting Waders](#)'. Edited by Richard Fuller. *Journal of Applied Ecology* 54, number 4 (August 2017): pages 1219 to 1229.
- Laidlaw, R.A., Smart, J., Smart, M.A., and Gill, J.A. '[The Influence of Landscape Features on Nest Predation Rates of Grassland-Breeding Waders](#)'. *Ibis* 157, number 4 (2015): pages 700 to 712.
- '[Land Use: Reducing Emissions and Preparing for Climate Change](#)'. London: Committee on Climate Change, 2018.
- Larkin, J., Sheridan, H., Finn, J.A., Denniston, H. and hUallacháin, D.Ó. '[Semi-Natural Habitats and Ecological Focus Areas on Cereal, Beef and Dairy Farms in Ireland](#)'. *Land Use Policy* 88 (2019).
- Larkin, M. and Stanley, D.A. '[Impacts of Management at a Local and Landscape Scale on Pollinators in Semi-Natural Grasslands](#)'. *Journal of Applied Ecology* 58, number 11 (2021): pages 2505 to 2514.
- Laven, D.N., Jewiss, J.L. and Mitchell, N.J. '[Toward Landscape-Scale Stewardship and Development: A Theoretical Framework of United States National Heritage Areas](#)'. *Society and Natural Resources* 26, number 7 (2013): pages 762 to 777.
- Lavergne, S., Vanasse, A., Thivierge, M-N. and Halde, C. '[Using Fall-Seeded Cover Crop Mixtures to Enhance Agroecosystem Services: A Review](#)'. *Agrosystems, Geosciences & Environment* 4, number 2 (2021): e20161.
- Lawrence, A. and Dandy, N. '[Private Landowners' Approaches to Planting and Managing Forests in the UK: What's the Evidence?](#)' *Land Use Policy* 36 (1 January 2014): pages 351 to 360.
- Leader, A., Kinsella, J. and O'Brien, R. '[Engaging Commercial Dairy Demonstration Farmers in Farmland Biodiversity Management Communication](#)'. *The Journal of Agricultural Education and Extension*, October 2024, pages 1 to 26.
- Learmount, J., Glover, M.J. and Taylor, M.A. '[Resistance Delaying Strategies on UK Sheep Farms: A Cost Benefit Analysis](#)'. *Veterinary Parasitology* 254 (30 April 2018): 64–71.
- Learmount, J., Stephens, N., Boughtflower, V., Barrecheguren, A., Rickell, K., Massei, G. and Taylor, M. '[Three-Year Evaluation of Best Practice Guidelines for Nematode Control on Commercial Sheep Farms in the UK](#)'. *Veterinary Parasitology* 226 (15 August 2016): 116–23.
- Leck, C., Evans, N. and Upton, D. '[Agriculture – Who Cares? An Investigation of “Care Farming” in the UK](#)'. *Journal of Rural Studies* 34 (1 April 2014): 313–25.
- Liang, H. and Wu, Z. '[The Role of Single Landscape Elements in Enhancing Landscape Aesthetics and the Sustainable Tourism Experience: A Case Study of Leisure Furniture](#)'. *Sustainability* 16, number 23 (January 2024): 10219.
- Limbach, K. '[What Role for Environmental Cooperatives in Collective Agri-Environmental Schemes?](#)' *Journal of Environmental Planning and Management* 67, number 7 (2024): pages 1409 to 1433.
- Limpamont, A., Kittipanya-ngam, P., Chindasombatcharoen, N. and Cavite, H.J.M. '[Towards Agri-Food Industry Sustainability: Addressing Agricultural Technology Adoption Challenges through Innovation](#)'. *Business Strategy and the Environment* 33, no. 7 (2024): 7352–67.

- Liquete Garcia, M.D.C., Prakash, S., Addamo, A., Assouline, M., Cano, J.I.B., Bosco, S., Jesus Cardoso, A.D. and others. '[Scientific Evidence Showing the Impacts of Nature Restoration Actions on Food Productivity](#)'. Joint Research Centre (European Commission), 2022.
- Litschel, J., Berendt, F., Wagner, H., Heidenreich, S., Bauer, D., Welp, M. and Cremer, T. '[Key Actors' Perspectives on Agroforestry's Potential in North Eastern Germany](#)'. Land 12, number 2 (2023).
- Liu, J., Du, S. and He, Q. '[Research on the Impact of Information Scenarios on Retailers' Strategies for Purchasing Fresh Agricultural Products](#)'. Polish Journal of Environmental Studies 34, no. 2 (2025): 1243–54.
- Livingstone, D., Smyth, B.M., Cassidy, R., Murray, S.T., Lyons, G.A., Foley, A.M. and Johnston, C.R. '[Reducing the Time-Dependent Climate Impact of Intensive Agriculture with Strategically Positioned Short Rotation Coppice Willow](#)'. Journal of Cleaner Production 419 (2023).
- Livingstone, D., Smyth, B.M., Foley, A.M., Murray, S.T., Lyons, G. and Johnston, C. '[Willow Coppice in Intensive Agricultural Applications to Reduce Strain on the Food-Energy-Water Nexus](#)'. Biomass and Bioenergy 144 (2021).
- Livingstone, D., Smyth, B.M., Lyons, G., Foley, A.M., Murray, S.T. and Johnston, C. '[Life Cycle Assessment of a Short-Rotation Coppice Willow Riparian Buffer Strip for Farm Nutrient Mitigation and Renewable Energy Production](#)'. Renewable and Sustainable Energy Reviews 158 (2022).
- Livingstone, D., Smyth, B.M., Sherry, E., Murray, S.T., Foley, A.M., Lyons, G.A. and Johnston, C.R. '[Production Pathways for Profitability and Valuing Ecosystem Services for Willow Coppice in Intensive Agricultural Applications](#)'. Sustainable Production and Consumption 36 (2023): pages 281 to 291.
- Lloyd, I.L., Thomas, V., Ofoegbu, C., Bradley, A.V., Bullard, P., D'Acunha, B., Delaney, B. and others. '[State of Knowledge on UK Agricultural Peatlands for Food Production and the Net Zero Transition](#)'. Sustainability 15, number 23 (27 November 2023): 16347.
- Lobley, M., Saratsi, E., Winter, M. and Bullock, J. '[Training Farmers in Agri-Environmental Management: The Case of Environmental Stewardship in Lowland England](#)', 2013.
- de Loë, R.C., Murray, D. and Simpson, H.C. '[Farmer Perspectives on Collaborative Approaches to Governance for Water](#)'. Journal of Rural Studies 42 (2015): pages 191 to 205.
- Loos, J., Gällersdörfer, J., Hartel, T., Dolek, M. and Sutcliffe, L. '[Limited Effectiveness of EU Policies to Conserve an Endangered Species in High Nature Value Farmland in Romania](#)'. Ecology and Society 26, number 3 (2021).
- López, R., Clapperton, B.K. and Medina-Vogel, G. '[A Global Review of the American Mink \(Neovison vison\) Removal Techniques – Patagonia as a Case Study for Their Potential Application](#)'. Gayana 87, number 1 (2023): pages 43 to 62.
- Ludzuweit, A., Paterson, J., Wydra, K., Pump, C., Müller, K and Miller, Y. '[Enhancing Ecosystem Services and Biodiversity in Agrivoltaics through Habitat-Enhancing Strategies](#)'. Renewable and Sustainable Energy Reviews 212 (2025).
- Lukoseviciute, G., Pereira, L.N. and Panagopoulos, T. '[The Economic Impact of Recreational Trails: A Systematic Literature Review](#)'. Journal of Ecotourism 21, number 4 (2 October 2022): pages 366 to 393.
- MacDonald, M.A., Angell, R., Dines, T.D., Dodd, S., Haysom, K.A., Hobson, R., Johnstone, I.G. and others. '[Have Welsh Agri-Environment Schemes Delivered for Focal](#)

- [Species? Results from a Comprehensive Monitoring Programme](#)'. *Journal of Applied Ecology* 56, number 4 (2019): pages 812 to 823.
- Macfarlane, R. [Implementing Agri-Environment Policy: A Landscape Ecology Perspective](#)'. *Journal of Environmental Planning and Management* 41, number 5 (1998): pages 575 to 596.
- Mackay, R., and Prager, K. [The Dilemma of Upland Footpaths – Understanding Private Landowner Engagement in the Provision of a Public Good](#)'. *Scottish Geographical Journal* 137, numbers 1 to 4 (2 October 2021): pages 131 to 157.
- MacMillan, T. and Cusworth, G. [Farmer Co-Operation in the UK: Opportunities for the Industry](#)'. Report. Co-operatives UK and RAU, 10 October 2019.
- Maltby, E., Acreman, M., Blackwell, M.S.A., Everard, M. and Morris, J. [The challenges and implications of linking wetland science to policy in agricultural landscapes – experience from the UK National Ecosystem Assessment](#). (2013) *Ecological Engineering*, 56. 121-133.
- Maltby, J. [Avoiding Siloed Approaches: Integrating Psychological Insights into Sustainable Farming](#)'. *PLoS ONE* 19, number 10 October (2024).
- Malpas, L.R., Kennerley, R.J., Hirons, G.J.M., Sheldon, R.D., Ausden, M., Gilbert, J.C. and Smart, J. [The Use of Predator-Exclusion Fencing as a Management Tool Improves the Breeding Success of Waders on Lowland Wet Grassland](#)'. *Journal for Nature Conservation* 21, no. 1 (2013): 37–47.
- Manton, M. and Angelstam, P. [Macroecology of North European Wet Grassland Landscapes: Habitat Quality, Waders, Avian Predators and Nest Predation](#)'. *Sustainability* 13, number 15 (January 2021): 8138.
- Manton, M., Angelstam, P., Milberg, P. and Elbakidze, M. [Wet Grasslands as a Green Infrastructure for Ecological Sustainability: Wader Conservation in Southern Sweden as a Case Study](#)'. *Sustainability (Switzerland)* 8, number 4 (2016).
- Maohua, M. and Herzon, I. [Plant Functional Diversity in Agricultural Margins and Fallow Fields Varies with Landscape Complexity Level: Conservation Implications](#)'. *Journal for Nature Conservation* 22, no. 6 (December 2014): 525–31.
- Marchand, F., Cooreman, H., Pappa, E., Perifanos, I., Alexopoulos, Y., Debruyne, L., Chiswell, H., Ingram, J. and Koutsouris, A. [Effectiveness of On-Farm Demonstration Events in the EU: Role of Structural Characteristics](#)'. *Journal of Agricultural Education and Extension* 27, number 5 (2021): pages 677 to 697.
- Markiewicz-Keszycka, M., Carter, A., O'Brien, D., Henchion, M., Mooney, S. and Hynds, P. [Pro-Environmental Diversification of Pasture-Based Dairy and Beef Production in Ireland, the United Kingdom and New Zealand: A Scoping Review of Impacts and Challenges](#)'. *Renewable Agriculture and Food Systems* 38 (January 2023).
- Marr, E.J. and Howley, P. [Woodlots, wetlands or wheat fields? Agri-environmental land allocation preferences of stakeholder organisations in England and Ontario](#)' (2018), *Land Use Policy*, Elsevier, vol. 75(C), pages 673-681.
- Martens, K., Rogga, S., Hardner, U. and Piorr, A. [Examining Proximity Factors in Public-Private Collaboration Models for Sustainable Agri-Food System Transformation: A Comparative Study of Two Rural Communities](#)'. *Frontiers in Sustainable Food Systems* 7 (2023).
- Martin, A.R. and Lea, V.J. [A Mink-Free GB: Perspectives on Eradicating American Mink Neovison Vison from Great Britain and Its Islands](#)'. *Mammal Review* 50, number 2 (2020): pages 170 to 179.

- Martini, M., Patelli, S., Cassola, F.M., Iaria, J., Livornese, M., Prandelli, S., Santi, F. and others. [‘A Case Study on the Impact of Coppicing on Small Mammal Diversity: First Evidence from the High Agri Valley in the Basilicata Region, Italy’](#). *Journal for Nature Conservation* 82 (2024).
- Martin-Ortega, J., Rothwell, S.A., Anderson, A., Okumah, M., Lyon, C., Sherry, E., Johnston, C., Withers, P.J.A. and Doody, D.G. [‘Are Stakeholders Ready to Transform Phosphorus Use in Food Systems? A Transdisciplinary Study in a Livestock Intensive System’](#). *Environmental Science and Policy* 131 (2022): pages 177 to 187.
- Masi, M., Di Pasquale, J., Vecchio, Y. and Capitanio, F. [‘Precision Farming: Barriers of Variable Rate Technology Adoption in Italy’](#). Land. Multidisciplinary Digital Publishing Institute (MDPI), 2023.
- Maskell, L.C., Botham, M., Henrys, P., Jarvis, S., Maxwell, D., Robinson, D.A., Rowland, C.S. and others. [‘Exploring Relationships between Land Use Intensity, Habitat Heterogeneity and Biodiversity to Identify and Monitor Areas of High Nature Value Farming’](#). *Biological Conservation* 231 (1 March 2019): pages 30 to 38.
- Mason, L.R., Green, R.E., Hirons, G.J.M., Skinner, A.M.J., Peault, S.C., Upcott, E.V., Wells, E., Wilding, D.J. and Smart, J. [‘Experimental Diversionary Feeding of Red Kites Reduces Chick Predation and Enhances Breeding Productivity of Northern Lapwings Vanellus Vanellus’](#). *Journal for Nature Conservation* 64 (1 December 2021): 126051.
- Mason, L.R. and Smart, J. [‘Wader Chick Condition Is Not Limited by Resource Availability on Wader-Friendly Lowland Wet Grassland Sites in the UK’](#). *Wader Study* 122, number 3 (2015): pages 193 to 200.
- Mathevet, R., Thompson, J.D., Folke, C. and Chapin, F.S. [‘Protected Areas and Their Surrounding Territory: Socioecological Systems in the Context of Ecological Solidarity’](#). *Ecological Applications* 26, number 1 (2016): pages 5 to 16.
- Mathieu, A., Cogliastro, A. and Rivest, D. [‘Drivers of Tree Establishment in Planted Windbreaks and Riparian Buffers: A Case Study of Farms in Southern Quebec, Canada’](#). *Geoderma Regional* 37 (2024).
- Matthews, P.G., Fish, R.D. and Tzanopoulos, J. [‘Overcoming Barriers to Agri-Environmental Management at Landscape Scale: Balancing Farmer Coordination and Collaboration with the Aid of Facilitators and Pioneers’](#). *Journal of Environmental Management* 369 (2024).
- Matthews, R. [‘Quantifying the sustainable forestry carbon cycle’](#). *Forest Research* (2022).
- Matzdorf, B. and Lorenz, J. [‘How Cost-Effective Are Result-Oriented Agri-Environmental Measures?—An Empirical Analysis in Germany’](#). *Land Use Policy* 27, number 2 (April 2010): pages 535 to 544.
- McAuliffe, G.A., Zhang, Y., Collins, A.L., [‘Assessing catchment scale water quality of agri-food systems and the scope for reducing unintended consequences using spatial life cycle assessment \(LCA\)’](#) *Journal of Environmental Management*, (2022)
- McDonagh, J. [‘Designation, Incentivisation and Farmer Participation—Exploring Options for Sustainable Rural Landscapes’](#). *Sustainability* 14, number 9 (5 May 2022): 5569.
- McGee, M., Regan, M., Moloney, A.P., O’Riordan, E.G., Lenehan, C., Kelly, A.K. and Crosson, P. [‘Grass-Based Finishing of Early- and Late-Maturing Breed Bulls within Suckler Beef Systems: Performance, Profitability, Greenhouse Gas Emissions and Feed-Food Competition’](#). *Livestock Science* 279 (January 2024): 105392.
- McGrath, K., Regan, Á., Kennedy, E. and Russell, T. [‘Development of an Animal Health Testing Tool to Reduce Antimicrobial Use on Farms: Perceptions, Implications, and](#)

- [Needs of Irish Dairy Farmers and Farm Veterinarians](#)'. Irish Veterinary Journal 77, no. 1 (2024).
- McGrory, R.E., Briers, R.A., Tomlin, C., Findlay, M.A., Kerslake, L.J., Riddle, N. and White, P.J.C. ['Impacts of Forest Extent, Configuration and Landscape Context on Presence of Declining Breeding Eurasian Curlew Numenius Arquata and Implications for Planning New Woodland'](#). Forest Ecology and Management 572 (2024).
- McGurk, E., Hynes, S. and Thorne, F. ['Participation in Agri-Environmental Schemes: A Contingent Valuation Study of Farmers in Ireland'](#). Journal of Environmental Management 262 (May 2020): 110243.
- McKenzie, A.J., Emery, S.B., Franks, J.R. and Whittingham, M.J. ['FORUM: Landscape-Scale Conservation: Collaborative Agri-Environment Schemes Could Benefit Both Biodiversity and Ecosystem Services, but Will Farmers Be Willing to Participate?'](#) Journal of Applied Ecology 50, number 5 (2013): pages 1274 to 1280.
- McKenzie, A.J., Vickery, J.A., Leifert, C., Shotton, P. and Whittingham, M.J. ['Disentangling the Effects of Fertilisers and Pesticides on Winter Stubble Use by Farmland Birds'](#). Basic and Applied Ecology 12, no. 1 (1 February 2011): 80–88.
- McMahon, C., McCoy, M., Ellison, S.E., Barley, J.P., Edgar, H.W.J., Hannah, R.E.B., Malone, F.E., Brennan, G.P. and Fairweather, I. ['Anthelmintic Resistance in Northern Ireland \(III\): Uptake of "SCOPS" \(Sustainable Control of Parasites in Sheep\) Recommendations by Sheep Farmers'](#). Veterinary Parasitology 193, no. 1–3 (March 2013): 179–84.
- McWherter, B., Sherren, K. and Hunar, A. ['From Learner to Leader: Exploring Learning, Motivations, and Roles of Regenerative Grazing Mentors'](#). Agroecology and Sustainable Food Systems, 2025.
- Medina-Vogel, G., Muñoz, F., Moeggenberg, M., Calvo-Mac, C., Barros-Lama, M., Ulloa, N., Pons, D.J. and Clapperton, B.K. ['Improving Trapping Efficiency for Control of American Mink \(Neovison Vison\) in Patagonia'](#). Animals 12, number 2 (2022).
- Medlock, J.M. and Vaux, A.G.C. ['Impacts of the Creation, Expansion and Management of English Wetlands on Mosquito Presence and Abundance – Developing Strategies for Future Disease Mitigation'](#). Parasites & Vectors 8, no. 1 (3 March 2015): 142.
- Meier, E.S., Lüscher, G., Herzog, F. and Knop, E. ['Collaborative Approaches at the Landscape Scale Increase the Benefits of Agri-Environmental Measures for Farmland Biodiversity'](#). Agriculture, Ecosystems & Environment 367 (15 June 2024): 108948.
- Merlo, M., Hennessy, T., Buckley, C. and O'Mahony, J. ['A Comparison of Animal and Plant-Based Proteins from an Economic, Environmental, and Nutritional Perspective in the Republic of Ireland'](#). Agricultural Systems 221 (2024).
- Miettinen, J., Hallikainen, V., Valkonen, S., Hökkä, H., Hyppönen, M. and Rautio, P. ['Natural Regeneration and Early Development of Scots Pine Seedlings after Gap Cutting in Northern Finland'](#). Scandinavian Journal of Forest Research 39, number 2 (17 February 2024): pages 89 to 100.
- Milford, A-B., Keech, D. and Muiruri, S.W. ['Community Supported Agriculture's Perceived Positive Impacts on Mental Health and Vegetable Consumption in Norway and the UK'](#). Agricultural and Food Economics 13, no. 1 (2025).
- Mill, A.C., Crowley, S.L., Lambin, X., McKinney, C., Maggs, G., Robertson, P., Robinson, N.J., Ward, A.I. and Marzano, M. ['The Challenges of Long-Term Invasive Mammal](#)

- [Management: Lessons from the UK](#)'. Mammal Review 50, number 2 (2020): pages 136 to 146.
- Mills, B.E., Brorsen, B.W. and Arnall, D.B. '[Using Grid Soil Sampling to Determine Profit-Maximizing Phosphorus Application Rates in Wheat](#)'. Journal of Agricultural and Resource Economics 46, number 2 (2021): pages 269 to 286.
- Miralles-Wilhelm, F. '[Nature-Based Solutions in Agricultural Landscapes for Reducing Tradeoffs between Food Production, Climate Change, and Conservation Objectives](#)'. Frontiers in Water 5 (19 December 2023).
- Moffat, A., Low, J.R. and Christie, M. '[Adaptation of Native Woodlands in Scotland. Issues Paper](#)'. Climate X Change, Forest Research, Scottish Natural Heritage, 2012.
- Mölder, A., Meyer, P. and Nagel, R.V. '[Integrative Management to Sustain Biodiversity and Ecological Continuity in Central European Temperate Oak \(Quercus Robur, Q. Petraea\) Forests: An Overview](#)'. Forest Ecology and Management 437 (2019): pages 324 to 339.
- Mondelaers, K., Aertsens, J. and Huylenbroeck, G.V. '[A Meta-analysis of the Differences in Environmental Impacts between Organic and Conventional Farming](#)'. Edited by G Van Huylenbroeck. British Food Journal 111, number 10 (26 September 2009): pages 1098 to 1119.
- Moore, F. '[Supporting Farmers in Agro-Ecological Transition: A Systems Perspective of Regenerative Grazing in Wales](#)'. University of Hull, 2024.
- Moore, H., Pandolfi, F. and Kyriazakis, I. '[Familiarity with and Uptake of Alternative Methods to Control Sheep Gastro-Intestinal Parasites on Farms in England](#)'. Veterinary Parasitology 221 (15 May 2016): 1–8.
- Moore, P.A.J, Li, H., Burns, R., Miles, D., Maguire, R., Ogejo, J., Reiter, M.S., Buser, M.D. and Trabue, S. '[Development and Testing of the ARS Air Scrubber: A Device for Reducing Ammonia Emissions from Animal Rearing Facilities](#)'. Frontiers In Sustainable Food Systems 2 (15 June 2018).
- Morandin, L.A/, Long, R.F. and Kremen, C. '[Hedgerows Enhance Beneficial Insects on Adjacent Tomato Fields in an Intensive Agricultural Landscape](#)'. Agriculture, Ecosystems and Environment 189 (2014): pages 164 to 170.
- Morgan, S.L., Marsden, T., Miele, M., and Morley, A. '[Agricultural Multifunctionality and Farmers' Entrepreneurial Skills: A Study of Tuscan and Welsh Farmers](#)'. Journal of Rural Studies 26, no. 2 (1 April 2010): 116–29.
- Morgans, L.C., Bolt, S., Bruno-McClung, E., van Dijk, L., Escobar, M.P., Buller, H.J., Main, D.C.J. and Reyher, K.K. '[A Participatory, Farmer-Led Approach to Changing Practices around Antimicrobial Use on UK Farms](#)'. Journal of Dairy Science 104, number 2 (2021): pages 2212 to 2230.
- Morris, F. and Davies, R.G. '[Drivers of Natural Colonisation and Regeneration within Planted Woodlands in England: Towards an Integrated Approach to Increase Resilience](#)'. Forest Ecology and Management 579 (2025).
- Morris, R.K.A., Alonso, I., Jefferson, R.G. and Kirby, K.J. '[The Creation of Compensatory Habitat—Can It Secure Sustainable Development?](#)' Journal for Nature Conservation 14, no. 2 (July 2006): 106–16.
- Morris, W., Henley, A. and Dowell, D. '[Farm Diversification, Entrepreneurship and Technology Adoption: Analysis of Upland Farmers in Wales](#)'. Journal of Rural Studies 53 (2017): pages 132 to 143.

- Morse, A. [‘Collaboration and Policy Implementation: A Case Study of a Farmer Group in North Wales’](#) (2021) The Wales Centre for Public Policy. United Kingdom. Accessed: 21 Aug 2025.
- Moxey, A., and Moran, D. [‘UK Peatland Restoration: Some Economic Arithmetic’](#). Science of The Total Environment 484 (June 2014): pages 114 to 120.
- Moyo, H., Davies, W.P., Cannon, N.D. and Conway, J.S. [‘Influences of One-Year Red Clover Ley Management on Subsequent Cereal Crops’](#). Biological Agriculture & Horticulture 31, number 3 (3 July 2015): pages 193 to 204.
- Mulkeen, C.J., Gormally, M.J., Swaney, W.T., Healy, M.G. and Williams, C.D. [‘Sciomyzidae \(Diptera\) Assemblages in Constructed and Natural Wetlands: Implications for Constructed Wetland Design’](#). Wetlands 44, number 1 (8 December 2023): 5.
- Mulkerrins, M.J., Gottstein, M., Gorman, M., Russell, T., Ryan, M. and Lynch, M.B. [‘Could the Influence of Monitor Farm Programmes on Practice Change Be BETTER? Lessons from Sheep Farmers and Advisors in Ireland’](#). Journal of Agricultural Education and Extension 29, number 5 (2023): pages 653 to 678.
- Müller, J., Boch, S., Prati, D., Socher, S.A., Pommer, U., Hessenmöller, D., Schall, P., Schulze, E.D. and Fischer, M. [‘Effects of Forest Management on Bryophyte Species Richness in Central European Forests’](#). Forest Ecology and Management 432 (2019): pages 850 to 859.
- Murphy, B., Crosson, P., Kelly, A.K. and Prendiville, R. [‘An Economic and Greenhouse Gas Emissions Evaluation of Pasture-Based Dairy Calf-to-Beef Production Systems’](#). Agricultural Systems 154 (June 2017): pages 124 to 132.
- Murphy, G., Hynes, S., Murphy, E. and O’Donoghue, C. [‘The Extent of Farmer Participation in the Rural Environment Protection Scheme – What Habitats Are Actually Being Protected?’](#), 2010.
- Mwangi, O., Mucheru-Muna, M., Kinyua, M., Bolo, P. and Kihara, J. [‘Organic Farming Practices Increase Weed Density and Diversity over Conventional Practices: A Meta-Analysis’](#). Heliyon 10, number 12 (June 2024)
- National Audit Office. [‘The Farming and Countryside Programme’](#). Department for Environment, Food & Rural Affairs, 2024.
- Natural Resources Wales. [State of Natural Resources Report \(SoNaRR\): Assessment of the achievement of sustainable management of natural resources](#). Natural Resources Wales (2021).
- NatureScot, [‘Evaluation and Monitoring of the Agri-Environment and Climate Scheme | NatureScot’](#), NatureScot, 20 May 2025.
- Nelson, K., Nelson, R. and Montgomery, W.I. [‘Colonisation of Farmland Deciduous Plantations by Woodland Ground Flora’](#). Arboricultural Journal 43, number 2 (3 April 2021): pages 115 to 133.
- Nettle, R., Major, J., Turner, L. and Harris, J. [‘Selecting Methods of Agricultural Extension to Support Diverse Adoption Pathways: A Review and Case Studies’](#). Edited by Callum Eastwood. Animal Production Science 64, number 1 (23 December 2022).
- [‘New £30 Million Funds Launched to Boost Innovation in Wales | GOV.WALES’](#), 8 June 2023.
- Niedermeier, A. and Robinson, J.S. [‘Hydrological Controls on Soil Redox Dynamics in a Peat-Based, Restored Wetland’](#). Geoderma 137, no. 3–4 (January 2007): 318–26.
- Nordén, B., Rørstad, P.K., Magnér, J., Götmark, F. and Löf, M. [‘The Economy of Selective Cutting in Recent Mixed Stands during Restoration of Temperate Deciduous Forest’](#). Scandinavian Journal of Forest Research 34, number 8 (2019): pages 709 to 717.

- Nthambi, M., Simpson, K., Bradfer-Lawrence, T., Dobson, A., Finch, T., Fuentes-Montemayor, E., Park, K., Watts, K. and Hanley, N. '[Economic Incentives for Woodland Creation on Farmland: Modelling the Impacts on Biodiversity](#)'. *Ecological Economics* 224 (1 October 2024): 108265.
- Oates, L.G., Undersander, D.J., Gratton, C., Bell, M.M. and Jackson, R.D. '[Management-Intensive Rotational Grazing Enhances Forage Production and Quality of Subhumid Cool-Season Pastures](#)'. *Crop Science* 51, number 2 (March 2011): pages 892 to 901.
- O'Connor, T., Meredith, D., McNamara, J., O'Hara, D. and Kinsella, J. '[Farmer Discussion Groups Create Space for Peer Learning about Safety and Health](#)'. *Journal of Agromedicine* 26, number 2 (3 April 2021): pages 120 to 131.
- O'Hagan, M.J.H., Matthews, D.I., Laird, C. and McDowell, S.W.J. '[Herd-Level Risk Factors for Bovine Tuberculosis and Adoption of Related Biosecurity Measures in Northern Ireland: A Case-Control Study](#)', *The Veterinary Journal* 213 (July 2016): 26–32
- Olagunju, K.O., Angioloni, S. and Canavari, M. '[Niche Markets for Sustainable Agri-Food Systems: A Systematic Review](#)'. *Heliyon* 11, no. 3 (2025).
- Olave, R.J., Smith, J. and McAdam, J.H. '[Drivers of Agroforestry Adoption in Northern Ireland in the Context of British and Irish Policy](#)'. *Agroforestry Systems* 99, no. 3 (2025).
- Olawale, R.A., Olawumi, M.A. and Oladapo, B.I. '[Sustainable Farming with Machine Learning Solutions for Minimizing Food Waste](#)'. *Journal of Stored Products Research* 112 (2025).
- Olsen, A., Frankena, K., Bødker, R., Toft, N., Thamsborg, S.M., Enemark, H.L. and Halasa, T. '[Prevalence, Risk Factors and Spatial Analysis of Liver Fluke Infections in Danish Cattle Herds](#)'. *Parasites & Vectors* 8, number 1 (15 March 2015): 160.
- O'Neill, A., Foy, R.H. and Phillips, D.H. '[Phosphorus Retention in a Constructed Wetland System Used to Treat Dairy Wastewater](#)'. *Bioresource Technology* 102, number 8 (April 2011): pages 5024 to 5031.
- O'Neill, C., Lim, F.K.S., Edwards, D.P. and Osborne, C.P. '[Forest Regeneration on European Sheep Pasture Is an Economically Viable Climate Change Mitigation Strategy](#)'. *Environmental Research Letters* 15, number 10 (October 2020): 104090.
- Opdam, P., Coninx, I., Dewulf, A., Steingröver, E., Vos, C. and van der Wal, M. '[Does Information on Landscape Benefits Influence Collective Action in Landscape Governance?](#)' *Current Opinion in Environmental Sustainability, Sustainability governance and transformation* 2016: Informational governance and environmental sustainability, 18 (1 February 2016): pages 107 to 114.
- Orczewska, A., Dulik, A., Długosz, P. and Depa, Ł. '[Intensive Agriculture vs. Invertebrate Biodiversity: A Case Study of Woodland Islets in a Matrix of Arable Land](#)'. *Agriculture* 14, number 8 (August 2024): 1400.
- Osbeck, M., Schwarz, G. and Morkvenas, Z. '[Dialogue on Ecosystem Services, Payments and Outcome Based Approaches: Background Brief](#)'. Stockholm Environment Institute, March 2013.
- Osipitan, O.A., Dille, J.A., Assefa, Y. and Knezevic, S.Z. '[Cover Crop for Early Season Weed Suppression in Crops: Systematic Review and Meta-Analysis](#)'. *Agronomy Journal* 110, number 6 (2018): pages 2211 to 2221.
- Palik, B.J., and Kastendick, D.N. '[Restoration of Woody Plant Communities in Red Pine Plantations on Abandoned Agricultural Land in Northern Minnesota, USA](#)'. *Forest Ecology and Management* 541 (2023).

- Paneva, M., and Panev, P. '[Methods of Cleaning and Disinfection of Drinking Water in Livestock Farms](#)'. Bulgarian Journal of Agricultural Science 30, number 3 (2024): pages 547 to 551.
- Parra-López, C., Abdallah, S.B., Garcia-Garcia, G., Hassoun, A., Sánchez-Zamora, P., Trollman, H., Jagtap, S. and Carmona-Torres, C. '[Integrating Digital Technologies in Agriculture for Climate Change Adaptation and Mitigation: State of the Art and Future Perspectives](#)'. Computers and Electronics in Agriculture 226 (2024).
- Pastick, J., Maurer, D. and Fahey, R.T. '[Testing the Effect of Restoration-Focused Silviculture on Oak Regeneration and Groundlayer Plant Communities in Urban–Exurban Oak Woodlands](#)'. Restoration Ecology 29, number 1 (2021).
- Pates, R., Duggett, J. and BEIS Research. '[Interim Impact Evaluation of the Agri-Tech Catalyst Phase 2: Final Report](#)', BEIS Research Paper Number 2020/023, July 2020.
- Patton, M., Feng, S., MacAntsaioir, S., Devlin, D., Farrell, D., Farmer, L. and Bansback, B. '[Evolution of Agri-Food Supply Chains to Enhance Competitiveness: Literature Review](#)'. Agri-Food and Biosciences Institute (2018).
- Paut, R., Sabatier, R., Dufils, A. and Tchamitchian, M. '[How to Reconcile Short-Term and Long-Term Objectives in Mixed Farms? A Dynamic Model Application to Mixed Fruit Tree - Vegetable Systems](#)'. Agricultural Systems 187 (2021).
- Pedersen, N.K., Schmidt, I.K. and Kepfer-Rojas, S. '[Drivers of Tree Colonization, Species Richness, and Structural Variation during the Initial Three Decades of Natural Forest Colonization in Abandoned Agricultural Soils](#)'. Forest Ecology and Management 543 (2023).
- Pedersen, S.M., Erekalo, K.T., Christensen, T., Denver, S., Gemtou, M., Fountas, S., Isakhanyan, G. and others. '[Drivers and Barriers to Climate-Smart Agricultural Practices and Technologies Adoption: Insights from Stakeholders of Five European Food Supply Chains](#)'. Smart Agricultural Technology 8 (1 August 2024): 100478.
- Pellegrini, G., de Mattos, C.S., Otter, V. and Hagelaar, G. '[Exploring How EU Agri-Food SMEs Approach Technology-driven Business Model Innovation](#)'. International Food and Agribusiness Management Review 26, number 3 (2023): pages 577 to 595.
- Pelletier, N., Pirog, R. and Rasmussen, R. '[Comparative Life Cycle Environmental Impacts of Three Beef Production Strategies in the Upper Midwestern United States](#)'. Agricultural Systems 103, number 6 (July 2010): pages 380 to 389.
- Perks, M., Khomik, M., Bathgate, S., Chapman, S., Slee, B., Yeluripati, J., Roberts, D. and Morison, J. '[Agroforestry in Scotland – Potential Benefits in a Changing Climate](#)'. Climate X Change, Forest Research, 2018.
- Phillips, D.L., Goode, J.D. and Hart, J.L. '[Spatial Patterns of Stand Structure and Canopy Disturbance in a Fire-Maintained Pinus Palustris Woodland](#)'. Applied Vegetation Science 25, number 2 (2022).
- '[Piloting an Outcomes Based Approach in Scotland \(POBAS\) Project, Phase 1 Report](#)'. NatureScot, September 2020.
- Polyakov, M., Edwards, P., Kaine, G., Burton, M. and Stahlmann-Brown, P. '[Evaluating Incentives to Encourage Native Afforestation on Private Lands in Aotearoa–New Zealand](#)'. Landscape and Urban Planning 244 (2024).
- Popescu, C., Oprina-Pavelescu, M., Dinu, V., Cazacu, C., Burdon, F.J., Forio, M.A.E., Kupilas, B. and others. '[Article Riparian Vegetation Structure Influences Terrestrial Invertebrate Communities in an Agricultural Landscape](#)'. Water (Switzerland) 13, number 2 (2021).
- Porteus, T.A., Short, M.J., Hoodless, A.N. and Reynolds, J.C. '[Movement Ecology and Minimum Density Estimates of Red Foxes in Wet Grassland Habitats Used by](#)

- [Breeding Wading Birds](#)'. European Journal of Wildlife Research 70, no. 1 (28 December 2023): 8.
- Porton, G., Wrigley, R., Scott, C.E. and Spracklen, D.V. '[Natural Colonisation Rates in a UK Upland Landscape under Different Conservation Management Approaches Following Sheep Removal](#)'. Ecological Solutions and Evidence 5, number 2 (2024): e12338.
- Prager, K. '[Implementing Policy Interventions to Support Farmer Cooperation for Environmental Benefits](#)'. Land Use Policy 119 (2022).
- Prager, K. and Creaney, R. '[Achieving On-Farm Practice Change through Facilitated Group Learning: Evaluating the Effectiveness of Monitor Farms and Discussion Groups](#)'. Journal of Rural Studies 56 (2017): pages 1 to 11.
- Proskynitopoulou, V., Lorentzou, S., Yaman, R., Blanch, G., Herbert, B., Rubio Rincon, F. J., Moradi, N., Verdi, L., Dalla Marta, A., Dimopoulos Toursidis, P., Vourros, A., Garagounis, I. and Panopoulos, K. '[Mobile Solution for Digestate Transformation to High Added-Value Products](#)'. Journal of Cleaner Production 477 (2024).
- Pywell, R.F., Heard, M.S., Woodcock, B.A., Hinsley, S., Ridding, L., Nowakowski, M. and Bullock, J.M. '[Wildlife-Friendly Farming Increases Crop Yield: Evidence for Ecological Intensification](#)'. Proceedings of the Royal Society B: Biological Sciences 282, number 1816 (2015).
- Pywell, R.F., Meek, W.R., Loxton, R.G., Nowakowski, M., Carvell, C. and Woodcock, B.A. '[Ecological Restoration on Farmland Can Drive Beneficial Functional Responses in Plant and Invertebrate Communities](#)'. Agriculture, Ecosystems & Environment 140, no. 1–2 (January 2011): 62–67.
- Queiroz, P.W.V., Perrin, R.K., Fulginiti, L.E. and Bullock, D.S. '[An Expected Value of Sample Information \(EVS\) Approach for Estimating the Payoff from a Variable Rate Technology](#)'. Journal of Agricultural and Resource Economics. Colorado State University, 2023.
- Quinton, C.D., Hely, F.S., Amer, P.R., Byrne, T.J. and Cromie, A.R. '[Prediction of Effects of Beef Selection Indexes on Greenhouse Gas Emissions](#)'. Animal 12, number 5 (2018): pages 889 to 897.
- Radomyski, A., and Ashauer, R. '[A Site-Specific Indicator of Nitrogen Loads into Surface Waters from Conventional and Conservation Agriculture Practices: Bayesian Network Model](#)'. Ecological Indicators 145 (2022).
- Ranacher, L., Pollakova, B., Schwarzbauer, P., Liebal, S., Weber, N. and Hesser, F. '[Farmers' Willingness to Adopt Short Rotation Plantations on Marginal Lands: Qualitative Study About Incentives and Barriers in Slovakia](#)'. BioEnergy Research 14, number 2 (1 June 2021): pages 357 to 373.
- Rasmussen, L.V., Grass, I., Mehrabi, Z., Smith, O.M., Bezner-Kerr, R., Blesh, J., Garibaldi, L.A. and others. '[Joint Environmental and Social Benefits from Diversified Agriculture](#)'. Science 384, number 6691 (2024): pages 87 to 93.
- Ravetto S.R., Probo, M., Farruggia, A., Lanore, L., Blanchetete, A. and Dumont, B. '[A Biodiversity-Friendly Rotational Grazing System Enhancing Flower-Visiting Insect Assemblages While Maintaining Animal and Grassland Productivity](#)'. Agriculture, Ecosystems & Environment 241 (April 2017): pages 1 to 10
- Raymond, C.M., Reed, M., Bieling, C., Robinson, G.M. and Plieninger, T. '[Integrating Different Understandings of Landscape Stewardship into the Design of Agri-Environmental Schemes](#)'. Environmental Conservation 43, number 4 (2016): pages 350 to 358.

- Read, H., Bengtsson, V., Castro, A., Harris, R. and Wheeler, C.P. '[Restoration of Lapsed Beech Pollards in the Basque Region of Spain: Comparison of Different Cutting Techniques](#)'. *Arboricultural Journal* 43, number 3 (2021): pages 140 to 155.
- Redhead, J.W., Brown, M., Price, J., Robinson, E., Nicholls, R.J., Warren, R. and Pywell, R.F. '[National Horizon Scanning for Future Crops Under a Changing UK Climate](#)'. *Climate Resilience and Sustainability* 4, no. 1 (2025).
- Reichenspurner, M., Barghusen, R. and Matzdorf, B. '[Exploring Farmers' Perspectives on Collective Action: A Case Study on Co-Operation in Dutch Agri-Environment Schemes](#)'. *Journal of Environmental Planning and Management* 67, number 8 (2024): pages 1830 to 1851.
- Reiss, E.R. and Drinkwater, L.E. '[Ecosystem Service Delivery by Cover Crop Mixtures and Monocultures Is Context Dependent](#)'. *Agronomy Journal* 112, number 5 (2020): pages 4249 to 4263.
- Reynolds, J.C., Richardson, S.M., Rodgers, B.J.E. and Rodgers, O.R.K. '[Effective Control of Non-Native American Mink by Strategic Trapping in a River Catchment in Mainland Britain](#)'. *Journal of Wildlife Management* 77, number 3 (2013): pages 545 to 554.
- Rhymer, C.M., Robinson, R.A., Smart, J. and Whittingham, M.J. '[Can Ecosystem Services Be Integrated with Conservation? A Case Study of Breeding Waders on Grassland](#)'. *Ibis* 152, number 4 (2010): pages 698 to 712.
- Riley, M., Sangster, H., Smith, H., Chiverrell, R. and Boyle, J. '[Will Farmers Work Together for Conservation? The Potential Limits of Farmers' Cooperation in Agri-Environment Measures](#)'. *Land Use Policy* 70 (2018): pages 635 to 646.
- Roberts, W.M., Couldrick, L.B., Williams, G., Robins, D. and Cooper, D. '[Mapping the Potential for Payments for Ecosystem Services Schemes to Improve Water Quality in Agricultural Catchments: A Multi-Criteria Approach Based on the Supply and Demand Concept](#)'. *Water Research* 206 (2021).
- Robotham, J., Old, G., Rameshwaran, P., Sear, D., Trill, E., Bishop, J., Gasca-Tucker, D., Old, J., and McKnight, D. '[Nature-Based Solutions Enhance Sediment and Nutrient Storage in an Agricultural Lowland Catchment](#)'. *Earth Surface Processes and Landforms* 48, number 2 (2023): pages 243 to 258.
- van Roekel, J., Kopicki, R., Broekmans, J. E. C., & Boselie, D. M. '[Building agri-supply chains: Issues and guidelines](#)'. (2002) In D. Giovannucci (Ed.), *A guide to developing agricultural markets and agro-enterprises* (World Bank). Washington, DC: World Bank.
- Roellig, M., Costa, A., Garbarino, M., Hanspach, J., Hartel, T., Jakobsson, S., Lindborg, R. and others. '[Post Hoc Assessment of Stand Structure Across European Wood-Pastures: Implications for Land Use Policy](#)'. *Rangeland Ecology and Management* 71, number 5 (2018): pages 526 to 535.
- '[Rotational Grazing Improves Farm's Grass Quality without Need to Reseed](#)', 26 October 2020.
- '[Rotational Grazing Shown to Increase Soil Organic Matter on Welsh Farm](#)', Business Wales. Accessed: 24 May 2021.
- Rouquette, F.M., Sollenberger, L.E. and Vendramini, J.M.B. '[Grazing Management and Stocking Strategy Decisions for Pasture-Based Beef Systems: Experimental Confirmation vs. Testimonials and Perceptions](#)'. *Translational Animal Science* 7, number 1 (1 January 2023)
- Rowe, E., Norton, L., McVittie, A., Watson, C., Wagner, M., Waterton, C. and Smith, L. '[Using Fuzzy Cognitive Mapping to Assess the Sustainability Impacts of Transitioning](#)

- to [Pasture-Fed Production in the UK Beef Sector](#)'. Renewable Agriculture and Food Systems 40 (2025).
- Royal Forestry Society ['Bringing woodland into management. The missed opportunity in England and Wales'](#). January 2019. Royal Forestry Society.
- Rubio-Delgado, J., Schnabel, S., Lavado-Contador, J.F. and Schmutz, U. ['Small Woody Features in Agricultural Areas: Agroforestry Systems of Overlooked Significance in Europe'](#). Agricultural Systems 218 (2024).
- Ryan, D.J., and Hill, K.M. ['Public Perceptions on the Role of Wayfinding in the Promotion of Recreational Walking Routes in Greenspace—Cross-Sectional Survey'](#). Wellbeing, Space and Society 3 (1 January 2022): 100111.
- Sabatini, G. A., de Almeida Borges, F., Claerebout, E., Gianechini, L. S., Höglund, J., Kaplan, R. M., Lopes, W. D. Z., Mitchell, S., Rinaldi, L., von Samson-Himmelstjerna, G., Steffan, P., & Woodgate, R. ['Practical Guide to the Diagnostics of Ruminant Gastrointestinal Nematodes, Liver Fluke and Lungworm Infection: Interpretation and Usability of Results'](#). Parasites & Vectors 16 (8 February 2023): 58.
- Sage, R.B., Wilson, S. and Powell, T. ['Using Fledged Brood Counts of Hedgerow Birds to Assess the Effect of Summer Agri-Environment Scheme Options'](#). Ecological Indicators 57 (2015): pages 376 to 383.
- Šálek, M., Kalinová, K. and Reif, J. ['Conservation Potential of Semi-Natural Habitats for Birds in Intensively-Used Agricultural Landscapes'](#). Journal for Nature Conservation 66 (2022).
- Sánchez-García, C., Button, E.S., Wynne-Jones, S., Porter, H., Rugg, I. and Hannam, J.A. ['Finding Common Ground: Co-Producing National Soil Policy in Wales through Academic and Government Collaboration'](#). Soil Security 11 (2023).
- Sands, B., and Noll, M. ['Toxicity of Ivermectin Residues in Aged Farmyard Manure to Terrestrial and Freshwater Invertebrates'](#). Insect Conservation and Diversity 15, number 1 (2022): pages 9 to 18.
- SAOS, [KTIF Final Report East/West Beef Grazing Collaboration Pilot](#). Scottish Government, (2021).
- Saraev, V., Low, W.H., Beauchamp, K. and Perks, M. ['The Potential for Agroforestry to Reduce Net GHG Emissions in Scotland through the Woodland Carbon Code'](#). Climate X Change, Forest Research, 2022.
- Sawyer, A., Jardine, M., Loyd, D. ['Project HELIX Annual Report 2023-4'](#), Food Innovation Wales, 2024.
- Sawyer, E., Yesuf, G., Wade, R. and Yildirim, A. ['Understanding & evaluating on-farm food loss and waste in the UK'](#) (Report for the Transforming UK Food Systems SPF Programme) 2023. Cranfield University; University of Reading; University of Leeds.
- Saunders, M., Perks, M., Slee, B., Ray, D. and Matthews, R. ['Can Silvo-Pastoral Agroforestry Systems Contribute to Scotland's Emission Reduction Targets?'](#) Climate X Change, Forest Research, 2016.
- Schaub, S., Ghazoul, J., Huber, R., Zhang, W., Sander, A., Rees, C., Banerjee, S. and Finger, R. ['The Role of Behavioural Factors and Opportunity Costs in Farmers' Participation in Voluntary Agri-Environmental Schemes: A Systematic Review'](#). Journal of Agricultural Economics 74, number 3 (2023): pages 617 to 660.
- Schmid, R.B., Welch, K.D., Teague, R. and Lundgren, J.G. ['Adaptive Multipaddock \(AMP\) Pasture Management Increases Arthropod Community Guild Diversity Without Increasing Pests'](#). Rangeland Ecology & Management 94 (May 2024): pages 141 to 148.

- Schulze Walgern, A., Hecker, O., Walther, B., Boelhauve, M., & Mergenthaler, M. '[Farmers' Attitudes in Connection with the Potential for Rodent Prevention in Livestock Farming in a Municipality in North Rhine-Westphalia, Germany](#)'. *Animals* 13, number 24 (December 2023): 3809.
- Schüler, S., Arimond, I., Hass, A., Koch, M., Huber, J.M., Ruwisch, V., Bartens, M., Plieninger, T. and Westphal, C. '[Initiating Agri-Environmental Collaboration at Landscape Scale Requires Bridging Structures, Regional Facilitators and Addressing the Expectations of Actors](#)'. *People and Nature* 7, number 2 (2025): pages 320 to 328.
- Scollo, A., Levallois, P., Fourichon, C., Motta, A., Mannelli, A., Lombardo, F. and Ferrari, P. '[Monitoring Means and Results of Biosecurity in Pig Fattening Farms: Systematic Assessment of Measures in Place and Exploration of Biomarkers of Interest](#)', *Animals* 12, no. 19 (October 2022): 2655.
- Scott, A., and Shannon, P. '[Local Landscape Designations in Scotland: Opportunity or Barrier to Effective Landscape Management?](#)' *Landscape and Urban Planning* 81, number 3 (2007): pages 257 to 269.
- Scottish Forestry. '[Woodland Expansion Advisory Group - June 2012](#)'. Accessed 20 March 2025.
- Selemetas, N., Phelan, P., O'Kiely, P. and De Waal, T. '[The Effects of Farm Management Practices on Liver Fluke Prevalence and the Current Internal Parasite Control Measures Employed on Irish Dairy Farms](#)'. *Veterinary Parasitology* 207, numbers 3 to 4 (January 2015): pages 228 to 240.
- Sellers, L.A., Long, R.F., Jay-Russell, M.T., Li, X., Atwill, E.R., Engeman, R.M. and Baldwin, R.A. '[Impact of Field-Edge Habitat on Mammalian Wildlife Abundance, Distribution, and Vectored Foodborne Pathogens in Adjacent Crops](#)'. *Crop Protection* 108 (2018): pages 1 to 11.
- Service, T., Cassidy, R., Atcheson, K., Farrow, L., Harrison, T., Jack, P. and Jordan, P. '[A National-Scale High-Resolution Runoff Risk and Channel Network Mapping Workflow for Diffuse Pollution Management](#)'. *Journal of Environmental Management* 368 (2024).
- Shao, G., Martinson, G.O., Corre, M.D., Luo, J., Niu, D. and Veldkamp, E. '[Conversion of Cropland Monoculture to Agroforestry Increases Methane Uptake](#)'. *Agronomy for Sustainable Development* 45, number 1 (2025)
- Sharp, R., Bellamy, A.S., Clear, A., Finnigan, S.M., Furness, E., Meador, E., Metcalfe, H. and others. '[Implications and Impacts of Aligning Regional Agriculture with a Healthy Diet](#)'. *Journal of Cleaner Production* 449 (5 March 2024): 141375.
- Shorthall, O., Green, M., Brennan, M., Wapenaar, W. and Kaler, J. '[Exploring Expert Opinion on the Practicality and Effectiveness of Biosecurity Measures on Dairy Farms in the United Kingdom Using Choice Modeling](#)', *Journal of Dairy Science* 100, no. 3 (March 2017): 2225–39.
- Sikombe, S., Muleya, F., Phiri, J., Zulu, S., Simasiku, P. and Situtu, M. '[Key Elements for Promoting Public-Private Partnerships in Research and Innovation](#)'. *Cogent Business and Management* 11, number 1 (2024).
- Simonetto, M., Sgarbossa, F., Battini, D. and Govindan, K. '[Closed Loop Supply Chains 4.0: From Risks to Benefits through Advanced Technologies. A Literature Review and Research Agenda](#)'. *International Journal of Production Economics* 253 (1 November 2022): 108582.

- Sinner, J., Tadaki, M., Kilvington, M., Challies, E., Tane, P. and Robb, C. '[Great Expectations for Collective Management: The Mismatch between Supply and Demand for Catchment Groups](#)'. Ecology and Society 30, number 1 (2025).
- Siriwardena, G.M., Cooke, I.R. and Sutherland, W.J. '[Landscape, Cropping and Field Boundary Influences on Bird Abundance](#)'. Ecography 35, number 2 (2012): pages 162 to 173.
- Skuce, R.A., Allen, A.R. and McDowell, S.W.J. '[Herd-Level Risk Factors for Bovine Tuberculosis: A Literature Review](#)'. Veterinary medicine international (2012) 621210.
- Sloan, K. '[The Greater the Challenge, the More Diverse the Community Must Be to Solve It – the Case of the Agri-Food System](#)'. International Journal of Food Science and Technology 59, number 9 (2024): pages 6693 to 6697.
- Slocum, S. and Curtis, K. '[Farm Diversification through Farm Shop Entrepreneurship in the UK](#)' (2017) Journal of Food Distribution Research, 48(2), 35–51.
- Smart, J., Wotton, S.R., Dillon, I.A., Cooke, A.I., Diack, I., Drewitt, A.L., Grice, P.V. and Gregory, R.D. '[Synergies between Site Protection and Agri-Environment Schemes for the Conservation of Waders on Lowland Wet Grasslands](#)'. Ibis 156, number 3 (2014): 576–90.
- Smart, J., Gill, J.A., Sutherland, W.J. and Watkinson, A.R. '[Grassland-Breeding Waders: Identifying Key Habitat Requirements for Management](#)'. Journal of Applied Ecology 43, no. 3 (2006): 454–63.
- Smith, B.M., Aebischer, N.J., Ewald, J., Moreby, S., Potter, C. and Holland, J.M. '[The Potential of Arable Weeds to Reverse Invertebrate Declines and Associated Ecosystem Services in Cereal Crops](#)'. Frontiers in Sustainable Food Systems 3 (10 January 2020).
- Smith, J., Westaway, S., Mullender, S., Giannitsopoulos, M. and Graves, A. '[Making Hedgerows Pay Their Way: The Economics of Harvesting Field Boundary Hedges for Bioenergy](#)'. Agroforestry Systems 97, number 3 (2023): pages 291 to 303.
- Smith, L.G., Kirk, G.J.D., Jones, P.J. and Williams, A.G. '[The Greenhouse Gas Impacts of Converting Food Production in England and Wales to Organic Methods](#)'. Nature Communications 10, number 1 (22 October 2019): 4641.
- Smith, L.G., Westaway, S., Mullender, S., Ghaley, B.B., Xu, Y., Lehmann, L.M., Pisanelli, A. and others. '[Assessing the Multidimensional Elements of Sustainability in European Agroforestry Systems](#)'. Agricultural Systems 197 (2022).
- Smith, O.M., Cohen, A.L., Rieser, C.J., Davis, A.G., Taylor, J.M., Adesanya, A.W., Jones, M.S. and others. '[Organic Farming Provides Reliable Environmental Benefits but Increases Variability in Crop Yields: A Global Meta-Analysis](#)'. Frontiers in Sustainable Food Systems 3 (27 September 2019): 82.
- Smith, R.G., Warren, N.D. and Cordeau, S. '[Are Cover Crop Mixtures Better at Suppressing Weeds than Cover Crop Monocultures?](#)' Weed Science 68, number 2 (March 2020): pages 186 to 194.
- Smith, R. P., May, H. E., Burow, E., Meester, M., Tobias, T. J., Sassu, E. L., Pavoni, E., Di Bartolo, I., Prigge, C., Wasyl, D., Zmudzki, J., Viltrop, A., Nurmoja, I., Zoche-Golob, V., Alborali, G. L., Romantini, R., Dors, A., Krumova-Valcheva, G., Koláčková, I., Aprea, G., ... Daskalov, H. '[Assessing Pig Farm Biosecurity Measures for the Control of Salmonella on European Farms](#)', Epidemiology and Infection 151 (2023): e130.
- Smith, A.E.O, Doidge, C., Lovatt, F. and Kaler. J. '[A Survey of British Sheep Farmers: Practices, Opinions and Knowledge Surrounding the Management of Sheep Scab.](#)' Preventive Veterinary Medicine 214 (May 1, 2023): 105898.

- Snow, L.C., Warner, R.G., Cheney, T., Wearing, H., Stokes, M., Harris, K., Teale, C.J. and Coldham, N.G. '[Risk Factors Associated with Extended Spectrum Beta-Lactamase Escherichia Coli \(CTX-M\) on Dairy Farms in North West England and North Wales.](#)' Preventive Veterinary Medicine 106, number 3 (October 1, 2012): pages 225 to 234.
- Soil Association. '[Trees and Woodland in the farmed landscape: A farmer-led approach towards a diverse, resilient and vibrant agroforestry and farm woodland economy for England.](#)' Soil Association (2022).
- Sollen-Norrin, M., Ghaley, B.B. and Rintoul, N.L.J. '[Agroforestry Benefits and Challenges for Adoption in Europe and Beyond](#)'. Sustainability (Switzerland) 12, number 17 (2020).
- Späti, K., Huber, R. and Finger, R. '[Benefits of Increasing Information Accuracy in Variable Rate Technologies](#)'. Ecological Economics. Elsevier B V, 2021.
- Spiro, A., Hill, Z. and Stanner, S. '[Meat and the future of sustainable diets—Challenges and opportunities](#)'; Nutrition Bulletin, October 2024
- Spray, C., Arthur, S., Bergmann, E., Bell, J., Beevers, L. and Blanc, J. '[Land Management for Increased Flood Resilience](#)'. Aberdeen: Scotland's Centre of Expertise for Waters (CREW), 2015.
- Sprenkle-Hyppolite, S., Griscom, B., Griffey, V., Munshi, E. and Chapman, M. '[Maximizing Tree Carbon in Croplands and Grazing Lands While Sustaining Yields](#)'. Carbon Balance and Management 19, number 1 (2024).
- Srhir, S., Jaegler, A. and Montoya-Torres, J.R. '[Uncovering Industry 4.0 Technology Attributes in Sustainable Supply Chain 4.0: A Systematic Literature Review](#)'. Business Strategy and the Environment 32, number 7 (2023): pages 4143 to 4166.
- Srivastava, A.K., Vanitha, T., Devi, Y.S. and Gupta, S. '[Revolutionizing Agriculture with IoT and Artificial Intelligence](#)'. In Agriculture 4.0: Smart Farming with IoT and Artificial Intelligence, pages 1 to 21, 2024
- Stadig, L.M., Tuytens, F.A.M., Rodenburg, T.B., Verdonckt, P., Wauters, E., Borremans, L. and Reubens, B. '[Opportunities for Short Rotation Coppice Production on Free-Range Chicken Farms in Flanders: Farmers' Perceptions and Cost-Benefit Analysis](#)'. Renewable Agriculture and Food Systems 35, number 3 (2020): pages 286 to 295.
- Staley, J.T., Amy, S.R., Adams, N.P., Chapman, R.E., Peyton, J.M. and Pywell, R.F. '[Re-Structuring Hedges: Rejuvenation Management Can Improve the Long Term Quality of Hedgerow Habitats for Wildlife in the UK](#)'. Biological Conservation 186 (2015): pages 187 to 196.
- Staley, J.T., Botham, M.S., Chapman, R.E., Amy, S.R., Heard, M.S., Hulmes, L., Savage, J. and Pywell, R.F. '[Little and Late: How Reduced Hedgerow Cutting Can Benefit Lepidoptera](#)'. Agriculture, Ecosystems and Environment 224 (2016): pages 22 to 28.
- Staley, J.T., Sparks, T.H., Croxton, P.J., Baldock, K.C.R., Heard, M.S., Hulmes, S., Hulmes, L., Peyton, J., Amy, S.R. and Pywell, R.F. '[Long-Term Effects of Hedgerow Management Policies on Resource Provision for Wildlife](#)'. Biological Conservation 145, number 1 (2012): pages 24 to 29.
- Staley, J.T., Wolton, R. and Norton, L.R. '[Improving and Expanding Hedgerows—Recommendations for a Semi-Natural Habitat in Agricultural Landscapes](#)'. Ecological Solutions and Evidence 4, number 1 (2023).
- Staton, T., Breeze, T.D., Walters, R.J., Smith, J. and Girling, R.D. '[Productivity, Biodiversity Trade-Offs, and Farm Income in an Agroforestry versus an Arable System](#)'. Ecological Economics 191 (2022).

- Stieger, M. and Mckenzie, P. '[Riparian Landscape Change: A Spatial Approach for Quantifying Change and Development of a River Network Restoration Model](#)'. Environmental Management 74, number 5 (2024): pages 853 to 869.
- Stiles, W. '[Are Riparian Buffer Strips an Opportunity to Increase Tree Cover on UK Farms Whilst Simultaneously Reducing the Impact of Agricultural Pollution?](#)' Farming Connect. Aberystwyth University, 2019.
- Stockdale, A. and Barker, A. '[Sustainability and the Multifunctional Landscape: An Assessment of Approaches to Planning and Management in the Cairngorms National Park](#)'. Land Use Policy 26, number 2 (2009): pages 479 to 492.
- Stoeva, S., Van Gompel, R., Van den Bossche, L., Slavova, P. Grivins, M. and Mileiko, I. '[Understanding Collaboration in Short Food Supply Chains: A Focus on Collaborative Relationships, Interaction Mechanisms and Relational Benefits](#)'. Agricultural and Food Economics 12, no. 1 (30 December 2024): 49.
- Stone, J. and Rahimifard, S. '[Resilience in Agri-Food Supply Chains: A Critical Analysis of the Literature and Synthesis of a Novel Framework](#)'. Supply Chain Management: An International Journal 23, no. 3 (27 March 2018): 207–38.
- Storm, H., Seidel, S.J., Klingbeil, L., Ewert, F., Vereecken, H., Amelung, W., Behnke, S. and others. '[Research Priorities to Leverage Smart Digital Technologies for Sustainable Crop Production](#)'. European Journal of Agronomy 156 (1 May 2024): 127178.
- Storr, T., Simmons, R.W. and Hannam, J.A. '[The Use of Cover Crops in the UK: A Survey](#)', December 2018.
- Strauss, V., Paul, C., Dönmez, C. and Burkhard, B. '[Carbon Farming for Climate Change Mitigation and Ecosystem Services – Potentials and Influencing Factors](#)'. Journal of Environmental Management 372 (2024).
- Stroh, P.A., Mountford, J.O., Araya, Y.N. and Hughes, F.M.R. '[Quantifying Soil Hydrology to Explain the Development of Vegetation at an Ex-Arable Wetland Restoration Site](#)'. Wetlands 33, number 2 (April 2013): pages 311 to 320.
- Sturtevant, B.R., and Hanberry, B.B. '[Processes Underlying Restoration of Temperate Savanna and Woodland Ecosystems: Emerging Themes and Challenges](#)'. Forest Ecology and Management 481 (2021).
- Surucu-Balci, E. and Tuna, O. '[The Role of Collaboration in Tackling Food Loss and Waste: Salient Stakeholder Perspective](#)'. Journal of Cleaner Production 367 (20 September 2022): 133126.
- Sutherland, L.A., Burton, R.J.F., Adamsone-Fiskovica, C., Hardy, C., Elzen, B., Debruyne, L. and Flanigan, S. '[Full Article: Inclusivity of on-Farm Demonstration: Gender, Age, and Geographic Location](#)' 27, number 5 (2021): pages 591 to 613.
- Sutherland, L.A. and Marchand, F. '[On-Farm Demonstration: Enabling Peer-to-Peer Learning](#)'. Journal of Agricultural Education and Extension 27, number 5 (2021): pages 573 to 590.
- Sutherland, L-A. and Huttunen, S. '[Linking Practices of Multifunctional Forestry to Policy Objectives: Case Studies in Finland and the UK](#)'. Forest Policy and Economics 86 (1 January 2018): pages 35 to 44.
- Sutton, G., Bennett, J. and Bateman, M. '[Effects of Ivermectin Residues on Dung Invertebrate Communities in a UK Farmland Habitat](#)'. Insect Conservation and Diversity 7, number 1 (2014): pages 64 to 72.
- Takacs, B., Stegemann, J.A., Kalea, A.Z. and Borrión, A. '[Comparison of environmental impacts of individual meals - Does it really make a difference to choose plant-based meals instead of meat-based ones?](#)' Journal of Cleaner Production, Volume 379, Part 2, 2022.

- Tammaru, T., Valdma, D., Tiitsaar, A., Kaasik, A., Õunap, E., Remm, J. and Teder, T. [‘Landscape-Level Determinants of Butterfly Species Richness in Northern Europe: A Country-Wide Survey Reveals the Paramount Importance of Forest Land’](#). *Biological Conservation* 286 (2023).
- Tang, Z., Vallabh, D., Wang, Y., Huang, Y., Han, J.-C., Zhou, Y., Wang, L., Ahmad, M., Yousaf, M., Wang, Y., & Huang, Y. [‘Net-Zero Farming: Trigenation with Carbon Capture and Storage’](#), *Renewable Energy* 238 (2025).
- Tattersall, F.H., Macdonald, D.W., Hart, B.J., Johnson, P., Manley, W. and Feber, R. [‘Is Habitat Linearity Important for Small Mammal Communities on Farmland?’](#) *Journal of Applied Ecology* 39, number 4 (2002): pages 643 to 652.
- Taylor, R.F., McGee, M., Kelly, A.K. and Crosson, P. [‘Bioeconomic and Greenhouse Gas Emissions Modelling of the Factors Influencing Technical Efficiency of Temperate Grassland-Based Suckler Calf-to-Beef Production Systems’](#). *Agricultural Systems* 183 (August 2020): 102860.
- Taylor, N.M., Wales, A.D., Ridley, A.M. and Davies, R.H. [‘Farm Level Risk Factors for Fluoroquinolone Resistance in E. Coli and Thermophilic Campylobacter Spp. on Poultry Farms.’](#) *Avian Pathology* 45, number 5 (September 2, 2016): pages 559 to 568.
- Teague, R. and Kreuter, U. [‘Managing Grazing to Restore Soil Health, Ecosystem Function, and Ecosystem Services’](#). *Frontiers in Sustainable Food Systems* 4 (29 September 2020): 534187.
- Tempesta, T. and Vecchiato, D. [‘The Value of a Properly Maintained Hiking Trail Network and a Traditional Landscape for Mountain Recreation in the Dolomites’](#). *Resources* 7, number 4 (December 2018): 86.
- Teodoro, J.D., Baird, J. and Otung, I. [‘Longitudinal Network Analysis on a Farmers’ Community of Practice and Their Changes in Agricultural Systems Management’](#). *Society and Natural Resources* 36, number 2 (2023): pages 90 to 107.
- Terré, M., Bosch, C., Bach, A., Fàbregas, F., Biel, C., Rusiñol, M., Bofill, S., Calderer, M., Jubany, I., & Martínez-Lladó, X. [‘Exploring the Use of Tertiary Reclaimed Water in Dairy Cattle Production’](#), *Journal of Cleaner Production* 229 (August 2019): 964–73.
- Tisocco, S., Lenahan, J.J., Zhan, X. and Crosson, P. [‘Financial Assessment of Integrating Anaerobic Digestion with Cattle Farming for Biomethane Production – Implications for Farm Economics and the Supply Chain’](#). *Biomass and Bioenergy* 195 (2025).
- Tiwasing, P., and Pate, L. [‘Exploring Edible Insects as Feed in the UK: Current Challenges and Future Prospects’](#). *Journal of Insects as Food and Feed* 11, no. 1 (2025): 139–55.
- Thomas, E., Riley, M. and Spees, J. [‘Knowledge Flows: Farmers’ Social Relations and Knowledge Sharing Practices in “Catchment Sensitive Farming”](#)’. *Land Use Policy* 90 (2020).
- Thompson, C.W., Elizalde, A., Cummins, S., Leyland, A.H., Botha, W., Briggs, A., Tilley, S. and others. [‘Enhancing Health through Access to Nature: How Effective Are Interventions in Woodlands in Deprived Urban Communities? A Quasi-Experimental Study in Scotland, UK’](#). *Sustainability (Switzerland)* 11, number 12 (2019).
- Toderi, M., Francioni, M., Seddaiu, G., Roggero, P.P., Trozzo, L. and D'Ottavio, P. [‘Bottom-up Design Process of Agri-Environmental Measures at a Landscape Scale: Evidence from Case Studies on Biodiversity Conservation and Water Protection’](#). *Land Use Policy* 68 (2017): pages 295 to 305.

- Tolhurst, B.A., Ward, A.I. and Delahay, R.J. '[A Study of Fox \(Vulpes Vulpes\) Visits to Farm Buildings in Southwest England and the Implications for Disease Management](#)', European Journal of Wildlife Research 57, no. 6 (2011): 1227–30.
- Tomlinson, A. '[Holistic Approach to Bovine Tuberculosis – There Is More to Control than Just Testing](#)', In Practice 45, no. 7 (September 2023): 369–440.
- Townsend, L.C., and Noble, C. '[Variable Rate Precision Farming and Advisory Services in Scotland: Supporting Responsible Digital Innovation?](#)' Sociologia Ruralis 62, number 2 (2022): pages 212 to 230.
- Tumwebaze, R.P., Walsh, J.N. and Lannon, J. '[Knowledge Management in the Agriculture Sector: A Systematic Literature Review](#)'. Knowledge Management Research and Practice 23, number 2 (2025): pages 131 to 148.
- Turner, J.A., Williams, T., Nicholas, G., Foote, J., Rijswijk, K., Barnard, T., Beechener, S. and Horita, A. '[Triggering System Innovation in Agricultural Innovation Systems: Initial Insights from a Community for Change in New Zealand](#)'. Outlook on Agriculture 46, number 2 (2017): pages 125 to 130.
- Valkonen, S. and Siitonen, J. '[Tree Regeneration in Patch Cutting in Norway Spruce Stands in Northern Finland](#)'. Scandinavian Journal of Forest Research, 2 April 2016.
- Van der Heyden, C., Brusselman, E., Volcke, I.P. and Demeyer, P. '[Continuous Measurements of Ammonia, Nitrous Oxide and Methane from Air Scrubbers at Pig Housing Facilities](#)'. Journal of Environmental Management. Academic Press, 2016.
- Varah, A., Jones, H., Smith, J. and Potts, S.G. '[Temperate Agroforestry Systems Provide Greater Pollination Service than Monoculture](#)'. Agriculture, Ecosystems and Environment 301 (2020).
- Vašková, H. and Saska, P. '[Comparison of Organic and Conventional Agriculture in the Czech Republic: A Systematic Review](#)'. Agriculture 14, number 11 (19 November 2024): 2087.
- Vechi, N.T., Falk, J.M., Fredenslund, A.M., Edjabou, M.E. and Scheutz, C. '[Methane Emission Rates Averaged over a Year from Ten Farm-Scale Manure Storage Tanks](#)'. Science of the Total Environment. Elsevier B V, 2023.
- Veen, M. van der. '[Agricultural Innovation: Invention and Adoption or Change and Adaptation?](#)' World Archaeology 42, number 1 (March 2010): pages 1 to 12.
- Velarde-Pajares, S., Wills, K., Hajdu, I., Tipene, T. and Kalaugher, E. '[Silvopastoral Agroforestry Systems for Dryland Corners in Canterbury Farms](#)'. Journal of New Zealand Grasslands 86 (2024): pages 223 to 235.
- Veldkamp, E., Schmidt, M., Markwitz, C., Beule, L., Beuschel, R., Biertümpfel, A., Bischel, X. and others. '[Multifunctionality of Temperate Alley-Cropping Agroforestry Outperforms Open Cropland and Grassland](#)'. Communications Earth and Environment 4, number 1 (2023).
- Vickery, J.A., Feber, R.E. and Fuller, R.J. '[Arable Field Margins Managed for Biodiversity Conservation: A Review of Food Resource Provision for Farmland Birds](#)'. Agriculture, Ecosystems & Environment 133, no. 1 (1 September 2009): 1–13.
- Vickery, J.A., Feber, R.E. and Fuller, R.J. '[Arable Field Margins Managed for Biodiversity Conservation: A Review of Food Resource Provision for Farmland Birds](#)'. Agriculture, Ecosystems & Environment 133, no. 1 (1 September 2009): 1–13.
- Victor, L. and Field, C. '[Farm Advisory Service Enhanced Monitoring and Evaluation: Prepared for Scottish Government](#)'. United Kingdom: Scottish Government, September 2019.

- Vymazalová, P., Košulič, O., Hamřík, T., Šipoš, J., and Hédli, R. '[Positive Impact of Traditional Coppicing Restoration on Biodiversity of Ground-Dwelling Spiders in a Protected Lowland Forest](#)'. *Forest Ecology and Management* 490 (2021).
- Waddell, E.H., Fuentes-Montemayor, E., Park, K.J., Carey, P., Guy, M., Macgregor, N.A. and Watts, K. '[Larger and Structurally Complex Woodland Creation Sites Provide Greater Benefits for Woodland Plants](#)'. *Ecological Solutions and Evidence* 5, number 2 (2024): e12339.
- Wagner, M., Bullock, J.M., Hulmes, L., Hulmes, S. and Pywell, R.F. '[Cereal Density and N-Fertiliser Effects on the Flora and Biodiversity Value of Arable Headlands](#)'. *Biodiversity and Conservation* 26, number 1 (1 January 2017): pages 85 to 102.
- Wagner, M., Waterton, C. and Norton, L.R. '[Mob Grazing: A Nature-Based Solution for British Farms Producing Pasture-Fed Livestock](#)'. *Nature-Based Solutions* 3 (December 2023): 100054.
- Walker, K.J., Critchley, C.N.R., Sherwood, A.J., Large, R., Nuttall, P., Hulmes, S., Rose, R. and Mountford, J.O. '[The Conservation of Arable Plants on Cereal Field Margins: An Assessment of New Agri-Environment Scheme Options in England, UK](#)'. *Biological Conservation* 136, no. 2 (1 April 2007): 260–70.
- Wallace, E.E., McShane, G., Tych, W., Kretzschmar, A., McCann, T. and Chappell, N.A. '[The Effect of Hedgerow Wild-Margins on Topsoil Hydraulic Properties, and Overland-Flow Incidence, Magnitude and Water-Quality](#)'. *Hydrological Processes* 35, number 3 (2021).
- Wallenhammar, A-C., Gunnarson, A., Hansson, F. and Jonsson, A. '[Quantification of Plasmodiophora Brassicae Using a DNA-Based Soil Test Facilitates Sustainable Oilseed Rape Production](#)'. *Plants (Basel, Switzerland)* 5, number 2 (22 April 2016): 21.
- Wall-Reinius, S., Kling, K.G. and Ioannides, D. '[Access to Nature for Persons with Disabilities: Perspectives and Practices of Swedish Tourism Providers](#)'. *Tourism Planning & Development* 20, number 3 (4 May 2023): pages 336 to 354.
- Wang, Y., Möhring, N. and Finger, R. '[When My Neighbors Matter: Spillover Effects in the Adoption of Large-Scale Pesticide-Free Wheat Production](#)'. *Agricultural Economics (United Kingdom)* 54, number 2 (2023): pages 256 to 273.
- Ward, A. I., Tolhurst, B. A., Walker, N. J., Roper, T. J., & Delahay, R. J. '[Survey of Badger Access to Farm Buildings and Facilities in Relation to Contact with Cattle](#)', *The Veterinary Record* 163 (26 July 2008): 107–11.
- Ward, A.I., Judge, J. and Delahay, R.J. '[Farm Husbandry and Badger Behaviour: Opportunities to Manage Badger to Cattle Transmission of Mycobacterium Bovis?](#)' (2010) *Preventive veterinary medicine*, 93(1), 2–10.
- Watts, S.H. '[Montane Willow Scrub Restoration in Scotland: Reviewing 30 Years of Progress to Reestablish the Altitudinal Treeline](#)'. *Restoration Ecology* 33, number 1 (2025).
- Waygood, U.A. '[Agri-Environment Evidence Annual Report 2023. A summary of recently published projects](#)' (2024). Natural England Research Report, NERR138. Natural England
- Weiss, M., Kozel, P., Zapletal, M., Hauck, D., Prochazka, J., Benes, J., Cizek, L. and Sebek, P. '[The Effect of Coppicing on Insect Biodiversity. Small-Scale Mosaics of Successional Stages Drive Community Turnover](#)'. *Forest Ecology and Management* 483 (2021).

- Welsh Government, '[£21m Food Innovation Project Set to Safeguard Thousands of Welsh Jobs | GOV.WALES](#)', 23 March 2017.
- Welsh Government. '[Strategies and interventions to support the timber industry: literature review](#).' (2025)
- Welsh Government. '[Wales Innovates: Creating a Stronger, Fairer, Greener Wales](#)', 2023.
- Welsh Government. '[Woodlands for Wales: The Welsh Government's Strategy for Woodlands and Trees](#)'. (2018).
- Wenzel, W.W., Philipsen, F.N., Herold, L., Kingsland-Mengi, A., Laux, M., Golestanifard, A., Strobel, B.W. and Duboc, O. '[Carbon Sequestration Potential and Fractionation in Soils after Conversion of Cultivated Land to Hedgerows](#)'. *Geoderma* 435 (2023).
- Westaway, S., Grange, I., Smith, J. and Smith, L.G. '[Meeting Tree Planting Targets on the UK's Path to Net-Zero: A Review of Lessons Learnt from 100 Years of Land Use Policies](#)'. *Land Use Policy* 125 (1 February 2023): 106502.
- Westerink, J., Jongeneel, R., Polman, N., Prager, K., Franks, J., Dupraz, P. and Mettepenningen, E. '[Collaborative Governance Arrangements to Deliver Spatially Coordinated Agri-Environmental Management](#)'. *Land Use Policy* 69 (2017): pages 176 to 192.
- Westlake, S. '[Land Use: Policies for a Net Zero UK](#)'. Committee on Climate Change, 2020.
- Weston, G. and Philip, L.J. '[The Sheep and Trees Initiative: A First Step towards Integrated Agroforestry in Scotland?](#)' *Scottish Geographical Journal* 136, numbers 1 to 4 (2 January 2020): pages 140 to 162.
- Whitfield, S., Reed, M., Thomson, K., Christie, M., Stringer, L.C., Quinn, C.H., Anderson, R., Moxey, A. and Hubacek, K. '[Managing Peatland Ecosystem Services: Current UK Policy and Future Challenges in a Changing World](#)'. *Scottish Geographical Journal*, 8 November 2011, pages 1 to 22.
- Whytock, R.C., Fuentes-Montemayor, E., Watts, K., De Andrade, P.B., Whytock, R.T., French, P., Macgregor, N.A. and Park, K.J. '[Bird-Community Responses to Habitat Creation in a Long-Term, Large-Scale Natural Experiment](#)'. *Conservation Biology* 32, number 2 (2018): pages 345 to 354.
- Williams, C.D., Hayes, M., McDonnell, R.J., Anderson, R., Bleasdale, A. and Gormally, M.J. '[Factors Affecting Wetland Ground Beetle \(Carabidae\) Assemblages: How Important Are Habitats, Conservation Designations and Management?](#)' *Insect Conservation and Diversity* 7, number 3 (2014): pages 206 to 222.
- Wilson, A., Vickery, J. and Pendlebury, C. '[Agri-Environment Schemes as a Tool for Reversing Declining Populations of Grassland Waders: Mixed Benefits from Environmentally Sensitive Areas in England](#)'. *Biological Conservation* 136, number 1 (April 2007): pages 128 to 135.
- Wilson, G.J., Carter, S.P. and Delahay, R.J. '[Advances and Prospects for Management of TB Transmission between Badgers and Cattle](#)', *Veterinary Microbiology* 151, no. 1–2 (July 2011): 43–50.
- Wolfert, S., Verdouw, C., van Wassenae, L., Dolfsma, W. and Klerkx, L. '[Digital Innovation Ecosystems in Agri-Food: Design Principles and Organizational Framework](#)'. *Agricultural Systems* 204 (2023).
- Wood, J.M., Tegeler, A.K. and Ross, B.E. '[Vegetation Management on Private Forestland Can Increase Avian Species Richness and Abundance](#)'. *Condor* 122, number 4 (2020).
- Woodcock, B.A., Lawson, C.S., Mann, D.J. and McDonald, A.W. '[Effects of Grazing Management on Beetle and Plant Assemblages during the Re-Creation of a Flood-](#)

- [Plain Meadow](#)'. *Agriculture, Ecosystems & Environment* 116, numbers 3 to 4 (September 2006): pages 225 to 234.
- Woodcock, B.A., Savage, J., Bullock, J.M., Nowakowski, M., Orr, R., Tallowin, J.R.B. and Pywell, R.F. '[Enhancing Floral Resources for Pollinators in Productive Agricultural Grasslands](#)'. *Biological Conservation* 171 (March 2014): 44–51.
- Wool, R., Breckenridge, G., Ziv, G. and Gosal, A.S. '[Delineating the Spatial Drivers of Agri-Environment Scheme Adoption at Field and Farm Levels](#)'. *Journal of Environmental Management* 348 (December 2023): 119407.
- Worrall, F. and Clay, G.D. '[The Impact of Sheep Grazing on the Carbon Balance of a Peatland](#)'. *Science of The Total Environment* 438 (November 2012): pages 426 to 434.
- Wuijts, S., Claessens, J., Farrow, L., Doody, D.G., Klages, S., Christophoridis, C., Cvejić, R. and others. '[Protection of Drinking Water Resources from Agricultural Pressures: Effectiveness of EU Regulations in the Context of Local Realities](#)'. *Journal of Environmental Management* 287 (2021).
- Wynne-Jones, S. '[Understanding Farmer Co-Operation: Exploring Practices of Social Relatedness and Emergent Affects](#)'. *Journal of Rural Studies* 53 (1 July 2017): pages 259 to 268.
- Xu, X., Chen, X., Hou, J., Cheng, T.C.E., Yu, Y. and Zhou, L. '[Should Live Streaming Be Adopted for Agricultural Supply Chain Considering Platform's Quality Improvement and Blockchain Support?](#)' *Transportation Research Part E: Logistics and Transportation Review* 195 (2025).
- Yadav, V.S., Singh, A.R., Raut, D.R., Mangla, S.K., Luthra, S. and Kumar, A. '[Exploring the Application of Industry 4.0 Technologies in the Agricultural Food Supply Chain: A Systematic Literature Review](#)'. *Computers and Industrial Engineering* 169 (2022).
- Yang, A.L., Rounsevell, M.D.A., Wilson, R.M. and Haggett, C. '[Spatial Analysis of Agri-Environmental Policy Uptake and Expenditure in Scotland](#)'. *Journal of Environmental Management* 133 (2014): pages 104 to 115.
- Yousefi, M., Dray, A. and Ghazoul, J. '[Assessing the Effectiveness of Cover Crops on Ecosystem Services: A Review of the Benefits, Challenges, and Trade-Offs](#)'. *International Journal of Agricultural Sustainability* 22, number 1 (31 December 2024): 2335106.
- Zani, C.F., Lopez-Capel, E., Abbott, G.D., Taylor, J.A. and Cooper, J.M. '[Effects of Integrating Grass-Clover Leys with Livestock into Arable Crop Rotations on Soil Carbon Stocks and Particulate and Mineral-Associated Soil Organic Matter Fractions in Conventional and Organic Systems](#)'. *Soil Use and Management* 38, number 1 (2022): pages 448 to 465.
- Zaralis, K., and Padel, S. '[Effects of High Stocking Grazing Density of Diverse Swards on Forage Production, Animal Performance and Soil Organic Matter: A Case Study](#)'. In *Innovative Approaches and Applications for Sustainable Rural Development*, edited by Alexandros Theodoridis, Athanasios Ragkos, and Michail Salampasis, pages 131 to 146. Springer Earth System Sciences. Cham: Springer International Publishing, 2019.
- Zhao, G., Ye, C., Dennehy, D., Liu, S., Harfouche, A. and Olan, F. '[Analysis of Barriers to Adopting Industry 4.0 to Achieve Agri-Food Supply Chain Sustainability: A Group-Based Fuzzy Analytic Hierarchy Process](#)', *Business Strategy and the Environment* 33, no. 8 (2024): 8559–86.

- Zhao, G., Jones, P., Liu, S., Lopez, C., Dennehy, D. and Chen, X. '[Analysis of the Drivers of Industry 4.0 Technology Deployment to Achieve Agri-Food Supply Chain Sustainability: A Hybrid Approach](#)', 2023.
- Zhao, M., Guerrero, A. Munaf, M.A., Lauwers, L. and Mouazen, A.M. '[Within-Field Spatial Variability and Potential for Profitability of Variable Rate Applications](#)'. Precision Agriculture. Springer, 2023.
- Zhou, X., Asioli, D. and Jürkenbeck, K. '[Investigating Consumers' Views on Foods from Soilless Farming Systems: A Review of the Literature and Discussion of Implications and Recommendations](#)'. Food Quality and Preference 126 (2025).
- Zinngrebe, Y., Pe'er, G., Schueler, S., Schmitt, J., Schmidt, J. and Lakner, S. '[The EU's Ecological Focus Areas – How Experts Explain Farmers' Choices in Germany](#)'. Land Use Policy 65 (1 June 2017): pages 93 to 108.
- Zitzmann, F. and Rode, M. '[Short-Rotation Coppice Managed According to Ecological Guidelines—What Are the Benefits for Phytodiversity?](#)' Forests 12, number 5 (2021).
- Żmihorski, M., Pärt, T., Gustafson, T. and Berg, A. '[Effects of Water Level and Grassland Management on Alpha and Beta Diversity of Birds in Restored Wetlands](#)'. Journal of Applied Ecology 53, no. 2 (2016): 587–95.
- Zuba-Ciszewska, M., Kowalska, A., Brodziak, A. and Manning, L. '[Organic Milk Production Sector in Poland: Driving the Potential to Meet Future Market, Societal and Environmental Challenges](#)'. Sustainability 15, number 13 (21 June 2023): 9903.
- Zwaan, D.R. de, Alavi, N., Mitchell, G.W., Lapen, D.R., Duffe, J. and Wilson, S. '[Balancing Conservation Priorities for Grassland and Forest Specialist Bird Communities in Agriculturally Dominated Landscapes](#)'. Biological Conservation 265 (2022).

Annex A

Search Strategies

Enhanced woodland management search strategy

Exclusion / Inclusion Criteria

Inclusion: Studies on woodland management, woodland and tree conservation and agroforestry. Specific focus on agricultural land and management alongside crops and livestock. Studies on woodland management for small-scale timber production.

Exclusion: Studies on industrial forestry; timber production. Studies on solely theoretical aspects without a practical focus.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: "habitat management", "habitat conservation", "habitat protection", "farming", "farmers", "agriculture", "woodland management", "woodland conservation", "woodland maintenance", "tree conservation", "agroforestry", "farmland trees", "farm woodland", "orchard", "tree cover", "silviculture"

Secondary Terms: "carbon sequestration" "woodland biodiversity" "climate adaptation", "ecosystem services", "flood prevention", "ancient woodland", "shelter", "invasive species", "scrub clearance", "halo thinning", "pollarding", "restocking", "coppicing", "sabrae planting", "thinning", "pruning"

Woodland and agroforestry creation search strategy

Exclusion / Inclusion Criteria

Inclusion: Studies on tree planting, woodland creation, increased tree cover and woodland planning. Specific focus on agricultural land. Studies on woodland management for small-scale timber production.

Exclusion: Studies on industrial forestry; timber production. Studies on solely theoretical aspects without a practical focus.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: “habitat management”, “habitat conservation”, “habitat protection”, “habitat creation”, “farming”, “farmers”, “agriculture”, “tree planting”, “woodland creation”, “tree canopy”, “woodland cover”, “tree cover”, “afforestation”

Secondary Terms: “carbon sequestration”, “climate adaptation”, “ecosystem services”, “flood prevention”, “agroforestry”, “low-density planting”, “natural regeneration”, “woodland creation plan”, “temperate”

Enhanced biosecurity search strategy

Exclusion / Inclusion Criteria

Inclusion: Studies on the implementation of biosecurity measures and livestock disease prevention. Specific focus on the outcomes of these measures.

Exclusion: Studies without a practical focus

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: “biosecurity”, “biosecurity measures”, “biosecurity practices”, “livestock”, “disease prevention”, “infectious disease”, “bio exclusion”, “biocontainment”, “disease control”, “biosafety”, “farming”, “farmers”, “agriculture”

Secondary Terms: “closed herds”, “livestock vaccination”, “livestock isolation”, “livestock quarantine”, “disease testing”, “disease spread”, “pest control”, “ventilation”, “disinfection”, “economic”

Tertiary Terms: “Foot and Mouth Disease”, “Johne’s disease”, “Bovine Viral Diarrhea”, “tuberculosis”, “bluetongue”, “liver fluke”, “sheep scab”, “pneumonia”, “avian influenza”, “bird flu”, “scrapie”, “parasites”, “enzootic abortion”, “mastitis”

Enhanced habitat management

Exclusion / Inclusion Criteria

Inclusion: Studies about the management of habitat types included within the defined list: Grassland - do not use avermectins; Wet grassland - management for breeding waders, wintering waders and waterbirds; Arable - fallow margins, unharvested conservation headlands, unsprayed crops, retain stubble after unsprayed crops.

Exclusion: Studies concerning management of habitats not included within the defined list. Studies detailing the creation of habitats as opposed to the management of them.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for evidence search

Keywords: “habitat management”, “habitat conservation”, “farm”, “farmers”, “agriculture”, “environmental impact”, “grassland”, “wet grassland”, “arable”

Secondary Terms: “avermectins”, “ivermectins”, “anthelmintic”, “waders”, “waterbirds”, “fallow margins”, “conservation headlands”, “unsprayed crops”, “retain stubble”

Implementation of Designated Site Management Plan

Exclusion / Inclusion Criteria

Inclusion: Studies on the management and enhancement of designated sites; the development and implementation of management plans.

Exclusion: Studies that only cover theoretical aspects without practical or management-oriented insights.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: "Designated sites", "management plans", "site management", "site enhancement", "management of designated sites", "conservation strategies", "conservation management", "SSSI", "ecosystem", "biodiversity", "farmer", "farm", "agriculture", "livestock", "climate adaptation"

Secondary Terms: "sustainable land management (SLM)", "biodiversity"

Hedgerow creation or restoration

Exclusion / Inclusion Criteria

Inclusion: Studies on farmland hedgerows, hedgerows conservation, hedgerow creation, hedgerow management.

Exclusion: Studies on urban hedgerows, garden planting.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: "habitat management", "habitat conservation", "habitat protection", "habitat creation", "farming", "farmers", "agriculture", "hedgerows", "hedges", "hedgerow planting", "hedge management", "farm hedging"

Secondary Terms: "biodiversity", "field margins", "field boundaries", "wildlife habitat", "wind protection"

Advanced Continuous Professional Development (CPD)

Exclusion / Inclusion Criteria

Inclusion: Studies on continuous professional development in agriculture and peer-to-peer learning.

Exclusion: Studies on agricultural education.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Some limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: "farming", "farmers", "agriculture", "CPD", "continuous professional development", "peer to peer", "participatory extension programme"

Secondary Terms: "profitability", "knowledge transfer", "peer learning", "dissemination", "animal health", "social", "environment", "sustainable", "continuous improvement", "behaviour change", "barriers", "economic", "productivity", "profit"

Improved soil health

Exclusion / Inclusion Criteria

Inclusion: Studies on soil testing as a farm practice.

Exclusion: Precision technologies with soil sensing. Studies that involve adoption of nutrient management plans / soil health plans more broadly (though noting this is in name of action). Studies that test soil or novel soil testing technologies.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Some limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: “soil test”, “soil analysis”, “soil sampling”, “soil pH test”

Secondary Terms: “farm”, “agri”, “agro”

Multispecies crop cover

Exclusion / Inclusion Criteria

Inclusion: Studies on multispecies cover crop.

Exclusion: For assessment of environmental impact we exclude studies on cover crop (single species) however due to very limited evidence on economic and social impact of multispecies vs single species we consider these.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Some limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: “multi species cover”, “mix cover”, “cover crop mix”, “under sowing”, “legume grass cover”

Secondary Terms: “adoption”, “uptake”, “scheme”, “incentive”, “economic”, “profit”, “social”, “ecological focus area”, “cover crops”

Peatland Management and Restoration

Exclusion / Inclusion Criteria

Inclusion: Studies on peatland management and / or restoration.

Exclusion: Studies outside of farmland/agricultural contexts.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Some limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: “peat”, “emissions”, “GHG”, “climate”, “historic”, “protection”, “restore”, “manage”

Secondary Terms: “economic”, “social”, “environmental”, “sustainable”, “agri”, “wales”, “uk”, “united kingdom”, “scotland”, “England”, “northern ireland”

Sustainable production

Exclusion / Inclusion Criteria

Inclusion: Studies on farm benchmarking, KPI tracking, and improving farm productivity and efficiency.

Exclusion: Evidence from non-comparable farming contexts and farming systems (e.g., rice paddy farming).

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Some limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: “benchmarking”, “industry benchmarking”, “KPI”, “key performance indicators”, “farm performance”, “farming”, “farmers”, “agriculture”, “farm management”, “methods”

Secondary Terms: “profitability”, “decision-making”, “efficiency”, “efficient”, “animal health”, “costs”, “profit”, “emissions”, “Farming Connect KPI tool”, “continuous improvement”, “behaviour change”, “data recording software”, “age of slaughter”, “rotational grazing”, “genetics”

Organic farming (support and conversion)

Exclusion / Inclusion Criteria

Inclusion: Studies that evaluate the benefits (environmental, social, economic) of organic farming.

Exclusion: Studies that look at the factors affecting the adoption of organic farming or the effectiveness of interventions to increase the uptake of organic farming.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: “organic”, “soil”, “farm”, “agri”, “production”, “environment”, “social”, “economic”, “emissions”, “GHG”, “greenhouse gas”, “yield”, “productivity”, “performance”, “biodiversity”, “well-being”, “health”

Secondary Terms: “benefit”, “comparison”, “review”, “meta-analysis”,

Creation of temporary and permanent habitats

Exclusion / Inclusion Criteria

Inclusion: Studies on the creation of temporary and permanent habitats, including their ecosystems, flora, and fauna. Evidence on methods, tools, or techniques for designing habitats.

Exclusion: Studies dealing with long-standing habitats rather than the design and creation of new ones. Studies that only cover theoretical aspects without having real-world applications,

e.g. unrealistic designs. Studies without measurable or documented evidence on the impact of habitat creation, especially in terms of biodiversity or ecological function.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: "habitat", "temporary habitat", "permanent habitat", "habitat creation", "habitat design", "habitat construction", "seasonal habitat", "ecosystem", "biodiversity", "farmer", "farm", "agriculture", "livestock", "climate adaptation", "artificial habitat", "habitat planning"

Secondary Terms: "reforestation", "ecosystem services", "species recovery", "hedgerows", "woodland", "trees", "scrub", "pond", "grassland", "landscape design", "waterbodies", "pollinators"

Improved public access to the countryside.

Exclusion / Inclusion Criteria

Inclusion: Studies on nature connection, access to nature, outdoor recreation and engagement. Specific focus on agricultural landscapes, public access to agricultural land, agricultural tourism and farmer engagement with local communities.

Exclusion: N/A

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: “nature connection”, “nature access”, “outdoor recreation”, “farm visits”, “agricultural tourism”, “agritourism”, “agricultural education”

Secondary Terms: “educational access” “farm schools”, “farm teaching”, “public access”, “public rights of way”, “public footpaths”

Improved water quality, water usage and flood mitigation.

Exclusion / Inclusion Criteria

Inclusion: Studies on: riparian buffers; water quality schemes; natural flood management solutions (NFM); water flow and impact on sediments and pesticides; mapping and observation tools such as Geographic Information System (GIS), Light Detection and Ranging (LIDAR), and aerial recognition; studies on biodiversity on riparian environment.

Exclusion: Studies on agroforestry and woodland.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: natural flood management, riparian buffers, water quality, flood mitigation, water use, water efficiency, water pollution, water resource, drinking water, catchment management

Secondary Terms: farmer, farm, agriculture, agro, ecosystem services

Improving air quality and lowering ammonia emissions

Exclusion / Inclusion Criteria

Inclusion: Studies on uptake of capital investments related to air quality / ammonia emissions as outlined in the scoping document.

Exclusion: Studies that do not consider air quality or ammonia and are not capital items.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords "variable rate application", "precision nutrient application", "precision nutrient management", "variable rate nutrient application", "variable rate fertilisation", "variable rate technology", "precision fertiliser application", "GPS nutrient application"

Secondary Terms: : "air scrubber", "livestock roofing", "manure store*", "slurry store", "slurry scraping", "trailing shoe", "shallow injection", "dribble bar", "hose reeler", "vacuum tanker", "pumped tanker", "band spreader", "umbilical hose"

Collaborative Innovation, Research and Development

Exclusion / Inclusion Criteria

Inclusion: Studies on innovation intervention, agricultural innovation, research and development programs including the private sector, research related to the adoption of new agricultural technologies and practices, and studies exploring the implementation of innovation and research and development findings in real-world agricultural settings

Exclusion: Studies on international agricultural innovations without clear applicability or relevance to the UK or Welsh context, research that is not specific to agriculture or does not explore innovations and technological developments in farming practices.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: "innovation" "research innovation projects" "collaboration" "agricultural technology" "precision agriculture" "collaborative Innovation" "supply chain management" "technology adoption", "skills development" "collaborative innovation" "stakeholder engagement" "research and development"

Secondary Terms: "farm", "research institution", "agri-food", "agriculture", "agri-tech"

Collaborative Landscape Scale Activity

Exclusion / Inclusion Criteria

Inclusion: Studies on landscape-level, collaborative actions between farmers and land managers/landowners – including national park authorities and management of designated sites.

Exclusion: Studies outside temperate zones and in significantly different farming contexts to those in Wales.

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: "landscape", "collaborative/collaboration/collaborate", "large scale", "partnership", "regional", "local", "integrated", "spatial", "targeting", "designated landscape/site/area", "national park", "protected area", "authority"

Secondary Terms: "farm", "farmer", "farming", "agri-environmental scheme", "conservation", "habitat", "ecosystem"

Collaborative Market and Supply Chain

Exclusion / Inclusion Criteria

Inclusion: Studies relating to support for activities; concentrating on added value, new markets and supply chain opportunities in agriculture and farming.

Exclusion: Studies relating solely to countries outside of Europe or without a practical focus (where possible).

Boundaries and Thresholds for Quality and Relevance

Quality: Evidence prioritised based on methodological robustness, such as peer-reviewed studies, systematic reviews, and meta-analyses.

Relevance: Limit to temperate farming contexts comparable to Wales (e.g., UK, northern Europe, parts of North America, New Zealand).

Keywords for Evidence Search

Keywords: "added value", "diversification", "collaboration", "network", "added value", "export", "knowledge transfer", "supply chain", "collaborate"

Secondary Terms: "farm", "consumer"

Annex B - Additional grey literature sources

- Agri-food and Biosciences Institute (AFBI)
- Agriculture Research Centre Coleg Sir Gar (ARC-CSG)
- Farming Connect
- College of Agriculture, Food and Rural Enterprise (CAFRE)
- Climate Change Committee (CCC)
- ClimateXChange (CXC)
- Centre of Expertise for Waters
- Scotland's Environment
- Department of Agriculture, Environment and Rural Affairs
- Department of Environment, Food and Rural Affairs
- Environment and Rural Affairs Monitoring & Modelling Programme
- Environmental valuation reference inventory
- EU Joint Research Centre
- Natural Resources Wales
- NatureScot
- Science Search Defra
- Scottish Government
- SEFARI
- Soil Association
- Teagasc - Agriculture and Food Development Authority
- The Economics of Ecosystems and Biodiversity
- TempAg - International Sustainable Temperate Agriculture Network
- Welsh Government