Farming for nature and public benefits: exploring viable futures in Northern Ireland

Technical Annexes

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Contents

This document has been created in support of the main report "Farming for nature and public benefits: exploring viable futures in Northern Ireland" that has been provided in electronic format. It provides extra insight into the approach taken and additional technical detail on the methods used in the study.

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Annex 1. Agricultural policy review

Farming in Northern Ireland interacts with three major policy domains concerned with Agriculture and Food, Nature and Environment, and Climate Change. These policy interactions define context in which farming futures will take shape.

1.1 Agriculture

Agriculture, occupying about 1 million ha, accounts for 76% of the total land area in Northern Ireland[1]. In spite of its dominant presence, its contribution to the NI economy has declined over time and is now relatively small. Although only about 1.4% and 2% of the total value of economic gross value added and employment respectively in Northern Ireland are associated with agricultural production, this is relatively high compared to the overall UK average. Grassland and livestock production dominate the sector, accounting for over 90% of agricultural land use and over 80% of the total annual output value of agricultural production by value [2].

There is a general policy focus in NI on growth in agricultural production and value added [5], driven mainly by export markets for dairy and livestock products, the domestic market for fresh produce, and food security. Commitments to growth are aligned with support for the rural economy and a Green Growth agenda[3].

The agricultural sector, and particularly the grazing livestock sub sector, is heavily policy dependent, with high levels of direct income support [4]. This is likely to continue under post Brexit arrangements over the medium term. While direct support secures livelihoods of otherwise vulnerable farming families, unless sufficiently targeted, it can inadvertently promote inefficient farming practices and businesses.

Policy dependency concurs with continuing structural challenges associated with relatively small, typically fragmented holdings [5], part time farming, retention of land by non-active farmers, an ageing farm population, and low investment, productivity and incomes. The strong farming lobby, underpinned by political interests, can make policy reform to address these structural challenges difficult. High levels of income support are likely to continue as opportunities are sought to improve productivity and reduce support dependency over time.

water[6], and improve environmental outcomes, animal welfare and public health. Of particular interest here are:

- continued direct income support payments in the form of Farm Sustainability Payments, although over time, funds may switch to other types of farm and environment support
- measures to improve productivity and environmental performance in the beef suckler sector.
- a Farming for Nature Package seeking to retain, maintain, restore and create habitats.
- farming for carbon measures to help deliver net Zero by 2050.

[1] https://www.daera-ni.gov.uk/sites/default/files/publications/daera/23.24.051%20Stats%20Review%20Internal%20for%202022%20Final.pdf
[2] https://www.daera-ni.gov.uk/articles/agricultural-census-northern-ireland
[3] https://www.daera-ni.gov.uk/articles/green-growth-strategy-northern-ireland-balancing-our-climate-environment-and-economy
[4] https://www.gov.uk/government/statistics/farm-incomes-in-northern-ireland-2021/22
[5] https://www.nienvironmentlink.org/site/wp-content/uploads/2021/12/Towards-a-Land-Strategy-for-NI_2015-Main-Report.pdf
[6] http://www.nienvironmentlink.org/site/wp-content/uploads/2021/12/16.17.079-Sustainable-Land-Management-Strategy-final-amended.pdf

- support for the intensive arable and horticultural sector to double the output in the next 5 to 7 years.

1.2 Climate Change and Nature

Policy Decisions for Agriculture in Northern Ireland are now firmly set in the context of a climate and nature emergency. The Climate Change (Northern Ireland) Act 2022[7] sets a target to reach net zero by 2050 and includes the need to use nature-based solutions where possible to enhance biodiversity and reduce GHG emissions. The Northern Ireland Environment Agency co-produced the JNCC Nature Positive 2030 (2021)[8] that recognises the need to address the twin crises of biodiversity loss and climate change. There are calls for NI to protect 30% of land and sea by 2030 to alleviate these crises in line with the post 2020 Global Biodiversity Framework agreed by COP15 of the Convention on Biological Diversity (CBD) (2022)[9]. This has implications for farm-based nature initiatives.

The Environmental Farming Scheme (EFS)[10] is the main mechanism for agri-environment policy, replacing the earlier Countryside Stewardship Programme. Uptake of has been slow, partly because of farmer perceptions of low reward for effort and of loss of income due to restrictions on land use. While the area of land receiving effective agri-environment measures may have helped slow the decline in nature, especially at the local scale and for selected target species, this has generally been insufficient to halt and reverse this trend[11]. Recognizing the poor health of many key nature areas, management plans are currently being produced for the Special Areas of Conservation network[12] funded through the Northern Ireland Rural Development Programme and DAERA's Environment Fund, and by NIEA. Change is, however, required at the larger scale and in the general farmed landscape. Extending and enhancing the support for farmers to embrace environmental options is central to this ambition.

1.3 Funding and Investments

Funding the Government's policy targets to restore nature in Northern Ireland is challenging: there is unlikely to be sufficient public funds[13]. Over the decade 2021- 2030, an estimated capital investment of £589 million is needed to meet nature related targets, which together with an annual spend of about £86 million/year, needs an equivalent new commitment averaging £180 million/year[14] over ten years. DAERA's 2023/24 budget for agriculture and agri-environment and the wider rural economy is £327 million.

In this context, RSPB make the case for Investing in Nature[15], with benefits for employment and local economies, but mindful of the limits of available fundings. Of particular resonance here, there is call for an enhanced and expanded agri-environment programme, a Nature for Climate Fund, and supporting new markets in ecosystem services, including biodiversity net gain that can attract private finance.

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[7] https://www.legislation.gov.uk/nia/2022/31/contents/enacted

[8] https://data.jncc.gov.uk/data/6de7bf27-055e-4407-ad29-4814e1613d90/nature-positive-2030-summary-report.pdf

[9] https://lordslibrary.parliament.uk/cop15-global-biodiversity-framework/

[10] https://www.daera-ni.gov.uk/topics/rural-development/environmental-farming-scheme-efs

[11] https://nbn.org.uk/wp-content/uploads/2019/09/State-of-Nature-2019-UK-full-report.pdf

[12] https://www.daera-ni.gov.uk/articles/conservation-management-plans-northern-irelands-special-areas-conservation

[13] Green Finance , 2021 The-Finance-Gap-for-UK-Nature-13102021.pdf (greenfinanceinstitute.co.uk)

[14] Rayment (2017 and 2019)24 for the RSPB, National Trust and Wildlife
Trusts, and eftec (2021) for the Green Finance Institute25.

[15] https://community.rspb.org.uk/getinvolved/b/steppingupnorthernireland/posts/northern-ireland-nature-investment-plan-launch

1.4 Future directions

While Government in NI shows continued strong support for the agriculture sector, the broad range of policy targets to be delivered and the limits to public finances are likely to require some rebalancing between direct income support and payments for targeted environmental outcomes. At the same time, the measures to improve productivity and sustainability in the sector can help to support rural livelihoods and protect and enhance nature if practical measures that make business sense can be found. This implies a combination of targeted incentives, advice and technical support, and actions to enable structural adjustment in the sector. Green finance, facilitating so called 'high integrity' markets[16], is also likely to have a greater role given limits to public funds.

The assessment of farming futures is set in this context, whereby policy seeks to simultaneously deliver range of agricultural production and environmental outcomes, while supporting a viable farming sector; developing strategies for farming with nature that make business sense.

[16] Young, D., et al., (2022) Financing Nature Recovery UK: Scaling Up High-Integrity Environmental Markets Across the UK. London, United, available at https://www.financingnaturerecovery.uk/publications

Annex 2. Natural capital assessment

2.1 The natural capital concept

Central to the approach used in this project is the concept of natural capital. Natural Capital is defined as "..elements of nature that directly or indirectly produce value or benefits to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions" (Natural Capital Committee 2014[17]). It is the stock of natural assets (e.g. soils, water, biodiversity) that produces a wide range of ecosystem services that benefit people. These benefits include food production, regulation of flooding and climate, pollination of crops, and cultural benefits such as aesthetic value and recreational opportunities (Figure 1).

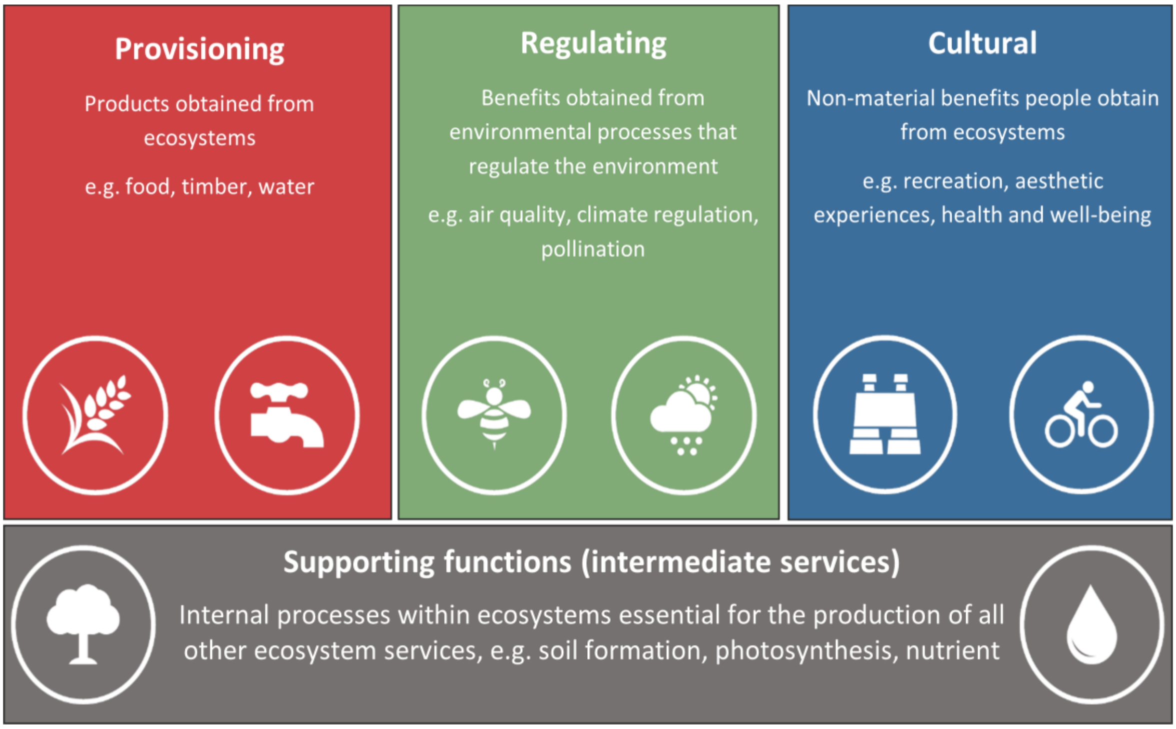


Figure 1 Key types of ecosystem services (based on MA 2005 [18]). Note that supporting or intermediate services are now categorised as ecological functions (CICES [19]). They are the underpinning structures and processes that give rise to ecosystem services.

This natural capital approach is increasingly being used in the agricultural sector to inform management and decision-making for nature-based solutions that will increase biodiversity and ecosystem service (or environmental) benefits on which society and agriculture itself depend. Here, we have used a spatial (GIS) approach to map the baseline natural capital (habitats) for each of the farms across the baseline and the two scenarios, the ecosystem services that are provided by these habitats, and the opportunities for creating new habitat to enhance biodiversity and ecosystem services. We have also used a natural capital accounting approach to estimate the monetary value of the benefits that flow from the habitats of each of the farms, and also in the economic appraisal of the baseline and scenarios.

17 Natural Capital Committee (2014) The state of natural capital: Restoring our natural assets. Second report to the Economic Affairs Committee. Natural Capital Committee, March 2014.

18 Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: Synthesis. Island Press, Washington D.C. https://www.millenniumassessment.org/en/index.html

19 Haines-Young, R. & Potschin, M. (2018) Common International Classification of Ecosystem Services (CICES) V5.1. Guidance on the application of the revised structure. Fabis Consulting.

2.2 Natural capital and biodiversity assessment

2.2.1 Farm habitat and management data

Information on the different habitats across the farms was essential for completing a natural capital assessment. Woodrow Environmental Consultants were commissioned to complete habitat surveys of each of the farms in the winter/spring of 2022/3 and to produce GIS layers for each farm containing the type and condition of the habitats. The habitats were classified to Phase 1 and a condition assessment was completed so the Biodiversity Metric 4.0 could be used within the project to set a biodiversity baseline for each of the farms. Additional notes were taken to highlight individual trees, or any other features of condition, for example, whether fields were poached. The total area of all farms, with the exception of Lyttle Farm, was surveyed. Only a 12.5ha area of Lyttle farm was surveyed, and as a result the mapping and the valuation focus on this area of the farm only. The farm is in fact 149ha, and the farm business and economic appraisals have accounted for this whole area. The scenario interventions and the natural capital valuation figures were scaled up to make this possible.

The natural capital assessment and valuation also required an understanding of how each of the farms were currently being managed, numbers and types of livestock, what improved grasslands were being used for (silage or grazing) and what crops were being grown.

2.2.2 Approach to mapping the farm baseline natural capital assets

The first and key step was to produce a detailed map of the current habitats present across each of the farms. This is an important component of any assessment of natural capital assets and is required before an assessment of the ecosystem services can be undertaken. The vegetation survey GIS layers created by Woodrow were used for this assessment, along with additional data outlined in Box 1 below. Each polygon of each farm had been classified into Phase 1 habitat types and were also classified into broader habitat groups.

Box 1: Data used to classify habitats in the farm basemap:

- Phase 1 habitat classification data
- Digital Terrain Model (10 m)
- Peat soil GIS layer from the Hutton Institute

2.2.3 Baseline biodiversity

We used the Biodiversity Metric 4.0, a relatively simple metric developed by Natural England (2022)[20], that calculates 'biodiversity units', to set a biodiversity baseline for the farms. The biodiversity unit score is based on a number of factors that influence the level of biodiversity: the area of the habitat, its distinctiveness and condition (area (ha) x distinctiveness score x condition score). Habitats that have a high distinctiveness†, are in good condition and cover a greater area will achieve a higher biodiversity unit score than smaller areas, with lower distinctiveness and condition scores. This metric is used in the development sector in England to test whether Biodiversity Net Gain (BNG) will be achieved post-development. Using the metric in this context was very useful, because it provided a score that can be used to predict how future (or indeed past) changes in habitats or habitat management impact on biodiversity.

As outlined above Woodrow Environment Consultants created a GIS layer recording the habitat type, and condition of each polygon within it from the on the ground survey. Condition as defined by the Biodiversity Metric 4.0 was captured using categories from 'good' to 'poor', and also included two N/A

20 Natural England. (2022) The Biodiversity Metric 3.1 auditing and accounting for biodiversity. Calculation Tool

†Habitat distinctiveness scores are based on rarity of the habitats, proportion that lies within protected sites, and whether it is a priority habitat.

categories for agriculture and other (non-natural) habitats (see Table 1). When used in the metric, these categories were given a score from 0-3 (Table 1). Distinctiveness scores are set scores in the Biodiversity Metric 4.0 which were assigned to each of the natural surface polygons of the natural capital baseline maps for each farm. The biodiversity units could then be calculated. The biodiversity units can be mapped, but in this project we used them as an overall score for each farm.

Table 1 Biodiversity Metric 3.1 condition categories and associated scores.

Category	Multiplier
Good	3
Fairly Good	2.5
Moderate	2
Fairly Poor	1.5
Poor	1
N/A – Agriculture	1
N/A - Other	0

The biodiversity baseline score in and of itself is not particularly informative. The power of this score lies in its comparison with past or future scenarios. Biodiversity units may be re-calculated in the future to track changes in habitat and landscape level biodiversity; or after a building project on the farm, it will indicate whether management changes have increased (a net gain) or decreased biodiversity.

2.2.4 Mapping the ecosystem services (physical flows)

Once a detailed habitat basemap had been created for each of the farms, it was then possible to quantify and map the benefits that these habitats (natural capital) provide to people. The following benefits (ecosystem services) were mapped where possible:

- Carbon storage
- Carbon sequestration
- Air purification
- Noise regulation
- Local climate regulation
- Pollinator visitation
- Food production
- Timber/woodfuel production
- Water flow regulation
- Water quality regulation
- Accessible nature

A variety of methods were used, and these are described for each individual ecosystem service in the section below. In all cases the models were applied at fine resolution to provide fine scale mapping across the area. The models are based on the detailed habitat information determined in each of the basemaps, together with a variety of other external data sets (e.g. digital terrain model, UK census data 2011, open space data, and many other data sets and models mentioned in the methods for each ecosystem service). Note, however, that many of the models are indicative (showing that certain areas have higher capacity or demand than other areas) and are not process-based mathematical models (e.g. hydrological models). In all cases the capacity and demand for ecosystem services is mapped relative to the values present for each site. For every ecosystem service listed, the capacity of the natural environment to deliver that service – or the current supply – was mapped at each of the four farms.

Carbon storage capacity

What is it and why is it important?

Carbon storage capacity indicates the amount of carbon stored naturally in soil and vegetation. Carbon storage and sequestration is seen as increasingly important as we move towards a low-carbon future. The importance of managing land as a carbon store has been recognised by the UK Government, and land use has a major role to play in national carbon accounting. Changing land use from one type to another can lead to major changes in carbon storage, as can restoration of degraded habitats.

How is it measured?
This model estimates the amount of carbon stored in each habitat type. It applies average values (tC/ha) for each habitat type taken from Natural England (2019)[21]. It then applies a multiplier[22] to these depending on which soil type the habitat occurs on. As such it does not take into account habitat condition or management, which can cause variation in amounts of carbon stored. It is calculated for each 10m by 10m cell across the study area. Scores are scaled on a 0 to 100 scale, relative to values present within the mapped area.
In all the ecosystem services maps that follow, the highest amounts of service provision and demand (hotspots) are shown in red, with a gradient of colour to blue, which shows the lowest amounts (coldspots).

Carbon sequestration

What is it and why is it important?

Carbon is sequestered (captured) by growing plants. While carbon storage (above) measures the stock of carbon in the natural environment, carbon sequestration measures its annual flow.

How is it measured?
This model estimates the amount of carbon sequestered by each habitat type. It applies average values (tCO_2e/ha/year) for each habitat type taken from Natural England (2021)[23] and the RSPB's Accounting for Nature report[24]. Note that for arable and improved grassland, the calculation takes into account the value of emissions from machinery, the production and use of fertilisers, and from other energy used in the production of crops, based on a life cycle analysis. Overall, these two habitats currently emit greenhouse gases, hence are displayed with a negative value. This service was calculated for each habitat polygon and is presented as tonnes of carbon equivalent per hectare per year (tCO_2e/ha/yr).

Air purification capacity (air quality regulation)

What is it and why is it important?

According to the Public Health England, air pollution is the biggest environmental threat to health in the UK, with between 28,000 and 36,000 deaths a year attributed to long-term exposure, with the greatest threats from particulate matter ($PM_{2.5}$) and nitrous oxides (NO_x). Even small changes can make a big difference, just a 1µg/m^3 reduction in $PM_{2.5}$ concentrations could prevent 50,000 new cases of coronary heart disease and 9,000 new cases of asthma by 2035[25]. Air pollution also contributes to climate change, reduces crop yields, and damages habitats and biodiversity.

Air purification capacity estimates the relative ability of vegetation to trap airborne pollutants or ameliorate air pollution. Vegetation can be effective at mitigating the effects of air pollution, primarily by intercepting airborne particulates (especially PM_{10} and $PM_{2.5}$) but also by absorbing ozone, SO_2, NO_X and ammonia. Trees provide more effective mitigation than grass or low-lying vegetation, although this varies depending on the species of plant. Coniferous trees are generally more effective than

21 Sunderland T, Waters RD, Marsh DVK, Hudson C, Lusardi J. (2019) Accounting for National Nature Reserves: A natural capital account of the National Nature Reserves managed by Natural England. Natural England Research Report, Number 078.

22 Lagas and Sweep (2020) Ecosystem service – carbon storage and sequestration.

23 Gregg, R. Elias, J., Alonso, I., Crosher, I., Muto, P. & Morecroft, M. (2021) Carbon storage and sequestration by habitat: a review of the evidence. (Second edition) Natural England Research Report NERR094.

24 RSPB (2017) Annexes to Accounting for Nature: A natural capital account for the RSPB's estate in England.

25 Public Health England (2018) Estimation of costs to the NHS and social care due to the health impacts of air pollution. Crown Copyright.

broadleaved trees due to the higher surface area of needles and because the needles are not shed during the winter.

How is it measured?
Air purification capacity was mapped using a an EcoServ R model. The model assigns a score to each habitat type, representing the relative capacity of each habitat to ameliorate air pollution. The cumulative score in a 20m and 100m radius around every 10m by 10m pixel was then calculated and combined. The benefits of pollution reduction by trees and greenspace may continue for a distance beyond the greenspace boundary itself, with evidence that green area density within 100m can have a significant effect on air quality. Therefore, the model extends the effects of greenspace over the adjacent area, with the maximum distance of benefits set at 100m. Note that the model does not take into account seasonal differences or differences in effect due to the prevailing wind direction.
The final capacity score was calculated for every 10m by 10m cell across the study area and was scaled on a 0 to 100 scale relative to values present within the mapped area. High values (red) indicate areas that have the highest capacity to trap airborne pollutants and ameliorate air pollution.

Noise regulation capacity

What is it and why is it important?

Noise regulation capacity is the capacity of the land to diffuse and absorb noise pollution. Noise can impact on health, wellbeing, productivity and the natural environment and the World Health Organisation (WHO) have identified environmental noise as the second largest environmental health risk in Western Europe (after air pollution). It is estimated that the annual social cost of urban road noise in England is £7 to £10 billion (Defra 2013[26]). Major roads, railways, airports and industrial areas can be sources of considerable noise but use of vegetation can screen and reduce the effects on surrounding neighbourhoods. Complex vegetation cover, such as woodland, trees and scrub, is considered to be most effective, although any vegetation cover is more effective than artificial sealed surfaces, and the effectiveness of vegetation increases with width.

How is it measured?
The EcoServ R noise regulation model was used, with some modifications. First, the capacity of the natural environment was mapped by assigning a noise regulation score to vegetation types based on height, density, permeability and year-round cover. Next, the noise absorption score in 30m and 100m radii around each point was modelled and the scores combined, which results in wider belts of vegetation receiving a higher score. The score was calculated for each 10 m by 10m cell across the study area, and is scaled on a 0 to 100 scale, relative to values present within the mapped area. High values (red) indicate areas that have the highest capacity to absorb noise pollution.

Local climate regulation capacity

What is it and why is it important?

Land use can have a significant effect on local temperatures. Urban areas tend to be warmer than surrounding rural land due to a process known as the "urban heat island effect". This is caused by urban hard surfaces absorbing more heat, which is then released back into the environment, coupled with energy released by human activity such as lighting, heating, vehicles and industry. Climate change impacts are predicted to make the overheating of urban areas and urban buildings a major environmental, health and economic issue over the coming years. Natural vegetation, especially trees / woodland and rivers, are able to have a moderating effect on local climate, making nearby areas cooler in summer and warmer in winter. Local climate regulation capacity estimates the capacity of an ecosystem to cool the local environment and cause a reduction in urban heat maxima.

How is it measured?
Local climate regulation capacity was mapped using an EcoServ R model. The model calculates the proportion of the landscape that is covered by woodland / scrub and water features within a 200m radius around each 10m-

26 Defra (2013) Noise pollution: economic analysis. Crown Copyright.

by-10m cell across the study area. However, temperature regulating effects of woodland and water will also occur in nearby adjacent areas, with the distance of the effect dependent on the patch size of the natural area. To incorporate this effect, a buffer was applied around each woodland / water patch, with wider buffers modelled around larger natural sites. Note that this model only includes woodland / scrub and water features which provide the most significant effects. All green space is beneficial compared to artificial sealed surfaces, so a future iteration of the model could include all natural surfaces. In addition, effect of the sea was added in as a proxy, the real effect is likely to be more complex.
The final capacity score was calculated for each 10m-by-10m cell across the study area, and was scaled from 0 to 100, relative to values present within the mapped area. High values (red) indicate areas that have the highest capacity to regulate temperatures, keeping them cool in the summer and warmer in the winter.

Water flow capacity

What is it and why is it important?

Water flow capacity is the capacity of the land to slow water runoff and thereby potentially reduce flood risk downstream. Following a number of recent flooding events in the UK and the expectation that these will become more frequent over the coming years due to climate change, there is growing interest in working with natural process to reduce downstream flood risk. These projects aim to "slow the flow" and retain water in the upper catchments for as long as possible. Maps of water flow capacity can be used to assess relative risk and help identify areas where land use can be changed.

How is it measured?
A bespoke model was developed, building on an existing EcoServ R model and incorporating many of the features used in the Environment Agency's catchment runoff models used to identify areas suitable for natural flood management. Runoff was assessed based on the following three factors:
Roughness score – Manning's Roughness Coefficient provides a score for each land use type based on how much the land use will slow overland flow.
Slope score – based on a detailed digital terrain model, slope was re-classified into a number of classes based on the British Land Capability Classification and others.
Each indicator was normalised from 0-1, then added together and projected on a 0 to 100 scale, as for the other ecosystem services. Note that this is an indicative map, showing areas that have generally high or low capacity and is not a hydrological model. High values (dark orange and red) indicate areas that have the highest capacity to slow water runoff.

Water quality capacity

What is it and why is it important?

Water quality capacity maps the risk of surface runoff becoming contaminated with high pollutant and sediment loads before entering a watercourse, with a higher water quality capacity indicating that water is likely to be less contaminated. Note that although urban diffuse pollution is partially captured in the model at catchment scale, the focus is on sedimentation risk from agricultural diffuse pollution, hence built-up areas are not particularly well accounted for in the existing model.

How is it measured?
A modified EcoServ R model was developed, which combines a coarse and fine-scale assessment of pollutant risk.
At a coarse scale, catchment land use characteristics were used to determine the overall level of risk. The percentage cover of sealed surfaces and arable farmland in each sub-catchment (EA Waterbody catchment) was calculated and the values were re-classified into several risk classes. There is a strong link between the percentage cover of these land uses and pollution levels, with water quality particularly sensitive to the percentage of sealed surfaces in the catchment.
At a fine scale, a modification of the Universal Soil Loss Equation (USLE) was used to determine the rate of soil loss for each cell. This is based on the following three factors:

- **Distance to watercourse** – using a least cost distance analysis, taking topography into account.
- **Slope length** – using a flow accumulation grid and equations from the scientific literature. Longer slopes lead to greater amounts of runoff.

- **Land use erosion risk** – certain land uses have a higher susceptibility to erosion and standard risk factors were applied from the literature. Bare soil is particularly prone to erosion.
- **Watershed risk** – for each catchment area there is a score for the risk of pollution.

Each of the three fine scale indicators and the catchment-scale indicator were normalised from 0-1, then added together and projected on a 0 to 100 scale. As previously, this is an indicative map, showing areas that have generally high or low capacity and is not a process-based model. High values (red) indicate areas that have the greatest capacity to deliver high water quality (least sedimentation risk).

Food production capacity

What is it and why is it important?

Food production models the capacity of the land to produce food under current farming practices. Farming is the dominant land-use in the study area, with arable being much more dominant than grassland for livestock grazing. These land covers provide the largest proportion of food. However, food is produced from a range of other habitats, albeit to a lesser extent. The ability of habitats to provide food, accounting for Agricultural Land Classification, was mapped.

How is it measured?

The methodology follows that outlined in Smith (2020)[27] and was developed for the Eco-metric tool. Broad habitats in Stoke Bardolph were assigned a score based their relative ability to provide food:

- Arable, improved grassland – 10
- Orchards, allotments – 7
- Semi-natural and rough grasslands – 6
- Marshy grassland – 4
- Wood pasture and parkland – 3
- Bog/heath, domestic gardens, broadleaved and mixed woodlands - 1

This was mapped in GIS and then weighted by the Agricultural Land Class in which it occurred. The weighting was based on typical dry yield and an additional multiplier for versatility, following Smith (2020):

Grade 1 – 3.03
Grade 2 – 2.40
Grade 3 – 1.33
Grade 4 – 0.67
Grade 5 – 0.50

To maintain compatibility with the other ecosystem services maps, the weighted scores were scaled on a 0 to 100 scale, relative to values present within the mapped area.

Timber / woodfuel capacity

What is it and why is it important?

Forestry remains an important component of the rural economy and many areas of woodland are still valued primarily on their timber value. Timber is an important product of woodlands and is the raw resource of the timber industry. Sustainably managed woodland produces timber that is important in contributing to processing mills and factories that produce wood-based products and wood fuel for the generation of renewable heat and electricity.

How is it measured?

Information on the species mix and yield class was obtained from the Forestry Commission's National Inventory of Woodland and Trees Regional Report for Nottinghamshire County (2002), and Forest Research's Ecological Site Classification tool (http://www.forestdss.org.uk/geoforestdss/). This was used to determine the average yield of timber (m^3) per hectare per year. This was then mapped in GIS and, to maintain compatibility with the

27 Smith, A. (2020) Natural Capital in Oxfordshire: Short report. Environmental Change Institute, University of Oxford.

other ecosystem services maps, the scores were scaled on a 0 to 100 scale, relative to values present within the mapped area.

Accessible nature capacity

What is it and why is it important?

The importance of access to greenspace is being increasingly recognised due to the multiple benefits that it can provide to people. In particular there is strong evidence linking access to greenspace to a variety of health and wellbeing measures. Research has also shown that there is a link between wellbeing and perceptions of biodiversity and naturalness. Natural England and others have published guidelines that promote the enhancement of access, naturalness and connectivity of greenspaces.

The two key components of accessible nature capacity are therefore public access and perceived naturalness. Both of these components are captured in the model, which maps the availability of natural areas and scores them by their perceived level of “naturalness”.

How is it measured?
Accessible nature capacity was mapped using an EcoServ R model. In the first step, accessible areas are mapped. These are defined as:

- Areas 10m either side of linear routes such as Public Rights of Way, pavements and Sustrans routes. Note that there was no data for permissive paths.
- Publicly accessible areas such as country parks, CRoW access land, local nature reserves, accessible woodlands, and beaches and other accessible coastal areas.
- Areas of green infrastructure marked as accessible, including parks, playgrounds, and other amenity greenspaces.

These areas were then scored for their perceived level of naturalness, with scores taken from the scientific literature. Naturalness was scored in a 300m radius around each point, representing the visitors experience within a short walk of each point.
The resulting map shows accessible areas, with high values representing areas where habitats have a higher perceived naturalness score. Scores are on a 1 to 100 scale, relative to values present within the study area. White space shows built-up areas or areas with no public access.
Larger continuous blocks of more natural habitat types will have higher scores than smaller isolated sites of the same habitat type. One consequence is that linear routes, such as footpaths, that pass through land with no other access will not score highly.

2.2.5 Habitat opportunity mapping method

Once the baseline ecosystem services provision had been mapped for each of the four farms, we wanted to understand what the options were on each of the farms to restore or create habitat that connected up existing habitat networks within and around the sites. This would create corridors for the movement of species across the landscape and enhance biodiversity. We also wanted to reveal the opportunities for restoring or creating habitat that would increase the environmental benefits delivered by the farms. This was done using habitat opportunity mapping.

Habitat opportunity mapping is a Geographic Information System (GIS) based approach used to identify potential areas for the expansion of key habitats. It aims to identify possible locations where new habitat can be created that will be able to deliver particular benefits whilst taking constraints (such as existing land uses or historic sites) into account. In this project, opportunities for new habitats across a range of different benefits have been mapped. This has included mapping opportunities for the following:

1) To enhance biodiversity (broad habitats outlined below)
2) To reduce surface runoff
3) To reduce soil erosion and improve water quality

Opportunities for increasing carbon sequestration and storage is equivalent to the broadleaved woodland and mire opportunities maps, so these are not listed separately above. Opportunities for increasing the other ecosystem services mapped as part of the project could not be completed as they are based on demand mapping. Demand mapping was not appropriate in this project due to the rural location of the farms. Please note that the mapping identifies areas based on landscape-scale ecological principles or indicative ecosystem services models and does not take into account local site-based factors that may impact suitability. Any areas suggested for habitat creation will require ground-truthing before implementation. The maps should be seen as a tool to highlight key locations and to guide decision making rather than an end in themselves.

Mapping opportunities for biodiversity

The importance of landscape-scale conservation and ecological networks has become increasingly recognised over recent years. Many wildlife sites have become isolated in a landscape of unsuitable habitats and efforts are now being directed towards linking existing habitat patches and increasing connectivity. Species are more likely to survive in larger habitat networks, can move and colonise new sites, and are more resilient to climate change and other detrimental impacts.

Habitat opportunity mapping to enhance biodiversity follows this ethos by using ecological networks to identify potential areas for new habitats. Identified areas will be ecologically connected to existing habitats, thereby expanding the size of the existing network, increasing connectivity and resilience, and potentially increasing the ecological quality of the new site. It was performed for three key habitat groupings, incorporating the main semi-natural habitats across the farm. The broad habitats and their constituent types are shown in the table below.

Broad habitats and constituent types

Broad habitat	Specific habitats included
Mire	Bogs and upland flushes, fens and swamps.
Semi-natural grassland	Acid, neutral, calcareous, rough and semi-improved grasslands.
Heathland	Includes all heathland types (including wet and dry heaths) and grass-heath mosaics.
Broadleaved and mixed woodland	Broadleaved and mixed woodland types (excludes coniferous woodland, parkland or individual trees).
Wet grassland and wetlands	Marshy grassland, floodplain grazing marsh, lowland fen and swamp (reedbed)

Biodiversity opportunity mapping followed a four-step process, as explained below, and was based on the approach developed by Catchpole (2006)[28] and Watts et al. (2010)[29]. Note that opportunity areas for the three broad habitats often overlap, and no attempt has been made to ascertain the most suitable habitat at a particular location.

1. *Landscape permeability*

This step involves assessing the permeability of the landscape to typical species from each habitat type and builds on work carried out by JNCC, Forest Research and others. Generic focal species are assessed for each habitat type as there is a lack of ecological knowledge to be able to repeat the process for multiple different individual species, and generic species provide an average assessment for species typical of each habitat type.

28 Catchpole, R.D.J. (2006). Planning for Biodiversity – opportunity mapping and habitat networks in practice: a technical guide. English Nature Research Reports, No 687

29 Watts, K., Eycott, A.E., Handley, P., Ray, D., Humphrey, J.W. & Quine, C.P (2010). Targeting and evaluating biodiversity conservation action within fragmented landscapes: an approach based on generic focal species and least-cost networks. Landscape Ecology, 25: 1305–1318.

It is assumed that a species will have optimal dispersal capabilities in the habitat in which it is associated, and hence the landscape is fully permeable if it consists only of this primary habitat. Each of the remaining habitat types is then assigned a permeability score that shows how likely and how far the species will travel through that habitat. Habitats are scored on a scale from 1 (most permeable) to 50 (least permeable). Permeability scores are based on expert scores compiled by JNCC. Once tables had been compiled showing permeability scores for each habitat, high resolution maps are then produced using bespoke modelling, showing the permeability of the landscape for generic species from each broad habitat type.

2. *Habitat networks*

Step 2 uses the permeability map created above, along with information on average dispersal distances, to map which habitat patches are ecologically connected and which are ecologically isolated from each other. Dispersal distances are obtained from JNCC, which has performed a review of the scientific literature to ascertain the dispersal distances of a range of species for each habitat type. These are typically species of small mammals, smaller birds, butterflies, and plants. The average dispersal distance for each habitat is shown in the table below:

Dispersal distance in optimal habitat:	
Mire	1.0 km
Semi-natural grassland	2.0 km
Heathland	1.2 km
Broadleaved and mixed woodland	3.0 km
Wet grassland & wetlands	2.0 km

3. *Identifying constraints*

The habitat network map created in Step 2 can be used to indicate where new habitat could be created; any habitat created within the existing network would be ecologically connected to existing patches. However, in reality a number of constraints exist that need to be taken into account when producing opportunity maps. The aim of this step, therefore, is to produce a series of maps of constraints that can be used to show where habitat cannot or should not be created. The following constraints were used in the mapping:

- Land-use constraints – infrastructure (roads, railways, and paths), urban (all buildings), gardens, and water (standing and running), as it is highly unlikely that these would be available for habitat creation.
- Historic sites – the location of Scheduled Monuments and Registered Parks and Gardens across the study area and a 30m buffer is applied around each individual site, as recommended by Historic England.
- National Grid gas pipelines, overhead lines and cables – data is obtained from the National Grid and a 10m buffer is applied around both features. This constraint is only applied when woodland opportunities are being mapped, as it would not be possible to plant trees in these areas, although grassland and wetland habitats would be feasible.
- High quality habitats – existing habitats of high nature conservation interest will be identified from the basemap as it would not make sense to destroy existing high-quality habitat to create new habitat of a different type.

4. Habitat opportunity for biodiversity

In the next step, the constraints map is used to exclude areas that would be unsuitable or unavailable for new habitat. Two layers of habitat opportunity are then created:

- **Buffer opportunity** – this layer identifies habitat opportunity areas that are immediately adjacent to existing habitat patches and fall within the previously identified ecological network.
- **Stepping-stone opportunity** – this layer identifies potential sites that fall outside of the ecological network, but are immediately adjacent to it. These areas could potentially be used to create stepping-stone habitats that could link up more distant habitat patches.

For both opportunity layers, a minimum threshold size is set at 0.1 ha, to remove tiny fragments of land and to replicate the minimum sizes of habitat creation grant schemes. As the above process identifies portions of land in relation to the ecological network for each habitat, it often results in thin slivers of land being identified adjacent to existing habitats, which bear no relationship to existing fields and boundaries. As habitat creation or restoration projects usually operate on whole fields, an additional step was taken to identify those fields that present buffer opportunities. To do this, the layer was overlaid on to the basemap to identify whole fields that are immediately adjacent to existing habitat patches and are not constrained by the factors described in Step 3. Parts of these fields fall within the previously identified ecological network and creating new habitat will extend the network. To remove spurious results where only a tiny fraction of a field fell within a buffer zone, fields where less than 10% of the whole field overlapped with the buffer zone were removed. In the same way, the steppingstone layer was also overlain to identify whole fields that fall outside of the ecological network but are immediately adjacent to it.

When the maps are presented they combine the buffer and stepping stone opportunities and prioritise them into three groups: (1 – high priority) opportunities to buffer and connect up areas of habitat with national designations (e.g. SSSI) and ancient woodland, (2 – medium priority) opportunities to buffer and connect up areas of habitat of local importance (e.g. local nature reserves and wildlife sites), and (3- low priority) all other opportunities. The opportunities are presented both as networks and fields.

Mapping opportunities for ecosystem services

This opportunity mapping is a different approach to the biodiversity opportunity mapping, and is based on the ecosystem service mapping that has been completed as part of this project.

Opportunity mapping to reduce surface runoff

There is a growing interest in working with natural processes to reduce downstream flood risk. These projects aim to “slow the flow”, reduce surface water runoff and retain water away from the main river channels for as long as possible. The most likely approach to achieve this aim will involve planting woodland, although measures could also include woody debris dams and attenuation ponds in upstream areas. Opportunity mapping to reduce surface runoff will be undertaken based on the water flow model that Natural Capital Solutions use, and highlights areas across the whole catchment where changing land-use would have the greatest impact on reducing runoff.

Constraints are identified and mapped in the same way as for the biodiversity opportunity mapping outlined above. These locations are then erased from the water flow regulation map completed as part of the ecosystem service mapping, to leave a map showing water flow regulation in all unconstrained locations. This is then classified into percentiles and the top 50% extracted into another map. This map shows the top 50% of areas of land across the study area, broken down into three classes - 10%, 11-25%, and 26-50% - where surface water runoff is currently highest and where there are no constraints on potentially altering land use.

The final opportunity map identifies a large number of very small polygons and many polygons do not coincide with fields, the scale over which management and land use change is likely to take place. Therefore, as for biodiversity opportunity areas, it is considered beneficial to identify whole fields offering the greatest opportunity to reduce surface water runoff. To do this, all the previously identified constraints are removed or erased from the underlying habitat basemap. The degree of intersection between the opportunity map and the underlying fields (polygons) in the basemap is then calculated. Fields where at least 50% of the field overlaps with the opportunity map are selected and exported to a new layer. Finally, very small polygons are deleted so that only fields and plots at least 0.1 ha in size are included in the final map.

Opportunity mapping to reduce soil erosion and improve water quality

Agricultural and diffuse urban pollution have a major impact on water quality in lowland areas in the UK. Hard engineered solutions such as water treatment plants are much less effective in these circumstances than when dealing with point source pollutants, and there is growing interest in catchment sensitive farming and working with natural processes to tackle this issue. These aim to reduce the amount of sediment and pollutants entering the watercourses in the first place by, for example, adjusting farming practices and planting riparian buffer strips. Opportunity mapping focussed on identifying areas at the highest risk of sedimentation and soil erosion based on catchment land use characteristics, distance to a watercourse, slope length and land use erosion risk. It highlights areas across the whole catchment where changing land use would have the greatest impact on reducing soil erosion and hence improving water quality. Note that the focus is on sedimentation risk from agriculture, and built-up areas are not as well accounted for in the existing model.

Constraints are identified and mapped in the same way as before. These areas are erased from the water quality regulation map to leave a map showing water quality regulation in all unconstrained locations. This is then classified into percentiles and the top 50% extracted into another map. This map shows this top 50% of areas of land across the study area, broken down into three classes - 10%, 11-25%, and 26-50% - where sedimentation risk and soil erosion are currently highest and where there are no constraints on potentially altering land use.

As for water flow, the final opportunity map identifies a large number of very small polygons and long thin polygons that do not coincide with fields. The long thin polygons usually follow watercourses and are useful at identifying locations where riparian buffer stirps would be appropriate. However, there may also be opportunities for whole fields to be converted to other habitats (especially woodland). Therefore, whole fields offering the greatest opportunity to reduce soil erosion were identified. To do this, all the previously identified constraints are removed or erased from the underlying habitat basemap. The degree of intersection between the opportunity map and the underlying fields (polygons) in the basemap is then calculated. Fields where at least 50% of the field overlaps with the opportunity map are selected and exported to a new layer. Finally, very small polygons are deleted so that only fields and plots at least 0.1 ha in size are included in the final map.

2.2.6 Opportunity mapping results

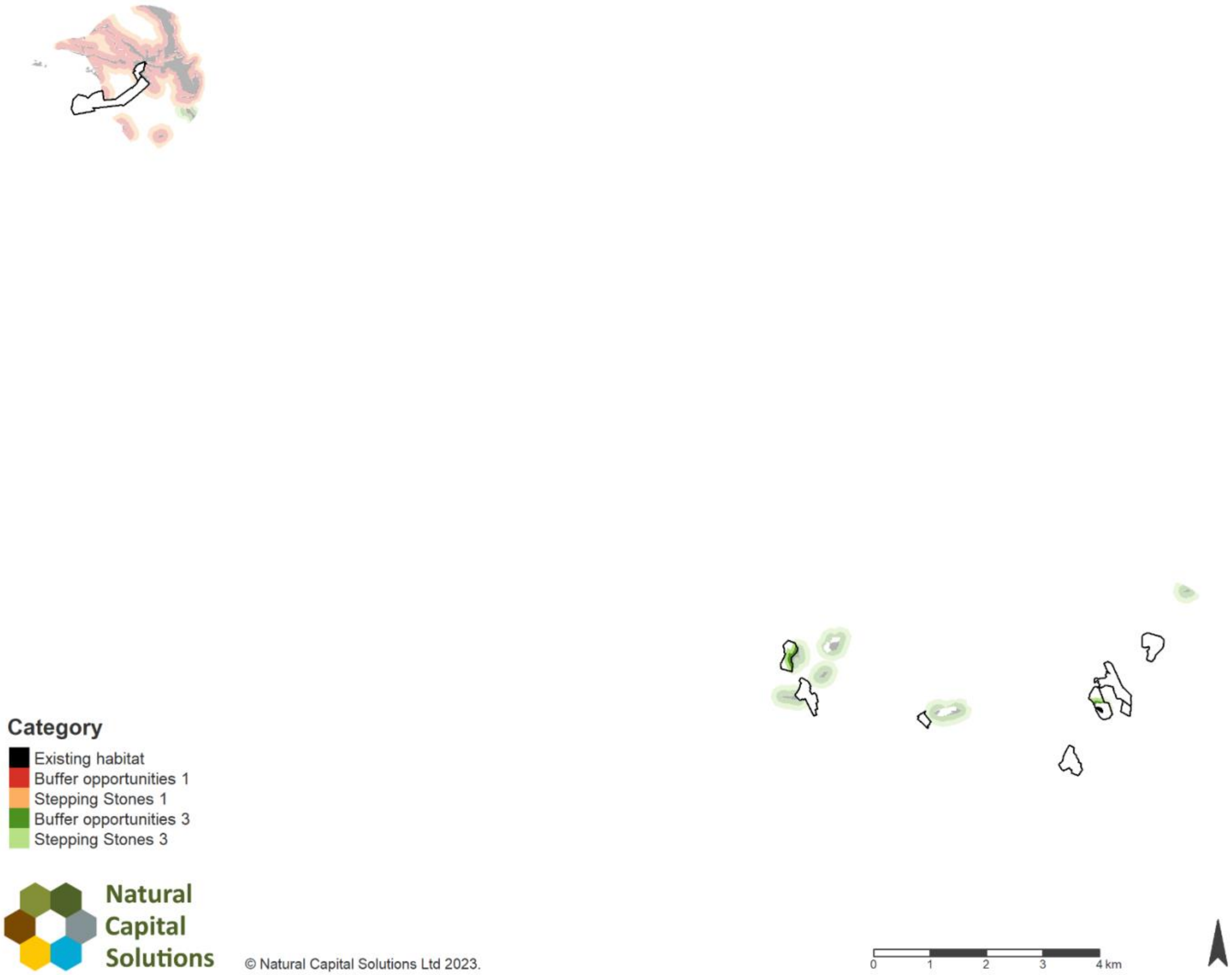
Opportunity mapping was completed to guide the type and location of the packages of interventions that would be implemented under Scenarios 1 and 2. All the farms unsurprisingly sit in a predominantly intensive agricultural landscape. Semi-natural habitats do occur, but tend to be small in area and fragmented, particularly where Farms C and D are located (Counties Antrim and Down). This means that there were no opportunities found to create new habitat that connected up existing semi-natural habitat networks for Farms C and D, and few opportunities for Farms A and B. We summarise the findings of the opportunity mapping for Farms A and B below:

Farm A

There were some opportunities for buffering and connecting up broadleaved woodlands with low priority ones at two of the lowland farm sites in the southwest and the southeast (Map 1). There was also an opportunity for creating wetland areas in one of the lowland sites to the south east of the farm (in the same place as woodland opportunities) (Map 2). There were no opportunities to create semi-natural grassland, heathland, or bog habitats on the farm that would connect up existing habitats. More numerous opportunities existed to create semi-natural habitats that would increase water flow and quality regulation at this farm (Maps 3 & 4). For example, woodland, semi-natural grasslands and wet grasslands at the lowland sites.

Farm B

At this farm there were opportunities to create broadleaved woodland and semi-natural grassland habitats in the southern site (Maps 5 & 6). Opportunities also existed to create semi-natural habitats that would increase water flow and quality regulation at this farm (Maps 7 & 8). For example, woodland, semi-natural grasslands and wet grasslands at the two lowland sites.



Map 1 Network woodland buffer and stepping stone opportunities for Farm A.

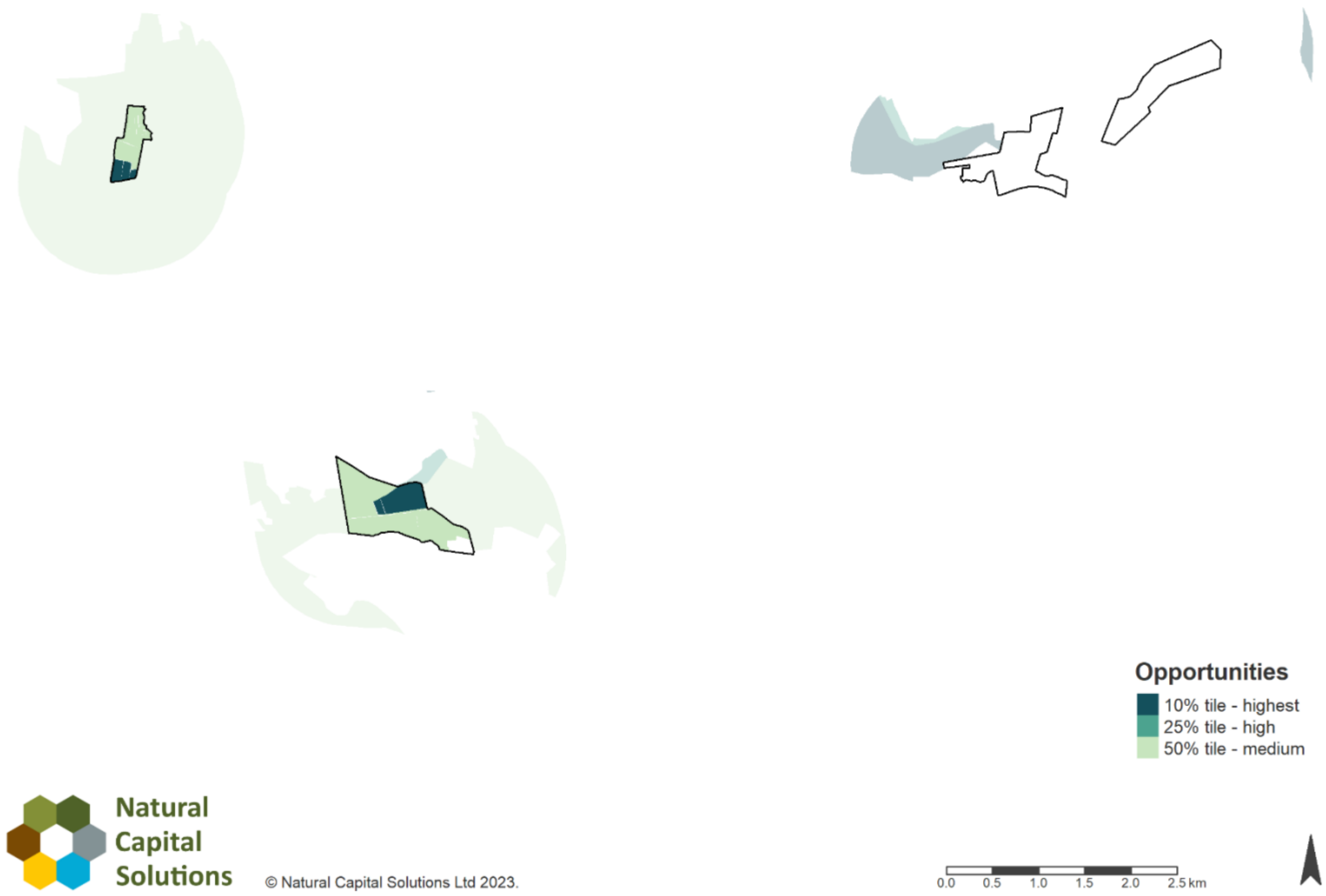
Map 2 Network lowland wetland buffer and stepping stone opportunities for Farm A.

Map 3 Water flow regulation opportunity areas across Farm A.

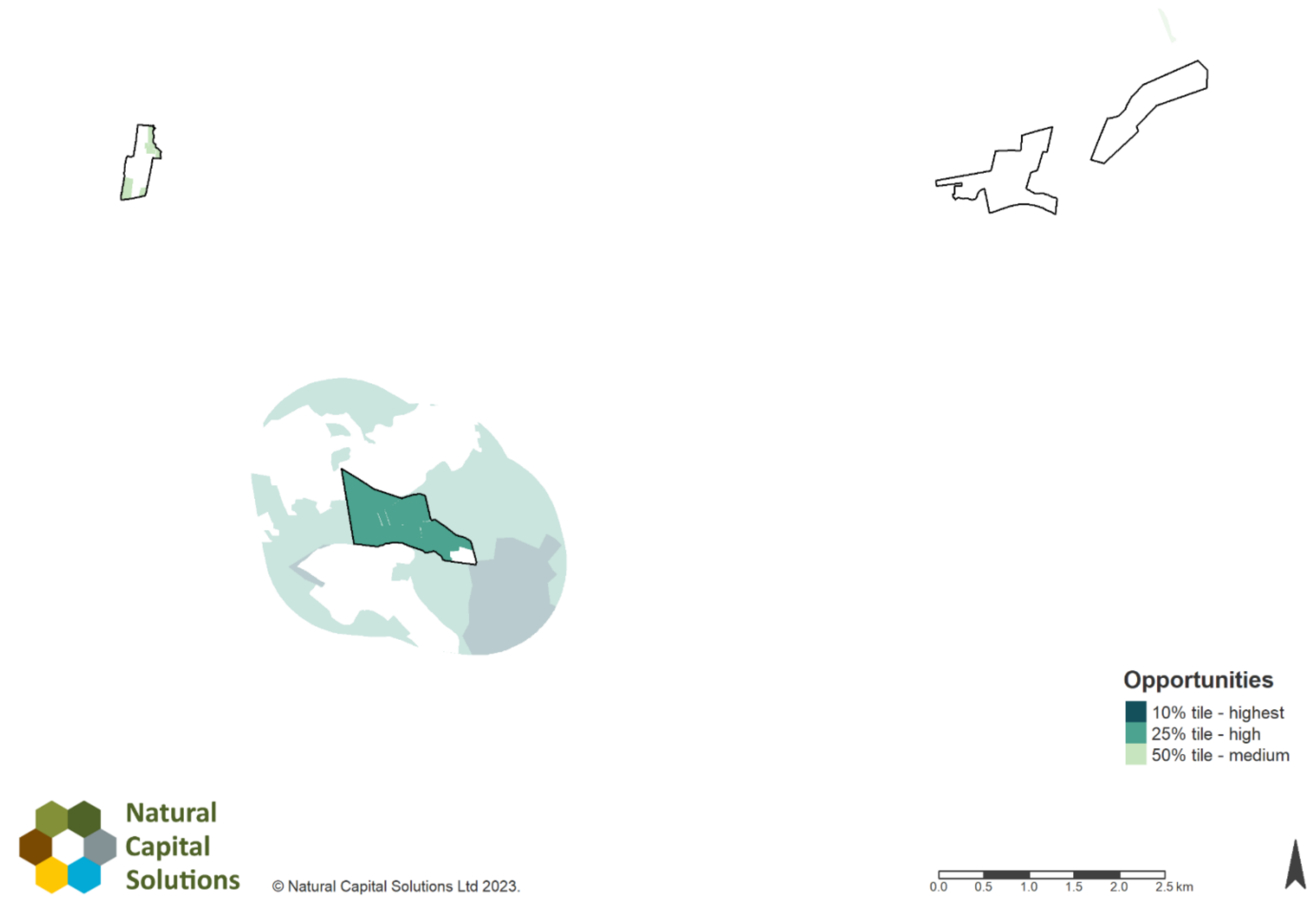
Map 4 Water quality regulation opportunity areas across Farm A.

Map 5 Network woodland buffer and stepping stone opportunities for Farm B.

Map 6 Network semi-natural grassland buffer and stepping stone opportunities for Farm B.



Map 7 Water flow regulation opportunity areas across Farm B.



Map 8 Water quality regulation opportunity areas across Farm B.

2.2.7 Options appraisal

After research into the current EFS wider and higher options (DAERA 2023)[30] it was possible to come up with suitable packages of options under Scenario 1 for each farm. The natural capital basemaps, maps of ecosystem service provision, biodiversity units and biodiversity and ecosystem service opportunity maps were used to guide the type and location of interventions that would enhance the provision of environmental benefits and habitat level biodiversity in both Scenarios 1 and 2.

We liaised with the RSPB NI biodiversity officers to guide the tailoring of interventions to support birds of conservation importance where they occurred. This was on the two upland/lowland cattle and sheep farms (Farm A and B) that were important for breeding curlew. At these farms we were not able to create new woodland within 500m of breeding wader sites, or create more hedgerows. Ponds and scrapes on grazed grassland was a priority for the farms to continue to be attractive to these birds of conservation importance.

It was also important to be realistic about what could be achieved on the farms, particularly for Scenario 2, although the aim was to still be quite ambitious here. We communicated with the case study farmers to access farm accounts and ascertain current farm management and aspirations for the farm business, to understand what level of nature restoration could be accommodated.

Once we had established packages of interventions under both scenarios for each of the farms, we created natural capital maps that reflected how the habitats would change. We did this by altering and re-running the baseline natural capital map and biodiversity baseline (see Sections 2.2.2 and 2.2.3 above). We then re-ran the ecosystem service provision mapping for the two scenarios for each farm (following the method in Section 2.2.4). The impact on ecosystem service provision of the packages of options in each of the scenarios could then be compared. It was also possible to compare the results across the farms to see how this more nature focused farming impacted on the different farming sectors.

2.3 Natural capital accounting / valuation

2.3.1 Quantifying physical and monetary flows

A natural capital accounting approach was used to value the environmental benefits that flow from the case study farms in the baseline and across Scenarios 1 and 2. A natural capital account first measures and values the natural capital assets of an area, based on the flow of ecosystem services and associated benefits from those assets. The following elements of a natural capital account for the study area were created:

- **Asset register** – the area and type of natural capital assets (completed as part of the natural capital asset mapping outlined in Section 2.2.2).
- **Physical flow account** – the biophysical annual flow of ecosystem services.
- **Monetary flow account** – the monetary value of the benefits calculated per annum.

The last step of natural capital accounting then compares the benefits to the costs (capital and operational expenditure), in the form of a balance sheet to derive a net natural capital asset value. Here, the benefits and costs comparison is completed in the context of the farm businesses, and this step of the natural capital accounting is tackled in the economic appraisal. See the Farm business appraisal in Annex 3 below for details on the methods.

It was possible to quantify and value the provision of a suite of ecosystem services that flow from the natural capital assets of the study area: air quality regulation, carbon sequestration, timber

30 DAERA Environmental Farming Scheme (EFS) https://www.daera-ni.gov.uk/topics/rural-development/environmental-farming-scheme-efs

production, flood reduction by woodland and water quality. It was not possible to quantify and value any cultural services for the farms, e.g. recreation, physical health or educational value, as there were no data on the number of people visiting, activities and level of exercise. It is important to understand that the ecosystem services it was possible to quantify and value here are not all of the services that will be flowing from the natural capital of the farms. Those valued have established methods and data available. So, this represents an incomplete picture of the value that is delivered by these farms, the value is likely to be higher. Nonetheless the valuation is a good indication of the magnitude and direction of change in the value of environmental benefits with changes in farm habitat and management. Please note that we did not present the value of the agricultural production service in the Valuation of environmental benefits chapter of the report as this was the focus of the Farm business and Economic appraisal chapters.

Annual monetary flows of ecosystem services were calculated in line with the System of Environmental-Economic Accounting (SEEA) framework and accounting principles (2017)[31], and the British Standard for Natural Capital Accounting for Organisations (BS 8632:2021)[32]. They were based on the latest valuation techniques available in the scientific literature, and recent Defra guidance bringing together the latest valuation approaches for ecosystem services (Defra ENCA, 2020)[33].

The annual monetary flows were discounted across the lifetime of the natural capital assets to produce a Present Value. We take into account the pattern of expected future flows of values associated with each service. For carbon sequestration and air pollution regulation there is data on how these flows change over time available from the UK Government (see references below). However, for the other services we have had to assume a constant flow over the asset's lifetime. Where possible we have based these annual and monetary flows on averages over the most recent 5 years. We also consider asset lifetime - the period over which services are expected to be provided. We calculate the Present Value over an asset life of 50 years as this seems a reasonable timeframe over which to assume renewable natural capital assets will last. It is standard to use 50 years in natural capital accounts, although sometimes this can extend to 100 years. In the case of a broadleaf woodland asset, 100 years would seem reasonable, but for other assets this may be shorter. A discount rate was then used to convert the expected stream of service flows into a current period estimate of overall value. The discount rate expresses a preference of the owner of an asset to receive income now rather than in the future. We applied the recommended HM Treasury standard discount rate[34] of 3.5% to the first 30 years of the asset life, and 3% from years 31-50 for all services.

Carbon balance

The carbon balance was derived from the sum of the carbon dioxide sequestered and GHG emissions across all habitats on the farms (woodland, agricultural emissions associated with grassland/arable and livestock, and all other habitats). Sequestration and emissions are measured in tonnes of carbon equivalent (tCO_2e). As this is a natural capital assessment, carbon sequestration is an ecosystem service and GHG emissions are a dis-service, the former is presented as a positive number and the emissions are reported as a negative number. It is important to note that this is the opposite way round to standard emissions reporting. A range of methods were used to capture the sequestration and emissions from the study area habitats.

The annual physical flow of the carbon sequestration service was calculated for the majority of habitats e.g. woodland on peat, heathland and bog (not including woodland on mineral soils and

31 System of Environmental-Economic Accounting (SEEA) Central Framework (2012) and Experimental Ecosystem Accounting principles (2017).

32 British Standard BS 8632 (2021) Natural capital accounting for organisations: https://www.bsigroup.com/en-GB/standards/bs-86322021/. Although this standard it aimed at applying natural capital accounting at the organisational level, the principles are the same when applied to geographic areas.

33 Defra (2020) Enabling a Natural Capital Approach (ENCA). Available at: https://www.gov.uk/guidance/enabling-a-natural-capital-approach-enca on 1 July 2020.

34 HM Treasury (2019) The Green Book. Crown Copyright.

agricultural habitats) by using sequestration and emissions data taken from Natural England (2021)[35], RSPB (2017)[36], with more detailed data on GHG flux from land covers on deep and shallow peat soils and from degraded peat bogs from Evans et al. (2017)[37]. It was assumed that woodland or woody habitats (e.g. hedgerows and tree corridors) on shallow peat soils did not cause any emissions. Usually, emissions from woodland on shallow peat are associated with commercial forestry practices, which were not applicable in this study. There were small areas on three of the farms where tree corridors, hedgerows or scrub skimmed the edges of a deep peat areas. Emissions have, therefore, been accounted for in these instances. However, in reality these emissions are likely to be lower or negligible due to (i) inaccuracies associated with the coarse nature of the GIS peat soils data (the data were 100m x 100m), and (ii) assumptions made about the level of emissions associated with trees, hedgerows and scrub (we assume hedgerows and scrub to be 50% of the emissions or sequestration of woodland because we don't have accurate emissions or sequestration factors for these habitats, it could actually be lower).

Carbon sequestration from woodland, parkland, hedges and scrub were calculated following the UK Woodland Carbon Code methodology and look-up tables (Woodland Carbon Code 2021)[38]. An average annual sequestration rate was used for coniferous woodland (averaged over a 60-year forestry period) and deciduous woodland (averaged over a 100-year forestry period). Parkland areas were assumed to have 20% tree cover, hedges and scrub were set at 50% of the broadleaved sequestration rate of woodland.

The greenhouse gas emissions associated with the livestock on the farms were calculated by multiplying the area of each grazed habitat type, crop type and the numbers of livestock by emissions figures for each grassland type and livestock type in Bateman et al. (2013[39]). These emission figures are based on three types of agricultural emissions:

- Emissions from typical farming practices (e.g. tillage, sowing, spraying, harvesting, and the production, storage and transportation of fertilizers and pesticides).
- Emissions of N2O from fertilizers.
- Emissions of N2O and methane from livestock, caused by enteric fermentation and the production of manure.

The monetary flows were calculated using the Government's central carbon price for 2023 (DBEIS 2021)[40]. Note that there is a new method for modelling carbon prices and the results present a non-traded value based on abatement costs. This carbon price is now only modelled up to 2050 due to the high level uncertainty after this year. However, the Government Green Book advises an annual growth rate of 1.5% for every year after 2050 for discounting purposes. The present value (PV) of the ability of the woodland to sequester carbon into the future was calculated by summing the values for each year over a 50-year period, after discounting using the standard discount rate suggested in HM Treasury (2019)[41]. The HM Treasury also provides low and high estimates of current and future non-traded carbon prices. These were used to provide a sensitivity analysis to the economic valuation of this ecosystem service.

35 Gregg, R. Elias, J., Alonso, I., Crosher, I., Muto, P. & Morecroft, M. (2021) Carbon storage and sequestration by habitat: a review of the evidence. (Second edition) Natural England Research Report NERR094.

36 RSPB (2017) Annexes to Accounting for Nature: A natural capital account for the RSPB's estate in England.

37 Evans, C., Artz, R., Moxley, J., Smyth, M-A., Taylor, E., Archer, N., Burden, A., Williamson, J., Donnelly, D., Thomson, A., Buys, G., Malcolm, H., Wilson, D., Renou-Wilson, F. (2017). Implementation of an emission inventory for UK peatlands. Report to the Department for Business, Energy and Industrial Strategy, Centre for Ecology and Hydrology, Bangor.88pp.

38 Woodland Carbon Code (2021) Carbon calculation guidance v2.4 March 2021. Forestry Commission.

39 Bateman, I. J. et al. (2013) Bringing ecosystem services into economic decision-making: Land use in the United Kingdom. Science 341 45-50.

40 DBEIS (2021) Carbon priced and sensitivities 2020-2050 for appraisal, in HM Treasury (2018) The Green Book. Central Government guidance on appraisal and evaluation, version 3. London.

41 HM Treasury (2019) The Green Book. Crown Copyright.

Air quality regulation

The ability of the woodland, hedges, scrub, grassland and heathland vegetation across the farms and scenarios to adsorb particulate matter ≤2.5µm in diameter ($PM_{2.5}$) was estimated. Quantifying the physical flow of the air quality regulation service provided by the woodland and grassland is based on the adsorption calculation in Powe & Willis (2004)[42] and the method in ONS (2016)[43]. The deposition rates for $PM_{2.5}$ in coniferous woodland, deciduous woodland, and grassland were taken from Powe & Willis (2004). Average background pollution concentrations for $PM^{2.5}$ were calculated using Defra data for the county in which the farm was located (Mapping background data for local authorities https://uk-air.defra.gov.uk/data/laqm-background-maps?year=2018). The surface area index of coniferous and deciduous woodlands in on-leaf and off-leaf periods is taken from Powe & Willis (2004). The proportion of dry days in 2021 (rainfall <1mm) for Northern Ireland was estimated using MET office regional value data (http://www.metoffice.gov.uk/climate/uk/summaries/datasets). The proportion of on-leaf relative to off-leaf days is estimated at the UK level using the average number of bare leaf days for five of the most common broadleaf tree species (ash, beech, horse chestnut, oak, silver birch) in the UK using the Woodland Trust data averages tool.

The air quality regulation service is valued using guidance from Defra that provides estimates of the damage costs per tonne of emissions across the UK (Defra 2021)[44]. These are social damage costs based on avoided mortality and morbidity. Therefore, it is assumed that the value of each tonne of adsorbed pollutant by the woodland and grassland habitats is equal to the average damage cost of that pollutant. The $PM_{2.5}$ damage cost estimates depend on the location (urban size or rural, so is adjusted for lower population densities) and source of pollution. The rural damage costs were applied to the study area (these are an average across rural areas, rather than a specific value associated with the study area). The Defra damage cost of $PM_{2.5}$ is in 2017 prices, and so was adjusted to reflect inflation up to 2023. The value is also subject to an uplift of 2% per annum to reflect the assumption that willingness to pay for health will rise in line with economic growth, as recommended by Defra (2021)[31]. Defra (2021) provide low, central and high damage costs which were used in the sensitivity analysis. Although pollution from particulate matter may not be as high in this rural study area as in a city, it is present. In addition, there is ammonia pollution from agriculture, which has similar human health impacts. Valuing the service in this way can also illustrate the cost savings delivered by the woodland take up of ammonia.

Timber and woodfuel production

For existing woodland, potential annual physical flows of timber/woodfuel production were calculated in terms of average annual yield, by multiplying the yield class of the different species by the area of each woodland type (these were established when valuing the carbon sequestration of woodland, see carbon balance section above). The annual monetary flows for the woodland areas were calculated by multiplying the yield by the standing price of timber or woodfuel. The average price for softwood in 2020 is taken from the Forestry Commissions Coniferous Standing Sales Price Index (Forestry Commission 2020[45]). The price for broadleaved timber in 2023 ranged from £50 to high quality timber reaching £350 per m^3 standing (ABC 2022[46]). To convert to a present value the annual value is multiplied by the standard government discount rate for each respective year up to 50 years. It is assumed that the area of woodland remains static and the unit price is also assumed to be constant. Low and high estimates were calculated to be 0.75 and 1.25 times the central estimate respectively for the sensitivity analyses.

42 Powe, N., A., & Willis, K.G. (2004) Mortality and morbidity benefits of air pollution (SO2 and PM10) absorption attributable to woodland in Britain. Journal of Environmental Management, 70, 119-128.

43 ONS (2016) Annex 1: Background and methods for experimental pollution removal estimates. UK National Accounts.

44 Defra (2021) Air quality damage costs guidance. Crown Copyright.

45 Forestry Commission (2020) Timber price indices. Data to March 2020.

46 ABC (2022) The agricultural budgeting and costing book. 94th edition, Argo Business Consultants.

The timber and woodfuel production approach used here is a way of estimating a value of all of the woodland in the region (commercial forestry and semi-natural woodlands). It is not to suggest that the woodlands in the area will be used for this purpose or to suggest that this is the only value of woodlands. We recognise that other benefits (regulating and cultural) are provided by woodland which is captured in the other services valued. It is important to recognise that the value of the other benefits from woodland combined are much higher that the timber and woodfuel value (e.g. woodland carbon sequestration, air quality regulation, flood reduction by woodland and water quality regulation by woodland, and social value).

Reduction of flood risk by woodland

All natural surfaces can take up water, but it remains difficult to quantify and value for most habitats. A study by Forest Research[47], that has been included in the Defra ENCA service data book, and has been used in the new Environment Agency Natural Capital Register and Account Tool (NCRAT) V1[48], allows this to be quantified and valued for woodland. The physical flow is measured as the m^3 of annual flood water storage provided by woodland, derived from Broadmeadow et al. (2018)[49]. This is valued using a replacement-cost (rather than damage cost) approach, which applies annualised average capital and operating costs of flood reservoir storage that might be created in situations where flood risk would arise in the absence of the ecosystem service. The total area of woodland cover in each scenario was simply multiplied by the annual flood storage (canopy interception and annual average soil water capacity) provided by woodland in Great Britain (in the absence of suitable data for Northern Ireland). The proportion of this woodland that occurred on a floodplain was then used to calculate floodplain storage. The sum of these was then valued by multiplying it by the central estimate of the replacement cost adjusted to 2023 prices. To convert to a present value the annual value was multiplied by the standard government discount rate for each respective year up to 50 years. Low and high estimates were calculated to be 0.75 and 1.25 times the central estimate respectively for the sensitivity analyses.

Water quality

Two different approaches were used to value the benefits of woodland on water quality, both matching the approach taken to valuation used by the Forestry Commission when developing their EWCO[50]. The first, or "water quality" approach is based on the annual cost of agricultural diffuse pollution in England, which was estimated by Defra[51] to range from £748-1,307M (in 2014 prices), which was itself based on an earlier study by IGER[52]. This amount is divided by the total area of agricultural land in England of 9.16 M ha, to give an average cost of £82-143 per ha per year. Note that this represents a national average of all types of agriculture and arable cropping. Agricultural diffuse pollution can also vary greatly by location. The lower estimate was taken as a lower bound estimate of water quality benefits and inflated to 2023 prices.

The second, or "riparian" approach was based on the Environment Agency's NWEBS toolkit[53]. NWEBS calculates the value of improving the quality of 1km of river, based on a willingness to pay study. We

47 Broadmeadow, S. et al. (2018) Valuing flood regulation services of existing forest cover to inform natural capital accounts. Forest Research.

48 Environment Agency Natural Capital Register and Account Tool, Version 1. (January 2021).

49 Broadmeadow, S. et al. (2018) Valuing flood regulation services of existing forest cover to inform natural capital accounts. Forest Research.

50 Forestry Commission (2022) England woodland creation offer grant manual. V3.0. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1093023/EWCO_Grant_Manual_v3.0_.pdf

51 Defra (2018) Water Quality and Agriculture: Basic Measures Impact Assessment. IA No: Defra1819.

52 IGER (2006). Benefits and Pollution Swapping: Cross-cutting issues for Catchment Sensitive Farming Policy. Research Report WT0706CSF for Defra, Institute of Grassland and Environmental Research.

53 EA (2013b) Valuing Environmental Benefits. External Briefing Note, Environment Agency.

used the value for improving rivers from poor to moderate levels, as recommended by the EA and also matching the FC EWCO approach. NWEBS provides values for each catchment in England and Wales[54], hence we used the average across both for Northern Ireland. The NWEBS figure is based on 6 equal components, a number of which were directly related to biodiversity and recreation. To avoid double counting, these elements were stripped out, leaving 2 out of 6 components (so using 2/6 of the value), following the approach taken by FC EWCO. This derived an annual value of £368 per hectare, and was inflated to 2023 prices. To convert to a present value the annual value was multiplied by the standard government discount rate for each respective year up to 50 years. Low and high estimates were calculated to be 0.75 and 1.25 times the central estimate respectively for the sensitivity analyses.

2.3.2 Additional results from the valuation of environmental benefits

The central annual monetary flows (£2023) of the environmental benefits were presented in the report for each of the five ecosystem services quantified. Here, we also present the Present Values for those central annual values (Tables 2-13 below), and a sensitivity analysis that reveals the lower and upper values around them (Section 2.3.3 Tables 14-25).

Farm A

Table 2 Annual physical flows, annual monetary flows and present values for the Farm A baseline condition.

Ecosystem services	**Annual physical flow**	**Annual monetary flow (£2023)**	**Present Value (£ million)**
Carbon balance (tCO2e/yr)	-235.30	-64,000	-2.12
Sequestration by woodland	8.09	2,200	0.07
Emissions from woodland on peat soil	-1.09	-300	-0.009
All other habitats	32.86	8,900	0.29
Agricultural emissions	-275.16	-74,800	-2.48
Air quality (tPM2.5/yr)	0.15	5,400	0.19
Timber production (m3/yr)	7.31	400	0.009
Flood reduction by woodland (m3)	166.83	80	0.002
Water quality regulation by woodland (ha of woodland)	0.95	100	0.002
Total	**-**	**-58,000**	**-1.91**

54 EA (2013a). Updating the National Water Environment Benefit Survey values: summary of the peer review. Environment Agency.

Table 3 Annual physical flows, annual monetary flows and present values for the Farm A Scenario 1.

Ecosystem services	**Annual physical flow**	**Annual monetary flow (£2023)**	**Present Value (£ million)**
Carbon balance (tCO2e/yr)	-66.01	-16,900	-0.55
Sequestration by woodland	9.14	2,500	0.08
Emissions from woodland on peat soil	-1.63	-400	-0.01
All other habitats	76.72	20,900	0.69
Agricultural emissions	-146.23	-39,800	-1.31
Air quality (tPM2.5/yr)	0.16	5,900	0.21
Timber production (m3/yr)	19.74	1,000	0.02
Flood reduction by woodland (m3)	552.27	300	0.006
Water quality regulation by woodland (ha of woodland)	2.40	300	0.007
Total	**-**	**-9,300**	**-0.30**

Table 4 Annual physical flows, annual monetary flows and present values for the Farm A Scenario 2.

Ecosystem services	**Annual physical flow**	**Annual monetary flow (£2023)**	**Present Value (£ million)**
Carbon balance (tCO2e/yr)	12.05	-3,300	0.10
Sequestration by woodland	29.20	7,900	0.26
Emissions from woodland on peat soil	-1.60	-400	-0.01
All other habitats	81.15	22,000	0.73
Agricultural emissions	-96.70	-26,300	-0.87
Air quality (tPM2.5/yr)	0.31	11,500	0.41
Timber production (m3/yr)	141.03	7,700	0.19
Flood reduction by woodland (m3)	5380.07	2,700	0.06
Water quality regulation by woodland (ha of woodland)	18.32	1,900	0.04
Total	-	**27,000**	**0.82**

Farm B

Table 5 Annual physical flows, annual monetary flows and present values for the Farm B baseline condition.

Ecosystem services	Annual physical flow	Annual monetary flow (£2023)	Present Value (£ million)
Carbon balance (tCO2e/yr)	-114.38	-31,100	-1.03
Sequestration by woodland	0.16	40	0.001
Emissions from woodland on peat soil	0.00	0.00	0.00
All other habitats	148.45	40,400	1.33
Agricultural emissions	-262.99	-71,500	-2.37
Air quality (tPM2.5/yr)	0.37	13,400	0.48
Timber production (m3/yr)	30.71	1,700	0.04
Flood reduction by woodland (m3)	1912.69	900	0.02
Water quality regulation by woodland (ha of woodland)	3.99	400	0.009
Total	-	**-14,600**	**-0.46**

Table 6 Annual physical flows, annual monetary flows and present values for the Farm B Scenario 1.

Ecosystem services	Annual physical flow	Annual monetary flow (£2023)	Present Value (£ million)
Carbon balance (tCO2e/yr)	-109.66	-29,800	-0.98
Sequestration by woodland	0.16	40	0.001
Emissions from woodland on peat soil	0.00	0.00	0.00
All other habitats	148.45	40,400	1.33
Agricultural emissions	-258.27	-70,300	-2.33
Air quality (tPM2.5/yr)	0.37	13,400	0.48
Timber production (m3/yr)	30.67	1,700	0.04
Flood reduction by woodland (m3)	1,911.81	900	0.02
Water quality regulation by woodland (ha of woodland)	3.98	400	0.009
Total	**-**	**-13,400**	**-0.43**

Table 7 Annual physical flows, annual monetary flows and present values for the Farm B Scenario 2.

Ecosystem services	Annual physical flow	Annual monetary flow (£2023)	Present Value (£ million)
Carbon balance (tCO2e/yr)	193.63	52,700	1.74
Sequestration by woodland	0.16	40	0.001
Emissions from woodland on peat soil	0.00	0.00	0.00
All other habitats	266.20	72,400	2.40
Agricultural emissions	-72.73	-19,800	-0.65
Air quality (tPM2.5/yr)	0.45	16,500	0.59
Timber production (m3/yr)	88.27	4,800	0.11
Flood reduction by woodland (m3)	4,240.80	2,100	0.05
Water quality regulation by woodland (ha of woodland)	11.46	1,200	0.02
Total	**-**	**77,300**	**2.54**

Farm C

Table 8 Annual physical flows, annual monetary flows and present values for the Farm C baseline condition.

Ecosystem services	Annual physical flow	Annual monetary flow (£2023)	Present Value (£ million)
Carbon balance (tCO2e/yr)	-561.71	-152,800	-5.06
Sequestration by woodland	83.17	22,600	0.75
Emissions from woodland on peat soil	-0.94	-300	-0.008
All other habitats	11.52	3,100	0.10
Agricultural emissions	-655.46	-178,300	-5.91
Air quality (tPM2.5/yr)	0.29	19,200	0.68
Timber production (m3/yr)	76.88	4,200	0.10
Flood reduction by woodland (m3)	1755.36	900	0.02
Water quality regulation by woodland (ha of woodland)	9.99	1,000	0.02
Total	**-**	**-127,400**	**-4.22**

Table 9 Annual physical flows, annual monetary flows and present values for the Farm C Scenario 1.

Ecosystem services	Annual physical flow	Annual monetary flow (£2023)	Present Value (£ million)
Carbon balance (tCO2e/yr)	-234.60	-63,800	-2.11
Sequestration by woodland	105.22	28,600	0.94
Emissions from woodland on peat soil	-1.48	-400	-0.01
All other habitats	35.25	9,600	0.31
Agricultural emissions	-373.59	-101,600	-3.37
Air quality (tPM2.5/yr)	0.44	29,100	1.04
Timber production (m3/yr)	162.96	9,000	0.22
Flood reduction by woodland (m3)	3720.63	1,900	0.04
Water quality regulation by woodland (ha of woodland)	21.16	2,100	0.05
Total	**-**	**-21,700**	**-0.75**

Table 10 Annual physical flows, annual monetary flows and present values for the Farm C Scenario 2.

Ecosystem services	Annual physical flow	Annual monetary flow (£2023)	Present Value (£ million)
Carbon balance (tCO2e/yr)	132.91	36,200	1.19
Sequestration by woodland	236.74	64,400	2.13
Emissions from woodland on peat soil	-20.91	-5,700	-0.18
All other habitats	25.72	7,000	0.23
Agricultural emissions	-108.65	-29,600	-0.98
Air quality (tPM2.5/yr)	1.00	66,200	2.36
Timber production (m3/yr)	450.67	24,800	0.61
Flood reduction by woodland (m3)	14930.66	7.400	0.18
Water quality regulation by woodland (ha of woodland)	58.53	5,900	0.14
Total	**-**	**140,500**	**4.50**

Farm D

Table 11 Annual physical flows, annual monetary flows and present values for the Farm D baseline condition.

Ecosystem services	**Annual physical flow**	**Annual monetary flow (£2023)**	**Present Value (£ million)**
Carbon balance (tCO2e/yr)	-18.55	-5,000	-0.16
Sequestration by woodland	0.79	200	0.007
Emissions from woodland on peat soil	0.00	0	0
All other habitats	0.00	0	0
Agricultural emissions	-19.33	-5,300	-0.17
Air quality (tPM2.5/yr)	0.02	1,200	0.04
Timber production (m3/yr)	0.00	0	0
Flood reduction by woodland (m3)	0.00	0	0
Water quality regulation by woodland (ha of woodland)	0.00	0	0
Total	**-**	**-3,800**	**-0.12**

Table 12 Annual physical flows, annual monetary flows and present values for the Farm D Scenario 1.

Ecosystem services	**Annual physical flow**	**Annual monetary flow (£2023)**	**Present Value (£ million)**
Carbon balance (tCO2e/yr)	10.60	2,900	0.09
Sequestration by woodland	18.27	5,000	0.16
Emissions from woodland on peat soil	0.00	0	0
All other habitats	3.92	1,000	0.03
Agricultural emissions	-11.59	-3,200	-0.10
Air quality (tPM2.5/yr)	0.05	3,600	0.12
Timber production (m3/yr)	15.91	900	0.02
Flood reduction by woodland (m3)	363.20	200	0.004
Water quality regulation by woodland (ha of woodland)	2.07	200	0.005
Total	**-**	**7,800**	**0.25**

Table 13 Annual physical flows, annual monetary flows and present values for the Farm D Scenario 2 (the values are the same for silvo-pastoral and arable with woodfuel or orchard).

Ecosystem services	**Annual physical flow**	**Annual monetary flow (£2023)**	**Present Value (£ million)**
Carbon balance (tCO2e/yr)	26.89	7,300	0.24
Sequestration by woodland	28.98	7,900	0.26
Emissions from woodland on peat soil	-1.67	-500	-0.01
All other habitats	2.50	700	0.02
Agricultural emissions	-2.92	-800	-0.02
Air quality (tPM2.5/yr)	0.12	8,300	0.29
Timber production (m3/yr)	41.19	2,300	0.05
Flood reduction by woodland (m3)	940.49	500	0.01
Water quality regulation by woodland (ha of woodland)	5.35	500	0.01
Total	**-**	**18,900**	**0.61**

2.3.3 Sensitivity analysis

A sensitivity analysis examined the low, central and high present value estimates of all the benefits we valued for each scenario across each of the farms (Table 2.3…).

Farm A

Table 14 Sensitivity analysis showing low, central, and high present value estimates of the benefits provided by natural capital assets of Farm A baseline condition.

	Low (£)	**Central (£)**	**High (£)**
Carbon balance (tCO2e/yr)	-1.06	-2.12	-3.18
Air quality (tPM2.5/yr)	0.04	0.19	0.60
Timber production (m3/yr)	0.01	0.009	0.01
Flood reduction by woodland (m3)	0.00	0.002	0.00
Water quality regulation by woodland (ha of woodland)	0.00	0.002	0.00
Total	**-1.00**	**-1.92**	**-2.58**

Table 15 Sensitivity analysis showing low, central, and high present value estimates of the benefits provided by natural capital assets of Farm A Scenario 1.

	Low (£)	**Central (£)**	**High (£)**
Carbon balance (tCO2e/yr)	-0.27	-0.55	-0.83
Air quality (tPM2.5/yr)	0.05	0.21	0.65
Timber production (m3/yr)	0.02	0.02	0.03
Flood reduction by woodland (m3)	0.01	0.006	0.01
Water quality regulation by woodland (ha of woodland)	0.01	0.007	0.01
Total	**-0.21**	**-0.34**	**-0.18**

Table 16 Sensitivity analysis showing low, central, and high present value estimates of the benefits provided by natural capital assets of Farm A Scenario 2.

	Low (£)	Central (£)	High (£)
Carbon balance (tCO2e/yr)	0.05	0.10	0.16
Air quality (tPM2.5/yr)	0.09	0.41	1.26
Timber production (m3/yr)	0.14	0.19	0.23
Flood reduction by woodland (m3)	0.04	0.06	0.08
Water quality regulation by woodland (ha of woodland)	0.03	0.04	0.05
Total	**0.20**	**0.48**	**1.30**

Farm B

Table 17 Sensitivity analysis showing low, central, and high present value estimates of the benefits provided by natural capital assets of Farm B baseline condition.

	Low (£)	Central (£)	High (£)
Carbon balance (tCO2e/yr)	-0.51	-1.03	-1.54
Air quality (tPM2.5/yr)	0.11	0.48	1.48
Timber production (m3/yr)	0.03	0.04	0.05
Flood reduction by woodland (m3)	0.01	0.02	0.02
Water quality regulation by woodland (ha of woodland)	0.007	0.009	0.01
Total	**-0.39**	**-0.56**	**-0.10**

Table 18 Sensitivity analysis showing low, central, and high present value estimates of the benefits provided by natural capital assets of Farm B Scenario 1.

	Low (£)	Central (£)	High (£)
Carbon balance (tCO2e/yr)	-0.49	-0.98	-1.48
Air quality (tPM2.5/yr)	0.11	0.48	1.48
Timber production (m3/yr)	0.03	0.04	0.05
Flood reduction by woodland (m3)	0.01	0.02	0.02
Water quality regulation by woodland (ha of woodland)	0.007	0.009	0.01
Total	**-0.37**	**-0.52**	**-0.04**

Table 19 Sensitivity analysis showing low, central, and high present value estimates of the benefits provided by natural capital assets of Farm B Scenario 2.

	Low (£)	Central (£)	High (£)
Carbon balance (tCO2e/yr)	0.87	1.74	2.62
Air quality (tPM2.5/yr)	0.13	0.59	1.83
Timber production (m3/yr)	0.08	0.11	0.14
Flood reduction by woodland (m3)	0.03	0.05	0.06
Water quality regulation by woodland (ha of woodland)	0.02	0.02	0.03

Total	**1.03**	**2.28**	**4.31**

Farm C

Table 20 Sensitivity analysis showing low, central, and high present value estimates of the benefits provided by natural capital assets of Farm C baseline condition.

	Low (£)	**Central (£)**	**High (£)**
Carbon balance (tCO2e/yr)	-2.53	-5.06	-7.60
Air quality (tPM2.5/yr)	0.15	0.68	2.12
Timber production (m3/yr)	0.08	0.10	0.13
Flood reduction by woodland (m3)	0.02	0.02	0.03
Water quality regulation by woodland (ha of woodland)	0.02	0.02	0.03
Total	**-2.27**	**-4.22**	**-5.29**

Table 21 Sensitivity analysis showing low, central, and high present value estimates of the benefits provided by natural capital assets of Farm C Scenario 1.

	Low (£)	**Central (£)**	**High (£)**
Carbon balance (tCO2e/yr)	-1.06	-2.11	-3.17
Air quality (tPM2.5/yr)	0.23	1.04	3.21
Timber production (m3/yr)	0.17	0.22	0.28
Flood reduction by woodland (m3)	0.03	0.04	0.06
Water quality regulation by woodland (ha of woodland)	0.04	0.05	0.07
Total	**-0.59**	**-0.75**	**0.43**

Table 22 Sensitivity analysis showing low, central, and high present value estimates of the benefits provided by natural capital assets of Farm C Scenario 2.

	Low (£)	**Central (£)**	**High (£)**
Carbon balance (tCO2e/yr)	0.60	1.19	1.79
Air quality (tPM2.5/yr)	0.52	2.36	7.28
Timber production (m3/yr)	0.46	0.61	0.76
Flood reduction by woodland (m3)	0.14	0.18	0.23
Water quality regulation by woodland (ha of woodland)	0.11	0.14	0.18
Total	**1.82**	**4.50**	**10.26**

Farm D

Table 23 Sensitivity analysis showing low, central, and high present value estimates of the benefits provided by natural capital assets of Farm D baseline condition.

	Low (£)	Central (£)	High (£)
Carbon balance (tCO2e/yr)	-0.08	-0.16	-0.25
Air quality (tPM2.5/yr)	0.01	0.04	0.13
Timber production (m3/yr)	0	0	0
Flood reduction by woodland (m3)	0	0	0
Water quality regulation by woodland (ha of woodland)	0	0	0
Total	**-0.07**	**-0.12**	**-0.11**

Table 24 Sensitivity analysis showing low, central, and high present value estimates of the benefits provided by natural capital assets of Farm D Scenario 1.

	Low (£)	Central (£)	High (£)
Carbon balance (tCO2e/yr)	0.05	0.09	0.14
Air quality (tPM2.5/yr)	0.03	0.12	0.40
Timber production (m3/yr)	0.02	0.02	0.03
Flood reduction by woodland (m3)	0.003	0.004	0.01
Water quality regulation by woodland (ha of woodland)	0.003	0.005	0.006
Total	**0.09**	**0.25**	**0.58**

Table 25 Sensitivity analysis showing low, central, and high present value estimates of the benefits provided by natural capital assets of Farm D Scenario 2. Note that the values are the same whether using apple trees or broadleaves for woodfuel for the silvo-pastoral and silvo-arable systems.

	Low (£)	Central (£)	High (£)
Carbon balance (tCO2e/yr)	0.12	0.24	0.36
Air quality (tPM2.5/yr)	0.06	0.29	0.91
Timber production (m3/yr)	0.04	0.05	0.07
Flood reduction by woodland (m3)	0.008	0.01	0.01
Water quality regulation by woodland (ha of woodland)	0.01	0.01	0.02
Total	**0.24**	**0.61**	**1.37**

This analysis demonstrates the overall sensitivity of the natural capital values. The overall natural capital present value ranges significantly. These large difference highlight the challenges of placing a monetary value on some services.

This analysis also shows the high levels of uncertainty inherent in valuing ecosystem service benefits. Valuation of ecosystem services should be seen as appropriate at indicating the approximate magnitude of benefits, but not their exact values. It has allowed the comparison of values for a broad suite of services to be compared across the scenarios of each farm. It also demonstrates the range of benefits that the natural environment can provide on these farms under each of the scenarios. However, these results need to be interpreted with care, and in the knowledge that whilst the highest quality and most readily available data and methods were used, there are limitations and assumptions that need to be considered (Table 26).

Work is progressing rapidly on the calculation of physical and monetary flows of ecosystem services from natural capital assets, but it remains a developing area. A number of ecosystem services remain difficult to quantify and value. Some are highly location specific, for example, water flow and impact on downstream flood risk. This can be quantified and valued by running detailed hydrological and flood risk modelling, but it is difficult to generalise. Others, such as water quality can be modelled but are very difficult to value, while there are additional cultural services, such as aesthetic experiences, cultural heritage, spiritual experience and sense of place that are difficult to quantify. Consequently, the valuations presented in this section place values on several key benefits, but these are necessarily incomplete.

Table 26 Summary of uncertainties in the calculation of physical flows and monetary values of each natural capital benefit, and an overall assessment of confidence, using a red, amber, green (RAG) rating.

Natural capital benefits	Assessment of uncertainties	RAG rating
Air quality regulation	Biophysical estimates based on averages for broadleaved and coniferous trees and grassland. Valuation follows ONS guidance.	
Carbon balance	Well studied. Standardised carbon lookup tables available, with agricultural emissions receiving increasing attention as part of climate change accounting. Valuation uses UK Government non-traded carbon price.	
Timber production	Well studied over many years as part of forestry management. Valuation uses market prices.	
Flood reduction	The SWAT+ (Soil & Water Assessment Tool) model was utilised to extract m^3 of water regulation per year. This model can assess the impacts of land use management on hydrology and water quality.	
Water quality	The “water quality” Figure is crude and a lower-bound estimate as it simply gives the average damage cost of agriculture over England. The “riparian” Figure is based on a large number of major assumptions and should be treated with caution.	

Annex 3. Farm business appraisal

3.1 Context and aim

The study explored options for plausible futures for representative types of farms in Northern Ireland that could reconcile agricultural and environmental objectives while maintaining the viability of the farm as a business. The Annex is not intended to stand alone. It provides supporting material for the main report on methods and results.

3.2 Objectives

The objectives were, using illustrative real case study farms, to identify, relative to the baseline situation, the financial implications for the farm business of two possible future Scenarios of the uptake of environmental options. Scenario 1 involves the adoption of option currently available under EFS and Scenario 2 uses a broader range of options to deliver enhanced environmental outcomes. A secondary objective was to assess the wider economic value of agricultural benefits, selected quantified ecosystem services and agri-environment benefits, net of costs, of the scenarios for each case study farm.

3.3 Approach

3.3.1 Selection of case study farms

Four case study farms were sought to representative of the *__type__* of farms in Northern Ireland as well as geographic spread. Approximately 80% of farms by number in Northern Ireland are beef and sheep farms, 10% are diary, about 5% are arable, mainly general cropping (there are very few cereal- only farms), less than 1% are specialist horticultural, and the balance are pig, poultry and other farms[55]. In this context, the selected case study farms comprised two sheep and beef farms (one in the east and one in the east), one dairy farm and one arable farm. The particular farms were selected because the business owners were willing to participate in the study.

The two LFA livestock grazing farms at 113 ha and 180ha, mainly producing sheep with beef, are larger than the average size of 90 ha for the sub sector, but average in size for the amount of labour employed on the farm. While the dairy farm at 112 ha (excluding woodland) is near to the average dairy farm size of 125 ha, very high milk yields and zero grazed system puts it in the top 10% of dairy farms by performance. The arable farm at 150 ha, relative to an average size of 65 ha for general cropping farms, is a relatively rare example of a specialist salad and vegetable production, operating within a cereals/grass-for-energy rotation.

The particular characteristics of the farms mean that caution is required when transferring from the specific to the general case. Nonetheless, the farms are considered representative of the major ‘types’ of farms in Northern Ireland and of the challenges facing business owners as they seek to align agricultural and environmental objectives while securing business viability. We appreciate the willingness of the farmers to take part in the study.

3.3.2 Data sources and collection methods

Farm business data were obtained from two main sources, namely:

[55] DAERA. 2023. Statistical Review of Northern Ireland Agriculture 2022. Belfast:DAERA.

(i) published statistics on farm incomes and performance in Northern Ireland [56, 57] [58]over the period 2016/2017 – 2021/22, supported by farm management data from elsewhere in the UK [59, 60];

(ii) farm-specific physical and financial data, including financial accounts, provided by the farmers and subject to confidentiality agreements, obtained by email and telephone correspondence, supported by a personal visit to each farm in early June 2023.

Data from farms were corroborated with NI data sets according to farm type. 2022/23 harvest year prices were used throughout, with data from prior years adjusted for inflation, (serving to dampen the effects of recent spikes in agricultural output and inputs prices).

Critical assumptions were subject to sensitivity analysis to produce a range of estimates. A brief review of agricultural and environmental policy in Northern Ireland informed the analysis and the interpretation of results

3.3.3 Steps in the financial analysis

Figure 1 shows the steps involved in assessing the financial impact on the farm business of the land use and management changes associated with the adoption of the environmental options under each scenario in the process. The steps are described in turn, supported below by the results generated for Farm A as an illustrative case.

1 Information on existing farmland use, crop areas, livestock numbers and on land and enterprise management was collected in discussion with the farmer for the baseline situation, supported by a structured questionnaire and data collection checklists.

2 Farmland use and management data were combined with information from the ecological and habitats survey to support the identification of environmental enhancement opportunities under each of the two change Scenarios. This was done by major habitat type and the main (often fragmented) blocks of land that make up the farm.

3 The mapping of environmental opportunities was simultaneously aligned with a menu of agri-environment options for Scenario 1 based on current EFS options and for Scenario 2 which included EFS and a broader range of options.

4 The Scenarios were then described in terms of the take up of agri-environment options for the main blocks of land and habitats by type and area. These were aggregated at the farm scale for each Scenario in terms of the type and extent of take up.

[56] https://www.northernireland.gov.uk/news/northern-ireland-agricultural-incomes-2022
[57] https://www.daera-ni.gov.uk/news/farm-performance-202122
[58] DAERA. 2023. Statistical Review of Northern Ireland Agriculture 2022. Belfast:DAERA.
[59] Redman, G. (2022, 2023). The John Nix Pocketbook for Farm Management. 52nd and 53rd editions, Melton Mowbray, Agro-Business Consultants
[60] https://www.fas.scot/publication/farm-management-handbook-2022-23/

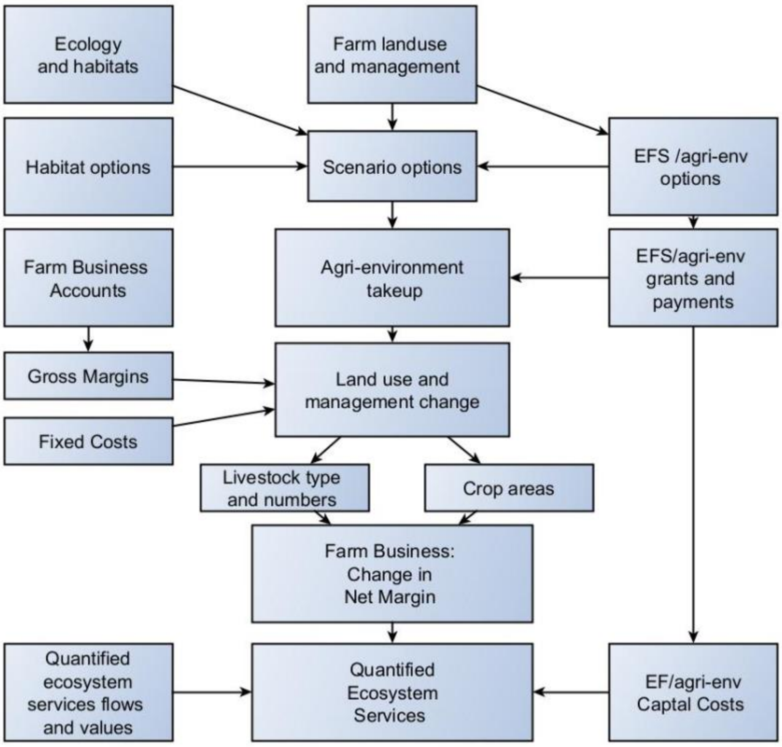


Figure 1: Steps in the method to assess the financial impact of environmental scenarios on the case study farms

5 The capital and revenue payments associated with the take up EFS and other agri-environment options were estimated. It was assumed that capital costs are recovered by grant awards, and that annual payments constitute an additional annual revenue stream for the farm, net of 28% operation and maintenance cost.

6 The impact of the take up of agri-environment options on farm management and agricultural production were determined for each Scenario, regarding changes in crop in areas, livestock numbers due to reductions in stocking rates, switches in land use, or taking land out production (e for field boundary or pond creation).

7 Data on farm business income was collected from the farmer, including access to company accounts (three years) where available, to construct estimates of Farm Net income. The latter comprised net revenue from Agriculture, agri-environment income, and Basic Payment Scheme (BPS) income subsidy. Diversification income was not included. Data from the farm were corroborated with DAERA Farm Income data (2015/6-2021/22). Estimates of Farm Gross Output, Gross Margin, Farm Fixed Costs and Net Farm Margin per ha and for the whole farm were derived. Costs were included for family labour. For livestock production, financial indicators were expressed per Livestock Unit £/LU (Dairy Cow Equivalent =1LU), and then converted to £/ha according to stocking rate (LU/ha) that changed according to environmental option. The Information provided by the farmer was treated in confidence. The financial estimates are indicative and for the purposes here. $£_{2022}$ prices were used throughout.

8 Information on land use and management change (6above) was combined with the farm financial data (7 above) to derive estimates of *changes* in Gross Output, Gross Margin and Net Margin at the farm scale for each scenario. Changes in fixed costs reflected the degree of change in farm output and the structure of fixed costs on the farm. Estimated extra annual

revenue from agri-environment take up was added to the estimated main farm annual financial flows to produce estimates of annual Net Margin including agri-environment income. It is assumed that BPS payments continue at baseline rates. The possible reduction of BPS income can be considered separately.

9 For the purpose of economic appraisal, estimates of Net Annual Flows of benefits were derived for the baseline and each Scenario by farm at full development, where:

> Net Annual Flow = Agricultural Net Margin + Quantified Ecosystem Services (as described in Annex 2) + Agri-environment Benefits (based on agri-environment payments) – Annual equivalent agri-env capital and administration costs.

Capital costs were increased by 20% to cover design, supervision and administration. A 15% surcharge was applied to agri-environment payments to cover administration.

Net Annual Flows were estimated as £/farm and £/ha. Benefit: cost (B:C) ratios were derived to compare the extra benefits (the first three terms in the Net Annual Flow above) with the extra Annual Costs.

10 Estimates were derived for central, best single estimate values. Sensitivity analysis considered the effect of variation in assumptions on key output indicators.

The results of the Case Study Farm Analysis are given in a separate section of this annex.

3.4 Agri-environment Capital Grants and Annual Payment Rates

Table 1 shows the assumed rates for agri-environment options for Scenarios 1, based on current EFS rates. The assumed take-up is shown for each farm. The take up on farm B for the baseline case is substantial and these carry through to Scenario 1.

Table 2 shows the options and rates for Scenario 2 where different from Scenario 1. Rates for some options are assumed at higher rates than current EFS and are based on rates elsewhere in the UK, notably ELMs and options such as the English Woodland Creation Offer. The assumed take up of option for each farm is shown.

Table 1: Agri-environment options and rates for Scenario 1 and take up by farm

Scenario 1	options by farmer				A	B	C	D
	EFS rates , 2022/23		Capital	Revenue				
			£	£/year				
NTC	native tre yr1	£/ha	2925		x	x	x	x
NTC op	yr 2-5	£/ha		465	x	x	x	x
AWC	wetland creation	£/m2		3	x	x		
ENW/NRV	New woo Woodland blocks	£/ha	2146	350		x		
NTW	woodland Native tree corridor	£/ha	2146	350		x		
WWU/WA	Woodland remedial managem	£/ha		65		x	x	
DBS	Small dam	£/dam	62			x		
DSW	Swales	£/m	22.95			x		
COS	scrapes	£/m2	2.77		x	x		
SPF	stock proff fencing	£.m	6		x	x		
GPS	gates	£/unit	190		x	x		
SPE	ELEC FENCE KIT		352		x	x		
RBG	RBG reed bed rem	£/ha		50	x	x		
LPA	limeston paving grqsslan man	£/ha		230		x		
CAG	CALC GRASS	£/ha		230	x	x		
WAG	GRAZED WOODLAND	£/ha		65	x	x		
UHG	MOORLAND REM	£/ha		40	x	x		
BBG	MORROLAND BLANKET BOG RE	£/ha		40	x	x		
PRG	Purple Moor Grass	£/ha		180	x	x		
LMA	l/land mead rem	£/ha		230	x	x		
CFR	floodplain graz marsh	£/ha		180	x	x		
LMR	lowland rem man	£/ha		195	x	x		
PRC	Rush control year 1	£/ha	89.34		x	x		
RFC	year 2-5	£/ha		35	x	x		
BWG	breeding wader habitat	£/ha		195		x		
LPA	limeston paving grqsslan man	£/ha		230		x		
RBG	Reed Bed Remedial	£/ha		50		x		
LFP	lapwing fallow plot	£/ha		699		x		
HRF	heather flailing yr 1	£/ha		59		x		
PAN	Pollinator margins on improve	£/ha		465			x	
WFM 10m	Wildflower margins	£/ha		2530			x	x
WFC	Winter feed for birds	£/ha		590			x	x
FNG/RBG	Marshy Grassland	£/ha	1700	50			x	
RGM 6m	Rough grass margins	£/ha	842	707			x	x
RBS 2m	Riparian ungrazed bu=ffer	£/ha	30350	350			x	
RBW 10m	Riparian ungrazed	£/ha	7630	360			x	
CUM	other tall ruderal on margins	£/ha		702				x
RWS	retention of winter stubble	£/ha		85			x	
PNH	Hedges	£/m	16	0.1			x	x
LAY	Hedges restore	£/m	16	0.1			x	x
	Pond	£/m2	3	300				

Table 2: Agri-environment options and rates for Scenario 2 and take up by farm

Options Scenario 2 by farmers			Capital	Revenue	A	B	C	D
2022/23			£	£/year				
New woodland		£ /ha	7000	350	x	x	x	x
New woodlands: riparian/wet		£ /ha	7000	350	x	x	x	x
EAF	Ceation sylvo alley grassland	£ /ha	2400	205			x	x
EAF	Ceation sylvo alley arable	£ /ha	2400	205				x
	Scrub	£ /ha		149			x	
Creation of woodland pasture		£ /ha	2200	205	x	x		
Grassland neutral species rich with low ir		£ /ha	650	205	x	x	x	
Rest. Grass calcareous		£ /ha	750	290		x		
Rest Grass floodplain		£ /ha	800	225		x		
Rest Grass marshy		£ /ha	1700	180	x	x	x	
Restore : Mosaic acid heathalnd		£ /ha	1050	250	x	x		
Grassland,Acid,Unimproved		£ /ha	428	235	x			
Grassland,Acid,Semi-improved		£ /ha	350	205	x			
Expand Bog , sagnum blanket		£ /ha	2000	85	x	x	x	
Modified Bog		£ /ha		85	x			
Expand Swamp		£ /ha	2500	40		x		
Flush and spring,Acid/Neutral,		£ /ha	2500	40	x			
Ponds		£/m2	3	600	x	x		
Scrapes		£/m3	3	400	x	x		
PAN	Pollinator margins. imp grass	£/ha		465			x	
WFM 10m	Wildflower margins	£/ha		2530			x	x
WFC	Winter feed for birds	£/ha		590			x	x
RGM 6m	Rough grass margins	£/ha	842	707			x	x
RBS 2m	Riparian ungrazed bu=ffer	£/ha	30350	350			x	
RBW 10m	Riparian ungrazed	£/ha	7630	360			x	
RWS	retention of winter stubble	£/ha		85			x	
CUM	other tall ruderal on margins	£/ha		707				x
PNH	Hedges and trees	*£/m*	17	0.2	x	x	x	x

3.5 Economic Appraisal

Data from the Farm cases provide a simplified and incomplete assessment of the overall economic performance of the scenario interventions at the farm scale (Table 3).

Table 3: Indicative incremental annual monetary flows £/ha by farm for the baseline and at full development by scenario (central estimates)

		A	B	C		D
022/23		Fermanagh Livestock	Antrim Livestock	Antrim dairy		Down Arable
Scenario 1 relative to the baseline				Scenario 1	Scenario 1A	
Agric net margin	a	1	1	-580	-155	-37
Ag env benefits	b	102	10	180	55	58
Eco systems services	c	427	7	866	513	194
Total net benefits	d = a+b+c	530	19	467	412	216
Annual costs (including admin)	e	63	5	107	33	32
Net Annual benefits after costs	f = d-e	467	14	360	379	184
Ratio : annual benefits to costs	**d/e**	**8.5**	**3.8**	**4.4**	**12.4**	**6.8**
Scenario 2 relative to the baseline				Scenario 2	Scenario 2A	
Agric net margin	a	2	32	-1213	-187	-11
Ag env benefits	b	146	76	194	107	146
Eco systems services	c	670	482	2196	743	556
Total net benefits	d = a+b+c	817	589	1177	663	691
Annual costs (including admin)	e	179	84	187	119	134
Net Annual benefits after costs	f = d-e	638	505	990	545	557
Ratio : annual benefits to costs	**d/e**	**4.6**	**7.0**	**6.3**	**5.6**	**5.2**

Agricultural Net Margin, Quantified Ecosystem Services and Agri-environment Benefits are shown for Scenarios 1 and 2 for each farm relative to the baseline. Agri-environment payments are used here to estimate the value to society of environmental benefits. Estimated Agric-environment Capital and Administrative costs comprise annualized capital costs (amortised at 3.5% discount rate over 30 years) plus a 20% uplift for administration, plus 15% annual charge for the administration of agri-environmental payments based on the rates shown. The payment of BPS is excluded here.

The Net Annual Benefits after deducting equivalent annual costs are shown for the Scenarios relative to the baseline. A gradient of beneficial change is shown in Net Annual Benefits for each farm moving from the baseline through the Scenarios of change

The livestock farms (A and B) show improvement in Net Annual Flow with limited reduction in Agricultural Net Margin. There is opportunity on the intensively managed farms (Farms C and D) to increase the provision of Quantified Ecosystem Services and Agri-environment benefits while maintaining high Agricultural Net Margins.

The simple ratios of *extra* annual Benefits (Agricultural Net Margin plus Quantified Ecosystem Services plus Agri-environment Benefits) to *extra* annual Costs (Agri-environment capital and administrative costs) indicate the broad direction and magnitude of change relative to the baseline for each Scenario.

All Scenarios of change produce positive Benefit (B): Cost (C) ratios for the assumption made. A comparison of incremental benefits and costs between Scenario 1 and 2 shows that in all cases there is a positive B: C ratio of progressing from Scenario 1 to 2. The estimates are 2.4, 7.2, 2.9 and 4.7 for farms A, B, C and D respectively.

The indicative ratios here are based on central values. Low to high estimates range between about – 75% and + 25% of these central values. The estimates are not intended as a substitute for formal cost-benefit analysis.

3.6 Sensitivity Analysis

The central estimates of key indicators are particularly sensitive to changes in agricultural output prices, variable costs and farm scale fixed costs, especially for the dairy (Farm C) and arable farms (D), reflecting their relatively high costs structures. (Table 4). By comparison the financial outcomes for grazing livestock farms are sensitive to the annual BPS and environmental payments.

For example, a 10% change in agricultural output prices or yields results in 12%, 50% and 100% change in Net Agricultural margins for the livestock, dairy and arable farm cases respectively, and a 10% change in input costs changes Agricultural Net Margins by about 10%, 20% and 49% for the farms respectively.

All agricultural products rose by 39% over the 5-year period 2018 – 2022 (DAERA, 2023). Beef and sheep prices rose by 14% and 25% respectively, and milk prices by over 50%. Over the same period input prices rose by 45% indicating a squeeze on Agricultural Margins in most sectors except dairy. During the 2018 to 2022 period prices (using UK GDP deflators) rose by 7% (prior to 2022/23 price spikes).

The revenue effect of recent (2022/23) high output prices has been significantly moderated by higher input prices.

Policy interventions need to allow for inherent variability and likely farmer responses. Furthermore, Gross Margins (£/ha/year) are often three to four times greater for the top 25% and bottom 25% performing farms across all farm type. Thus, the cost of taking up environmental options on high performing farms in terms of agricultural income foregone is much higher on high performing farms, as illustrated by Farms C and D.

A reasonable range for the estimates of Agricultural Net Margins is -25% (low) and +10% (high) of the central estimates for the livestock farms, and -50% (low) to + 15% (high) for the dairy and arable farms.

Table 4: Sensitivity of key financial output indicators to assumptions

Sensitivity analysis : +/-% change in output indicators for a 10% +/- change in the initial central estimate of selected input variables considered independently

		Livestock (farms A and B)			Dairy (farm C)			Arable (farm D)		
Price or quantity estimate	Correl' with output indicator	Agric Net Margin	Farm Net Margin	EquivAnnual flows	Agric Net Margin	Farm Net Margin	Equiv Annual flows	Agric Net Margin	Farm Net Margin	Equiv Annual flows
Agric output prices /yields	+ve	12%	30%	12%	50%	44%	77%	100%	80%	100%
Agric variable costs (usage/prices)	-ve	7%	16%	6%	25%	20%	34%	40%	35%	50%
Farm Fixed costs	-ve	14%	28%	20%	21%	29%	30%	60%	50%	70%
BPS (farm income support)	+ve	0%	30%	0%	0%	2%	0%	0%	1%	0%
Agri- environ payments/revenues	+ve	0%	35%	5%	0%	3%	4%	0%	2%	1%
Agri-env capital costs	-ve	0%	0%	3%	0%	0%	2%	0%	0%	1%
Quantified Ecosystem services	+ve /-ve	0%	0%	8%	0%	0%	15%	0%	0%	2%

Note : mean responses over the range of scenarios by farm type)

% senstivities vary according to the size of the initial indicator estimate

3.7 Results of Farm Business Analysis: redacted version

The financial estimates here are indicative and draw on information provided in confidence by the farmers concerned, supported by secondary data sources, notably DAERA. The results exclude the contents of selected tables on gross margins and net margins for the farm business. These are available subject to the agreement on confidentiality.

The tables in this section are numbered in order for each farm case.

£$_{2022/23}$ prices are used throughout

3.7.1 FARM A: Fermanagh, Beef and Sheep

Overview of the baseline farm situation Fermanagh beef and sheep farm

The farm is a 115 ha Beef and Sheep farm comprising separate parcels of land with different habitats and farming land use. The furthest area, comprising heathland, is 10 miles from the farmstead. The utilizable agricultural area is 112 ha (88 ha after adjusting to improved grassland equivalent) (Table 1):

Table 1: Farm A broad habitats and areas

Broad habitats	Agric area ha	Adjusted factor	Adjusted agric area ha
Grassland, improved	73.3	1.00	73.3
Grassland, semi-natural	9.3	0.75	7.0
Grassland, marshy (non NFM)	5.5	0.25	1.4
Grassland , marshy NFM	0.0	0.25	0.0
Heathland	24.1	0.25	6.0
	112.2		87.7

The livestock numbers for a typical year (Table 2) are 106 equivalent livestock units (LU, where 1 dairy cow = 1 LU)

Table 2: Farm A Livestock numbers and Livestock Units

Stock type	nr	LU/hd	LU	% of LU
Ewe and lamb	300	0.18	53.4	50%
Store lambs	110	0.06	6.6	6%
Rams	8	0.08	0.6	1%
Beef cows	27	0.75	20.3	19%
Beef cattle sold as stores	50	0.5	25.0	23%
Bull	1	0.65	0.7	1%
Total LU			106.5	100%

Stocking comprises a beef sucker herd (Belted Galloway and Charolais X Limosin) with about 25- 30 beef cows, producing progeny all year round, weaned at about 6 months transferring to finishing unit with 16-month bull beef finished on grass or over wintered according to age. Total other cattle are about 50 covering a range of ages.

About 300 ewes (Suffolk lowland x Mule or x texel) produce an average of 1.5 lambs/ewe mainly finished on grass by October, with some brought in for finishing, usually at 45kg. Replacement ewes are carried over. Sheep are mainly confined to better grasslands. (Sheep numbers were reportedly reduced in 2023).

Overall stocking rates on the farm are low. There are about 106 livestock units on a total farmed area of 112 ha, equivalent to about 0.95 Lu/ha and about 1.22 Lu/ha equivalent on 88 adjusted ha after allowing for the different carrying capacity of land types

Regarding grassland management, fertiliser applications rates are low generally, and particularly recently in response to high fertiliser prices. On Improved grassland, slurry and manures from stock houses are first applied to improved grassland, followed by chemical applications as required. About 15-16 tonnes of 20:10:10 are applied to about 73 ha in a typical year, equivalent to about 40 kgN/ha to 45 kgN/ha, although application rates are probably double this (approaching 100kgN/ha) on the 25 ha or that is cut twice for baled silage.

On the heathland Belted Galloway suckler beef cows are grazed at low stocking rates for a limited summer 12-week period during June/July/August. There are about 15 cows and progeny on 24 ha. This is equivalent to about 11 livestock units (15 beef cows x 0.75 LU/head) on 24 ha for 12/52 weeks = equivalent stocking of 0.11 LU/ha (11/24 x 12/52). It was noted that other graziers might stock at more than twice these levels.

The wet grassland is used for limited summer grazing, about 10- 12 weeks, with stocking rates equivalent to about 10% of improved grassland. Turnout dates in spring are mid to late March, with cattle brought in by end October. Sheep can stay out all year except about 6 weeks in late January through to lambing in March

The farmer, who has alternative employment, manages the farm with his son who is fully employed on the farm. Together with other family members, there are about 1.7 Full Time Equivalent labour inputs, with most inputs during the spring.

The famer recognised the dependency of the farm as a business on direct income support (Basic Payment Scheme). In the absence of this, it is possible farm income would be negative. Some limited grant and annual income come from the Environmental Farming Scheme. (An application currently submitted and under review was included in the baseline).

The farmer is concerned about the impacts of intensive farming on the natural environment and wildlife. He observes, however, that farmers have responded to the incentives for increased production especially on marginal land but notes that this has been made possible by the relatively high level of direct income support – the Basic Payment. While expressing sympathy for the conventional responses towards intensive farming, (without prompting) he expressed the view that a much bigger share of current farm income support could be redirected towards environmental payments rather than pursuing marginal agricultural benefits. He emphasised, however, the importance of doing this in ways that maintained the viability of small family businesses that depend on farming for their livelihoods. He saw participation in the Farming for the Future Project as a way of exploring these possibilities.

The estimated enterprise and farm Gross Outputs and Gross Margins are shown in Table 3. Estimates of variable and fixed costs were constructed from farm accounts and corroborated with DAERA sources for Disadvantaged Area beef and sheep farms. Expected Gross Margin per ha is about £250/ha/year and per Livestock Unit is about £265/LU/year

Table 3: Farm A estimated annual Gross Output and Gross Margins from agricultural activities

Table redacted for confidentiality

Table 4 shows the estimated annual Net Margin (before other income) for Farm A after deduction of Fixed Costs based on farm accounts and corroborated against DAERA data. Fixed costs include the cost of paid labour (1 FTE) a charge for unpaid family labour. Expected Net Margin is negative before other sources of income at about £365/ha/year. _Other income sources, notably BPS together with revenue from a current EFS application under review reduce the expected annual deficit. Excluding unpaid family labour gives a positive Net Margin of about £114/ha/year

Table 4: Farm A estimated annual Net Margin

Table redacted for confidentiality

Scenario 1

Scenario 1 involves the introduction of a range of EFS options applied across a range of habitats on the farm (Table 5). The total estimated capital is £63,700, equivalent to £3,460/ha/year discounted at 3.5% over 30 years. It is assumed that capital costs are fully funded under EFS agreements. The expected annual revenue from the package of EFS options is about £20,800/year, an average of £184/ha/year)

Table 5: Farm A Scenario 1 take up of EFS options and capital costs and annual payments

		options efs	units	nr	Average Cap cost £ / unit	Cap cost £	Equiv An cost	Annual revenues £/ha£	£/year
A11/A111	Woodland,Broadleaved,(unknown type)	NTC	ha	1.7	2146	3575	194	372	620
B12	Grassland,Acid,Semi-improved	PRC, RFC WAG	ha	3.5	221	783	43	87	308
B22	Grassland,Neutral,Semi-improved	LMA/LMR, NTC on 0.15 ha	ha	45.6	0	0	0	205	9359
B31	Grassland,Calcareous,Unimproved	CAG	ha	5.6	272	1517	82	240	1343
B4	Grassland,Improved,		ha	10.6	0	0	0	0	0
B4f	Grassland,Improved,(floodplain/grazing	CFR gazring marsh	ha	20.4	0	0	0	180	3676
D6	Mosaic: acid grassland, wet heath,,	SPF, GPS, UHG, BBG, SPE, PRG	ha	24.0	994	23899	1299	214	5132
F1	Swamp,,	AWC, RBG	ha	1.1	5000	5682	309	50	57
G	Water (inland),(unknown),		unit	1.0	4029	4029	219	0	0
J21/J22	Boundaries,Intact hedge,	TEB/LAY equiv	m	1512.0	16	24192	1315	0.2	302
J23	Boundaries,Hedge and trees,		ha	0.5	0	0	0	0.0	0
						63677	3462		20797
Average £/ha over 113 ha						564	30.6		184

The adoption of EFS options under Scenario 1 results in a reduction in livestock carrying capacity of 31 LU/year (29 % of the baseline stocking) and reduction in Gross Margin of £8,200/year (Table 6)

Table 6: Farm A Scenario 1 Changes in habitat areas, stocking rates and resultant changes in Gross output, Gross Margin and Net Margin (before agri-environment revenue and changes in fixed costs)

scenario 1					Difference			Change	
						stocking	Change		
HabCode_	HabNmPLUS	Habitat	area_ha	% area	ha	rates	in LU	£ GO	£ GM
A11	Woodland,B	Broadleaved wc	1.6	1%	0.66	0.00	0	0	0
A111	Woodland,B	Broadleaved wc	0.0	0%	0.03	0.00	0	0	0
A3	Parkland/sca	Trees / Parklanc	0.0	0%	0.00	0.00	0	0	0
B12	Grassland,A	Semi-natural gra	3.5	3%	0.00	0.75	0	0	0
B22	Grassland,N	Semi-natural gra	45.6	40%	45.61	0.75	34	19654	9082
B31	Grassland,C	Semi-natural gra	5.6	5%	0.00	0.75	0	0	0
B4	Grassland,In	Improved grassl	10.6	9%	-62.24	1.25	-78	-44692	-20651
B4f	Grassland,In	Marshy grasslan	20.4	18%	20.42	0.75	15	8799	4066
B5	Grassland,M	Marshy grasslan	0.0	0%	-5.47	0.5	-3	-1572	-727
D6	Mosaic: acid	Heathland	24.0	21%	0.00	0.15	0	0	0
							0	0	0
F1	Swamp,,	Fen, marsh and	1.1	1%	1.14	0.1	0	65	30
G	Water (inlar	Water	0.1	0%	0.15	0	0	0	0
J21	Boundaries,	Hedgerows	0.3	0%	0.00	0	0	0	0
J22	Boundaries,	Hedgerows	0.1	0%	0.00	0	0	0	0
J23	Boundaries,	Hedgerows	0.4	0%	-0.25	0	0	0	0
J26	Boundaries,	Mixed / other /	0.0	0%	-0.05	0	0	0	0
			113.6				-31	-17747	-8200

The changes in key financial indicators are shown in Table 7 for Scenario 1. Fixed costs reduce by about £8,300/year. This is based on an assessment of the structure of fixed costs on the farm and scope for reducing components of fixed costs that are that are linked to output, including labour, machinery operating and contractor costs, and general expenses. After these adjustments Net Margin from agriculture is similar to the baseline. Additional revenue from EFS minus additional operating costs increases total Net Margin (agric plus agri-environment by about £11,600/year, about £100/ha/year, before BPS.

Table 7: Farm A Scenario 1 A in Summary of Change in Net Margin

	£/year	£/ha/year
Change in GO	-17747	-158
Change in GM	-8200	-73
Change in FC	-8307	-74
Change in Net Margin	107	1
Scenario 1 EFS	20847	186
Baseline EFS	4878	44
Extra efs	15969	143
Less EFS ops	4471	40
Extra EFS rev less ops	11498	103
Net Agric + EFS	11605	104

Scenario 2

Scenario 2 involves the introduction of a range of agri-environment options extending beyond the current provision and assuming enhanced payment rates for some options based on rates paid elsewhere in the UK (Table 8). The total estimated capital is £63,700, equivalent to £3,460/ha/year discounted at 3.5% over 30 years. It is assumed that capital costs are fully funded under agri-environment agreements. The expected annual revenue from the package of options is about £26,800/year, and average £239/ha/year), a 30% increase on scenario 1.

Table 8: Farm A Scenario 2 take up of agri-environment options and capital costs and annual payments

Interventions : Options and annual receipts	**Capital costs**						Annual payments	
Components	units	nr	£/unit	Total £	Equiv Ann cost £/year *	% capital	£/ha/yr	£/yr
Woodlands								
New woodland	ha	5.2	7,000	36,437	1,981	13%	350	1822
New woodlands: riparian/wet	ha	10	7,000	67,926	3,693	25%	350	3396
Creation of woodland pasture	ha	3	2,200	6,698	364	2%	205	624
Field Management								
and neutral *species rich* with low inputs	ha	44.4	650	28,843	1,568	11%	205	9097
Rest. Grass calcareous	ha	5.6	750	4,189	228	2%	290	1620
Rest Grass floodplain	ha	11.4	800	9,110	495	3%	225	2562
Rest Grass marshy	ha	3.6	1,700	6,073	330	2%	180	643
Restore : Mosaic acid heathalnd	ha	16.9	1,050	17,759	966	7%	250	4228
Expand Bog	ha	8.4	2,000	16,887	918	6%	85	718
Expand Swamp	ha	2.5	2,500	6,211	338	2%	40	99
Hedges and trees	m	1,512	17	25,705	1,398	9%	0.2	1000
Ponds	m2	7500.0	3	22,500	1,223	8%	0	600
Scrapes	m2	7500	3	22,500	1,223	8%	0	400
Total				**270,838**	**14,726**	100%		26809
£/ha		92.8		2,414	131			239

The adoption of options under Scenario 2 results in a reduction in livestock carrying capacity of 50 LU/year (47 % of the baseline stocking) and reduction in Gross Margin of 13,400/year (Table 9).

Table 9: Farm A Scenario 2 Changes in habitat areas, stocking rates and resultant changes in Gross output, Gross Margin and Net Margin (before agri-environment revenue and changes in fixed costs)

			Change in area	Stocking rates	Change in	Change in GO	GM
		ha	ha	LU/ha	LU	£	£
A11	Woodland,Broadleaved,(unk	Broadleaved woodland	4.25	0	0	0	0
A111	Woodland,Broadleaved,Sem	Broadleaved woodland	0.95	0	0	0	0
A111w	Wet Woodland,Broadleaved,	Broadleaved woodland	9.70	0	0	0	0
A112_B22	Woodland,Broadleaved,Plan	Silvo-pastoral	3.04	0.80	2.4	1399	647
B12	Grassland,Acid,Semi-improv	Semi-natural grassland	-3.55	0.50	-1.8	-1020	-471
B22	Grassland,Neutral,Semi-imp	Semi-natural grassland	44.37	0.75	33.3	19119	8835
B31	Grassland,Calcareous,Unimp	Semi-natural grassland	0.00	0.75	0.0	0	0
B4f	Grassland,Improved,		-72.83	1.25	-91.0	-52302	-24168
B4f	Grassland,Improved,(floodpl	Marshy grassland	11.39	0.75	8.5	4906	2267
B5	Grassland,Marshy,	Marshy grassland	-1.90	0.50	-1.0	-546	-252
D6	Mosaic: acid grassland, wet h	Heathland	-7.12	0.15	-1.1	-614	-284
E161	Bog,Sphagnum,Blanket bog	Bog	8.44	0.00	0.0	0	0
F1	Swamp,,	Fen, marsh and swamp	2.48	0.10	0.2	143	66
G	Water (inland),(unknown),	Water	0.55	0.00	0.0	0	0
J21	Boundaries,Intact hedge,	Hedgerows	0.00	0.00	0.0	0	0
J22	Boundaries,Defunct hedge,	Hedgerows	0.22	0.00	0.0	0	0
J23	Boundaries,Hedge and trees,	Hedgerows	0.05	0.00	0.0	0	0
J26	Boundaries,Dry ditch,	Mixed / other / uncertain	-0.05	0.00	0.0	0	0
Total					-50.3	-28914	-13361

The changes in key financial indicators are shown in Table A10 for Scenario 2. Fixed costs reduce by about £13,500/year. This is based on an assessment of the structure of fixed costs on the farm and scope for reducing components of fixed costs that are that are linked to output, including labour, machinery operating and contractor costs, and general expenses. After these adjustments Net Margin from agriculture is similar to the baseline. Additional revenue from agri-environment minus additional operating costs increases total Net Margin (Agriculture plus agri-environment) by about £16,000/year, about £140/ha/year, before BPS.

Table A10: Farm A Scenario 2 Summary of Change in Net Margin

Change in agricultural net income	£/year	£/ha/year
Change in GO	-28914	-258
Change in GM	-13361	-119
Change in FC	-13534	-121
Net change	174	2
scen 2 agri-env	26809	239
baseline efs	4878	44
extra agri-env	21932	196
extra cost ops	6141	55
extra agri env after ops	15791	141
Net Agric + agri-env	15965	143

Net Margins by Scenario

Agricultural Net margins for Farm A (Table 11) remain around minus £40,000 /year and minus £364/ ha/year under both scenarios before subsidies and other income. Reduced Gross Margins are offset by reduced Fixed Costs

Table 11: Farm A Agricultural Net Margin by Scenario

£ Whole farm/year

	Baseline	Scenario 1	Scenario 2
Gross output	61206	43459	32292
Gross margin	28282	20082	14921
Fixed costs	69250	60943	55716
Agric net margin	-40968	-40861	-40794

£/ha/year

	Baseline	Scenario 1	Scenario 2
Gross output	546	387	288
Gross margin	252	179	133
Fixed costs	617	543	497
Agric net margin	-365	-364	-364

Whole Farm Net Margin improves from the about minus £15,000/year for the baseline to about minus £3,650 under Scenario 1 to a positive £1,300/year under scenario 2 (Table 12). These estimates include costs for unpaid family labour. The Farm Net Margins assume that full entitlement to BPS continues under all Scenarios. It is likely that, as discussed in the Main Report, widespread take up of environmental options across the agriculture sector in Northern Ireland might require a relative reduction in BPS payments. The continued dependency on BPS under the Scenarios on this Farm is apparent. A reduction in BPS, unless accompanied by an increase in agri-environment payments would question farm viability.

Table 12: Farm A Farm Net Margins by Scenario

£ Whole farm/year

	Baseline	Scenario 1	Scenario 2
Agric net margin	-40968.1	-40861.34	-40794.186
BPS	20847	20847	20847
Agri-env	4869	16367	21236
Net margin	-15252	-3647	1289

£/ha/year

	Baseline	Scenario 1	Scenario 2
Agric net margin	-365	-364	-364
BPS	186	186	186
Agri-env	43	146	189
Net margin	-136	-33	11

Estimated Agriculture, agri-environment and Quantified Ecosystem Services

The estimated annual value of selected quantified ecosystem services for Farm A taken from the earlier Annex are given in Table A13.

Table 13: Farm A Estimated Quantified Ecosystem Services
£/year

	Base	Scenario 1	Scenario 2
Carbon	-64236	-17980	-6954
Air Quality	5389	5900	11459
Timber	401	1085	7748
Water related	180	587	4608
Total	-58266	-10408	16861

Estimated Net Ecosystem Services from Farm A

Data on Agricultural Net Margin are combined with benefit estimates of ecosystem services, agri-environment benefits (based on payment values), less annual capital costs of scenario implementation (Table 14). No additional costs are included here for the administration of the environmental schemes. There is a substantial and successive improvement in the combined net value of annual flows from the baseline through Scenario 1 to Scenario 2. The incremental gain is greatest for Scenario 1. The relatively high capital costs in Scenario 2 reflect the investment in habitat restoration, the full benefit of which is underestimated here.

Table 14: Farm A: Estimated net annual flows of selected ecosystem services

£/year	Base	Scenario 1	Scenario 2
Agric net margin	-40968	-40861	-40794
Quantified Ecosystem	-58266	-10408	16861
Ag env benefit	4869	16367	21236
Agr env capital costs	0	-3462	-14726
NET	-94365	-38365	-17423

£/ha/year	Base	Scenario 1	Scenario 2
Agric net margin	-365	-364	-364
Quantified Ecosystem	-519	-93	150
Ag env benefit	43	146	189
Agr env capital costs	0	-31	-131
NET	-841	-342	-155

3.7.2 FARM B: Antrim, Beef and Sheep

Farm B is a grazing livestock farm in Country Antrim comprising 180 ha of utilizable agricultural land in separate parcels comprising a range of habitats (Table 1) involving lowland improved grassland near to farm stead, and semi natural and upland heathland some distance away.

Table 1: Farm B broad habitats and areas

	ha	%	adj ha	total adj h
Improved grassland	86.3	48%	1.00	86.3
Semi improved	58.6	32%	0.75	44.0
Heathland	34.5	19%	0.25	8.6
Bog	1.00	1%	0.15	0.2
Total	180.4	100%		139.0

The livestock numbers for a typical year (Table 2) are equivalent to 90 livestock units (LU, where 1 dairy cow or 5 lowland ewes with lambs = 1 LU). Stocking rates are low at 0.5 LU/ha, 0.65 LU/ ha adjusting for the carrying capacity of land.

Table 2: Farm B Livestock numbers and Livestock Units

Stock type	nr	LU/hd	LU	% of LU
E&L l/la	200	0.20	40.0	45%
E&L u/la	180	0.18	32.4	36%
Gimmers	110	0.06	6.6	7%
Rams	8	0.08	0.6	1%
Beef cows	27	0.38	10.1	11%
Beef cattle sold as st	0	0.50	0.0	0%
Bull	0	0.65	0.0	0%
Total LU			89.8	100%

Excludes woodland and other at 5.4 ha

The sheep enterprise a lowland flock of about 200 ewes (Llyn and texel cross) and an upland flock of about 180 ewes (Scottish blackface). 100 sheep retained as gimmers that typically produce lambs in their second year, – some of which are sold. Sheep are outside all the year. Generally lambing occurs relatively late in April. Sheep are fed conserved haylage in winter or the remnants of clamp silage if necessary. Lambing rates are typically 1.5 lambs per ewe for lowland ewes and 1.2 to 1.4 lambs per ewe for upland ewes.

A suckler beef cow unit of 27 head (angus/limosin/Charolais cross), operated by a neighbouring farmer, resides on the farm during the winter period for 5 months only. Cows are brought inside for calving. Parochially referred to as a 'Bed and breakfast '(agistered) system, the service is paid for by the week. Cows are fed on cut silage (clamp silage) from the farm. They return to the owner in the spring and are not grazed on the farm. For the purpose here, the revenues and costs of this overwintering unit are attributed to the farm.

All sheep and cattle are grass fed, with little concentrate feed. Chemical fertiliser is applied to about 18 ha to 20ha of cut grass each year to produce clamp silage, a remnant of the farm as a dairy unit, and haylage in equal amounts by dry matter weight. Fertiliser rates where applied are about £50 kg N/ha, plus some organic manures, probably approaching 75kg N/ha for the conserved area. No chemical fertiliser is otherwise applied. Winter feed conservation is carried out by contractor as part of the agistering arrangement.

The farm has already adopted a wide range of EFS options across the holding (Table 3). This includes capital costs for stock proof fencing and gates, initial costs for primary rush control, and annual payments for remedial management for moorland and moorland blanket bog, purple moor grass and pasture, and breeding waders, amongst other interventions. The total value of annual payments was about £23,000 in 2022. Additionally extensive upland works have been carried out on upland peat areas under a separately funded restoration project including dams and ponds and sediment traps.

The farm is operated by the farmer and his son, with help from other family members. Total labour is reported at 1.3 Full Time Equivalents.

The farmer has taken advantage of the opportunities provide by the higher EFS options whilst simultaneously reducing stocking levels to those compatible with the requirements of the scheme, the capacity of available family labour and personal motivations and interests. In many respects the farm is an exemplar of what can be achieved. The farmer is non the less critical of the administrative burden of the EFS and of the system of penalties that can apply if there is variation from the terms of the agreement, particularly when, he argued, quantification of measures in the plan and the field, such as areas or linear meters, is contested.

Table 3: Farm B: Baseline take up of EFS options

Baseline take up of EFS			
Totals	areas	unit rates	
	ha	£/ha/year	£/year
EFS code			
UHG	3	40	124
BBG	23	40	940
PRG	38	180	6925
BWG	66	195	12903
LPA		230	0
WAG			0
SPF			0
GPS			0
SPC			0
PRC			0
RFC	61	45	2760
total £/year	193		**23652**
average £/ha			123

The farmer

The estimated enterprise and farm Gross Outputs and Gross Margins are shown in Table 4. Estimates of variable and fixed costs were constructed from farm accounts and corroborated with DAERA sources for Disadvantaged Area beef and sheep farms. Expected Gross Margin per ha is about £155/ha/year and per Livestock Unit is about £311/LU/year

Table 4: Farm B estimated annual Gross Output and Gross Margins from agricultural activities
Table redacted for confidentiality

Table 5 shows the estimated annual Net Margin (before other income) after deduction of Fixed Costs based on farm accounts and corroborated against DAERA data. Fixed costs include the cost of paid labour (1.3 FTE) a charge for unpaid family labour. Expected Net Margin is negative before other sources of income at about minus £290/ha/year. _Other income sources, notably BPS together with revenue from a current EFS application give a Net Margin of £42/ha/year. Excluding unpaid family labour gives a positive Net Margin of about £197/ha/year

Table 5: Farm B estimated annual Net Margin

Table redacted for confidentiality

Scenario 1

Scenario 1 involves the take up of additional EFS options (Table 6). The additional capital costs are £9,100 and the additional annual payments are £2,627/year, £1,892 /ha/year after additional operating costs at 28%.

Table 6: Farm B Scenario 1 additional EFS take up.

DBS 12 dams at £62/dam on acid grass, 50 dams on heathland
DSW 100m at £100/m, 31m at £100/m (peat)
COS scrapes at 5000m2 at£0,45/m
PRG at 3.5ha at £180/year
LPG 2.7 ha at £699/ha /year
PRG to BWG reclassification on 7 ha, £110 total/year

The estimated land taken was 6.1 ha at 0.5LU/ha= 3.1 LU

As a result of a land take of 3.1 ha, stocking on the farm reduces by 3.1 LU/year.
The changes in key financial indicators are shown in Table 7 for Scenario 1. Fixed costs reduce by between £890/year to £1, 100/year (default). This is based on an assessment of the structure of fixed costs on the farm and scope for reducing components of fixed costs that are that are linked to output, including labour, machinery operating and contractor costs, and general expenses. After these adjustments Net Margin from agriculture is similar to the baseline. Additional revenue from EFS minus additional operating costs increases total Net Margin (agric plus agri-environment by about £2,000/year, about £11/ha/year, before BPS, slightly higher if the alternative FC estimate is used.

Table 7: Farm B: Estimated change in farm net margin £/year under Scenario 1

	£	£/ha
Change in GO	-1982	-11
Change in GM	-948	-5
Change in FC*	-1119	-6
Net change	171	1
Additional EFS	2627	14
additional op costs	736	4
Net EFS	1891	10
Net change after EFS	2063	11
Alternative FC change *	-892	-5
Net Change	399	2
Net Change after EFS	2291	12

* 1.4% default all fixed costs excl rents and interest
** 1.1 % reduction in labour, machinery ops and general expenses only

Scenario 2

Scenario 2 involves the introduction of a range of agri-environment options extending beyond the current provision and assuming enhanced payment rates for some options based on rates paid elsewhere in the UK (Table 8). The total estimated capital is about £200,000, equivalent to £11,000/ha/year discounted at 3.5% over 30 years. It is assumed that capital costs are fully funded under agri-environment agreements. The expected annual revenue from the package of options is about £19,000/year, and average £105/ha/year).

Table 8: Farm B: Scenario 2 Estimated capital costs and annual revenue from EFS payments for scenario 2 relative to the baseline

	Capital costs							Environmental payments	
Habitat ref	**Components**	units	nr	£/unit	Total £	Equiv Ann cost £/year *	% cap cos	£/ha	£
A11/A111	**Woodlands**								
	New woodland	ha	7	7,000	52,325	2,845	26%	350	2616
	New woodlands: riparian/wet	ha	3.825	7,000	26,778	1,456	13%	100	383
	Creation of woodland pasture	ha	0	2,200	0	0	0%		0
							0%		
	Field Management						0%		
B11	Grassland Semi-natural grassla	ha	19.2	650	12,475	678	6%	205	3935
B12	Grassland,Acid,Semi-improve	ha	24.5	350	8,591	467	4%	235	5768
B5	Grassland,Marshy,	ha	8.5	1,700	14,373	781	7%	180	1522
D6	Mosaic: acid grassland, wet he	ha	12.2	1,050	12,808	696	6%	250	3050
E17	Modified bog	ha			0	0	0%	0	0
E161	Bog,Sphagnum,Blanket bog	ha	3.0	2,000	6,055	329	3%	85	257
E21/F1	Flush and spring,Acid/Neutral	ha	12.1	2,500	30,258	1,645	15%	40	484
G/G2u	Water		0.2				0%		
G	Ponds	m2	5000.0	3	15,000	816	7%		600
	Scrapes	m2	7500	3	22,500	1,223	11%		400
	Total				**201,163**	**10,937**	100%		19015

Table 9: Farm B: Scenario 2 Changes in habitat areas, stocking rates and resultant changes in Gross output, Gross Margin and Net Margin (before agri-environment revenue and changes in fixed costs)

			scenario 2		Difference	LU	Change	GO	GM
HabCode_	HabNmPL	Habitat	area_ha	area_percentage		Lu/ha	Lu	£	£
A11	Woodlanc	Broadleav	0.163	0%	0.000	0	0.0	0	0
A111	Woodland,Broadlea		0		-3.825	0	0.0	0	0
A111w	Wet Woo	Broadleav	11.300	6%	11.300	0	0.0	0	0
A31	Parkland/	Trees / Pa	0.039	0%	0.000	0	0.0	0	0
B11	Grassland	Semi-natu	19.193	10%	19.193	0.75	14.4	9355	4474
B12	Grassland	Semi-natu	82.372	45%	24.547	0.75	18.4	11964	5722
B4	Grassland,Improvec		0.000		-85.212	1.15	-98.0	-63683	-30458
B4/Bu	Pastures	Improved	0.289	0%	-0.974	1.15	-1.1	-728	-348
B5	Grassland	Marshy gr	8.455	5%	8.455	0.5	4.2	2747	1314
D6	Mosaic: a	Heathlanc	46.702	25%	12.198	0.5	6.1	3964	1896
E17	Modified bog		0.000		-0.896	0	0.0	0	0
E161	Bog,Spha	Bog	3.027	2%	3.027	0	0.0	0	0
E21	Flush and	Fen, mars	11.748	6%	11.748	0.1	1.2	763	365
F1	Swamp,,	Fen, mars	0.355	0%	0.355	0.1	0.0	23	11
G	Water (in	Water	0.184	0%	0.086	0	0.0	0	0
G2u	Running v	Water	0.428	0%	0.000	0	0.0	0	0
J21	Boundarie	Hedgerov	0.052	0%	0.000	0	0.0	0	0
J22	Boundarie	Hedgerov	0.335	0%	0.000	0	0.0	0	0
J23	Boundarie	Hedgerov	0.330	0%	0.000	0	0.0	0	0
J25	Boundarie	Mixed / o	0.061	0%	0.000	0	0.0	0	0
J26	Boundarie	Mixed / o	0.118	0%	0.000	0	0.0	0	0
J37	Built-up a	Built-up a	0.398	0%	0.000	0	0.0	0	0
J4	Bare grou	Mixed / o	0.092	0%	0.000	0	0.0	0	0
							-54.8	-35595	-17024

Table 10: Farm B: Estimated change in farm net margin £/year under Scenario 2

	£/year	£/ha/year
Change in GO	-35595	-197
Change in GM	-17024	-94
Change in FC	-22769	-126
Net change	5745	32
Additional EFS	19015	105
additional op costs	5324	30
Net EFS	13691	76
		0
Net change after EFS	19435	108
Alternative FC change **	-18140	-101
Net Change	1115	6
Net Change after EFS	14806	82

* 1.4% default all fixed costs excl rents and interest
** 1.1 % reduction in labour, machinery ops and general expenses only

Net Margins by Scenario

Agricultural Net Margins for Farm B (Table 11) remain negative under the Scenario. Reduced Gross Margins are offset by reduced Fixed Costs such that losses on the agriculture account decline under Scenario 2

Table 11: Farm B Agricultural Net Margin by Scenario

£/year	Baseline	Scenario 1	Scenario 2
Gross output	58335	56353	22740
Gross margin	27901	26953	10876
Fixed costs	80679	79560	57910
Agric Net margin	-52779	-52607	-47034

£/ha/year	Baseline	Scenario 1	Scenario 2
Gross output	323	312	126
Gross margin	155	149	60
Fixed costs	447	441	321
Agric Net margin	-293	-292	-261

After inclusion of BPS and agri-environment payments Net Farm Margin improves. It is assumed that BPS continues at the baseline rate for Scenarios. The implications of reducing BPS from current rates is apparent.

Table 12: Farm B Farm Net margins by Scenario

£/year	Baseline	Scenario 1	Scenario 2
Agric Net margin	-52779	-52607	-47034
BPS	36621	36621	36621
Agri-env	23652	25544	37343
Net margin incl Other	7495	9558	26930

£/ha/year	Baseline	Scenario 1	Scenario 2
Agric Net margin	-293	-292	-261
BPS	203	203	203
Agri-env	131	142	207
Net margin incl Other	42	53	149

Estimated Agriculture, agri-environment and Quantified Ecosystem Services

Table 13: Farm B Estimated Quantified Ecosystem Services

	Base	Scenario 1	Scenario 2
Carbon	-33939	-32652	44785
Air Quality	13441	13438	16546
Timber	1687	1685	4849
Water rela	1357	1356	3275
Total	-17454	-16173	69456

Estimated Net Ecosystem Services from Farm B

The net value of selected service flows from Farm B increase through the scenarios and become positive under Scenario 2

Table 14: Farm B Estimated net annual flows of selected ecosystem services including agriculture

£/year	Base	Scenario 1	Scenario 2
Agric net margin	-52779	-52607	-47034
Quantified Ecosystem Services	-17454	-16173	69456
Agri-env benefits	23652	25544	37343
Agr env capital costs	0	-495	-10937
NET	-46581	-43731	48827
£/ha	Base	Scenario 1	Scenario 2
Agric net margin	-293	-292	-261
Quantified Ecosystem Services	-97	-90	385
Agri-env benefits	131	142	207
Agr env capital costs	0	-3	-61
NET	-258	-242	271

Capital and annual agricultural environment costs here exclude administration costs.

3.7.3 FARM C: Antrim, Dairy

Farm and use and system

Farm C operates an intensive zero grazed dairy enterprise County Antrim. The farm comprises a total of 270 acres: 120 acres owned and 150 tenanted on short-term leases, some under the conacre system. Actual rented areas can vary annually according to need. 236 acres are agriculturally useable: 30 acres are woodland and 6-acre farmstead, tracks and other areas.

Agricultural land use is mainly ryegrass ley on about 200 acres, typically reseeded every 7 years. There are about 15 to 20 acres of winter sown whole crop harvested oats/wheat, and 8 -10 acres of semi-improved permanent grassland.

Table 1: Farm C Farmland use and areas

Broad habitats	Agric area ha	Adjusted factor	Adj ha
Grassland improved	96.9	1.00	96.88
Grassland marshy	5.8	0.50	2.88
Arable - whole crop	9.4	1.00	9.39
Total	112.0		109.2
Woodland	10.0		
Total agric and woodland	122.0		

The number of dairy cows. beef cows and progeny, and equivalent Livestock Units (218 LU) are given in Table 2. The diary herd contains 145 Friesian/Holstein milk cows, yielding an average 9,500 litres/cow/year on a grass and concentrate (average 3t/cow/year) diet, plus home bred replacements (about 30- 40 yearlings and heifers?). Cows are housed all year in newly equipped buildings with slatted floors and automated slurry handling.

Table 2: Farm C Farm livestock types and numbers

Stock type	nr	LU/hd	LU	% of LU
milk cows	145	1.00	145.0	66%
Dairy replacement units	40	1.17	46.6	21%
Beef cows	18	0.75	13.5	6%
Beef cattle sold as stores	25	0.5	12.5	6%
Bull	1	0.65	0.7	0%
Total LU			218	100%

A small sucker unit of 15 beef cows (angus/limosin X) and progeny (typically 25 other cattle in total) are housed and/or summer grazed on the permanent grassland area. Suckler progeny are finished at 22-24 months, sold at 360-400 kg deadweight.

Total livestock units (cow equivalent LU) are approximately 218. On about 110 ha of forage, this gives about 2.1 (2.2 LU/ha on the improved grassland only). Thus, milk yields on the farm are 'very high' and stocking rates are 'high' relatives to NI dairy sector averages.

Grassland management involves mainly rye grass leys, reseeded every 7 years or so. The zero grazing system involves 4 cuts (by contractor) of clamp silage per season, in some cases five. Nitrogen applications are typically 2 x 50kg bags/acre of 27% N fertiliser per cut for the first two cuts, and 1.75 bags/acre for the two subsequent cuts and about 1.5 for the final cut if applied. On this basis total application rates are about 250-280 kgN/ha from chemical fertiliser, plus potentially a further 40 -50 kgN/ha from slurry (at about 18 -22 kgN/LU/year). At this application, total t Dry Matter (DM) of silage is probably about 10 - 11 t DM/ha (about 50 t Wet Matter at about 20% DM).

There is no take-up of Environmental Farming Scheme (EFS) options at present. The Basic Payment scheme income is about £34,000/year (before payments of entitlements). Agricultural development grants have been obtained for improved housing and slurry handling and storage.

The farm employs about 2.5 fulltime equivalent units of labour , comprising 1 full time (lead role) family member, about 0.8 FTE hired craft grade dairy herdsman, and about 0.7 other family labour inputs.

Discussion with the farmer confirmed their interest in building environment for nature into the existing farming system, particularly exploring EFS options (scenario 1) for the farm woodlands, field boundaries and corners, and the marginal grassland areas of the farm. They perceived that this could be done while maintaining the existing intensive zero-grazing system and multi-cut silage on ryegrass leys.

Regarding scenario 2, the farmer perceived a nature/environmental outcome driven approach would probably require a fundamental change in the dairy enterprise, returning to a lower input: output grazing-based approach. While questioning the viability of such an option for the farm, he was interested to learn what such an option might look like, and what the business implications might be, particularly regarding the scope for a lower input: output system that can maintain overall profitability and livelihoods, while delivering benefits to nature.

After note: the application of Scenario 1 required a large reduction in stocking rates associated with reducing the improved grass area to the point where a zero grazed system was no longer feasible. The reduced stocking rate would not be feasible on the farm given the existing high costs structure. An alternative scenario was created to enable the existing dairy system to continue. Similarly, Scenario 2 in its original form is unlikely to support a viable dairy unit given the reduction required in improved grassland and the need to provide access to grazing on this fragmented site. For this reason, a revised Scenario 2 was created to enable the current herd to be retained within an agro-forestry system. While in the longer term it would be feasible to explore a low input: low output dairy system on the farm, this was not possible within the time available for this study. It is noted that in the past, a traditional dairy unit operated alongside an arable/grass rotation.

Estimated financial indicators for Farm C are given in Tables 3 and 4.

Table 3: Farm C estimated annual Gross Output and Gross Margins from agricultural activities

Table redacted for confidentiality

Table 4: Farm C estimated annual Net Margin

Table redacted for confidentiality

Scenario 1

The take-up of EFS options for farm C under Scenario 1 as originally constructed is shown in Table 5. The total estimated capital is £149,400, equivalent to about £8,150/ha/year discounted at 3.5% over 30 years. It is assumed that capital costs are fully funded under EFS agreements. The expected annual revenue from the package of EFS options is about £30,500/year, and average £273/ha/year)

Table 5: Farm C Scenario 1 take up of EFS options and capital costs and annual payments

Components			units	nr	£/unit	Total £	Equiv Ann cost £/year *	£/unit	£ total
Woodlands									
New woodland	Woodland blocks	ENW/NRW	ha	9.0	2,925	26,325	1,431	350	3,150
New woodlands	Native tree corridors NT	NTW	ha	2.2	2,146	4,678	254	350	763
Woodland remedial management		WWU/WAG/	ha	10.0	0		0	65	649
Creation of woodland pasture			ha	0	0	0	0		0
Field Management						0	0		
Pollinator margins on improved grass areas		PAN	ha	2.4		0	0	**465**	1,116
Wildflower margins		WFM 10m	ha	4.0		0	0	2,530	10,120
Winter feed for birds		WFC		4.0		0	0	590	2,360
Marshy Grassland		FNG/RBG		5.3	1700	9,010	490	50	265
Rough grass margins		RGM 6m		15.3	841.5	12,875	700	707	10,817
Riparian ungrazed bu=ffer		RBS 2m		0.4	30350	12,079	657	350	139
Riparian ungrazed		RBW 10m		0.4	7630	3,037	165	360	143
retention of winter stubble		RWS	ha	6.6	0	0	0	85	558
Boundaries						0	0		0
Hedges		PNH	m	3995.7	16	63,252	3,439	0.1	400
Hedges restore		LAY	m	650.5	16	10,668	580	0.1	65
Pond			m2	2500	3	7,500	408	300	300
Total				4646		**149,424**	**8,124**		**30,546**
£/ha (264 ha)						1,334	73		273

The adoption of EFS options under Scenario 1 results in a reduction in livestock carrying capacity of 79 LU/year (equivalent to 36% of the baseline stocking) and reduction in Gross Margin of £94,700/year (Table 6)

Table 6: farm C Scenario 1 Changes in habitat areas, stocking rates and resultant changes in Gross output, Gross Margin and Net Margin (before agri-environment revenue and changes in fixed costs)

HabCode_B	Habitat	Difference	Lu/ha	Change in LU	GO £	GM £
A11	Woodland,Broadleaved,(unknown type)	**11**	**0.0**	**0**	**0**	**0**
A112	Woodland,Broadleaved,Plantation	0	0.0	0	0	0
B21	Grassland,Neutral,Unimproved	0	1.0	0	954	482
B22_ng	Grassland,Neutral,Semi-improved[non graze	26	0.2	5	12461	6300
B4	Grassland,Improved,	-36	2.2	-79	-188345	-95226
B5	Grassland,Marshy,	0	0.5	0	-250	-127
J11	Cultivated/disturbed land,Arable,	-3	1.8	-5	-12108	-6122
J21	Boundaries,Intact hedge,	1	0.0	0	0	0
J22	Boundaries,Intact hedge,	0	0.0	0	0	0
J23	Boundaries,Hedge and trees,	0	0.0	0	0	0
		0		-79	-187289	-94692

As discussed earlier, this order of reduction in stocking would render the current dairy system financially non-viable and would not support a zero grazed system and the existing cost structure of the farm. For this reason, a modified Scenario was constructed that reduced the uptake of EFS and degree of change in land use (Table 7). Capital costs are about £46,700, equivalent to about £2,500 /year, and annual revenues from EFS are about £9,300

Table 7: Farm C Scenario 1A Estimated capital costs and annual revenue from EFS payments

				Capital costs			Revenue	
Components		units	nr	£/unit	Total £	Equiv Ann cost £/year *	£/unit	£ total
Woodlands								
New wooc Woodlanc	ENW/NRV	ha	4.5	2,925	13,163	716	350.0	1,575
New wooc Native tre	NTW	ha	0.5	2,146	1,073	58	350.0	175
Woodland remedial	WWU/WA	ha	10.0	0			65.0	649
Creation of woodland pasture		ha	0	0	0	0	0.0	0
Field Management				0	0	0		
Pollinator margins o	PAN	ha	1.6	0	0	0	465.0	729
Wildflower margins	WFM 10m	ha	1.6	0	0	0	2,530.0	3,965
Winter feed for bird	WFC		1.3	0	0	0	590.0	767
Marshy Grassland	FNG/RBG		5.6	1,700	9,435	513	50.0	278
Rough grass margins	RGM 6m		0.4	842	337	18	707.0	283
Riparian ungrazed bu	RBS 2m		0.4	30,350	12,140	660	350.0	140
Riparian ungrazed	RBW 10m		0.4	7,630	3,052	166	360.0	144
retention of winter s	RWS	ha	6.6	0	0	0	85.0	558
Boundaries			5.6	0	0	0	0.0	0
Hedges	PNH	m	0.0	16	0	0	0.1	0
Hedges restore	LAY		0.0	16	0	0	0.1	0
Pond		m2	2500	3	7,500	408	300.0	300
Total			0		**46,699**	**2,539**		**9,263**
£/ha (264 ha)					417	23		83

The modified Scenario 1A reduces stocking by 21 LU/year (about 10% of the baseline) and Gross margin by about £25,000/year (table 8)

Table 8: farm C Scenario 1A Changes in Net Margin

		Diff, ha	Lu/ha	Change in LU	GO £	GM £
A11	Woodland,Broadleaved,(	**5**	0	**0**	**0**	**0**
A112	Woodland,Broadleaved,F	**5**	0	1	1193	603
B21	Grassland,Neutral,Unimp	**0**	1	0	954	482
B22_ng	Grassland,Neutral,Semi-i	5	1	3	6326	3199
B4	Grassland,Improved,	-9	2	-19	-46255	-23386
B5	Grassland,Marshy,	0	1	0	-250	-127
J11	Cultivated/disturbed lanc	-3	2	-5	-12108	-6122
J21	Boundaries,Intact hedge,	**1**	0	0	0	0
J22	Boundaries,Intact hedge,	0	0	0	0	0
J23	Boundaries,Hedge and tre	0	0	0	0	0
		0		-21	-50140	-25350

The summary of expected changes in net revenue to Farm C is given in Table 9. The modified Scenario 1A substantially reduced the loss of agricultural income but has lower agri-environmental income relative to the original Scenario1.

Table 9: Farm C Summary of changes in net income from agriculture and EFS payments for Scenario 1 and 1A

Change in agricultural net income	scenario 1		scenario 1 A	
	£	£/ha	£	£/ha
Change in GO	-187289	-1522	-50140	-407
Change in GM	-94692	-769	-25350	-206
Change in FC	-23922	-194	-6404	-52
Net change	-70769	-575	-18946	-154
EFS revenue	30,546	248	9,263	75
extra efs costs	8553	70	2594	21
Extra EFS annual rever	21,993	179	6,669	54
baseline EFS	0	0	0	0
efs inlc baseline	21993	179	6669	54
Net change + efs	-48776	-396	-12277	-100

Scenario 2

Scenario 2 as originally constructed involved a substantial area of land taken out of production for field margins and woodland creation as well as the withdrawal of artificially fertilised improved grass leys. Capital costs are £205,000 and an equivalent annual cost of £16,000, with annual revenues of about £33,000/year (Table 10).

Table 10: Farm C Scenario 2 Estimated capital costs and annual revenue from agri-environment take-up

				Capital costs				Revenue	
						Equiv Ann cost			
Components		units	nr	£/unit	Total £	£/year *	% capital	£/ha	£/year
Woodlands									
New woodland	EW) base	ha	6.0	2,925	17,579	956	6%	350	2104
New woodlands: riparian/wet		ha	0.0	2,925	0	0	0%	350	0
Creation of woodland pasture	EAF	ha	49.8	2,146	106,871	5,811	36%	205	10209
Scrub (or agro forestry)			20.6					149	3075
with low input grassland									0
Woodland remeidal management		ha	10.0					65	650
species rich with low inputs		ha	0.4	650	260	14	0%	205	82
Grassland neutral species rich with low inputs			39.8	500	19,920	1,083		182	7251
Pollinator margins on improved grass area PAN									
Wildflower margins	WFM 10m		1.3					2530	3289
Winter feed for birds	WFC		1.3					590	767
Riparian ungrazed bu=ffer	RBS 2m		0.8	842	656	36		707	551
Riparian ungrazed	RBW 10m		0.3	30,350	7,891	429		350	91
					0				
								465	0
Grass marshy		ha	8.9	1,700	15,113	822	5%	180	1600
Bog creation		ha	19.1	2,000	38,220	2,078	13%	85	1624
Hedges and trees		m	5,029	17	85,493	4,648	29%	0.2	1006
Ponds		m2	1100.0	3	3,300	179	1%		600
Total					**295,303**	**16,056**	100%		32900
£/ha			71.9		2,636	143			294

The reduction of stocking under the original Scenario 2 is 164 LU, units (75% of the baseline), with a loss of Gross margin of £198,000/year (Table 11). This would render dairying infeasible on the farm. The Farm would probably convert to livestock grazing.

Table 11: Farm C Scenario 2 Change in Revenues associated with agri-environment take-up

			area	Stocking	Change	GO	GM
			ha	LU/ha	Lu	£	£
A11	Woodland,Broadleaved,(unk	Broadleaved woodland	6	0	0	0	0
A112	Woodland,Broadleaved,Plan	remedial man half grazed	5	0	1	1789	905
A112o_B2	Woodland,Broadleaved,Plan	Silvo-pastoral	50	1	50	118792	60061
A22	Scrub,Scattered,	Scrub	21	1	10	24617	12446
B21	Grassland,Neutral,Unimprov	Semi-natural grassland	0	1	1	1193	603
B4	Grassland,Improved,	Improved grassland	-97	2	-213	-508412	-257050
B5	Grassland,Marshy,	Marshy grassland	9	1	4	10603	5361
J11	Cultivated/disturbed land,Ar	Arable	-9	2	-17	-40318	-20384
E17	Bog,Wet modified bog,	Bog	19	0	0	0	0
G1u	Standing water,(unknown),	Water	0	0	0	0	0
J21	Boundaries,Intact hedge,	Hedgerows	1	0	0	0	0
J22	Boundaries,Intact hedge,	Hedgerows	0	0	0	0	0
J23	Boundaries,Hedge and trees,	Hedgerows	0	0	0	-4	-2
			0		-164	-391739	-198061

An alternative Scenario 2A was constructed that moderated the introduction of environmental options while retaining the integrity of the dairy unit. This was achieved by introducing an agroforestry option while retaining improved grassland. (Table 12). Capital costs are £192,000, equivalent to £10,500/year. Annual revenue from agri-environment is about £18,100/year.

Table 12: Farm C Scenario 2 Uptake Agri-environment

Components		units	nr	£/unit	Total £	Equiv Ann cost £/year *	% capital		£/ha	£/year	£/unit	£ total
Woodlands												
New woodland	EW) base	ha	0.0	2,925	0	0	0%	incremen	350	0	360	0
New woodlands: riparian/wet		ha	0.0	2,925	0	0	0%	incrment	350	0	210	0
Ceation sylvo alley gr	EAF	ha	50.7	1,637	82,996	4,513	43%		205	10394	205	10,394
												0
												0
Field Management												
Grassland neutral *species rich* w		ha	0.0	650	0	0	0%		205	0	139	0
Field margins					0	0	0%			0		0
Pollinator margins on	PAN		1.3		0	0	0%		465	605	**465**	605
Wildflower margins	WFM 10m		1.3		0	0	0%		2530	3289	2,530	3,289
Winter feed for birds	WFC		1.3		0	0	0%		590	767	590	767
						0	0%			0		0
Rough grass margins	RGM 6m		0.8	842	656	36	0%		707	551	707	551
Riparian ungrazed bu	RBS 2m		0.3	30,350	7,891	429	4%		350	91	350	91
Riparian ungrazed	RBW 10m		0.3	7,630	1,984	108	1%		360	94	360	94
retention of winter st	RWS		0.0	0	0	0	0%		85	0	85	0
												0
												0
											223	0
Grass marshy	FNG/RBG	ha	5.8	1,700	9,792	532	5%		125	720	125	720
Bog creation		ha	0.0	2,000	0	0	0%		85	0	85	0
		ha			0	0	0%			0	40	0
Hedges and trees		m	5,029	17	85,493	4,648	45%		0.2	1006	0.2	1,006
Ponds		m2	1100.0	3	3,300	179	2%			600	0.1	83
Total					**192,112**	**10,445**	100%			**18116**		**17,598**
£/ha			11.0		1,715	93				162		157

Under modified Scenario 2A, stocking is reduced by 30 LU (14%), and gross margin by £35,800/year (Table 13). Agro-forestry involves alley production of culinary apples sold as a standing crop at £394/ha, net of costs on 10 ha, £3,940/year.

Table 13: Scenario 2A Changes in habitat areas, stocking rates and resultant changes in Gross output, Gross Margin and Net Margin (before agri-environment revenue and changes in fixed costs)

		area area ha	LU Stocking LU/ha	ch LU Change Lu	GO £	GM £
A11	Woodland Broadleaved woodl	0.0	0.0	0	0	0
A112	Woodland Broadleaved woodl	5.0	0.2	1	1789	905
A112o_B2	Woodland Silvo-pastoral	0.0	1.0	0	0	0
A22	Agro-forestry Alley grass	50.7	1.8	89	212853	107617
B21	margins Gr Semi-natural grassl	5.2	0.5	3	6727	3401
B4	Grassland, Improved grassland	-48.0	2.2	-106	-251897	-127357
B5	Grassland, Marshy grassland	0.0	0.5	0	0	0
J11	Cultivated Arable	-9.4	1.8	-17	-40318	-20384
E17	Bog,Wet m Bog	0.0	0.0	0	0	0
G1u	Standing w Water	0.1	0.0	0	0	0
J21	Boundarie Hedgerows	1.5	0.0	0	0	0
J22	Boundarie Hedgerows	-0.1	0.0	0	0	0
J23	Boundarie Hedgerows	0.0	0.0	0	0	0
				-30	-70846	-35819

The changes in financial indicators for Farm C for Scenarios 2 and 2A Change is given in Table 14. Agri-environment revenues do not compensate for the large decrease in agricultural net income under Scenario 1. There is loss of about £9,000/year inclusive of agri-environment revenues for scenario 2. This includes net revenue from apple produced from the agro-forestry component at £3,970//year net. A wood fuel option would alternatively give a net return of about £124/ha, £1,240/year. These estimates include the costs of apple or wood coppicing establishment.

Table 14: Farm C Summary Scenario 2 and 2A

	Scenario 2		Scenario 2A	
	£	£/ha	£	£/ha
Change in GO	-391739	-3183	-66872	-543
Change in GM	-198061	-1609	-31845	-259
Change in FC	-50037	-407	-9049	-74
Net change	-148024	-1203	-22796	-185
revenues from agri-env				
extra agri-environmer	32900	267	18116	147
extra maintenance	9212	75	5072	41
net of maint	23688	192	13043	106
Net margin + agri-enc	**-124336**	**-1010**	**-9752**	**-79**
Alternative fixed costs assumption				
FC reduction	46291	376	8372	68
Net change	-144278	-1172	-22118	-180
net margin +efs	-120590	-980	-9075	-74

areas include farm woodlands, total 123 ha
GM includes 10 ha of culinary apples at £394ha/year as standing crop on 10 ha (£3,974/year)
alternatively Woodfuel chips margin would be £124/ha/year , £1,240/year

Net Margins by Scenario

Agricultural net margins fall under the modified scenarios 1A and 2A, but not as drastically as they do under the original Scenarios (Table 15). After inclusion of BPS and agri environment payments (Table 16) Scenarios 1A and 2A return net margins that are about 90% of baseline estimates, retaining the existing dairy f arm business enterprise.

Table 15: Farm C Agricultural Net Margin by Scenario

	Baseline	Scenario 1	Scenario 1A	Scenario 2	Scenario 2A
Gross output	520611	333322	470471	128872	453739
Gross margin	263217	168525	237867	65157	231372
Fixed costs	164730	140808	158326	114693	155681
Agric net margin	98487	27718	79541	-49536	75691
	Baseline	Scenario 1	Scenario 1A	Scenario 2	Scenario 2A
Gross output	4267	2732	3856	1056	3719
Gross margin	2157	1381	1949	534	1896
Fixed costs	1350	1154	1298	940	1276
Agric net margin	807	227	652	-406	620

Table 16: Farm C Farm Net Margins by Scenario

£/year					
	Baseline	Scenario 1	Scenario 1A	Scenario 2	Scenario 2A
Agric net margin	98487	27718	79541	-49536	75691
BPS	23000	23000	23000	23000	23000
Agri-env	0	21993	6669	23688	13043
Net margin	121487	72711	109211	-2849	111735
£/ha/year					
	Baseline	Scenario 1	Scenario 1A	Scenario 2	Scenario 2A
Agric net margin	807	227	652	-406	620
BPS	188	188	188	188	188
Agri-env	0	180	55	194	107
Net margin	996	596	895	-23	916

Estimated Agriculture, agri-environment and Quantified Ecosystem Services

The estimated annual values of selected quantified ecosystem services for Farm C taken from the earlier Annex are given in Table 17.

Table 17: Farm C Estimated Quantified Ecosystem Services
£/year

	Base	Scenario 1	Scenario 1A	Scenario 2	Scenario 2A
Carbon	-152801	-63818	-105243	36155	-88548
Air Quality	19242	29134	24062	66170	28926
Timber	4224	8953	6339	24760	8514
Water related	1890	4007	2837	13385	3810
Total	-127444	-21724	-72005	140470	-47298

Estimated Net Ecosystem Services from Farm C

Data on Agricultural Net Margin are combined with benefit estimates of ecosystem services, agri-environment benefits (based on payment values), less annual capital costs of scenario implementation (Table 18). No additional costs are included here for the administration of the environmental schemes. The tradeoff between agricultural production and quantified ecosystem services in the Scenarios is apparent, especially in Scenario 2 that includes a large land take for farm woodland that generates a positive outcome value for the quantified nonagricultural ecosystem services (Table 17), but a negative agricultural value added (Table 18). Scenario 2A better balances agricultural and environmental outcomes.

Table 18: Farm C Estimated Quantified Ecosystem Services

£/year	Base	Scenario 1	Scenario 1A	Scenario 2	Scenario 2A
Agric net margin	98487	27718	79541	-49536	75691
Quantified Ecosystem Services	-127444	-21724	-72005	140470	-47298
Agri-environment payments	0	21993	6669	23688	13043
Agr env capital costs	0	-8124	-2539	-16056	-10445
NET	-28957	19862	11667	98565	30992
£/ha/year	Base	Scenario 1	Scenario 1A	Scenario 2	Scenario 2A
Agric net margin	807	227	652	-406	620
Quantified Ecosystem Services	-1044	-178	-590	1151	-388
Agri-environment payments	0	180	55	194	107
Agr env capital costs	0	-67	-21	-132	-86
NET	-237	163	96	808	254

3.7.4 FARM D: Down, Intensive Arable

The farmer and family operate an intensive arable farm including field vegetables near Newtownards, County Down, Northern Ireland. The farm comprises 142 ha (350 acres), mostly tenanted. Soils are mainly sandy clay loams and annual rainfall is about 900mm.

About 80 ha (200 acres) are down to grass which is used for bioenergy production using anerobic digestion. About 77ha (190 acres) is temporary rye grass leys cut 3 or 4 times with 2 x 50kg bags per acre of 28N:0P:5K applied between cuts, about 70kgN/ha, equivalent to 210 to 280 kgN/ha per year. About 4 ha (10 acres) are permanent grass, with lower fertiliser applications, some of it providing wildflower and bird cover habitats. This land is temporary ryegrass (e.g. 3- or 5-year ley) and included in the rotation for the cropping of field vegetables.

60 ha (150 acres) are under arable cropping at any one time including about 16 ha (40 acres) of cereals as a break crop (mainly spring barley) and maize (for bioenergy) and about 44 ha (110 acres) for field vegetables including leeks, brassicas, spring onions and red beetroot. Irrigation (mobile reel and rain gun (is applied as needed mainly for crop quality assurance, serviced from a borehole.

The Farm delivers fresh produce on contract to major supermarkets. It is a member of the Red Tractor producer accreditation scheme well as complying with the provenance requirements of its major buyers. This involves detailed records of inputs and processes to support traceability and assurance. The Farm has a well-established community outreach program and has received numerous food industry awards.

The farm employs about 25 people, mainly linked to field vegetable production and packing. Accommodation is provided for seasonal workers. In addition, labour and management inputs are provided by the farmer and other family members (FTE 2.5).

The farmer expressed much interest in opportunities to build nature into the farming system, referring to actions already taken under EFS and ongoing collaboration with RSPB (annual payments currently about £1,050/year). Three areas of land with potential for nature-based interventions were identified.

One parcel of land, comprising about 16 acres of which 10 acres are in brassicas and 6 in grass. The area is registered with the Soil Association for organic production (not all – 6 acres front and side of home farm). Another parcel, 18 acres of which 13 are down to grass for Bioenergy and 2 acres are included in the Environmental Farming Scheme for wildflower and for winter bird feed and 3 acres of cereals – one on its own (spring barley)

A third parcel (80 acres) on the west side of the Lough) is farmed (for grass bioenergy) on behalf of its owner who has expressed an interest in farming for nature. This area has not been surveyed as part of the project. It is possible that the options considered for the parts of the farm that have been surveyed could indicate possibilities for the site.

The scenarios to consider are:
Scenario 1, 'greening' the existing business through increased adoption of available EFS options into the existing farming system, including biodiversity enhancements associated with field boundaries and margins, winter cover crops, and herb rich grassland on marginal areas
Scenario 2, a 'restoration' approach focussing on nature/environment outcomes possibly involving a switch to herb rich grasslands possibly linked with agroforestry to support orchard cropping, extension of hedgerow and native tree corridors, winter cover crops, and possible extension of organic vegetable production (to be discussed). The purpose here is to explore the scope for increased nature and

environmental value while retaining the essential food and bio-energy production features and financial viability of the farm business.

Following the ecological assessment on 12.5 ha, it was agreed for the purpose of farm business analysis to uplift the assessment to the whole farm scale.

Table 1: Farm D land use and cropping

	Acres	Ha
land cover and crop areas		
Arable		
Cereals		
Sp Barley	30	12.1
Field vegetables		
Leek	45	18.2
Sp onions	25	10.1
Brassica : sping cabbage	30	12.1
Red Beet	10	4.0
parsley/heerbs	10	4.0
Total veg	120	48.6
Total arable	150	60.7
Grassland Improved	200	81.0
Total agric useable	350	141.7

Table 2 shows the estimated annual Net Margin (before other income) for Farm D for the combined arable and grass for energy enterprises after deduction of Fixed Costs. Estimates are based on farm accounts and corroborated against DAERA data. Fixed costs include the cost of paid labour a charge for unpaid family labour. Expected Net Margin before other sources of income is about £890/ha/year. Note, this is attributing all the value added on the farm, including assets and activities associated with the packhouse and preparation of fresh produce for market, to the land resource. Other income sources, notably BPS together with revenue from a current EFS application under review reduce the expected annual deficit.

Table 2: Farm D Estimated Annual Net Margin

Table redacted for confidentiality

Grass-for-energy on Farm D forms part of the rotation supporting intensive arable cropping (Tabe 3). It also provides scope for incorporating environmental options on the farm while retaining the area of high value arable cropping. The income foregone by taking arable land out of production is much higher than on grassland, especially on prime arable land. It is assumed in the analysis that follows that take-up of environmental options involves reduced output from the grassland areas of the farm. It is noted that the Farm currently has contracts to deliver grass to the local bioenergy processing operation.

Table 3: Farm D: Net Margin from grass for energy cropping

Yield	t Wet Matter	47
Dry Matter	% WM	25%
Price (AD)	£/tWM	36
Total	£/ha	1692
VC	£/ha	785
Gross margin	£/ha	907
FC	£/ha	557
Net margin	£/ha	350
BPS	£/ha	190
Including BPS	£/ha	540

Uplifting from the surveyed area to the whole farm

The ecology and habitat surveys for Farm D were conducted on 12.5 ha of the farm only. A high-level assessment of habitats and land use across the whole farm area enabled the Scenario options to be considered at the whole farm (142 ha) scale for the purpose of business analysis. While this assumption could be a source of estimation error, the approach is considered appropriate to provide indicative results of the Scenario impacts on the farm business.

Scenario 1

Scenario 1 involves the introduction of a range of EFS options applied across the farm (Table 4). The total estimated capital is £52,000, equivalent to £2,800/ha/year discounted at 3.5% over 30 years. It is assumed that capital costs are fully funded under EFS agreements. The expected annual revenue from the package of EFS options is about £13,700/year, an average of £97/ha/year). These interventions include the options currently included in the baseline (£1,039/year).

Table 4: Farm D: Scenario 1 Estimated capital costs and annual revenue from EFS payments for scenario

Components		0 units	nr	£/unit	Total £	Equiv Ann	£/unit	£ total
Woodlands								
New woodland	ENW/NRV	ha	3.48	2925	10179	553	350	1218
New woodlands	NTC	ha	1.7	2925	4973	270	350	595
Creation of woodland pasture		ha						
Field Management					0	0	465	0
Wildflower margins	WFM 10m	ha	3.1		0	0	2,530	7717
Winter feed for birds	WFC	ha	3.1		0	0	590	1800
other tall ruderal on ma	CUM		0.7		0	0	702	525
Rough grass margins	RGM		1.1	842	926	50	707	778
Boundaries								
Hedges	PNH	m	1342.0	16	21526	1,170	0.2	268
Hedges restore	LAY		894.7	16	14351	780	0	179
Total					51954	2825		13079
					less rev from existing			1,039
					additional income			**12,041**

About 13 ha of intensive grass is taken out of production, 6 ha of which is replaced by reduced input grass on field boundaries (at output 45% of improved grass yields) the estimated loss of Gross Margin is about £8,600/year. (Table 5). This is about 1 % of baseline gross margin.

Table 5: Farm D: Scenario 1 Change in Revenues

	area ha	GO £	GM £
Arable	0	0	0
Grass for energy	-13	-21827	-11702
Total	-13	-21827	-11702
extra revenue			
grassland ; reduced	6	4539	3140
grassland grazing	0	0	0
Total	6	4539	3140
net change	-7	-17288	-8562

The changes in key financial indicators are shown in Table 6 for Scenario 1. Fixed costs reduce by about £3,100/year, mainly reflecting reduction in fixed costs for bioenergy, including contractor costs. After these adjustments Net Margin from agriculture is reduced by about £5,500/year. Additional revenue from EFS minus additional operating costs at about £8,700/year result in an overall increase of about £3,200/year. An alternative reduced estimate for fixed costs savings gives about £2,500/year overall.

Table 6: Farm D: Scenario 1 Change in net Margin

	£	£/ha
Change in GO	-17288	-118
Change in GM	-8562	-58
Change in FC	-3092	-21
Change in NM	**-5470**	-37
EFS revenue	13079	89
baseline EFS	1,039	7
Extra EFS	12,041	82
Extra EFS less ops	8,669	59
Ch in NM and EFS	3,199	22
Alternative FC	-2420	-17
Adjusted NM	-6143	-42
Ch in NM + EFS	2527	17

Scenario 2

Scenario 2 involves the introduction of an agro forestry option in which the total area of arable cropping is maintained in a land allocation that is assumed for every 1 ha to give 0.2 ha agro-forestry and 0.7 ha arable equivalent, the balance being non-used field space. 1.42 ha of alley cropping agro-forestry including arable is required to provide 1 ha of arable cropping (1 ha /0.7 ha). The land required for the agroforestry displaces grass for energy. A total of 86 ha enters the agro-forestry rotation, half for arable and half for grass for energy. The permanent agroforestry area supports the rotation for arable and grass for energy as before. A linear culinary apple planation is assumed. Low to medium prices (£420/t) and yields (35t/ha achieved in year 8) are assumed based on an annual cash flow over 30 years discounted at 3.5%/year to give an equivalent annual Gross Output and Gross Margin.

The estimated capital costs of Scenario 2 for farm D are £255,300, equivalent to £13,900/year, and about £1,100/ha (Table 7). The main items are for agro-forestry establishment. It is assumed these are grant funded. Annual revenues assuming agro -forestry payments apply are about £30,000/year. Eligibility for agro-forestry grant and payments needs to be confirmed.

Table 7: Farm D; Scenario 2 Estimated capital costs and annual revenue from EFS payments for scenario 2

		Capital							Revenue	
Components		units	nr	£/unit	Total £	Equiv Ann cost £/year *	% capital		£/ha	£/year
Woodlands										
New woodland	NTC	ha	4.2	7,000	29,400	1,599	12%		350	1470
New woodlands: riparian/we		ha	0.0	7,000	0	0	0%		350	0
					0	0	0%			0
Agroforestry					0	0	0%			0
Sylvo grass energy	EAF	ha	43.0	2,200	94,600	5,144	37%		205	8815
							0%			0
Sylvo arable orchar	EAF	ha	43.0	2,200	94,600	5,144	37%		205	8815
Field Management		ha			0	0	0%			0
Wildflower margins	WFM 10m	ha	3.1	0	0	0	0%		2530	7717
Winter feed for birc	WFC	ha	3.1	0	0	0	0%		590	1800
other tall ruderal or	CUM	0.0	0.7	0	0	0	0%		707	529
Rough grass margin	RGM	0.0	1.1	841.5	926	50	0%		465	512
					0	0	0%			0
Field margins					0	0	0%			0
Hedges	PNH	m	1,342	16	21,472	1,167	8%		0.2	268
dges restore	LAY	0	895	16	14,315	778	6%		0.2	179
Total					255,313	**13,882**	**100%**	**0**	**5,402**	**30,104**
£/ha	ha	148.7				1,114				202
								less base		1,039
extra annual maintenance costs			0.28					extra efs rev		29,065
net of maint costs										**8,138**

The changes in net margin attributable to the introduction of agro-forestry with a fruit crop (apples) and displacement of grass for energy (17.2 ha) is shown in Table 8. Gross output rises considerably, but there is a small negative net change Gross margins (-£2,400/year), using cautious estimates for fruit prices and yields. The outcome for a woodfuel option is also shown.

Table 8: Farm D Scenario 2 Gross Output and Gross Margin for Agroforestry with apples or timber options

		GO	GM
Reduction in cropping area		£/year	£/year
Arable	ha		
Arable	0.00	0	0
Grass	-34.20	-57866	-31025
Total		-57866	-31025
extra revenue			
Grassland : grazed /cu margins			
Sylvo arable orchar	0.0	0	0
0.2 orchard ir	8.6	88272	14328
0.2 orchard ir	8.6	88272	14328
Sub total	17.2	176544	28656
net change with orchard		118678	-2369
Timber options			
0.2 timber 15	8.6	1064	1064
0.2	8.6	1064	1064
subtotal		2129	2129
Subtotal with timber		-55738	-28896

Net Margin from agriculture (excluding BPS) remains much the same (-£1,700/year) (Table 9). Additional revenue from agri-environment increases net margin by about £20,000/year, £127/ha/year. This assumes that agro-forestry is eligible for capital and revenue funding.

Table 9: Farm D: Change in Net margin

	£/year	£/ha/year
Change in GO	118678	798
Change in GM	-2369	-16
Change in FC	-669	-5
Change in NM	**-1699**	-11
Agri-env revenue	30104	202
Agri-env ops	8429	57
Extra agri-env	21,675	146
baseline EFS	1,039	7
CHh in agri-env	20,636	139
Ch NM + Agri-env	18937	127

Net Margins by Scenario

Agricultural Net margins for Farm D (Table 11) remain at about £120,000/year and £800/ha/year under both scenarios before subsidies and other income. There is little change in Fixed Costs.

Table 11: Farm D Agricultural Net Margin by Scenario

£ Whole farm/year

	Baseline	Scenario 1	Scenario 2
Gross output	1537004	1519716	1655682
Gross margin	983453	974891	981085
Fixed costs	857708	854616	857039
Agric net margin	125745	120275	124046

£/ha/year

	Baseline	Scenario 1	Scenario 2
Gross output	10343	10227	11142
Gross margin	6618	6560	6602
Fixed costs	5772	5751	5767
Agric net margin	846	809	835

Whole Farm Net Margin improves marginally under Scenario 1 assuming there is no reduction in arable cropping land. Scenario 2 shows an increase of £20.000/year, £134/ha (Table 12), assuming agro-forestry is eligible for support, and arable cropping is maintained. Business viability is maintained. Linear/alley cropping is potentially compatible with the farming system.

Table 12: Farm D Farm Net Margins by Scenario

£ Whole farm/year

	Baseline	Scenario 1	Scenario 2
Agric net margin	125745	120275	124046
BPS	27000	27000	27000
Agri-env	1039	9708	22713
Net margin	153784	156983	173759

£/ha/year

	Baseline	Scenario 1	Scenario 2
Agric net margin	846	809	835
BPS	182	182	182
Agri-env	7	65	153
Net margin	1035	1056	1169

Estimated Agriculture, agri-environment and Quantified Ecosystem Services

The estimated annual value of selected quantified ecosystem services for Farm A taken from the earlier Annex is given in Table 13.

Table 13: Farm D Estimated Quantified Ecosystem Services
£/year

	Baseline	Scenario 1	Scenario 2
Carbon	-57769	-36911	-3121
Air Quality	12415	17630	29948
Timber	0	1904	7235
Water related	0	852	3238
Total	-45354	-16525	37300

Estimated Net Ecosystem Services from Farm D

Data on Agricultural Net Margin are combined with benefit estimates of ecosystem services, agri-environment benefits (based on payment values), less annual capital costs of scenario implementation (Table 14). No additional costs are included here for the administration of the environmental schemes. There is a substantial and successive improvement in the combined net value of annual flows from the baseline through Scenario 1 to Scenario 2. The incremental gain is greatest for Scenario 2. The relatively high capital costs in Scenario 2 reflect the investment in agro-forestry

Table 14: Farm D: Estimated net annual flows of selected ecosystem services

	Base	Scenario 1	Scenario 2
Agric net margin	125745	120275	124046
Quantified Ecosystem Services	-45354	-16525	37300
Agri-environment payments	1039	9708	22713
Agr env capital costs	0	-2825	-13882
NET	81430	110633	170178
£/ha/year	Base	Scenario 1	Scenario 2
Agric net margin	846	809	835
Quantified Ecosystem Services	-305	-111	251
Agri-environment payments	7	65	153
Agr env capital costs	0	-19	-93
NET	548	745	1145