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Plugging the income gap: Assessing environmental options for upland farms: A case study in Pendle Hill, Lancashire

Authors: Alison Holt and Joe Morris

Contact details:
Dr A.R. Holt
Natural Capital Solutions Ltd
www.naturalcapitalsolutions.co.uk
alison.holt@naturalcapitalsolutions.co.uk

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Executive Summary

Context
Following the decision by the UK Government to withdraw from the European Union and the Common Agricultural Policy, direct income support to farmers (the Basic Payment Scheme (BPS)) will be replaced with a range of measures including a new Environmental Land Management (ELM) scheme. ELM will incentivise and reward land managers for safeguarding natural assets such as land, water, air and biodiversity, in order to secure a range of ecosystem services of benefit to people. In other words, 'public money' will pay for 'public goods'.

Aim and Approach
In this context, and focussing on the Pendle Hill area in the north west of England, we set out to answer two questions:

(i) What public benefits can upland hill farms provide under the proposed ELMs?
(ii) Can the financial rewards for implementing ELM-type options on upland farms make up for the loss of direct income support under the Basic Payment Scheme?

Following a review of policies affecting upland farmers, we addressed the above questions by applying the methods of natural capital assessment and farm business appraisal on three actual farm cases in the Pendle Hill area. From this we produced a generic representative case study for 'Pen Farm', a Less Favoured Area Grazing Livestock Farm of 146 ha, specialising in upland sheep and beef production. The case explored the extent to which participation in ELM could simultaneously deliver intended environmental outcomes and a financially sustainable farm business.

Results
A map-based register of natural assets classified Pen Farm into major habitat types and associated land use. These comprised mainly improved grassland in lower lying areas, small areas of woodland, and semi-natural grassland with moorland on the higher elevations. An assessment of selected existing baseline ecosystem services, using a mixture of qualitative and quantitative (mapping and natural capital accounting) measures, showed relatively high generation of provisioning services in terms of livestock production, but relatively low capacity under existing land use to provide regulating services (e.g. carbon sequestration, water quality and flow, air quality and habitat for biodiversity). There was moderate generation of some cultural services associated with enjoyment of the countryside, including health and well-being benefits. The mapping approach provided a way of quantifying services that could not be measured in the natural capital account (water quality and flow regulation). However, there is uncertainty in these estimates in relation to the water services, because the models used, developed for use at landscape scales, do not incorporate the impact of farm practices on the provision of these services.

Opportunities for generating public goods on Pen Farm were identified by aligning environmental options and associated changes in farming practices with the six main themes of ELMs, namely: Beauty, Heritage and Engagement; Clean Air; Mitigation of and Adaption to Climate Change; Clean and Plentiful Water; Protection from and Mitigation of Environmental Hazards; and Thriving Plants and Wildlife. ELM-type options included creating new woodland, introducing wood pasture (silviculture), promoting more diverse grassland management to improve biodiversity, using buffer strips and shelterbelts to protect and improve water quality and reduce run off from fields, and enhancing public access. It was shown that substantial increases in provision could be achieved across a broad range of ecosystem services that benefit people and nature, thereby achieving ELMs objectives and increasing the value of natural assets in the long term. This did, however, require a reduction in agricultural output associated with reduced livestock numbers and stocking intensity.

Reflecting conditions in the upland grazing sector as whole, the financial viability of Pen Farm was shown to be highly dependent on an annual net income from BPS of about £23,000. Comprehensive adoption of a range of ELMs options on the farm could help to close the income gap left by the loss of BPS. Assuming payment rates based on Countryside Stewardship (CS) agreements, the new options produced an extra net income (after costs) of about £18,000/year compared to that previously obtained under CS. This left a remaining net income gap of about £5,000/year after BPS withdrawal. The new ELMs type options, however, required a reduction in livestock stock numbers of about 22% that, after savings in costs, further increased the BPS income gap to about £6,700 per year (about minus £48 per ha of usable agricultural land). There was scope to close this remaining gap by additional income from wood products, from farm diversification associated, for example, with eco-tourism, and from further adjustments to improve the efficiency of farming activities.

These estimates are subject to considerable uncertainty, not least because of the year-to-year variation in agricultural commodity markets and prices, but also because the details of ELMs options and payments rates have yet to be announced. The legacy CS payments rates assumed here are mainly based on compensation to land managers for loss of income and additional costs. Outcome–based payments, a declared principle for ELMs, will probably result in higher payment rates. In the Pen Farm case for example, a 28% increase in payments rates per hectare for ELMs options above those based on the CS legacy rates assumed here would remove the BPS income gap, everything else remaining constant.

Conclusions

The Pen Farm case shows that take-up of ELM-type options sufficient to replace BPS income will require a transition to less intensive farming practices, and a reduction in livestock numbers and stocking rates. Indeed, withdrawal of BPS could, by exposing some of the hidden losses currently associated with upland livestock systems, encourage the move towards lower input but potentially higher value-added grassland and management practices, especially if this coincides with ELMs incentives.

The Pen case confirms the importance of designing ELMs options suited to the upland situation that can be combined to offer practical, appealing and financially viable solutions. Wide-ranging take-up of ELMs at the individual farm scale will probably also require coordinated and possibly collaborative working amongst land managers to achieve benefits at the landscape scale, simultaneously justifying higher incentives and payments. Achieving beneficial change will also require the longer view, including provision for funding of initial capital costs and flexible yet secure arrangements that can suit both tenants and landowners.

The Pen Farm case highlights the challenges facing upland farmers as they reset the balance of agricultural and environmental priorities. While the case shows how map-based natural capital and ecosystem services assessment methods can support decisions on future environmental options, it also confirms the need to make them better suited to context specific application at the farm scale. Future models will need, for example, to better incorporate the impacts of changes in stocking densities and agricultural inputs (fertilisers) on water quality and flow regulation. This will allow a more realistic farm-scale ecosystem service baseline to be set, so that the effectiveness of ELMs options to increase these benefits can be assessed.

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1. Introduction

This document reports on a study that explores the implications for upland farmers in the Pendle Hill area of Lancashire, of a change in agricultural and environmental policy that will replace direct income support with payments for land-based environmental services.

1.1 The environment and farming in and around Pendle Hill

Pendle Hill, an outlier of the Bowland Fells is an isolated and steep sided hill rising to 557m. Pendle Hill dominates the local area, commanding 360° views of North Wales, the Yorkshire 3 Peaks, Cumbria and West Yorkshire. Formed of layers of gritstone and limestone laid down in the Carboniferous era, and sculpted by glaciation, Pendle Hill today is largely treeless with a layer of peat on the highest plateau which is up to 3 metres deep in places. Large areas of the Hill are common land with the remainder being either estate tenanted or owner-occupied sheep and cattle farms. On the edge of the Pennines in East Lancashire the Hill receives over 1200mm of rain per year making farming difficult with a relatively short growing season.

There are approximately 125 farm businesses within the Pendle Hill Landscape Partnership (LP) area (120 km^2). The majority of these lie within the designated 'Less Favoured Area', with the higher altitude land being classed as 'Severely Disadvantaged'. These farm holdings average 86 ha in size, although 100 of them are under 100ha in extent. The latter average just 31ha, an indication of part time farming. Most farms are mainly sheep farms, with a mixture of beef cattle and dairy. The land consists of upland grass moor, rough grazing, and lower lying ‘in-bye’ grasslands of varying levels of agricultural improvement.

These current upland farming practices have been shaped in recent decades by the intensification of agriculture, initially in response to subsidised output prices, and more recently maintained by direct income subsidies (not linked to production) that underpin the financial viability of farm businesses. In turn these agricultural practices have shaped the appearance of the Pendle Hill landscape. The primacy given to agricultural output has impacted on the functioning of the upland ecosystem, its biodiversity and its ability to provide other ecosystem services and environmental benefits.

1.2 Purpose and aims

The decision by the UK Government to withdraw from the European Union, commonly referred to as Brexit, and consequently the EU Common Agricultural Policy, has prompted a major review of Agricultural and Environmental Policy. The proposals, currently under review, seek to remove the direct income support given to farmers (under the Basic Payment Scheme (BPS)) and replace this over time with a new Environmental Land Management (ELM) scheme (ELMs)[1].

In England, ELM is being introduced as a key element of Defra's 'Path to Sustainable Farming'[2]. This recognises the need to protect natural assets such as land and soils, air, water and biodiversity that are not only essential for the production of food, but also for the production of a wide range of other ecosystem services such as carbon sequestration, air pollution regulation, flood alleviation, water quality regulation, pollination and recreation. A central theme of ELM is to incentivise and reward land managers for safeguarding natural assets and securing a range of beneficial ecosystem services; in other words, using 'public money' for the production of 'public goods'.

Set in the context of Pendle Hill, the purpose of this study was to assess how the new ELMs is likely to impact on the upland farming sector, and what challenges and opportunities it will bring. It aimed to assess whether ELM can deliver a sustainable agriculture in the uplands that could promote habitat management and restoration at the same time as sustaining viable and profitable farm businesses. Specifically, we aimed to answer the following questions:

- What public benefits can upland hill farms provide under the proposed ELMs?

- Can the financial rewards for implementing ELM-type options on upland farms make up for the loss of direct income support under the Basic Payment Scheme?

This study is part of the 'What's a Hill Worth?' Project that sits within a programme run by the National Lottery Heritage funded Landscape Partnership (2018 to 2022), for which the Forest of Bowland Area of Outstanding Natural Beauty (AONB) is the lead partner. This programme looks to re-connect people with their landscape and their past, to safeguard the area's wildlife and heritage and to improve people's access to this popular countryside area.

In addition to addressing the above questions, the study reported here also shows how the methods of natural capital assessment can be combined with farm business management techniques to support decision making at the farm scale. These methods and their findings are developed through a generic case study in order to demonstrate the potential for wider application. The assistance provided by Pendle Hill Landscape Partnership (PHLP) and collaborating farmers is gratefully acknowledged.

[1] In this report we refer to 'ELM' as a concept and broad policy proposal as outlined in the Agriculture Act 2020 and to 'ELMs' as a scheme, yet to be implemented, that will contain specific measures, including arrangements for Environmental Land Management (ELM) options and payments.

[2] Defra. 2020. The Path to Sustainable Farming: An Agricultural Transition Plan, 2021 to 2024. November 30th 2020. Department for Environment, Food and Rural Affairs, London.

2. Approach

This section explains the methods used to address the study objectives. Further details are provided in the supporting Annexes.

2.1 The natural capital concept

The natural environment underpins human well-being and economic prosperity, providing multiple benefits to society. Yet it is consistently undervalued in decision-making. 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[3]). These benefits (often referred to as ecosystem services) include food production, regulation of flooding and climate, pollination of crops, and non-material cultural benefits such as aesthetic value and recreational opportunities (Figure 2.1).

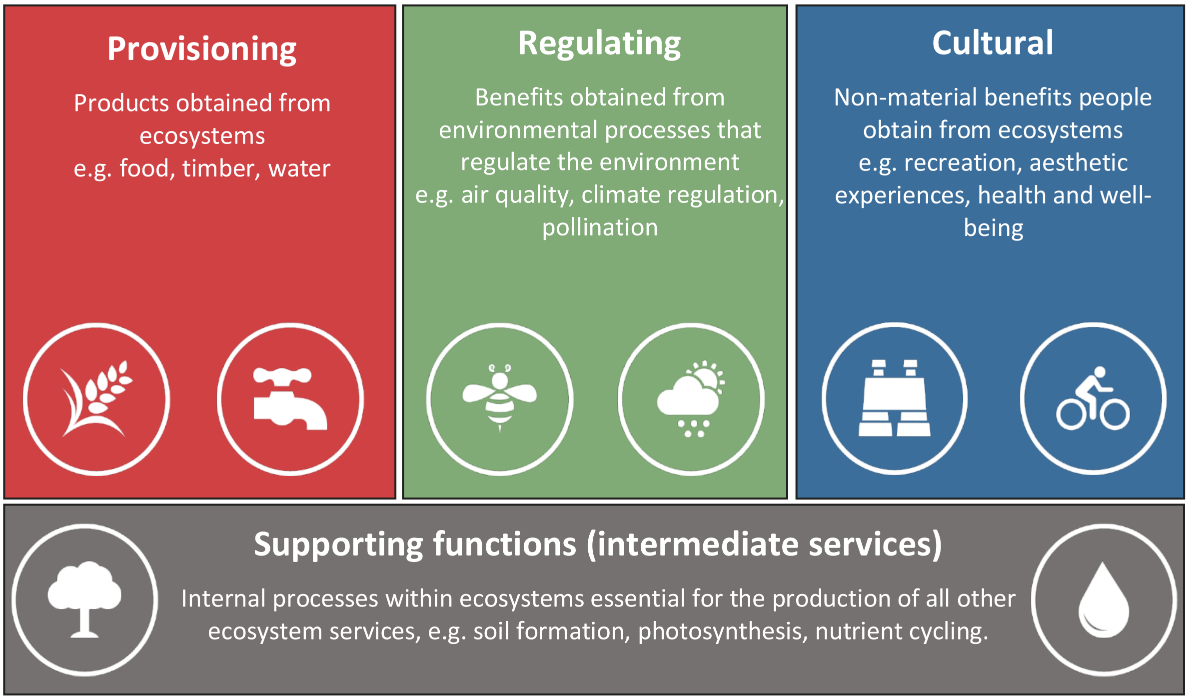

Figure 2.1 Key types of ecosystem services (based on MA 2005[4]). Note that supporting or intermediate services are now categorised as ecological functions (CICES[5]), they are the underpinning structures and processes that give rise to ecosystem services.

The proposed ELMs has been devised with the natural capital concept at its core. The concept, and its associated methods of assessment, can be used to understand

[3] 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.
[4] Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: Synthesis. Island Press, Washington D.C. https://www.millenniumassessment.org/en/index.html
[5] 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.

natural capital assets at the farm scale and across multiple farms at the scale of the rural landscape. A natural capital assessment can help to identify the extent and condition of farm assets, and the associated type and quantities of the flows of ecosystem service from those assets can be estimated. These service flows can where possible be valued in monetary terms to derive estimates of benefit. Information on the condition of farm natural assets, and the benefits derived from them, enables better land management decisions to be made by accounting for the long-term value of the asset and the services they provide.

A natural capital assessment can provide the evidence on which to ascertain whether a particular set of agri-environmental interventions can deliver the desired range of benefits provided by a farm or group of farms. It can help to show how the value of natural assets and associated services can be maintained or increased over time. It can also help to identify trade-offs and synergies between different land management options and the ecosystem services generated by them, such as food production, carbon sequestration and/or recreation. As such a natural capital assessment, as applied here, can guide decisions on the choice of environmental option, such as those contained within ELMs, to maximise potential benefit in the long term.

2.2 Pendle Hill farm case studies

In order to explore the challenges and opportunities that ELMs presents to the upland farm businesses in the Pendle Hill area, we first focused on three real case study farms. These were selected for us by the Pendle Hill LP to be representative of farms in the area. The three farmers concerned kindly volunteered to participate in the study.

The three case study farms were classed as Less Favoured Area Grazing Farms: one mainly sheep, one sheep and beef, and one mainly dairy with sheep. All had a proportion of their farm categorised as a Severely Disadvantaged Area, which was usually the higher ground on Pendle Hill consisting of upland heath, blanket bog and acid grassland used as rough grazing. The farms all had lower slopes and valley bottoms of improved grassland for grazing and forage making, usually classified as Disadvantaged Areas, with some small areas outside of LFA designation. The size of these farms varied considerably: two were between 100 and 200 ha, and one over 500 ha. They included tenant farmer and owner-occupiers. All farm businesses were heavily reliant on the Basic Payment Scheme (BPS). They also received income from Countryside Stewardship (CS). Each farm had signed up to CS options at the entry level, mid-tier and higher-level.

The findings of the individual farm assessments remain confidential to the farmers concerned. It was agreed, however, that we would draw on the methods and results of the three farms to support the creation of a single generic case study to represent farms in the Pendle Hill area, as explained below.

2.3 Natural capital assessment for Pendle Hill farms

The natural capital assets of the three farms were mapped and an asset register was created showing the habitat type, area and the proportion of the farm it covered. This was followed by a qualitative assessment of the ecosystem services provided by each farm. It was not possible to quantify and value all ecosystem services, so a qualitative assessment identified the whole suite of services that may be provided by the farm. A natural capital impacts and dependencies analysis was then undertaken (following the Natural Capital Coalition 2016[6]). Finally, the ecosystem service provision at each farm was modelled and mapped using EcoServ-GIS software, and the annual physical and monetary flows of ecosystem services were then estimated. The methods used for the three cases were subsequently used for the generic case (further details of the methods are given in Annex 2).

The natural capital and ecosystem service modelling and mapping approach used here is a well-established and robust approach developed to support decision making at the landscape scale. Application at the farm scale and context is, however, new. Here, we show how the natural capital approach can be adapted for use at the farm scale to identify the farm natural capital baseline and opportunities for enhancing ecosystem services through ELM-type interventions. We are aware that limitations may arise due to this change of scale and decision-making focus, compared with, for example, more detailed modelling of hydrological processes or carbon fluxes to show the effects of different land management practices at the field scale. Modelling to a finer resolution would, however, require more resources that those available here. While the study demonstrates the potential contribution of the methods used, it also identifies the need for refinement to suit assessment and decision support at the field and farm scales.

2.3 Farm business analyses

An assessment was made of the financial implications of the withdrawal of direct income support for Pendle Hill farms and the scope for maintaining their financial viability through rewards for ecosystem services generated under the proposed ELM scheme.

First, the current policy context affecting upland farms was reviewed focussing on the implications of the phased withdrawal of BPS and its replacement with ELMs (see Annex 1). Data from the annual Regional Farm Business Survey (2013-2019) was used to assess performance of the LFA sector and the dependency on income support. Second, the implications of policy change on farm income and viability at the farm scale were considered using the aforementioned three case studies. The relative importance of agriculture, agri-environment and BPS sources were assessed. Third, in collaboration with farmers, the natural capital assessments for each farm were used to determine opportunities for take up of future ELMs options. Finally, these opportunities were then carried forward into a farm business analysis to

[6] Natural Capital Coalition (2016) Natural capital protocol. Natural Capital Coalition. https://naturalcapitalcoalition.org/natural-capital-protocol/

estimate the changes in income and expenditure and, particularly, the extent to which ELM-type options could plug the income gap left by BPS withdrawal.

The results of each of the three farm case studies were provided confidentially to the farmers concerned. The methods and results developed for the three actual cases informed the approach to the generic case as explained below. All financial assessments were in $£_{2020}$ values.

2.4 Developing a generic case

Drawing on the results of the aforementioned cases, a generic Pen Farm case was constructed to represent a typical Pendle Hill farm. This fictional indicative case shows how the natural capital assessment and farm business analysis methods can be combined to support an appraisal of ELM-type options. For the assumptions made, it also shows the scope for plugging the BPS income gap. The Pen Farm case illustrates some of the challenges and issues facing upland farmers as they seek to adjust to new policy drivers.

Whilst Pen Farm is fictional, it is based on examples of real fields and unenclosed upland habitats in the Pendle Hill area of the Forest of Bowland AONB. Maps initially compiled for a natural capital assessment of the Forest of Bowland were used to construct maps for Pen Farm.

The Pen Farm case is used in the remainder of this document as the main vehicle for reporting the findings of the study.

2.5 Uncertainty

The natural capital and financial analyses used to construct the Pen Farm case involve a range of assumptions that are necessary to represent complex, varied and changing conditions, and to deal with gaps in information and knowledge. We have identified important sources of uncertainty and undertaken sensitivity analysis of major assumptions. It is noted that the eventual design and implementation of ELMs is currently unknown and will be the subject of Defra's ELM Trial and Test programme[7] and a National Pilot scheduled for 2021-2024.

3. Review of agricultural and environmental policy: Implications for the uplands

This section reviews the implications of proposed changes in agricultural and environmental policies in the United Kingdom associated with leaving the EU. Although the details of the proposed policy reforms are not yet known, the broad proposal is to redirect subsidies for income support into payments that provide incentives and rewards for farmers simultaneously to improve the sustainability of

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[7] Defra. 2020. 2020s Environmental Land Management. Policy Discussion Document. February 2020, Department for Environment, Food and Rural Affairs, London

agriculture and to protect and enhance the natural environment for the benefit of people and nature[8]. (Further details are provided in Annex 1.)

3.1 Policy reform

New policy initiatives of particular importance to agriculture, rural livelihoods and the natural environment are making their making their way through the legislative and implementation process. These are the Agriculture Act 2020[9] enacted in November 2020 and the Environment Bill 2019-2021[10] due for enactment in 2021.

Of particular interest here, The Agriculture Act 2020 contains a strong commitment to the principle of public payments for public goods. In this respect, farmers and land managers will be rewarded for actions that address six main objectives:

- protect and improve the land, water and air
- support thriving plants and wildlife
- reduce, and provide protection from, environmental hazards
- adapt to and mitigate climate change
- maintain, restore or enhance the beauty of heritage and increasing engagement and access to the environment
- improve the health and welfare of our livestock

Proposals for a new Environmental Land Management scheme (ELMs) places the above objectives under six main themes that reflect intended outcomes (Box 1). Building on the experience and lessons learned from previous agri-environment schemes, ELMs contains three components that vary in focus and application, namely:

Component 1: Sustainable Farming Incentives to encourage all farmers to adopt packages of actions, designed to suit particular types of land and farming systems, in order to deliver environmental outcomes on farms.

Component 2: Local Nature Recovery to help land managers to deliver locally targeted environmental priorities and outcomes, such as habitat creation, restoration and management.

Component 3: Landscape Recovery to deliver landscape and ecosystem recovery through long term landscape scale and land-use change projects, such as large-scale tree-planting and peatland restoration

BOX 1: Main ELM Themes and Objectives

BHE - beauty, heritage and engagement;
CA - clean air;
CC - Mitigation of and adaption to climate change;
CPW - clean and plentiful water;
HAZ - protection from and mitigation of environmental hazards; and
TPW – thriving plants and wildlife.

Defra[11] is currently consulting with stakeholders on the ELMs framework as work continues on detailed design and operational aspects. Although, the underlying

[8] Defra. 2020. The Path to Sustainable Farming: An Agricultural Transition Plan, 2021 to 2024. November 30th 2020. Department for Environment, Food and Rural Affairs, London
[9] https://www.legislation.gov.uk/ukpga/2020/21/contents/enacted
[10] https://services.parliament.uk/bills/2019-21/environment.html
[11] Defra. 2020a. as referred to above

principle of ELM is to reward farmers directly for the delivery of environmental *outcomes*, pragmatically Component 1 is likely to include payments for actions and farming practices that *are known to be associated with* environmental protection and improvements and are relatively easy to take-up by the majority of farmers. Payments are likely to be based on based on a mixture of compensation and incentive. Components 2 and 3 will focus more on targeted, context specific outcomes and are likely to involve some form of competitive bidding. Component 3 will support more ambitious interventions, including multi-farm collaborations, designed to achieve environmental impacts at the landscape scale.

As of mid-2020, Defra [12] have 57 ELMs Tests and Trials (T&T) underway involving farmer led groups, conservation and other organisations. Early findings point to the importance of the land management plans, including map-based natural capital assessments at the farm scale, that show the environmental baseline and the opportunities for the delivery of public goods.

With respect to payments, responses from T&T participants [13] suggest that 'income foregone plus costs' does not provide a strong financial incentive for ELMs take-up. Early feedback from T&T supports the principle of payments for outcomes while ensuring the financial stability and sustainability of the farm business, with payments ahead of the delivery of outcomes. Trial participants also identified the need for payments to cover additional capital costs and the cost of maintaining existing assets. Reflecting CS experience, payments could involve tiered or stacked payments and/or an 'uplift' factor to reflect the range and intensity of environmental outcomes, set with reference to the benefits generated by the services provided. The scope for supplementing ELMs payments with income from other sources, such as carbon credit and biodiversity offsetting, was also noted. These points are alluded to in the Pen Farm case.

A National Pilot for ELM is scheduled for the period 2021-24 involving up to 5,500 farmers to help prepare the way for phased implementation of ELMs over the period 2022-2028, concurrent with the gradual withdrawal of BPS.

3.2 Farming systems review

A review of the financial performance of Less Favoured Area (LFA) Grazing Livestock Farms for the period 2013/14 to 2017/18 inclusive [14] confirms the vulnerability of the upland sector to withdrawal of BPS support under the EU Common Agricultural Policy. During this period (adjusted to mid 2020 values[15]) the average LFA Grazing Livestock farm (170 ha) earned 62% of its annual revenue from agricultural activities, 22% from the Basic Payment Scheme (BPS), 12% from Agri-environment Schemes (AES) and 4% from diversification activities.

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[12] Defra. 2020c. Environmental Land Management tests and trials Quarterly evidence report Date: July 2020. Department for Environment, Food and Rural Affairs, London
[13] Defra. 2020c. as referred to above
[14] Harvey, D. and Scott C. 2019. Hill Farming in England. Farm Business Survey. Rural Business Research. Newcastle University, Newcastle. 2019 (and other years covering period 2013-2019)
[15] ONS. 2020. GDP Deflation Factors. Office of National Statistics, London

The withdrawal of the BPS and/or AES would render Farm Business Income (FBI) (a commonly used measure of farm profitability that does not include charges for unpaid family labour) near zero or negative (Figure 3.1). As reported by Harvey and Scott (2019), most LFA farms 'could not survive in their present form as commercial businesses without public payments'[16].

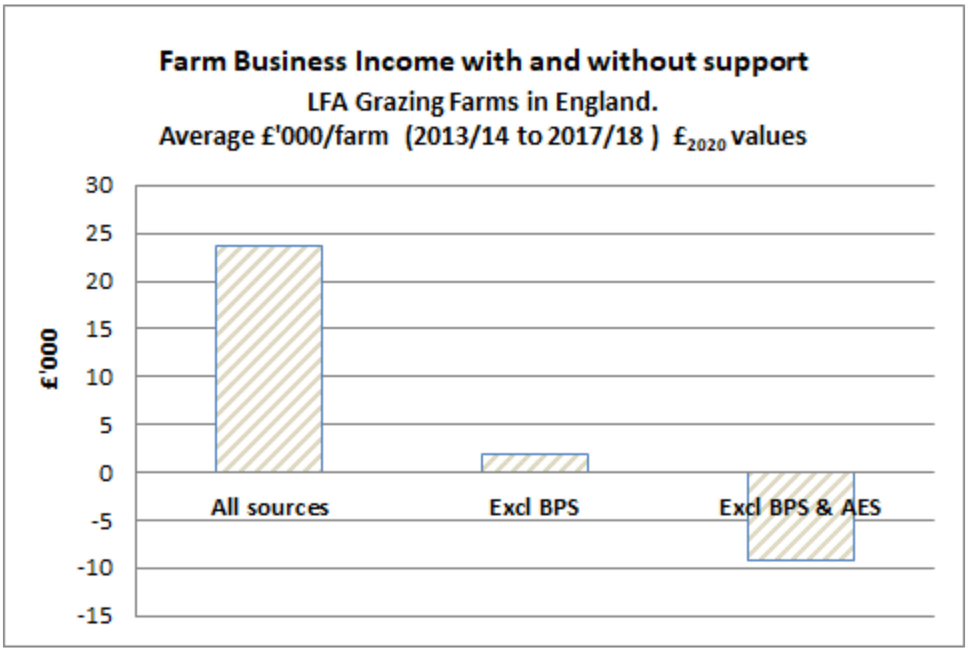

Figure 3.1 Average annual Farm Business Income with and without support for LFA Grazing Farms in England 2013/14 to 2017/18. Source: estimated from RBR data.

Policy dependency was the focus of a study and workshop carried out for the Northern Upland Chain Local Nature Partnership (NUCLNP)[17]. The conclusion was that, although there is scope for productivity improvements and opportunities to generate income from both on and off-farm diversification, these were unlikely to be sufficient to make good the gap arising from the loss of direct income support.

In this context, Clark et al.[18] have argued for a new business model for upland farms that requires switching to potentially more profitable lower input: lower output agricultural systems. This seeks to limit livestock numbers in line with the farm's natural capacity to produce energy from grass, removing (or significantly reducing) the need for artificial fertilizers, bought feeds, and other inputs commonly associated high stocking rates. An analysis of seven farm cases by Clark et al. showed that while such a switch would not be sufficient in most cases to achieve agricultural profitability in the absence of income support, it could enable the greater take-up of environmental management options and the achievement of environmental outcomes for which farmers could be rewarded.

[16] Harvey and Scott. 2019, as above

[17] ADAS, 2019. The Future of High nature Value farming systems and their ability to provide public goods in a post Brexit world in the NUCLNP. ADAS Ltd, Stoneleigh. January 2019

[18] Clark, C. Scanlon, B. and Hart, K. 2019. Less is More: Improving profitability and the natural environment in hill and other marginal farming systems. Report to RSPB, WLT and NT. November 2019

The Pen Farm case study explores the relationship between income from agriculture and environmental options under new ELM-type arrangements, and the scope for closing the income gap arising from the loss of BPS.

4. Pen Farm – a typical upland farm

This section introduces the Pen Farm case. It describes the baseline situation with reference to land use, natural capital and ecosystem services and compares this with the ELMs uptake scenario. Further details are given in Annex 2.

4.1 Pen Farm description

Pen Farm, located alongside Pendle Hill, near Clitheroe, Lancashire, is a beef and sheep farm. It has been held under an agricultural tenancy for 2 generations. The farm runs downhill from east to west, with rough grazing at the higher elevation, with improved pastures on the lower slopes to the valley bottom (Figure 4.1). The farm lies largely within the Less Favoured Area (LFA) designation, with the higher land in the Severely Disadvantage Area (SDA), and the lower land in the Disadvantaged Area (DA) (Figure 4.2). The fields in the north-west are the only ones that lie outside of the LFA designation.

The total area of the farm is 146 ha (360 acres) of which 139 ha is useable for agriculture (denoted as 139 'ha ua') (Table 4.1). This comprises about 100 ha of improved grassland mainly within the Disadvantaged Area (DA) designation, about 10 ha of which is managed under agri-environment agreements. The remainder, lying within the Severely Disadvantaged Area (SDA) designation, involves a range of less agriculturally productive land at higher elevations. Allowing for the latter gives a total adjusted agricultural area of about 111 ha (denoted 111 'ha adj')[19]. There is an additional shared area of about 30 ha common hill land that supports seasonal grazing. This is located on the top of Pendle Hill. (A description the farming system and land management practices is given in section 4.2 below.)

[19] The terms ua and adj are used in the case study to denote useable agricultural areas and adjusted areas respectively. The former indicates actual land area committed for agricultural use. The latter adjusts the estimate of useable agricultural area to reflect the equivalent livestock carrying capacity of land, expressed relative to that of improved pasture, in accordance with the methods used in the Farm Business Survey.

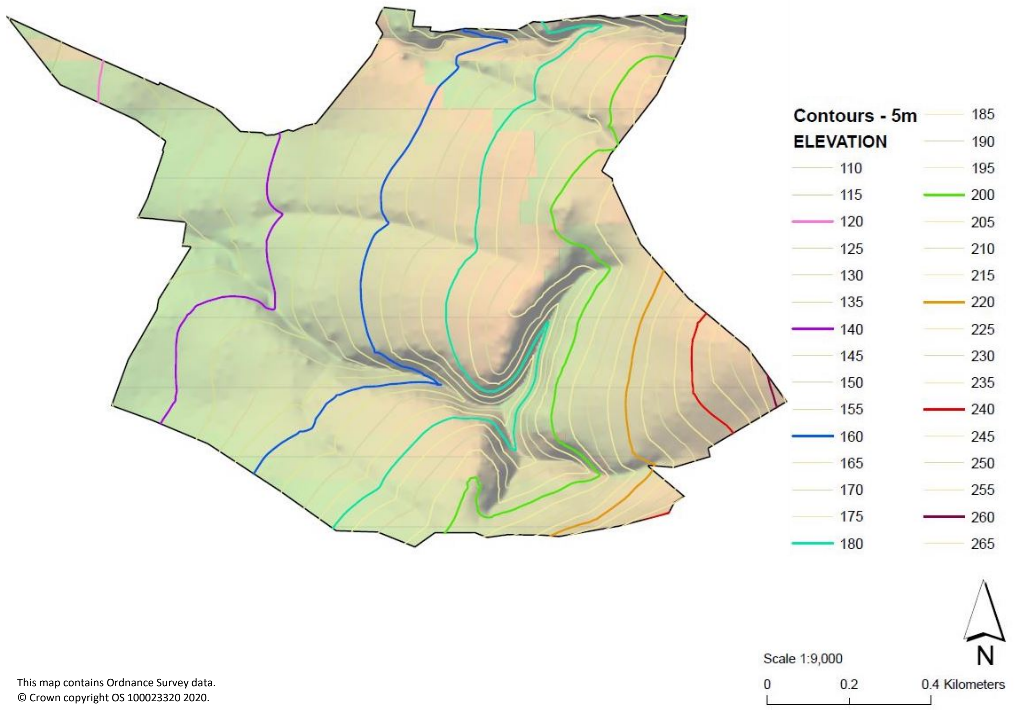

Figure 4.1 Elevations of Pen Farm.

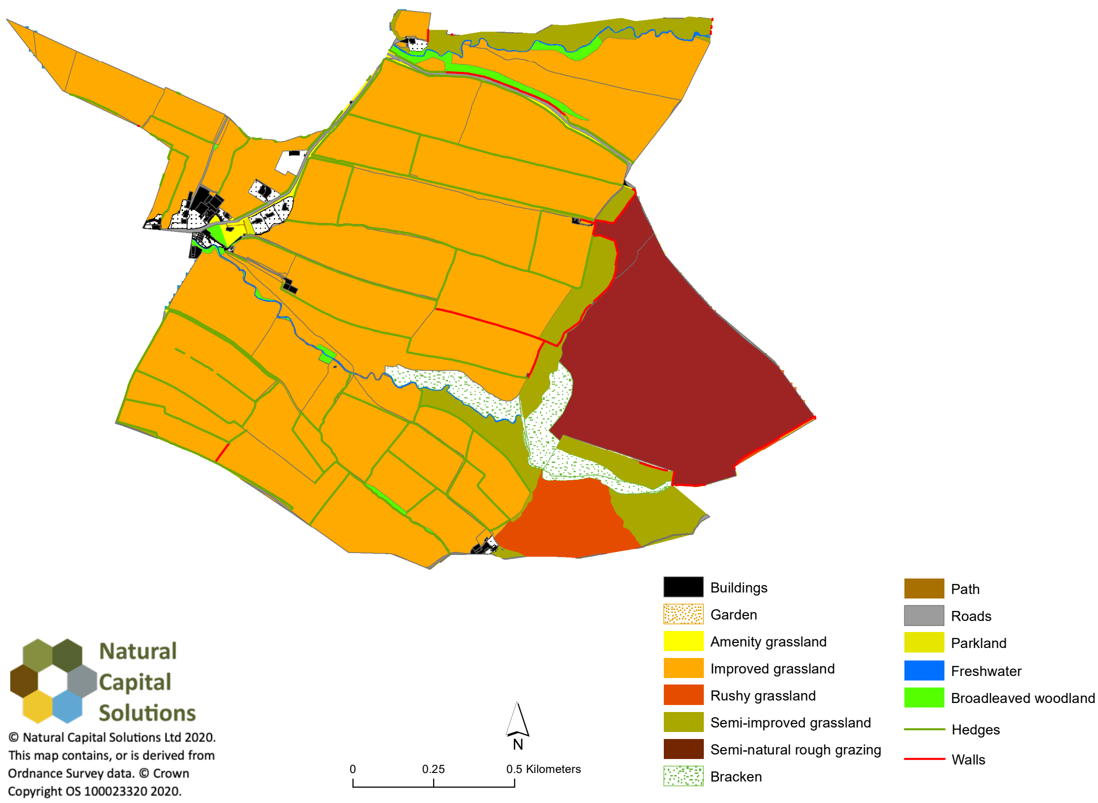

Figure 4.2 Natural capital assets of Pen Farm.

Table 4.1 Areas of land type and cover and adjusted agricultural area for Pen Farm

Land type and cover	Agric Area ha	Agric Adj factor	Agric Adj ha
PP Improved	89.6	1.00	89.6
PP Improved zero N	2.7	1.00	2.7
PP Species rich grass	7.5	1.00	7.5
Grassland: rushy	4.4	0.25	1.1
Semi -improved grassland	11.5	0.50	5.7
Semi natural rough grazing (bracken)	4.1	0.25	1.0
Semi natural rough grazing (moorland)	19.1	0.15	2.9
Adjusted ha	**138.9**	**0.80**	**110.5**
Moorland common	30.0	0.10	3.0
Adjusted ha incl common			**113.5**

Pen Farm has a number of Countryside Stewardship options in place (Figure 4.3). At the top of the farm in the east the enclosed semi-natural rough grazing has a lenient grazing option. Adjacent to this are areas of management of rough grazing for birds, also with lenient grazing (both of which also run outside the SDA). The area of rushy grassland inside the SDA is under low inputs with cattle grazing and rush control. Outside the SDA area there are small fields on the hillside in permanent grassland with very low inputs. At the bottom of the farm in the west are some temporary grassland fields that are managed to provide legume and herb rich swards. Hedgerows (3,700 metres) are managed and maintained along with 1.6 ha of broadleaved woodland. A traditional farm building is also being maintained.

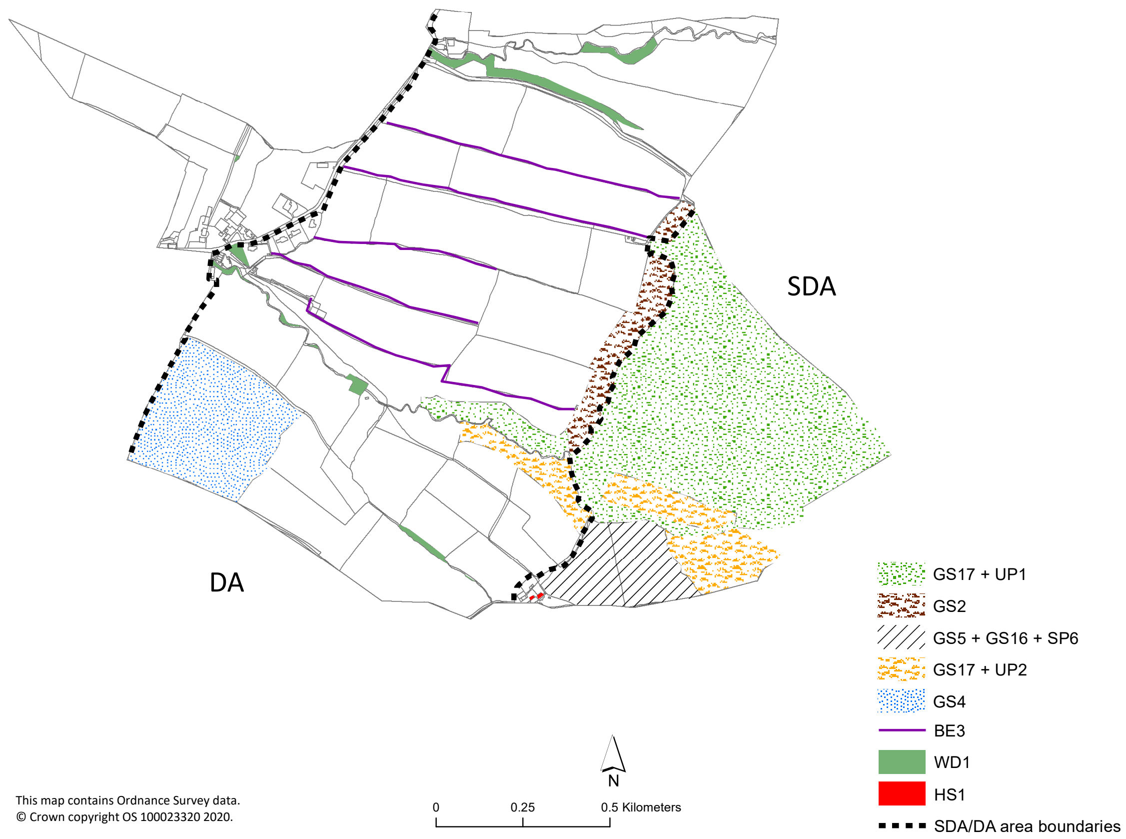

Figure 4.3 Countryside Stewardship options at Pen Farm. GS17 + UP1 - Enclosed rough pasture with lenient grazing; GS2 – Permanent grassland with very low inputs (non-SDA); GS5 + GS16 + SP6 = Very low input grassland (SDA) and cattle grazing and rush control; GS17 + UP2 – Management of rough grazing for birds and lenient grazing supplement; GS4 – Temporary grassland under legume and herb rich sward; BE3 – Management of hedgerows; WD1 – Maintenance of existing woodland; HS1 – Maintenance of traditional farm buildings. SDA – Severely Disadvantaged Area, DA – Disadvantaged Area.

4.2 Natural capital assessment

The natural capital assets of Pen Farm were assessed, together with the main ecosystem services generated under the existing land management practices. The results of this assessment are summarised here, supported by a more detailed reporting in Annex 2.

The Natural capital asset map (Figure 4.2) and the asset register (Table 4.2) shows that the Pen Farm baseline mainly consists of improved grassland habitat (68% of the farm area) and a range of semi-improved and semi natural grasslands (22%), as well as an area of shared moorland grazing outside of the farm boundary on Pendle Hill.

Table 4.2 Natural capital asset register for the baseline and ELMs scenarios showing the area of each habitat in hectares and the proportion of Pen Farm that it occupies, and the magnitude of the change in habitat area from baseline to the adoption of ELM-type options.

Broad habitat	Baseline		ELMs		
	Area (ha)	% Cover	Area (ha)	% Cover	Difference (ha)
Improved grassland	99.8	68.2	44.3	30.1	-55.5
Wood pasture, silvo-pastoral system	0	0	33.0	22.4	+33
Semi-natural grassland and rough grazing (to be gradually restored to heather moorland under ELMs)	19.1	13.1	20.6	14.1	+1.5
Semi-improved grassland (includes legume and herb rich pastures)	11.5	5.8	24.5	16.7	+13
Broadleaved woodland and hedges	1.6	1.1	12.4	8.4	+10.8
Rushy grassland	4.4	3.0	4.4	3.0	0
Bracken	4.1	2.8	0	0	-4.1
Scrub	0	0	2.5	1.7	+2.5
Roads	1.6	1.1	1.6	1.1	0
Garden	1.3	0.9	1.3	0.9	0
Buildings	1.1	0.8	1.1	0.8	0
Road verge	0.8	0.5	0.8	0.5	0
Freshwater	0.5	0.4	0.5	0.4	0
Amenity grassland	0.2	0.1	0.2	0.1	0
Parkland	0.1	0.04	0.1	0.04	0
Path	0.1	0.02	0.1	0.02	0

*Common land on dry modified blanket bog habitat outside of the farm boundary – 30 ha. Under the ELM-type options this becomes rewetted modified bog.

Pen Farm's natural capital assets supply a broad range of ecosystem services under existing land management practices (Table 4.3). These range from provisioning services such as livestock production, through the services that regulate local climate, air quality, water quality and flow, to the cultural services such as recreation, health and well-being. These services are essential for sustaining the farm business. For example, soil quality regulation underpins the production of good quality grass, and woodland and hedges provide local climate regulation providing shade and shelter for livestock. However, as with any land management that focuses on increasing the provision of one or a small suite of services (in this case the production of food), Pen Farm management also impacts on ecosystem service provision. For example, high livestock densities can cause soil compaction which can lead to increased runoff and flooding, and the predominance of improved grassland decreases biodiversity.

A qualitative assessment of service generation on Pen Farm is shown in Table 4.3. It demonstrates that the current land management practices at Pen Farm supply a wide range of services. Our assessment largely focuses on the provisioning and regulating services, but we must also emphasise the importance of the cultural services supplied. The aesthetic value of the upland farming landscape is valued by people, especially recreational visitors, and is tied into the landscape character with its stone walls and traditional buildings. The Farm also supports the important knowledge and traditions of farming.

Due to the current drivers of land management practices on the farm (incentivising intensification) the provision of certain ecosystem services and benefits are enhanced, whereas increasing the provision of others remain missed opportunities. For example, the lack of woodland and diverse grassland on the farm means that carbon sequestration capacity is lower than it could be, along with flood alleviation, and water quality regulation. However, the Countryside Stewardship options taken up have ensured the delivery of increased biodiversity and environmental benefits to a degree. For example, the grassland under legume and herb rich sward has increased the provision of the pollination service and is likely to increase floral and faunal biodiversity. Biodiversity is also increased by the management of rough grazing for birds. There are areas of the farm under very low inputs and lenient grazing which increases the provision of water quality and flow of regulation services.

Table 4.3 Qualitative estimation of the level of ecosystem service delivery from Pen Farm natural capital assets in the baseline and under the proposed ELM-type options. 0 - no delivery; 0.5 - some delivery but not significant, 1 - delivery, 2 -significant delivery, 3 - very significant delivery.

Ecosystem service category	Ecosystem service	Delivery score Baseline	Delivery score ELMs
Provisioning	Food: livestock production	3	2
	Fibre and fuel (timber/woodfuel, wool)	0.5	2
	Water (drinking, agricultural)	1	1
Regulating	Carbon sequestration and storage	0.5	2
	Local climate regulation	1	2
	Air quality regulation	0.5	2
	Water quality regulation and erosion control	0.5	2
	Water flow regulation	0.5	2
	Pollination	1	2
	Pest and disease regulation	0.5	2
	Noise attenuation	0.5	2
	Soil quality regulation	1	2
	Habitat and population maintenance (biodiversity)	1	2
Cultural	Aesthetic experiences	2	2
	Education, training and scientific investigation	2	3
	Recreation and tourism	2	3
	Characteristics and features of biodiversity that are valued	2	3
	Spiritual and cultural experiences	2	3

4.2.1 Ecosystem service mapping

The capacity of Pen Farm's natural capital assets to provide seven ecosystem services and one stock were modelled and mapped (see Annex 2 for detailed methods). These were carbon storage, carbon sequestration, air pollution regulation, agricultural production, noise regulation, water flow, water quality and accessible nature. In all cases the models used were applied at a 10m by 10m resolution to provide fine scale mapping across the farm. 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 for ecosystem services was mapped relative to the values present within the study area, on a scale from 0 (lowest) to 100 (highest). By way of example, we present maps of two selected ecosystem services, namely carbon sequestration (Figure 4.4) and water quality regulation (Figure 4.5) and a table of the overall service capacity scores (Table 4.4). The remaining maps are featured in Annex 2.

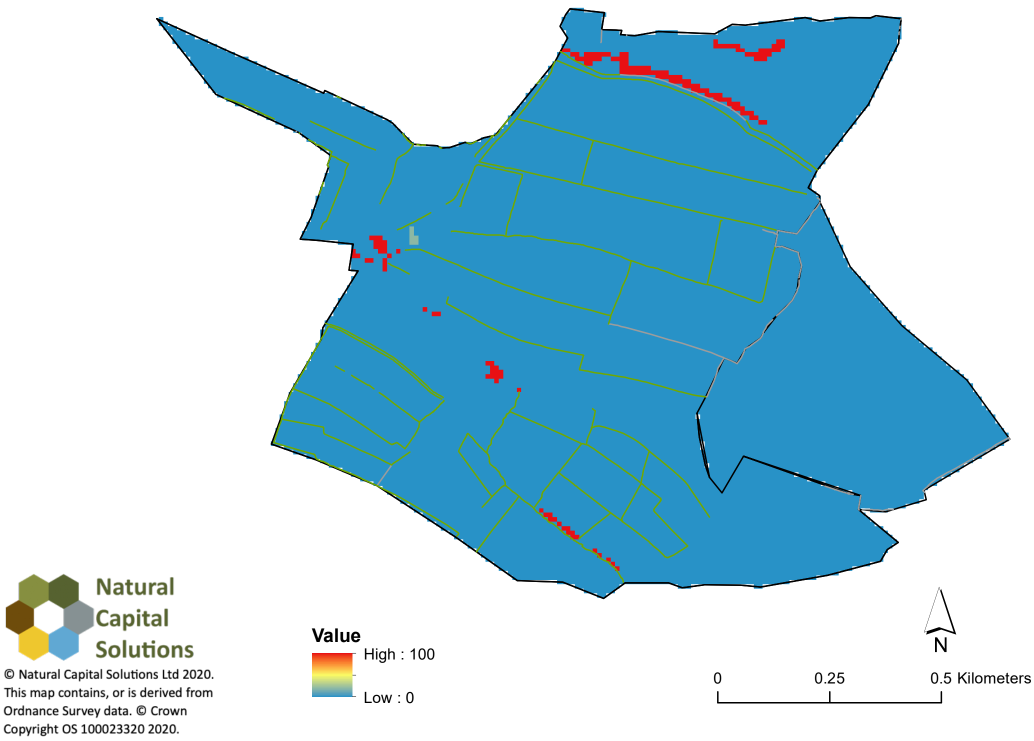

Figure 4.4 The capacity of woodland of Pen Farm to sequester carbon.

Figure 4.4 shows the relative capacity of the Pen Farm woodland assets to sequester carbon. All the existing woodland areas on the farm have the highest provision of this service (red areas on the map scoring 100). The model only focuses on woodland as we did not have spatial data for hedges, and there is relatively little information about sequestration rates of other habitats (and it is likely to be low in comparison). We were able to quantify the carbon sequestered from creating more diverse grasslands from improved grassland in the natural capital accounting approach outlined in the following section. The areas of low provision (in blue) on the map are potentially opportunities for creating woodland for carbon sequestration and biodiversity interest that would have to be weighed against other agricultural land uses.

The water quality capacity map (Figure 4.5) shows relatively high provision of the service in parts of the farm (orange/red areas). These tend to be areas away from water courses on land uses that have a lower risk of erosion and surface transport of sediment and pollutants to water courses. Lower areas of provision (blue), therefore, tend to be near water courses with a higher erosion and pollutant risk. These blue areas are where interventions for increasing water quality could potentially be targeted. For example, creating more complex vegetation cover that can filter water where improved and grazed grass exists, for example, grassland buffers with scrub, or riparian woodland.

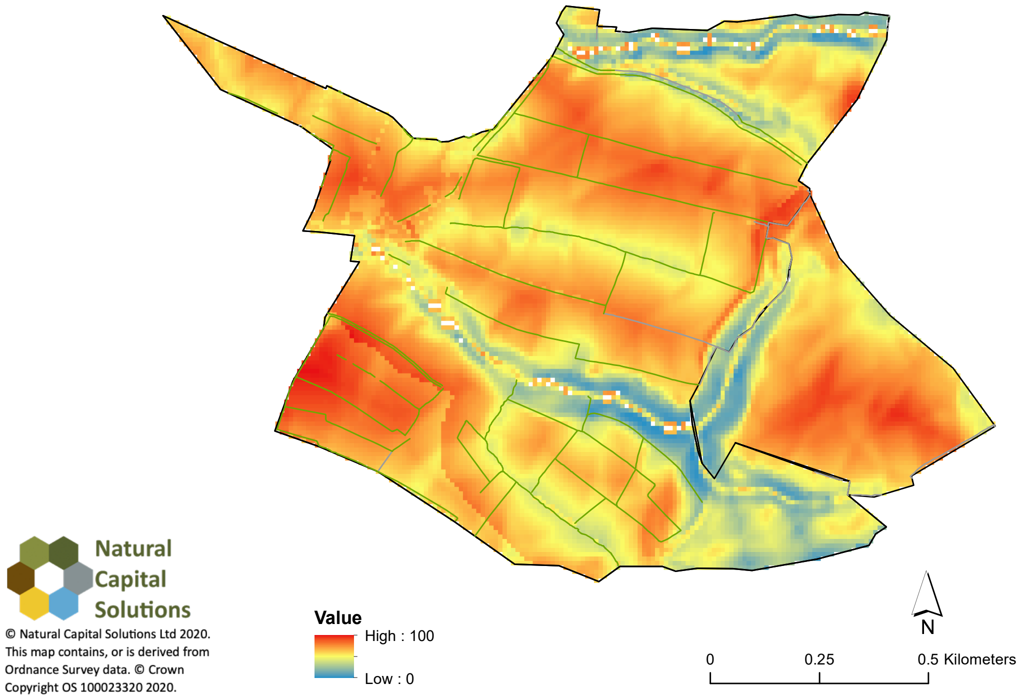

Figure 4.5 The capacity of the natural capital assets of Pen Farm to regulate water quality.

The overall capacity scores for each ecosystem service are shown in Table 4.4. The overall scores are derived for each service by averaging over the score for each 10x10m pixel of the farm map. The scores are highest for accessible nature, water flow and quality regulation services, meaning that the assets of the farm are able to support these services to a higher degree than the other services with a lower score. However, while these service models do take account of different agricultural habitats, they do not account for the impacts of farm practices, such as livestock density, or the amount of fertilizer applied, on the natural capital assets. Therefore, it is likely that the provision of water quality and flow regulation services are in reality lower than this. For example, it is likely that soil compaction from livestock and the predominance of heavily grazed improved grassland contributes to the flooding of the roads and villages at the bottom of the valley. It is also likely that fertilizer application on improved grassland, and livestock entering watercourses will impact on water quality. Due to the lack of trees and woodland on the farm, there are low scores for carbon sequestration, air pollution, local climate and noise regulation (Table 4.4).

Table 4.4 Mapped ecosystem service capacity scores (0-100) for Pen Farm baseline.

Ecosystem service	Score (0-100)
Accessible nature	51
Agricultural production	22
Carbon storage (please note this is a stock not a service)	22
Carbon sequestration by woodland	1
Air pollution regulation capacity	11
Local climate regulation / noise regulation capacity	11
Water flow regulation	41
Water quality regulation	54

* The farm estimates are based on the ecosystem service modelling and mapping for the Forest of Bowland AONB

4.2.2 Valuing the benefits

Estimates of the physical flows of selected ecosystem services (e.g. tonnes of carbon sequestered) were combined with estimates of monetary unit values to produce a partial natural capital account for Pen Farm (Table 4.5). The provision of carbon sequestration, air quality regulation and timber production are low, and so are the total monetary values. The costs of carbon emissions associated with agriculture and the common land are £5,429 per year. This is due to the management of improved grass and the livestock themselves. There are few trees to sequester carbon, the grassland is low quality in terms of diversity, and blanket bog on the common land is dry modified bog which contributes to significant carbon emissions. The baseline natural capital account shows, therefore, that Pen Farm is a net emitter of carbon – 350 tco_2e per year if the emissions from the common land are included, 215 tco_2e per year if not. The baseline farm business analysis (Section 5 below) estimated the value of the agricultural production of Pen Farm at minus £11,322 per year, net of costs.

Table 4.5 Annual physical and monetary (£2020) flow of ecosystem services provided by the natural capital of Pen Farm for the baseline and under the ELM-type options. Present values (PV) calculated over 50 years are in parenthesis. Physical and monetary flows in red are negative. The last column shows the difference in annual physical and monetary flows, including PV, between the baseline and the ELMs condition.

Ecosystem service	Baseline		ELMs		Difference	
	Annual physical flow	Annual monetary flow £2020 (£PV over 50 years)	Annual physical flow	Annual monetary flow £2020 (£PV over 50 years)	Annual physical flow	Annual monetary flow £2020 (£PV over 50 years)
Carbon sequestration (trees and hedges) *tCO_2e per year*	10.9	153 (41,045)	84.7	1,186 (318,943)	+73.8	+1,033 (277,898)
Carbon sequestered by increasing grassland quality *tCO_2e per year*	27.5	385 (103,553)	179.8	2,517 (677,047)	+152.3	+2,132 (573,494)
Air quality regulation (trees, hedges and grass) *$tPM_{2.5}$ per year*	0.03	2,289 (84,620)	0.33	24,069 (889,790)	+0.3	+21,780 (805,170)
Timber production *m^3per year*	6.6	106 (2,705)	61.0	1,007 (25,700)	+54.4	+901 (22,995)
Agricultural production *Livestock Units*	97	-11,322† (-288,953)	78	-41,179† (-1,050,944)	-19	-29,857 (-761,991)
GHG emissions from agriculture* *tCO_2e per year*	253	-3,539 (-952,683)	180	-2,522 (-677,803)	+73	+1,017 (274,880)
Carbon emissions from peat habitats *tCO_2e per year*	135	-1,890 (-508,351)	60	-840 (-225,934)	+75	+1,050 (282,417)

The price of carbon used is the Government's traded price for 2020 (£14)
*GHG emissions represent a cost rather than a benefit. The land-based emissions account for c.50% of the total emissions. The rest are associated with the livestock.
†Returns only to agriculture, does not include BPS and AES, but includes a charge for unpaid labour.

The results of the preceding natural capital assessment were used to identify opportunities for potentially beneficial interventions and the selection of ELM-type options for Pen Farm.

5. Farm Business Analysis

This section describes the farming system for Pen Farm. It assesses the baseline farm business performance associated with the main types of activity and income sources. It then considers the financial implications of adopting a range of ELMs-type options, and the extent to which the gap left by the withdrawal of BPS subsidies can be filled. Further details are contained in Annex 3.

5.1 Farming System

The farm type is classed as LFA Beef and Sheep (Table 5.1). There are about 500 sheep comprising mainly lowland/upland cross bred ewes along with pure hill ewes (85%:15% ratio). About a quarter of spring born lambs are carried over as 'gimmers' to produce ewes for breeding in the following year. A beef suckler cow unit produces calves in spring that are carried over the following winter to be finished on grass in summer.

Table 5.1 Estimated livestock numbers, types and stocking rates for Pen Farm.

		Baseline		
Stock type	LU/hd	nr	LU	% of LU
Ewe and lamb	0.12	500	57.7	60%
Breeding ewe lambs	0.06	185	11.1	11%
Rams	0.08	10	0.8	1%
Beef cows incl calf	0.9	17	15.3	16%
Beef cattle sold as stores	0.5	22	11.0	11%
Bull	0.65	1	0.65	1%
Total LU			96.6	100%
Land Areas			ha	
Total utilised agricultural area ha (excl common)			138.9	
Adjusted agric area ha (excl common m'land)			110.5	
Common Moorland			30.0	
Adjusted common moorland			3.0	
Adjusted farm area incl moorland ha			113.5	
Adjusted farm LU/ha (113.5 ha)			0.85	

LU = Grazing Livestock Units

Sheep and beef are mainly grass fed, with supplementary bought concentrate feed and some bulk feed for the cattle. On agriculturally improved pastures, about 75-80kgN/ha of chemical fertilizer is applied where grass is cut for silage, and about 50-60 kg N/ha where grazed only. Otherwise, fertilizer use follows stewardship prescriptions, whether zero or reduced applications of chemical and/or organic fertilizer.

There is the equivalent of 97 Livestock Units (LU) on Pen Farm of which about 72% are sheep and 28% are beef. The overall average stocking rate is about 0.85 LU/ha (Table 5.1), similar to an average of 0.86 LU/ha for LFA Beefs and Sheep farms in England.

The total labour employment is 1.6 Full Time Equivalents (FTE) mainly provided by family labour with occasional casual labour. Some agricultural contracting services are provided to neighbouring farms.

5.2 Farm Business Revenues and Costs

Table 5.2 contains key business indicators for Pen Farm. The main sources of Farm Business Income are Agriculture, Agri-environment Schemes (AES), Diversification and the Basic Payment Scheme (BPS)[20]. Total Farm Business Income is about £21,000/year (£190/ha adj), with agricultural making a negative return at about minus £9,500 (minus £86/ha adj). Charging for unpaid labour at £32,000/year (for 1.6 FTE) (£290/ha adj) makes Farm Corporate Income about minus £11,000/year (minus £100/ha adj), Net Farm Income, showing income to the family household, is about £22,900/year (£207/ha adj). After charges for unpaid labour, the return to the farm's managerial effort and capital invested in the business (Management and Investment Income) is about minus £5,950/year (about minus £54/ha adj).

In summary, the agricultural activities on the farm fail to break even (at minus £86/ha adj) before charges for unpaid family labour but would result in losses of about £370/ha adj if such charges are made. Net contributions (after estimated costs) from other farm-based sources, notably AES and BPS, are not sufficient to cover the estimated cost of unpaid family labour at 1.6 FTE.

The proportions of Total Gross Output (Revenue) and Farm Business Income attributable to different sources are shown in Table 5.3. BPS alone accounts for 25% of Gross Output by value and 111% Farm Business Income, a measure of farm profitability before payments for unpaid family labour are charged. Existing take up of AES options provides 7% of Total Output and 28% of Farm Business Income.

Table 5.3 Sources of Income as % of Gross Output and Farm Business Income: Pen Farm.

		Agric	AES	Div'n	BPS	Total
Pen Farm						
% of	Output	65%	7%	3%	25%	100%
% of	Farm Bus Inc	-45%	28%	6%	111%	100%
Average for LFA Grazing Livestock Farms (2015-2018)						
% of	Output	62%	12%	4%	22%	100%
% of	Farm Bus Inc	-50%	47%	11%	92%	100%

[20] This classification follows the methods used by the Regional Farm Business Survey. The Survey is a national programme that assesses the performance of farming in the UK on behalf of Government in support of policy. It uses a number of indicators of business performance. **Farm Business Income** is a commonly used indicator to show the annual return to all unpaid labour and capital invested in the farm, including land and buildings**. Farm Corporate Income** takes the former and deducts charges for unpaid family labour**. Farm Investment Income** shows the return to all capital invested in the farm business, after charges for unpaid labour and interest charges. **Net Farm Income i**ndicates the return to the farm household on their labour and tenant type capital. **Management and Investment Income** shows the return to the farm business's management inputs and capital invested (having deducted charges for unpaid family labour).

Table 5.2 Summary of Key Farm Business Indicators: Pen Farm*.

	Agriculture		AES		Diversification		BPS		Total	
	£/farm	£/ha	£/farm	£/ha	£/farm	£/ha	£/farm	£/ha	£/farm	£/ha
Total Ouput	69590	630	7500	68	3315	30	27421	248	107826	976
Variable Cost	39845	361	31	0	167	1	0	0	40044	362
Total Gross Margin	29745	269	7468	68	3148	29	27421	248	67783	613
Fixed Costs	39233	355	1543	14	3050	19	27421	36	71248	645
Total costs	79078	716	1575	15	2089	20	4113	36	86855	786
Farm Business Income	-9488	-86	5925	53	1227	10	23308	212	20972	190
Unpaid Labour	30350	275	366	3	1284	12	0	0	32000	290
Farm Corporate Income	-39838	-360	5559	50	-57	-2	23308	212	-11028	-100
Interest payments	1326	12	65	1	61	1	122	1	1574	14
Farm Investment Income	-38511	-348	5624	51	3	-1	23430	213	-9454	-86
							Inputed rent		0	0
							Ownership charges		3000	27
							Directors remun		500	5
							Unpaid labour		28800	261
							Net farm income		**22846**	207
							M&I Inc		**-5954**	-54

*£/ha estimates are per adjusted ha at 110.5 ha

Assuming Pen Farm is viable for the existing situation, the future financial viability of farm business is dependent on about £35,000/year of income support, of which AES contributes about £7,500 (£5,900 after costs including labour) and BPS contributes about £27,400 (about £23,300 net after costs).

On this basis, to retain current levels of Farm Business Income and Net Farm Income, Gross Income from Agri-environment agreements would need to increase by 3 to 4 times to compensate for the loss of annual BPS.

6. Proposed ELM-type options for Pen Farm

This section describes the selection of ELM-type interventions on Pen farm and their alignment with the main ELMs themes. Further details are provided in Annex 2.

6.1 Identification of ELM-type options

A range of interventions were identified to deliver a broad range of ecosystem services in accordance with the ELMs themes and objectives (Table 6.1). These were derived from the assessment of natural capital assets and associated ecosystem services (Section 4.2 above). The interventions were also chosen with the intention of generating sufficient income to off-set the loss of BPS.

The spatial location of these ELM-type interventions on Pen Farm is shown in Figure 6.1. Increasing the area of woodland and trees on the farm was deemed important because trees play a significant role in the provision of all the ecosystem services outlined in Table 6.1. The need for ELMs options to alleviate flooding, increase water quality, enhance biodiversity and improve public access were also identified.

Thus, suggested ELMs interventions include converting areas of improved grassland to woodland and wood pasture, and substantial plantings of woody shelterbelts (lines of densely planted trees with hedge planting either side) across fields instead of the traditional hedging at field boundaries. These interventions will increase carbon sequestration capacity, reduce air pollution, improve water quality through increased filtration capacity, slow the flow of water through the farm, regulate local climate to provide shelter for livestock, increase pollination, enhance biodiversity value, and provide additional cultural services associated with recreation and enjoyment of the countryside.

In addition, natural flood management interventions were identified that can also increase water quality, including, for example, grassland riparian buffer strips to trap and filter nutrients and sediment from run off. These buffers, along with the fencing of water courses, also deter livestock from entering streams. The buffer strips, especially within natural grassland areas, will increase both floral and faunal diversity. Ten woody debris dams have been suggested along streams, together with swales and ponds to slow and hold back the flow of water through the farm when there is heavy rain. The ponds can be positioned on or off-line with the latter used to re-wet rushy grassland habitats (see Figure 6.1). The positioning of these water flow interventions can be decided following detailed hydrological assessments. The position of these features in Figure 6.1 is, therefore, illustrative.

We have suggested the restoration of grassland habitats for increasing biodiversity, pollination and for sequestering carbon. Converting improved grassland to an increased quality grassland such as legume and herb rich sward sequesters carbon (at a rate of -3.67 $tCO_2\ ha^{-1}\ year^{-1}$ [21]). This conversion sequestration rate will be maintained for between 2 and 5 years before an equilibrium is reached. This will also provide habitat structure to impede water runoff. For the same reasons we also suggest the restoration of the heather and dry heath habitat which can also generate recreation and well-being benefits.

Restoration of the common land provides an additional environmental option. The blanket bog habitat here is low quality dry modified bog. Re-wetting the bog by blocking ditches will significantly reduce the carbon emissions from this habitat (emissions rates from 4.5 in the baseline to 2.5 $tCO_2e\ ha^{-1}\ year^{-1}$ after restoration[22]).

Restoring and maintaining the historic character of this rural landscape through the upkeep of traditional farm buildings and stone walls will increase cultural benefits. Wood pasture creation on the mid to lower slopes is also in line with historic land uses in the area. Access for recreation can be enhanced by improving footpath infrastructure and signage. There is scope to provide educational services for a range of users, including school, children, students and specialist interest groups.

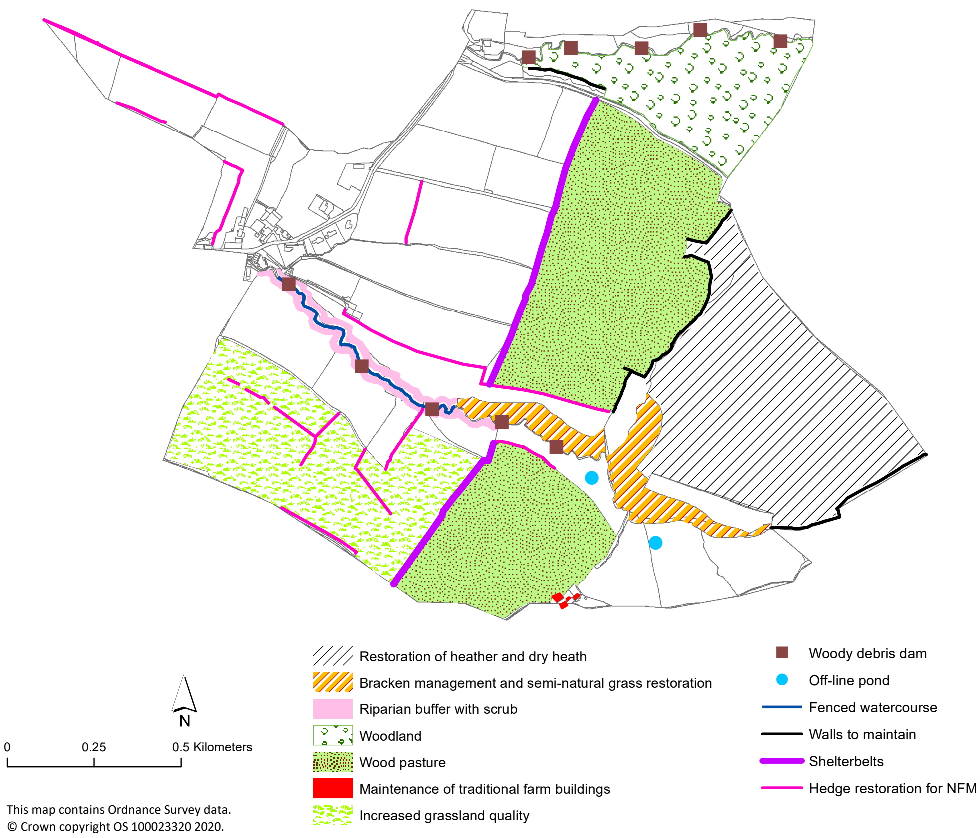

Figure 6.1 ELM-type options proposed for Pen Farm.

[21] Warner, D. (2008) Research into the current and potential climate change mitigation impacts of environmental stewardship. Defra report BD2302

[22] Evans et al. (2017) Implementation of an emissions inventory for UK peatlands. A report to the Department for Business, Energy & Industrial Strategy.

Table. 6.1 The ELM-type options proposed for Pen Farm, the ecosystem services they provide and the main ELMs themes and objectives into which they fall. CC – Mitigation of and adaptation to climate change; CPW – clean and plentiful water; HAZ – protection from and mitigation of environmental hazards; CA – clean air; TPW – thriving plants and wildlife; BHE – beauty, heritage and engagement.

ELMs Outcome Themes	**CC**	**CPW**	**HAZ**	**CA**	**TPW**	**TPW**	**BHE**	**BHE**
Intervention	Carbon sequestration	Water quality	Flood alleviation	Air pollution regulation	Pollination	Habitat restoration/creation	Recreation Health and well-being	Cultural heritage
Woodland	✓	✓	✓	✓			✓	
Wooded shelterbelts	✓	✓	✓	✓	✓	✓		
Riparian woodland/ grassland buffer with scrub	✓	✓	✓	✓	✓	✓	✓	
Ponds and swales		✓	✓			✓		
Woody debris dams		✓	✓			✓		
Increasing grassland quality		✓	✓			✓		
Hedge restoration and creation	✓	✓	✓	✓	✓	✓		
Restoration of heather and dry heath					✓	✓	✓	
Restoration of blanket bog	✓	✓	✓			✓		
Bracken removal, semi-natural grassland restoration and scrub management	✓				✓	✓		
Management of rough grazing for birds						✓		
Fenced watercourses		✓						
Maintenance of traditional farm buildings								✓
Maintenance of stone walls								✓
Improved public access							✓	
Educational visits								✓

These ELM-type interventions will significantly change the type and quality of natural capital assets and the ecosystems generated from them on Pen Farm (Table 4.2 above). The area of intensively managed grassland decreases by 56 ha to account now for only 30% of the total farm area. The semi-natural and semi-improved grasslands increase by 15 ha, and broadleaved woodland by 11 ha. New habitats of wood pasture and areas of natural scrub have been created. This changes the profile of ecosystem service provision (Table 4.3 above) reducing the capacity for food production by about 20%, but increasing the potential to produce timber fuel, and increasing the provision of all regulating services. The provision of the cultural services, for example, education, recreation, and health and well-being will be enhanced, as well as biodiversity.

The increases in ecosystem services under the ELM-type options is supported by the quantitative assessment shown in the natural capital account (Table 4.5 above). Carbon sequestration from trees and hedges has increased by 74 tCO_2e per year, and by 152 tCO_2e per year from increasing grassland quality. This is equivalent to an increase of £3,165 per year. Air quality regulation has increased by 0.3 $tPM_{2.5}$, a monetary increase of £21,780. The timber production service has increased by 54m^3 adding a value of about £900. There is a decrease in returns from agriculture due to a 20% reduction in livestock on the farm, as explained below. There is a reduction in emissions from agriculture and from the upland moorland common land equivalent to 148 tCO_2e per year, a saving of about £2,070 per year. This changes Pen Farm from a net emitter in the baseline to sequestering 24.5 tCO_2e per year under ELM-type options.

7. The Financial Implications of Future Environmental Options

This section considers the extra revenues and costs of increased take-up of environmental options under ELMs, the effect on Farm Business Income, and the extent to which the loss of BPS income support can be filled. Further details are contained in Annex 3.

7.1 Revenues and costs of new ELM-type options

A range of agri-environmental options have already been taken up on Pen Farm (Annex 3). These mainly include field and habitat management options, hedgerow management and refurbishment of traditional buildings. Current Countryside Stewardship agreements generate about £7,500/year income (£54/ha ua, £68/ha adj), about £5,600 after costs (Table 5.2).

As referred to above future ELM-type environmental options for Pen Farm include woodlands, woodland pasture with the equivalent of 10% plantings of trees by area, field and habitat management, water quality and regulation, improved public access and amenity.

Existing CS payment rates are used provisionally as a guide. It is not yet known what they will be under the new ELMs. It is possible that unit rates may increase to reflect benefit (outcome) rather than cost (income foregone) based pricing (see Section 3.1 above). The options assumed here are likely to apply under the different ELM components.

Taken together, the proposed interventions generate a potential revenue of about £33,000 (before costs), equivalent to about £240/ha over the 139 ha of ha of existing woodland and usable agricultural land (Table 7.1).

Some options require preparatory or establishment capital works that are fully or partially grant aided. Estimated capital costs for 'major' items, net of grants, are about £167,000, mainly for woodland creation (31%), wood pasture (19%) and stone wall restoration (13%). This gives a total equivalent annual cost of about £20,500/year (amortised over 10 years at 4%) equivalent to £148/ha ua/year for the farm's useable agricultural area of 139 ha. After grant aid at assumed rates, the cost to the farmer is about £2,400/year (£17/ha ua, £21/ha adj). Provision is made to charge for these extra capital costs in the financial appraisal below. (It is noted that funding of new capital and capital maintenance costs has been raised as an issue in ELMs design, see Section 3.1 above)

There are also other minor capital expenditures mainly associated with habitat creation and restoration, that are assumed to be covered in the normal operational costs of environmental options (costs are currently about 20% of annual AES revenues).

Table 7.1 ELM-type environmental options and estimated annual receipts for Pen Farm.

Option Types	units	nr	£/ha or m	£/year	CS ref*
Woodlands					
New woodland	ha	8.5	200	1700	WD1
Creation of woodland pasture	ha	33	409	13497	WD6
New woodlands: trees on slopes	ha	1.8	200	360	WD1 var
Woodland improvement	ha	1.64	100	164	WD2
Field Management					
Improved grass converted to species rich	ha	15	309	4635	GS4
Semi natural grassland restoration : bracken/scrub	ha	4.11	83	341	UP1, GS17
Semi natural grassland restoration (rushy/wet grass)	ha	4.43	134	594	GS5, SP6, GS16
PP very low inputs non SDA	ha	1	95	95	GS2
Semi improved grass SDA	ha	8.5	132	1122	UP2, GS17
Moorland habitat (sole use)	ha	19	83	1577	UP1, UP6
Moorland habitat (common)	ha	30	83	2490	UP1, UP6
Hedgerows management	m	3720	0.16	595	BE3
Take field corners out of prod	ha	1	365	365	GS1
Water quality, resources and regulation					
Riparian Buffer strips (excl woodlands)	ha	1.6	440	704	SW11
Ponds and swales (temp water storage)	ha	2	256	512	SW16
Leaky barriers /dams (temp water storage)	nr	2	256	512	SW16
Fencing off streams (water quality/erosion)	m	1083	0.08	87	FG1 (maint)
Livestock infrastructure					
Livestock feeding, drinking, yarding	m2	0	0	0	RP/LV
Cultural				0	
Archeological features grassland	ha	0	30	0	HS5
Improved public access	m	2,200	0.50	1100	new
Maintenance of Trad Buildings	m2	300	3.25	975	HS1
Stone wall maintenance	m	1720	0.50	860	BN12 (maint)
Educational visits	visit	3	290	870	ED1
Total revenue		£/year		33155	
		£/ha ua (139 ha)		239	
		£/ha adj (111 ha)		300	

*CS: Countryside Stewardship reference for types of options

8. Estimated impact on Farm Business Income

At full development, new environmental options generate an estimated £23,900 annual revenue after deductions for estimated annual costs, compared with existing AES agreements at £5,900, an increase of £18,000/year, helping to offset the net loss of £23,300 from BPS. (Table 8.1). Thus, after allowing for changes in costs, there remains a short fall of about £5,400 in net income before adjustments for impacts on income from agricultural activities.

Table 8.1 Estimated changes in Net income from new environmental options to offset BPS loss on Pen Farm.

		£/farm/year			£/ha adjusted*			£/ha ua*
		Revenue	**Costs**	**Net**	**Revenue**	**Costs**	**Net**	**Net**
Total new AES options	a	33155	9283	23871	300	84	216	172
Current annual receipt AES	b	7500	1575	5925	68	14	54	43
AES Change	a-b	25655	7708	17946	232	70	162	129
BPS	c	27421	4113	23308	248	37	211	168
new AES - BPS	a-c	5734	5170	563	52	47	5	4
Extra AES - BPS	(a-b)-c	**-1766**	3595	**-5362**	-16	33	-49	-39

* adj adjusted 111 ha, ua usable agricultural 139 ha, excluding shared moorland

Total costs of existing AES as % of revenue	21%
Total costs of new AES options as % of revenue (incl extra capital costs)	28%
Total cost for BPS as % BPS revenue	15%

The new environmental options on Pen Farm will impact on agricultural activities and outcomes, especially with respect to land take and reduced stocking rates[23]. The estimated net reduction in livestock numbers at the farm scale is 21.5 LU, about 22% of the existing total (see Annex 3, Table 3.7.2). This results in a reduction in Gross Output of £15,500 (£141/ha ua, £112/ha adj) and in Gross Margin (inclusive of grass and forage costs) of £6,600 (£48/ha ua, £60/ha adj) (Table 15). Most of the reduction in agricultural output is attributable to reduced stocking on land converted from improved grassland to wood pasture with reduced inputs [24] and to sole woodland.

The reduction in livestock numbers by about 22% will enable savings in the so called 'variable' costs of fertilisers and feed that are accounted for in the estimates of Gross Margins for the farm as a whole. There is also scope to achieve savings in costs that are conventionally regarded as 'fixed', but are likely to vary with big changes in farm output and land use. These include the cost of labour, machinery operations, contractors, water and electricity. A total saving of about £5,300/year, equivalent to about 7% of current total fixed costs, is assumed (see Annex 3, Table 3.7.3). About 67% of this saving associated with a reduction in agricultural output is in 'unpaid' family labour, valued at an equivalent cost of employment. It is noted that increased labour inputs are required for the new environmental options. It is possible that further adjustments could be made to grassland and livestock management to improve the financial performance of farming activities on Pen Farm, reducing the reliance on purchased feeds and fertilisers.[25]

For the assumptions made, the combined effect of changes in AES, BPS and agricultural production result in an estimated change in net income of minus £6,700/year, equivalent to £48/ha ua and £61/ha adj annually (Table 8.2). Further details of the impact on key financial indicators for Pen Farm are given in Annex 3).

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[23] A simple grassland model was used to estimate Dry Matter and Energy production from grassland according to nitrogen use, grazing /cutting, and grass growth class, assuming upland livestock regimes. See Annex 3.

[24] It is assumed that woodland land taken for plantings will be 10% of pre -grassland area, and that stocking rates per ha of woodland pasture will be 10 % lower than for sole grassland assuming grassland management practices otherwise remain unchanged. Evidence from Upland Agroforestry demonstration show pre-agroforestry stocking rates can be maintained with approximately 10% tree cover in poplar plantations. It is assumed that chemical inputs on improved grassland are reduced from about 75kgN/ha to 25KgN/ha under wood pasture, from 1.10 LU/ha to 0.72 LU/ha. Wood pasture stocking rates are thus assumed at 0.65 LU/ha (0.72 x 0.9). Revenues from wood fuel and biomass are considered separately. Zero N application would probably reduce stocking to about 0.57 LU/ha on grass, and about 0.51 LU/ha for wood pasture (0.57 x 0.9).

[25] See for example: Clark, C. Scanlon, B. and Hart, K. 2019. Less is More: Improving profitability and the natural environment in hill and other marginal farming systems. Report to RSPB, WLT and NT. November 2019. Some of these changes are feasible under current conditions. Withdrawal of BPs and the incentives provided by ELMs will, however, provide a stimulus.

Table 8.2 Changes in AES, Income Support and Agricultural Net Income under new environmental options for Pen Farm.

Change in AES and BPS support		£/year	£/ha (adj)*	£/ha (ua)**
Extra net income from AES	a	17946	162	129
Loss of net revenue from BPS	b	23308	211	168
Subtotal	a-b =c	-5362	-49	-39
Change in Agricultural Net Income				
Change in Agricultural Gross Margin	d	-6639	-60	-48
Savings in Fixed costs ***	e	5297	48	38
Subtotal	d-e=f	-1341	-12	-10
Total Change in Net Income	c+f	-6703	-61	-48

* adj adjusted 111 ha, ** ua usable agricultural 139 ha, excluding shared moorland
*** includes savings in unpaid family labour valued at employment cost
*** savings as % of total fixed costs = 7%
Av Stocking rate LU/ha (adj) 0.66 original 0.85 reduction 22%

It is noted that no allowance here has been made for future revenues from woodland products, notably from rotational coppicing of wood pasture. This could generate an estimated equivalent annual net income of £2,200 per year (see Annex section 3.8). Neither is allowance made for income from trading carbon or biodiversity offsetting credits. Carbon credits from woodland sequestration, for example could be worth about £1,186/year valued at £14/tCO_2e (see Table 4.5 above).

Thus, for the assumptions made, the wide ranging take up of ELM-type options on Pen Farm fails to fully close the BPS income gap. In the absence of additional ELMs income and/or agricultural efficiency gains, this could undermine the financial viability of the business. Furthermore, provisions need to be made for grant funding or loan assistance to fund the capital costs associated with major land use and habitat change, notably woodlands and wood pasture.

As noted earlier, however, the revenue estimates used here for new ELMs type options are based on the legacy rates of the existing CS agreements. These mainly use the principle of 'compensation' for income loss. In future, in the absence of BPS, it is anticipated that payment rates will be not only be more closely attuned to the full costs of ELM actions but also to the benefits of delivering the intended environmental outcomes in the farmed landscape. Treasury Guidance will require that the most economically efficient means are chosen: hence the use of competitive bidding for the higher ELM components within the overall funding constraints.

No changes in net revenue from diversification activities are assumed here, other than educational services that are included in agricultural income. There may be scope for increased farm based recreational services such as seasonal visitor accommodation, catering and bike hire, and letting of commercial workspace.

There is considerable uncertainty associated with above estimates. The estimate of the change in Net Income is particularly sensitive to estimates of Agricultural Gross

Output, that is stocking rates and/or livestock prices, and the revenue and payment rates for the ELM-type options. For example, a fall in Agricultural Gross Output of 43%, whether by stocking rates or livestock market prices, would make ELMs options more attractive, removing the BPS income gap, but this would reduce overall farm profitability and viability. A 28% rise in AES (ELMs type) payment rates (currently based on CS rates) would close the net income gap and retain current levels of Farm Business Income.

9. Implications of ELMs for upland farming

The case of Pen Farm illustrates the potential synergies and trade-offs between agriculture and new ELMs options as upland farmers seek to maintain the financial viability in the face of the post-Brexit policy reforms.

In the main, upland farms face a BPS income gap of between £150/ha and £180/ha after costs. This will require in many cases a three-fold increase in net income from new ELM-type options compared to the current take-up of Countryside Stewardship agri-environment agreements. Upland farmers will need to take up a wide-ranging package of ELMs options to plug this gap, as we have demonstrated in this generic case.

The transition to ELMs will require close scrutiny of the relationship between agriculture and intended environmental outcomes. Stocking rates and grassland management are a key factor influencing agricultural output on the upland farm, and a defining ‘pivot’ between agricultural and environmental outcomes. Achieving increased environmental outcomes and rewards under ELMs will require, amongst other things, a reduction in livestock numbers / stocking rates, less intensive grassland management practices and reduced use of artificial fertilisers.

The possible impact of reduced livestock numbers on income from agriculture is, however, not straightforward. Under current management practices, shielded by BPS support, much of ‘agricultural’ beef and sheep production in the upland sector is not profitable. Agricultural activities typically fail to make a positive contribution to whole farm business income, especially if the full cost of labour is charged.

The withdrawal of BPS is likely to expose the agricultural inefficiency associated with non-sustainable stocking intensities, making ELM-type options that require reduced livestock numbers more attractive on the average upland farm. Furthermore, the withdrawal of BPS is likely to promote less intensive livestock systems with lower outputs per ha but with improved ‘value added’ by reducing variable (e.g. feed and fertiliser) and fixed (e.g. labour, energy and machinery) costs. There is also scope for added value by marketing ‘upland’ quality produce through collaborative ventures. In this respect, there is potential synergy between the new ELMs and adaptive agricultural systems for the uplands. This management response will need technical and advisory support.

A key principle of ELMs is to base payments in future on the value of the outcomes delivered rather than, as in the past under Countryside Stewardship, basing them mainly on compensation to land managers for costs incurred and/or income foregone. This implies context specific valuation and reward systems.

It seems likely that ELMs Component 1 payments will be mainly cost based, with an incentive element to reflect relative benefit of particular options that are relatively easy to take-up and do not involve major changes in farming practices. Payments for Component 2 and 3 options will most likely include an important 'benefit' component for targeting context specific outcomes. The latter will also require that the 'environmental offer' made by an individual farm is set in the broader multi-farm and landscape setting. The benefit 'bonus' over and above costs, for example, might reflect the contribution to local water quality, flood risk management, or ecological connectivity. Particular bundles of ELMs options could qualify for these locally defined 'landscape' benefit bonuses.

Benefit-based rewards are also likely to favour multi-farm collaborations to deliver outcomes at the larger landscape scale under Components 2 and 3 of ELMs. These could include joint action to improve catchment water quality, alleviate flooding and help restore habitats that contribute to Nature Recovery Networks and Strategies. Our assessment of Pen Farm (together with our three participating farmers) indicates considerable opportunities for joint and collaborative working with cumulative environmental effects that can exceed individual actions. It will be important to support the preparation of such initiatives, while aligning funding opportunities from ELMs with other sources.

Some future ELMs options have implications for land tenure, and possibly rents, especially where these involve long term changes in the use of land and land-based assets. For example, there is considerable scope for upland peatland restoration, woodland and woodpasture (a type of agro-forestry) that involve long term commitments and rewards. A large proportion of upland farms are tenanted, and landlords may not favour long term arrangements under tenancy agreements. Indeed, landlords may see advantage in implementing these options directly as landowners, particularly at the landscape scale. Termination of tenancy agreements could be an unintended consequence. Agro-forestry, and particularly wood pasture, for example has considerable scope to combine agricultural and environmental outcomes under owned or tenanted arrangements. These longer management options may require special arrangements, including funding of capital costs, to suit the needs of landlords and tenants.

Implementation of ELMs, supported by tests, trials and a national pilot, will occur over a 7-year period through to 2028 alongside the phasing out of BPS. This will provide an opportunity for the preparation and adaptation of ELMs Components 2 and 3 relevant to local circumstances and practices of farmers in the Pendle Hill and adjoining areas. Set in the broader context of agricultural transition[26], ELMs can also help prepare land managers to participate in new markets by underpinning initial investments and reducing uncertainties, before joint or supplementary 'blended' funding options come on stream, for example through carbon, flood risk or

[26] Defra. 2020, The Path to Sustainable Farming: An Agricultural Transition Plan, 2021 to 2024. November 30th 2020. Department for Environment, Food and Rural Affairs, London

biodiversity net gain credits, or nature-based tourism and recreation. This will require forward visioning of what a viable Pendle Hill may look like, not only in terms of the mix of agricultural, environmental and other farm-based diversification activities, but also the level of financial and other rewards needed to sustain a vibrant upland farming sector.

10. Conclusions

Our assessment concludes that the adoption of ELM-type options on upland farms can deliver multiple public benefits associated with the main themes of the scheme. Upland farms would probably need to increase the income from environmental agreements from their present level by between 2 and 3 times to compensate for loss of BPS income support. The indicative case developed here suggests that it is possible to close the income gap left by BPS. This will, however, require very significant changes in land management and farming practices that will place more emphasis in the future on environmental outcomes rather than livestock production.

In most cases, as illustrated here, increasing the generation of public goods on upland farms will require reductions in livestock numbers and stocking rates, and changes in livestock and grassland management practices. Increasing woodland habitats is particularly important. Given that much of upland beef and sheep production is currently unprofitable without BPS support, there is scope at least in principle, to move to lower input, higher added value agricultural systems that simultaneously deliver agricultural and public benefits.

These changes are, however, conditional on the design of appropriate environmental options and rewards to farmers, as well as technical assistance and advice to support the transition towards more efficient upland systems that deliver multiple benefits. Such funding and support services can be provided by a mix of public and private agencies, including Protected Landscapes (AONBs and National Parks).

The natural capital approach as applied here for Pen Farm can help to support the design, selection and management of ELMs interventions. It can help to provide quantitative assessments of the current state of natural capital assets and flows of ecosystem services, and of environmental outcomes attributable to ELMs. In particular, the GIS map-based assessment and reporting methods lend themselves to the land-based approach that is at the core of ELMs. Furthermore, the approach can support digital monitoring and evaluation methods of scheme participation and achievements, with records kept at the farm and/or landscape scale.

While showing the potential of the natural capital approach, the Pen Farm case confirms the need to refine the methods to support decision making at the farm scale, and to derive estimates of changes in ecosystem services and values that are context specific. Whilst it is possible to use our approach to directly assess the impact of land management interventions, such as woody debris dams and new woodland planting, on specific outcomes such as improved water quality or reduction in flood risk, it was not feasible within the resources of this project.

Looking forward, the natural capital approach would benefit from a farm-based version that is more finely attuned to site and field scale conditions and practices such as stocking densities, and fertilizer and agrochemical application. This will allow a more realistic farm-scale ecosystem service baseline to be set, so that the efficacy of ELMs options to increase these benefits can be more accurately assessed. Such an assessment tool must be relatively easy to use and capable of guiding the selection of ELMs options to deliver both environmental and financial outcomes. The environmental contributions from individual farms can then be aggregated and considered in the context of local environmental targets and values, such as the priority for reducing flood risk or improving water quality.

The indicative Pen Farm case developed here shows the advantage of integrating the natural capital assessment with farm business accounting methods. As noted above, this can help land managers assess the financial implications of ELM-type options, and the possible impacts on viability of the farm in the longer term. The approach, with its register of assets, service flows and associated environmental options and payments, could also provide a framework for reporting the environmental performance of upland farms within future regional farm business surveys.

Annexes

Annex 1: Agricultural Policy Context

This Annex considers the broad policy context as this affects farming futures for the Pendle Hill area after the UK withdraws from the European Union (EU), commonly referred to as Brexit. Emerging policy frameworks for agriculture and the natural environment are considered, including proposals for a new environmental land management protocol. The commercial performance of farms in Less Favoured Areas such as Pendle Hill is reviewed, together with the implications for upland farming of major changes to income support post-Brexit. The scope and need for payments to farmers and land managers to protect and enhance natural capital and reward them for public goods that benefit people and nature is also identified.

1.1 Agricultural and Environment Policy Reform

The decision to leave the European Union (EU), commonly referred to as Brexit, has prompted a major review of agricultural and environmental policies in the United Kingdom and its devolved administrations. The withdrawal from the EU's Common Agricultural Policy (CAP) and the obligations under EU Environmental and other Directives has required a reassessment of the policy and supporting legal frameworks that shape the relationship between land-based economic activities such as farming and the natural environment.

The resetting of the post-Brexit policy framework aligns with wider pledges by Government towards sustainable development that are embedded in key policy commitments and targets. These include, for example, Defra's 25 year Environment Plan[27], which 'looks forward to delivering a Green Brexit' and The Climate Change promise to achieve net zero emissions by 2050[28].

New policy initiatives of particular importance to agriculture, rural livelihoods and the natural environment post-Brexit are making their making their way through the legislative and implementation process. These are the Agriculture Act 2020[29] enacted in November 2020 and the Environment Bill 2019-2021[30] (Box 1) due for enactment in 2021.

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[27] Defra. 2018. A green Future: Our 25 Year Plan to Improve the Environment. HM Government: London

[28] CCC. 2019. Net Zero: The UK's contribution to stopping global warming Committee on Climate Change May 2019

[29] https://www.legislation.gov.uk/ukpga/2020/21/contents/enacted

[30] https://services.parliament.uk/bills/2019-21/environment.html

1.2 Agricultural policy under review

Following the publication of the 25 Year Plan, Defra embarked on a consultation process of its ambitions for the future of food, farming and the environment. Under the title 'Health and Harmony'[31], Defra outlined proposals for a reformed agricultural policy that sought commitment to align objectives for food production alongside support for rural economies and the protection of natural assets and the environment. 'Public money for public goods' emerged as a guiding principle for future environmental policy[32].

The public goods principle features strongly in The Agriculture Act 2020 supporting the notion of rewarding farmers and land managers for actions:

- to protect and improve the land, water and air
- to support thriving plants and wildlife
- to reduce and provide protection from environmental hazards
- to adapt to and mitigate climate change
- to maintain, restore or enhance the beauty of heritage and increasing engagement and access to the environment
- to improve the health and welfare of our livestock

BOX 1: New Policy Proposals for England 2019-2021

The Environment Bill makes provisions for targets, plans and policies for improving the natural environment, including proposals to establish an Office of Environment Protection. The bill includes specific reference to waste and resource efficiency, air quality, water, nature and biodiversity. Of particular interest here, the Bill makes provisions for biodiversity gain in planning, nature recovery strategies and conservation covenants.

The Agriculture Act 2020 sets down provisions to make interventions and payments for agricultural and related purposes following the UK departure from the EU. This includes powers to modify retained aspects of EU legislation relating to agricultural and rural development payments in support of policy outcomes, as well as other measures of support and interventions.

Defra published 'The Path to Sustainable Farming' in November 2020 [33] that outlines its plans to discontinue area-based farm income support and divert the funds released into environmental and other objectives in accordance with the Agriculture Act 2020. The proposals under the 2020 Act include initiatives on Environmental Land Management (ELM), Animal Health and Welfare, Tree Health, Farming in Protected Areas and support for improving farm productivity and prosperity, including training, research and development.

[31] Defra . 2018. Health and Harmony: the future for food, farming and the environment in a Green Brexit February 2018. Cm 9577

[32] Defra. 2018. Moving away from Direct Payments Agriculture Bill: Analysis of the impacts of removing Direct Payments September 2018

[33] Defra. 2020. The Path to Sustainable Farming: An Agricultural Transition Plan, 2021 to 2024. November 30th 2020. Department for Environment, Food and Rural Affairs, London

1.3 The Environmental Land Management Scheme (ELMs)

ELMs is now seen as the main vehicle for incentivising and rewarding land managers for environmental protection and enhancement, replacing other programmes such as Countryside Stewardship that are currently funded under EU CAP (Box 2)[34]

The proposals for ELMs seek to align with and support the delivery of the goals of the 25 Year Environment Plan, the Climate Change Net Zero Emissions, and the commitments to flood security and a vibrant rural economy embedded within the Agricultural Act 2020. While work continues on the detailed design and operational aspects of ELMs in collaboration with land managers (Defra 2020b[35]), the Transition Plan outlines three main components[36] namely:

Component 1: Sustainable Farming Incentives will encourage farmers to take simple packages of actions to improve environmental outcomes that are suited to their land and farm types. These will focus on crop, grassland and livestock management, soil and water management, wildlife and biodiversity, and the protection of heritage assets. All farms will be eligible, and farmers will be encouraged to develop a whole farm plan for the purpose.

Component 2: Local Nature Recovery will support local nature recovery by helping land managers to deliver locally targeted environmental priorities and outcomes. The component will focus on: creating, managing and restoring habitats such as woodlands, wetlands and species rich grasslands; natural flood risk management, species management, rights of way infrastructure, educational services and heritage management. This component will probably involve collaborative joint action amongst land managers. Elements of this component will be competitive.

Component 3: Landscape Recovery: will focus on delivering landscape and ecosystem recovery through long term landscape scale and land-use change projects such as wetland creation and restoration, large-scale tree planting, peatland restoration projects. Actions under this component would align with local and national priorities. The component will be competitive.

BOX 2: Main ELMs Themes and Objectives

BHE - Beauty, Heritage and Engagement;
CA - Clean Air;
CC - Mitigation of and adaption to Climate Change;
CPW - Clean and Plentiful Water;
HAZ -Protection from and mitigation of environmental hazards; and
TPW – Thriving plants and wildlife

The details of ELM actions and payments have yet to be worked out, drawing on the lessons from the supporting programme of Test and Trials. Component 1 is likely to pay farmers for actions that are known to be associated with the desired outcomes. Farmers will probably be offered a menu of single or packaged options from which they can select. Although, the underlying principle of ELM is to reward farmers directly for the delivery of public goods, pragmatically Tier 1 is likely to include a large element of payments that compensate for income forgone or costs incurred,

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[34] Defra. 2019. The Future if RBAPS in English Agri-environment post Brexit. Anew Environmental Land Management Scheme

[35] Defra. 2020. Environmental Land Management Policy Discussion Document February 2020

[36] The ELM components were referred to as Tiers in preceding policy discussion documents.

set at levels that will encourage farmer uptake: a mixture of compensation and incentive.

The actions and payment mechanisms for Components 2 and 3 are likely to be much more output oriented, attuned to achieving spatially specific policy targets, and appraised using cost: benefit and economic efficiency criteria. It is likely that market mechanisms such as competitive bidding, possibly involving reverse auctions, will be used to allocate available funds.

At the time of writing, it is understood that Defra have compiled menus of actions that can be undertaken to deliver ELM objectives (as described in Box 2 above). The details of design, specificity to particular contexts, possible 'packages' of actions, and associated reward levels and systems have not yet been developed, nor subjected to the process of consultation, test, trial and piloting. Issues, such as for example, agreements and rewards for designed for tenant farmers where these might differ from those for landowners and questions of the relationship between ELM and legally binding regulatory requirements are likely to topics of further consultation.

Defra's ELMs proposals include a schedule for a design and implementation[37], including an initial Test and Trial Programme during 2019-2021. In July 2020, Defra reported on 57 ongoing ELM Tests and Trials (T&T)[38] involving those led by farmer groups, conservation bodies and Defra itself. Of particular interest here, early findings point to the importance of the land management plans, including map-based natural capital assessments, that show the environmental baseline and the opportunities for the delivery of public goods.

With respect to payments, evidence from T&T suggests that 'income foregone plus costs' is not a strong incentive for ELM take-up. Furthermore, Trial participants identified the need for payments to cover additional capital costs and the cost of maintaining existing assets. Payments over and above costs could involve tiered or stacked payments and/or an 'uplift' factor to reflect the range and intensity of environmental actions, set in the context of the benefits generated by the services provided. Early feedback from T&T support the principle of payments for outcomes while ensuring the financial stability and sustainability of the farm business, with payments ahead of the delivery of outcomes. The scope for supplementing ELM payments with income from other sources, such as carbon credit and biodiversity offsetting, was also noted. These points are others are alluded to in the Pen Case.

A National Pilot for ELM is scheduled for the period 2021-24 involving up to 5,500 farmers to help prepare the way for phased implementation over the period 2022-2028 alongside the gradual withdrawal of BPS[39]. Farmers with ongoing Countryside Stewardship may have the options of transferring them into ELMs.

For the purposes here, broad groups of actions that can be taken by Pendle Hill farmers have been identified, together with a broad assessment of their likely

[37] Defra. 2019. The Future if RBAPS in English Agri-environment post Brexit. A New Environmental Land Management Scheme

[38] Defra. 2020. Environmental Land Management tests and trials Quarterly evidence report Date: July 2020. Department of Environment, Food and Rural Affairs, London

[39] Defra 2020, The Path to Sustainable Farming: An Agricultural Transition Plan, 2021 to 2024. November 30th 2020. Department for Environment, Food and Rural Affairs, London

contribution to ELM objectives. These are discussed later with respect to Pen Farm, a generic case for upland farming.

1.4 Implications of Brexit and policy review for the upland grazing livestock sector

The initial proposal and subsequent decision to withdraw from the EU and within it the CAP have been accompanied by numerous assessments of possible impacts on the viability of agriculture in the UK[40 41]. The results confirm the high level of dependency of farms across most sectors of UK agriculture on a combination of direct farm income support and receipts from Agri-Environment Schemes (AES). The Upland Grazing Livestock sector is particularly vulnerable to withdrawal of CAP support.

Estimates of farm income in the Hill Farming sector are available from the Rural Farm Business Survey for Less Favoured Area (LFA) Grazing Livestock Farms (Harvey and Scott, 2019)[42]. Estimates of key indicators of farming performance for each of the four accounting years, 2013/14 through to 2017/18, have been combined here to produce overall average annual estimates for the Less Favoured Area Hill farms, adjusted for inflation and expressed in mid 2020 values[43].

Table 1.4.1 and Figure 1.4.1 show estimates of Farm Business Income (FBI) for the 'average' LFA Farm. FBI is a measure of the net profit generated by a business[44]. It is commonly used to consider the impact of policy change or regulation on farm business and incomes.

Figure 1.4.1 shows the contributions from the major sources of farm business income on the farm, namely from:

- *agriculture* (crops and livestock),
- *diversification* activities (such as contracting and holiday accommodation),
- *agri-environment* agreements (AES, such as Countryside Stewardship)
- *direct income support* (mainly the Basic Payment Scheme - BPS).

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[40] YAS. 2016. The Implications of 'BREXIT' for UK Agriculture. A report for the Yorkshire Agricultural Society. 2016: https://yas.co.uk/wp-content/uploads/2019/03/yas-fsn-brexit-full-report.pdf

[41] Buckwell, A. 2016. Agricultural Implications of BREXIT. Worshipful Company of Farmers http://ca1-fml.edcdn.com/downloads/WCF-Brexit-18.01.16-pdf.pdf?mtime=20160207094708

[42] Harvey, D. and Scott C. 2019. Hill Farming in England. Farm Business Survey. Rural Business Research (RBR). Newcastle University, Newcastle. 2019 (and preceding years covering period 2013-2018)

The RBR Hill farm Survey covers just over 200 farms per year, made up by area of 67% in Severely Disadvantaged Areas (SDA), much of it including Moorland, and 33% in Disadvantaged Areas (DA). Of the Survey farms , 63% are located from the north of England. A farm is classified as LFA if more than 50% of its area consists of LFA designated land. LFA farms with more than 50% in SDA are classified as SDA, otherwise DA. Most LFA farms are sheep and cattle farms. There are some dairy farms with land in within LFAs but these are relatively uncommon, and dairy land generally lies outside SDA and DA designations. Dairy farms are excluded for the assessment of LFA farm accounts.

[43] ONS. 2020. GDP Deflation Factors. Office of National Statistics, London

[44] For sole traders and partners FBI represents the return to all unpaid labour and the capital investments in the business, including land and buildings. For corporate businesses FBI represents the return on shareholder capital invested in the business.

Over the period 2013/14 – 2017/18, the average LFA Grazing Livestock farm (170 ha) earned 62% of its annual revenue from agricultural activities, 22% from the BPS, 12% from AES and 4% from diversification activities. Once costs are attributed to the various sources of FBI, the contribution of agriculture is negative at about minus £10k as shown in Figure 1.4.1 Contributions from other sources, notably AES (£11.1k) and BPS (£21.8k) produce an overall positive FBI of about £23.6k/year. (Note this does not include charges for unpaid family labour which is estimated at £28k/year).

Although there is considerable variation between years and between farms with the Hill sector, the overall message is clear (Figure 1.4.2). The withdrawal of income support (BPS) and/or AES would render FBI near zero or negative. As reported in RBR (2019), most LFA farms 'could not survive in their present form as commercial businesses without public payments', particularly those in the cattle sector[45]. Although the focus here is on vulnerability to income support, arrangements for post Brexit international trade are a further source of uncertainty for future farm gate sheep and cattle prices [46]. The removal of BPS support would, therefore, have a major effect on the range of indicators[47] used to assess farm businesses once various adjustments are made for charging for unpaid family labour, capital and interest charges, rental charges and managerial costs (Table 1.4.1 and Figure 1.4.3). Charging fully for unpaid family labour and for land charges at equivalent rents renders negative the profit available to provide a return on the managerial effort and capital invested (Management and Investment Income (MII)) for the average LFA farm, even including BPS. Without BPS, the negative estimate of MII increases by a factor of 3.

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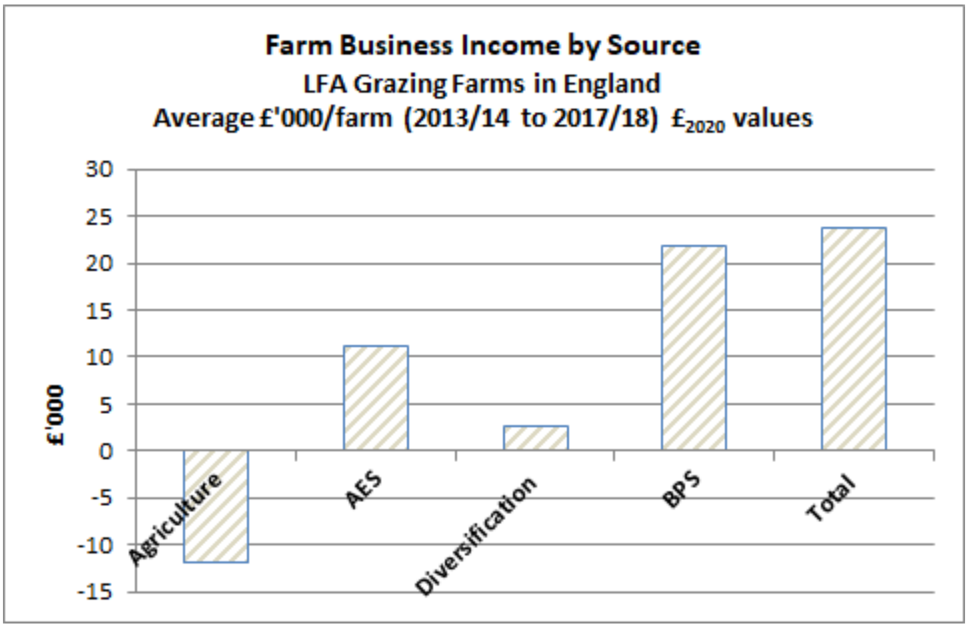
45 RBR 2019 - Harvey and Scott. 2019, as above

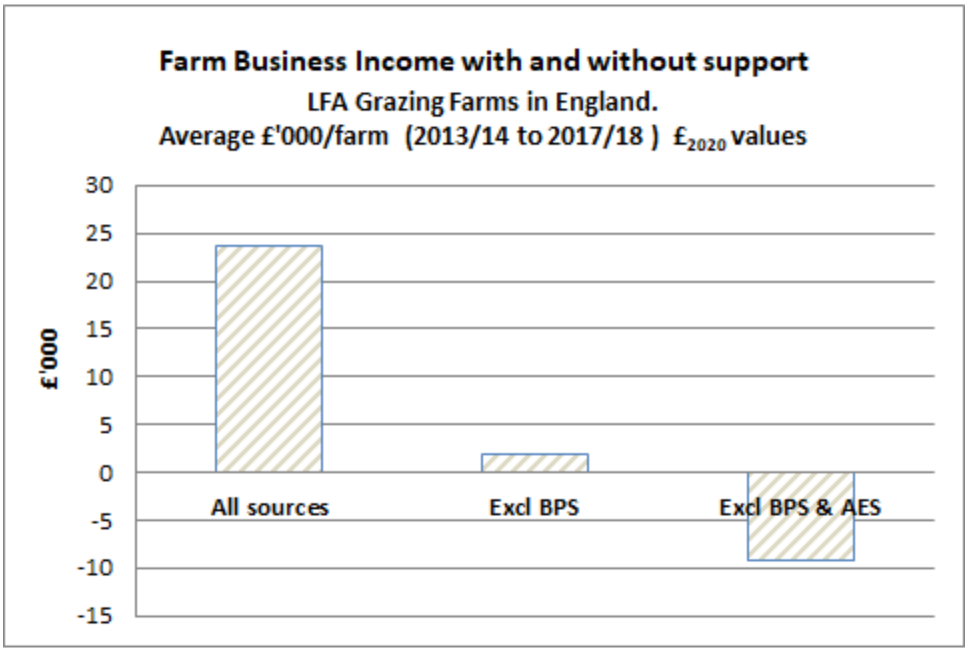
46 At the time of writing, it is not clear whether UJ-EU negotiations will include special arrangements for agricultural trade, or whether free access or tariffs may apply possibly under WTO terms, with consequences for farm gate prices. The CORVID pandemic in mid 2020 has disrupted UK domestic demand in the non-retail sector with variable but mainly depressant effects on sheep and cattle prices (AHDB, May 2020).

47 Net Farm Income is a measure of profit to tenant-type farming. It assumes all farms pay an equivalent rent. It shows the return to the farmers and spouse for all labour and managerial inputs and tenant type capital. Farm Investment Income shows the profit to all capital invested in the farm business whether borrowed or owned after all labour costs have been deducted. Management and Investment Income shows the profit (after labour and land costs) generated by, and hence the return to, the managerial and capital inputs in the business.



Source: based on RBR data for LFA farms

Figure 1.4.1 Farm Business Income by source for LFA Grazing Farms in England.



Source: based on RBR data for LFA farms

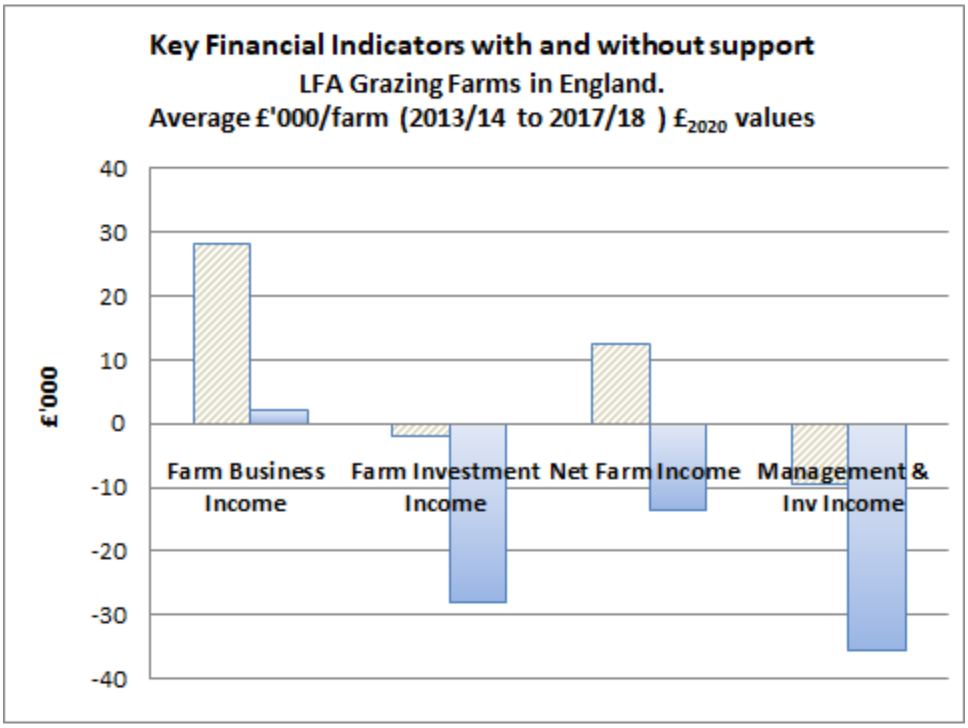
Figure 1.4.2 Farm Busines Income with and without support for LFA Grazing Farms in England.

Table 1.4.1 Farm Business Income by Source for LFA Grazing Farms in England.

Average £/farm (2013/14 to 2017/18) £$_{2020}$ values

.	Agriculture	AES	Diversification	BPS	Total
Total Ouput	72142	13671	4937	25333	116084
Variable Cost	41886	29	89	3	42007
Total Gross Margin	30256	13642	4848	25330	74077
Fixed Costs	42150	2497	2248	3524	50420
Farm Business Income	-11893	11145	2600	21806	23657
Unpaid Labour	26453	550	1174	0	28177
Farm Corporate Income	-38346	10594	1426	21806	-4520
Interest payments	2388	72	96	95	2650
Farm Investment Income	-35958	10666	1522	21901	-1869
Net Farm Income					12537
Management & Investment Income					-9576

Source: based on RBR data for LFA farms



Source: based on RBR data for LFA farms

Figure 1.4.3 Key financial indicators with and without support for LFA Grazing Farms in England.

Results from Rural Business Research (Harvey and Scott, 2019) point to considerable variation in the LFA sector, although even the top 25% of farm in terms of FBI fail to achieve a positive margin on agricultural activities alone. High performance in the sector appears to be associated more with the amount (£) and the rate (£/ha of receipts per adjusted ha) from AES and BPS than with agricultural performance.

Overall performance in terms of key financial indicators is currently highest for Severely Disadvantaged Area (SDA) Mixed Grazing and SDA Specialist Sheep farm

Types, but again this is more associated with higher AES and BPS net revenues on larger SDA farms.

The RBR (2019) sample includes 21 organic farms. These generally performed better than non-organic farms mainly because: (i) the 'losses' from agricultural production were lower, reflecting a combination of higher output value and lower costs per livestock unit and (ii). revenues from income support and diversification sources were higher on these larger farms with extensive areas of rough grazing.

1.5 Less Favoured Area farming prospects

It was in this context that ADAS (2019) [48], on behalf of the Northern Upland Chain Local Nature Partnership (NUCLNP), reviewed farm incomes and policy dependency for LFA Grazing Livestock systems in the north of England, including Lancashire and the Pendle Hill area.

1.5.1 Filling the income gap

NUCLNP held a workshop to consider the options for addressing the potential income gap due to withdrawal of BPS. Workshop participants considered the interventions identified by Defra for strengthening the ability of famers to cope with policy reform[49] , namely through:

- improvements in agricultural output and productivity, particularly by increased efficiency in the use of inputs, reduced costs and extra value-added,
- increased farm-based diversification, and
- undertaking environmental protection and improvement actions rewarded under the proposed ELMs

It was reported that workshop participants felt that although there was scope for productivity improvements and opportunities to generate income from both on and off-farm diversification, these were unlikely to be sufficient to make good the gap arising from the loss of direct income support. Participants also expressed a view, evident elsewhere, that loss of income support that rendered upland farms non-viable would put at risk the substantial contribution they currently make to public goods in the uplands.

The challenge of plugging the income-support gap is clearly evident. In very crude terms drawing on the Figures above, *revenues* from agriculture for the average LFA farm would need to increase by a factor of 1.4 to reinstate current average total farm revenues in the absence of BPS, and gross margins from agriculture (revenues less direct costs) would need to more than double. To maintain overall average FBI at current levels, the contribution for agriculture would need to increase from the current negative £10k to about £28k: a tall order by any measure. It is noted that these estimates are for the overall average case: there is considerable variation

[48] ADAS, 2019. The Future of High nature Value farming systems and their ability to provide public goods in a post Brexit world in the NUCLNP. January 2019

[49] Defra. 2018 Moving away from Direct Payments Agriculture Bill: Analysis of the impacts of removing Direct Payments September 2018

within and between the farming systems within the LGA livestock sector[50]. But the overall message is clear.

1.5.2 Improving the sustainability of upland farming systems

Set in the context of challenges to the viability of upland farms, (Clark et al., 2019[51]) used the accounts on 29 farms farm to explore the potential for achieving sustained profitability of upland and marginal farms under the three scenarios of current support arrangements, only agri-environment support and no support. They argue that, in line with evidence from RBR, current and previous agricultural support regimes have allowed and indeed encouraged many upland farmers to avoid facing up to the financial reality of their agricultural operations.

Clark et al (2019) suggest, however, that the financial performance of many upland farms can be substantially improved by increasing efficiency in input and resource use. This, they argue, is best achieved by a combination of:

- reducing direct inputs (especially feed and fertilisers) to a point where at least the extra revenue generated is sufficient to recover extra costs (implying that many upland farms currently are pushing for high outputs that beyond the point that makes economic sense; the costs of inputs are exceed the revenues obtained)
- reducing fam level overhead fixed costs, particularly associated with machinery ownership;
- generating revenue through increased pricing and marketing, and
- enhancing the delivery of public goods in return for public payments, made more possible by less intensive, more sustainable farming practices.

Clarke et al. (2019) argue for a new business model that operates within the environmental limits of the farm, especially limiting livestock numbers in accord with the farm's natural capacity to produce energy from grass: a so-called less intensive Maximum Sustainable Output (MSO). This removes (or significantly reduces) the need for artificial fertilizer, excessive bought feeds, and other inputs commonly associated high stocking rates. Essentially, this is a call for a switch to lower input: lower output but higher potential value-added systems than currently prevail.

Drawing on insights from 29 farms, applied to 7 farm case studies, they estimate that all 7 would fail to achieve positive Farm Business Income (as defined above) adopting existing farming practices if all current support was withdrawn. Confirming the extent of the challenge, however, a switch from current farming practices to the less intensive system position allowed only 1 out of the 7 cases to achieve positive income in the absence of any income support, although 2 of the cases could achieve positive farm business income if agri-environmental support was retained.

[50] These comments are made with particular reference to LFA beef and sheep farms. Dairy farms in LFA show relatively more favourable financial indicators but remain, due to limits of scale and carrying capacity, dependent on income support.

[51] Clark, C. Scanlon, B. and Hart, K. 2019. Less is More: Improving profitability and the natural environment in hill and other marginal farming systems. Report to RSPB, WLT and NT. November 2019

Clark et al.'s assessment further confirms the challenges facing upland farming. While there is scope for productivity improvements on LFA farms particularly by switching to less input-intensive methods, possibly operating at a larger scale, this is unlikely to be sufficient to maintain the financial viability of the majority of upland farms in the absence of BPS. They argue that existing, and likely future, agricultural profit margins in the sector for the most part fail to past the test for bankable investment funding (as alluded to in Management and Investment Income above). However, as pointed out in the NUCLNP Workshop, commercial return on investment has not been, and probably is unlikely, to become the dominant criterion for farming in the Upland Sector where lifestyle choices are important and valued. Furthermore, many of the skills and assets specific to the upland sector are not easily transferable elsewhere. While this can discourage change on the one hand, it can also promote a willingness to embrace change when new realistic opportunities are made available, especially by younger farmers.

1.6 Upland futures

Although the future for conventional upland commercial farming may not look bright in the absence of direct income support, there is considerable scope for LFA farmers to generate public goods that can be rewarded in the emerging policy landscape, especially under ELMs. This may require alignment with less intensive farming practices on all or part of LFA farms that can simultaneously increase agricultural value added. It is important, therefore, that ELMs options are designed specifically to address the needs and opportunities of the LFA sector, balancing the outcomes for farming and food, rural livelihoods and nature.

Annex 2: Natural Capital Assessment for Pen Farm

This Annex outlines the methods of the natural capital approaches used in this project, and reports on additional results of the assessment.

2.1 Methods

A variety of natural capital assessment approaches were applied to this project, from a qualitative impacts and dependencies analysis to a quantitative mapping and valuation of ecosystem services.

2.1.1 Ecosystem services, impacts and dependencies

We identified the ecosystem services on which Pen Farm depends and explored the possible impacts that the farm system has on its natural capital assets. This natural capital dependencies and impacts analysis followed the Natural Capital Protocol (2016). See section 2.2 below for results.

2.1.2 Qualitative ecosystem services assessment

A qualitative assessment of ecosystem services was also completed for Pen Farm baseline and ELMs scenario, to demonstrate the broad range of ecosystem services provided by the natural capital assets of the farm and the level of provision (no delivery to very significant delivery) of those services. This demonstrates the wide range of ecosystem services that are likely to be provided by on-farm natural capital. It is not possible to quantify all the ecosystem services provided, and presenting this alone would only give a partial picture.

2.1.3 Ecosystem services mapping

Creating a natural capital basemap

Before the flow or value of ecosystem services was calculated and mapped, it was necessary to map the natural capital asset baseline at Pen Farm. This was cut from a mapped baseline of the whole of the Forest of Bowland AONB that had been completed in a different project commissioned by the PHLP. The habitat basemap was created using EcoServ-GIS, a toolkit developed by the Wildlife Trusts, with a number of bespoke modifications. This approach used OS MasterMap polygons as the underlying mapping unit, and then a series of different data sets to classify each polygon to a detailed habitat type and to associate a range of additional data with each polygon. The following data was used to classify habitats:

- OS MasterMap topography layer
- OS VectorMap District data
- OS Open Greenspace data
- CORINE European land cover data
- CROME crop data
- Digital Terrain Model
- Hydrology of Soil Types

Polygons were classified into Phase 1 habitat types and into broader habitat groups. Multiple modifications were made to the EcoServ programme code to enable improved classification of habitats. Furthermore, upon initial completion, the basemap was carefully checked and manual alterations were made where necessary. Note, however, that the final map was not ground truthed for accuracy.

Mapping ecosystem services

The natural capital assets and ecosystem services had already been mapped for Pen Farm as part of a separate project to create a mapped baseline for the Forest of Bowland AONB. As a result, we were able to cut these maps to the Pen Farm scale. The following services were mapped:

- Carbon storage
- Carbon sequestration of woodland
- Emissions from deep peat soils (applied off-farm to common land)
- Local climate regulation
- Air pollution regulation capacity
- Agricultural production
- Noise regulation capacity
- Water flow
- Water quality
- Accessible nature

In all cases the models were applied at a 10m by 10m resolution to provide fine scale mapping across the area. The models are based on the detailed habitat information determined in the basemap, together with a variety of other external data sets (e.g. digital terrain model, UK census data 2011, 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 ES is mapped relative to the values present within the study area.

For every ecosystem service listed, the capacity of the natural environment to deliver that service – or the current supply – was mapped. Below is a description of how each service has been measured.

Carbon storage

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.

The EcoServ GIS carbon storage model was used. This model estimates the amount of carbon stored in the vegetation and the top 30cm of soil. It applies average values for each habitat type taken from a review of a large number of previous studies in the scientific literature. 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 between 0 to 100, relative to values present within the mapped area.

Carbon sequestration woodland

Carbon sequestration from woodland areas were calculated following the UK Woodland Carbon Code methodology and look-up tables (Woodland Carbon Code

2018)[52]. All Pen Farm woodland was broadleaved. Deciduous woodland sequestration rates were averaged over a 100-year period, as this is the length of a typical forestry cycle for deciduous woodland. Information on species composition was taken from the 'National Inventory of Woodland and Trees, England, Regional Report for the NW' (Forestry Commission 2002)[53] and AONB information sources. The annual sequestration rate for each woodland type were then multiplied by the area of each and added together to give the total annual sequestration estimate for woodland at the site. Parkland areas were included assuming a sequestration capacity of 20% of woodland, and dense continuous scrub was assumed to be 50%. Maps of the sequestration rate scaled from 0 to 100 were produced.

Emissions from deep peat soils (applied off farm to the common land)
The data sets of deep peat soils and deep peat soils over 50cm depth were merged. The shallow peat soils data were not included, as these are not considered to meet national definitions of peat (they are either shallower than true peat soils or have a lower density of carbon, Evans, E. (2017)[54] et al. Implementation of an emissions inventory for UK peatlands, a Centre for Ecology and Hydrology report to the Department for Business, Energy and Industrial Strategy). Emissions factors were assigned to the areas of deep peaty soils based on their broad habitat type (e.g. woodland, bog, improved grassland, heathland), and these were derived from the above study. The quality of bog/mire habitats were broken down further by habitat type (e.g. dry modified bog, wet modified bog, raised and blanket bog) and assigned an emission factor taken from the Peatland Code Field Protocol (2017)[55]. According to the Peatland Code, pristine peat, which can sequester rather than emit carbon, is very rare in Britain.

Table 2.1.1 Emissions factors for different habitats on deep peat soils.

Habitat	Emissions (tCO_2e/ha/year)
Woodland	7.34
Cropland	26.42
Extensive grassland (incl. heathland)	13.21
Intensive grassland	23.49
Bog habitats	
Drained peat (e.g. dry modified bog)	4.5
Degraded peat (e.g. wet modified bog)	2.5
Near natural condition (e.g. raised blanket bog)	1.1

Air purification capacity
Local climate regulation capacity was mapped using a modified version of the EcoServ 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

[52] Woodland Carbon Code (2018) Carbon calculation guidance v2. March 2018. Forestry Commission.
[53] Forestry Commission (2002) National Inventory of Woodland and Trees, England, Regional Report for the NW. Forestry Commission.
[54] Evans, C., Artz, J, Moxley, J. et al. (2017) Implementation of an emissions inventory for UK peatlands. A report to the Department of Business, Energy and Industrial Strategy.
[55] IUCN (2017) Peatland code. Field Protocol: Assessing eligibility, determining baseline condition category and monitoring change.Version 1.1. IUCN Peatland Programme.

a 20m and 100m radius around each 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 prevailing wind direction.

Agricultural production

The ability of habitats to provide food, accounting for the Agricultural Land Classification was mapped. Each broad habitat was assigned a score based on its ability to provide food. This was then weighted by the Agricultural Land Class in which it occurred (graded 1 to 5, decreasing in quality). This methodology has been taken from the 'eco-metric tool' that is being developed for Natural England, and features in the report Smith (2020)[56].

Table 2.1.2 Food provision scores assigned to each broad habitat.

Habitat	Score
Arable, horticulture, improved grassland, intensive orchards	10
Allotments	7
Semi-natural rough grassland	6
Wood pasture, traditional orchard	5
Marshy grassland	4
Bog/heath, domestic gardens, woodlands, hedges	1

Table 2.1.3 Agricultural Land Class grade and multiplier assigned to each.

ALC grade	Multiplier
1	3.03
2	2.40
3a	1.83
3	1.33
3b	1.00
4	0.67
5	0.50

Noise regulation capacity

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

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

noise in England is £7 to £10 billion[57]. 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.

The EcoServ noise regulation model was used, with some modifications. First, the capacity of the natural environment is 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 from 0 to 100, relative to values present within the mapped area.

Water flow capacity

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.

A bespoke model was developed, building on an existing EcoServ 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 two factors and mapped for each 10m by 10m cell across the study area:

- **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.

- **Standard % runoff** – was obtained from soil data and modified to reflect soil hydrological properties and their sensitivity to structural degradation from agricultural use (from Broadmeadow et al 2013). This was integrated with a layer

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[57] Defra (2013) Noise pollution: economic analysis. Crown Copyright.

showing impermeable areas where no soil was present (sealed surfaces, water and bare ground)

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.

Water quality capacity

Water quality capacity maps the risk of surface runoff water 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.

A modified version of an EcoServ 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 was calculated and the values were re-classified into a number of 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.

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.

Accessible nature capacity
Access to greenspace is being increasingly recognised for 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".

An EcoServ model was used to map accessible nature capacity. In the first step, accessible green spaces were mapped. These were determined from OS Mastermap Greenspace data, and data sets on local nature reserves, accessible woodlands and others. Greenspaces that did not have full public access (e.g. golf courses, institutional grounds) were removed from further analysis. The retained 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 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.

2.1.4 Ecosystem service valuation

The physical (e.g. tonnes of carbon) and monetary flows (value of the ecosystem service benefits) of Pen Farm ecosystem services were calculated for the baseline and the ELM scenario.

Air quality regulation
The ability of the woodland and grassland vegetation in Pen Farm to absorb particulate matter ≤2.5µm in diameter ($PM_{2.5}$) was measured. Quantifying the physical flow of the air quality regulation service provided by the woodland and grassland was based on the absorption calculation in Powe & Willis (2004[58]) and the method in ONS (2016[59]). The deposition rates for $PM_{2.5}$ in coniferous woodland, deciduous woodland, and grassland were taken from Powe & Willis (2004). Average

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[58] 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.
[59] ONS (2016) Annex 1: Background and methods for experimental pollution removal estimates. UK National Accounts.

background pollution concentrations for $PM_{2.5}$ were calculated using Defra data (Modelling of Ambient Air Quality 2018 and 2001). The surface area index of coniferous and deciduous woodlands in on-leaf and off-leaf periods was taken from Powe & Willis (2004). The proportion of dry days in 2020 (rainfall <1mm) for north-west England 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 was 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 was valued using guidance from Defra that provides estimates of the damage costs per tonne of emissions across the UK (Defra 2019[60]). These are social damage costs based on avoided mortality and morbidity. Therefore, it was assumed that the value of each tonne of absorbed pollutant by the woodland and grassland habitats was equal to the average damage cost of that pollutant. The $PM_{2.5}$ damage cost estimates depend on the location (urban size or rural) and source of pollution. The rural damage cost levels were used. When calculating the present value over 50 years, the absorption rate was assumed to be constant. The Defra damage cost of $PM_{2.5}$ is in 2017 prices, and so was adjusted to reflect inflation up to 2020. The value was 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 (2019). The central damage cost figures are presented in the monetary flow estimates, low and high damage costs from Defra (2019) were used in the sensitivity analysis.

Carbon sequestration

The annual physical flow of the carbon sequestration service was calculated as in Section 2.1.3 above.

Monetary flows were calculated using the Government's traded central carbon price for 2020 (DBEIS 2019[61]). We used the central traded carbon price (£14) as this is indicative of the value farmers might receive if they join carbon trading schemes. The present value (PV) of the ability of the woodland to sequester carbon over the next 50 years was calculated using the projected traded carbon prices for this period, and the discount rate from HM Treasury (2019[62]) of 3.5%. The HM Treasury also provides low and high estimates of current and future traded carbon prices. These were used to provide a sensitivity analysis to the economic valuation of this ecosystem service.

Greenhouse gas emissions from agriculture

Agricultural activities release CO_2 and other greenhouse gasses such as methane and NO_2 into the atmosphere, with emissions highly variable depending on the type of

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[60] Defra (2019) Air quality damage costs guidance. Crown Copyright.

[61] DBEIS (2019) Carbon priced and sensitivities 2010-2100 for appraisal in HM Treasury (2018) The Green Book. Central Government guidance on appraisal and evaluation, version 3. London.

[62] HM Treasury (2019) The Green Book. Crown Copyright.

farming practices employed. These emissions can therefore negate the benefits obtained through carbon sequestration of habitats within a site.

The greenhouse gas emissions of the site were calculated by multiplying the area of each crop type and the numbers of livestock by emissions figures for each crop type and livestock type in Bateman et al. (2013[63]). These emission figures are based on three types of agricultural emissions:

1. Emissions from typical farming practices (e.g. tillage, sowing, spraying, harvesting, and the production, storage and transportation of fertilizers and pesticides)
2. Emissions of N_2O from fertilizers
3. Emissions of N_2O and methane from livestock, caused by enteric fermentation and the production of manure

The total physical flow of greenhouse gas emissions was calculated by adding crop type and livestock emissions (in tCO2e). These were monetised using the DBEIS (2019) traded central carbon price, as described for carbon sequestration above, and discounted at the standard rate. The low and high traded carbon prices were used for the sensitivity analysis.

Greenhouse gas emissions from deep peat soils (off-farm common land)
The annual physical flow of the GHG emissions from deep peat soils service was calculated as in Section 2.1.3 above in tonnes of carbon equivalent. Monetary flows were calculated as for the GHG emissions from agriculture (see directly above).

Agricultural production
The physical annual flow of agricultural production was the number of livestock units in the baseline and the ELM scenario. The monetary value of agricultural production was calculated as part of the financial analysis. The figure is the return to farm operators once all expenses have been deducted, taking into account yields and farm gate prices, to give gross output, and subtracts typical variable costs (e.g. fertilizers, husbandry, feed and forage costs) and fixed costs (labour, machinery, fuel, buildings). These were then adjusted to remove the effects of Basic Farm Payments and any ELMs payments, to remove any charges for imputed (unpaid) rent, and to include charges for the imputed value of unpaid family labour. This gives a return (an economic rent) to the land resource itself. The Present Value was calculated over 50 years using the standard discount rate and assumes that livestock numbers stays approximately the same. The low and high production (+/- 20%) values were used for the sensitivity analysis.

Timber/woodfuel production
For existing woodland, 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. The average yield classes for each species of

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

woodland type were derived from the woodland carbon code (see carbon sequestration in Section 2.1.3).

The annual monetary flows for the woodland areas were calculated by multiplying the yield by the standing price of woodfuel. The price for broadleaved timber in 2015 ranged from £15 to high quality timber reaching £250 per m^3 standing (ABC 2015[64]). We assume the lowest value here for woodfuel and convert this to 2020 priced using Government deflators. To convert to a present value the annual value was multiplied by the standard government discount rate (3.5%) for each respective year up to 50 years. It was assumed that the area of woodland remains static and the unit price was 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.

2.2 Additional results

2.2.1 Pen Farm impacts and dependencies

The natural capital assets of Pen Farm give rise to a range of benefits (ecosystem services). A comprehensive list appears in Table 4.3 in the main report. The ecosystem services span provisioning, regulating, and cultural categories. They include food and timber production, the sequestration of carbon, air quality, noise, water quality and flow regulation, habitat for biodiversity, the provision of recreation, promoting health and well-being and aesthetic experiences.

Agriculture on Pen Farm depends on many of these benefits that flow from the on-farm natural capital assets for commercial food production (Table 2.2.1). For example, soil quality regulation is essential for producing good quality grass, woodland and hedges provide local climate regulation providing shade and shelter for livestock which may increase overall sheep health, and water flow regulation can avoid livestock sitting in wet conditions in flooded fields at valley bottoms, which will in turn decreases the incidence of pest and disease. Farming here also depends on cultural heritage. The livestock farming culture and community is sustained knowledge and behaviours that have built up over generations of farmers and shaped by the natural assets of the upland landscape. If this heritage and culture are eroded then livestock farming may cease to operate. This is an important consideration when bringing in a new system, such as ELMs, that aims to change farmer behaviour away from traditional practises.

As with any land management that focuses on increasing the provision of one or a small suite of services, Pen Farm management also impacts on ecosystem service provision. For instance, livestock at high densities can cause soil compaction and erosion, this can also affect soil structure and quality, maintaining grasslands and producing livestock can release GHG emissions, soil compaction and lack of structural vegetation can cause increased flooding, livestock in watercourses can decrease water quality and managing the natural environment as improved grassland decreases biodiversity.

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[64] ABC (2015) The agricultural budgeting and costing book. 81st edition, Argo Business Consultants.

Table 2.2.1 Pen Farm dependencies and impacts on ecosystem services benefits.

Dependencies	Impacts
Local climate regulation	Soil compaction and erosion
Water quality regulation	Decreased soil quality
Erosion control	Carbon and GHG emissions
Soil quality regulation	Increased flooding
Pest and disease control	Decreased water quality
Water flow regulation	Decreased pollination
Cultural heritage	Loss of biodiversity

2.2.2 Pen Farm ecosystem services

We first use a qualitative approach to assess the level of provision of ecosystem services from the Pen Farm baseline. Quantitative approaches are preferable, but methods do not yet exist to quantify all the ecosystem services that will be provided by Pen Farm. A qualitative assessment is, therefore, used to illustrate the broad range of services that will be provided at the farm-scale, ensuring that these are not forgotten when considering the results. Table 4.3 in the main report shows the provision scores for each ecosystem service flowing from the natural capital assets of Pen Farm. Food production unsurprisingly shows very significant delivery. Fuel production is lower showing that the woodland on the farm could deliver this service. Water provision is also possible but not significant. The regulating services show a low provision, this is due to there being only a small area of woodland with some hedges on the farm. These habitats play an important role in sequestering carbon, regulating climate, attenuating noise, filtering pollutants from the air and water and taking up surface water.

Diverse grassland and well-maintained hedges will contribute to pollination capacity, but the dominance of improved grassland and the need to increase the number of hedgerows on field boundaries means that it is a low provision for the Pen Farm baseline. Biodiversity will also be low due to the dominance of improved fields. The cultural services show a significant delivery as the farm has public footpaths across it up to Pendle Hill, which are well used, this increases recreation and tourism, health and well-being, and opportunities for cultural experiences. The upland agricultural landscape is also aesthetically valuable for people. Traditional farm buildings and stone walls play an important role in this valued service and also contribute to cultural value. The educational significance of the farm landscape is also important and supports the transfer of knowledge on farm management practices. Some of these services would have received a lower score if the Countryside Stewardship options were not in place (see Figure 4.3 in the main report). For example, the area of grassland under legume and herb rich sward has increased the provision of the pollination service and is likely to increase biodiversity. Biodiversity is also increased by the management of rough grazing for birds. There are also areas under very low inputs and lenient grazing which has increased the provision of water quality and flow regulation services.

The baseline ecosystem service provision of Pen Farm was also mapped. Below we outline the maps that do not feature in the main report.

Carbon storage

Areas of high carbon storage (Figure 2.2.1, in red) coincide with the woodland areas of Pen Farm. The improved grassland vegetation and soil do store some carbon, and storage increases in the area of semi-improved rough grazing at the higher elevations of the farm. The blue areas indicate the sealed surfaces of buildings and roads. Areas of low to medium provision may offer opportunities to increase carbon storage through the planting of trees and hedges, but also through improved soil management and avoiding compaction.

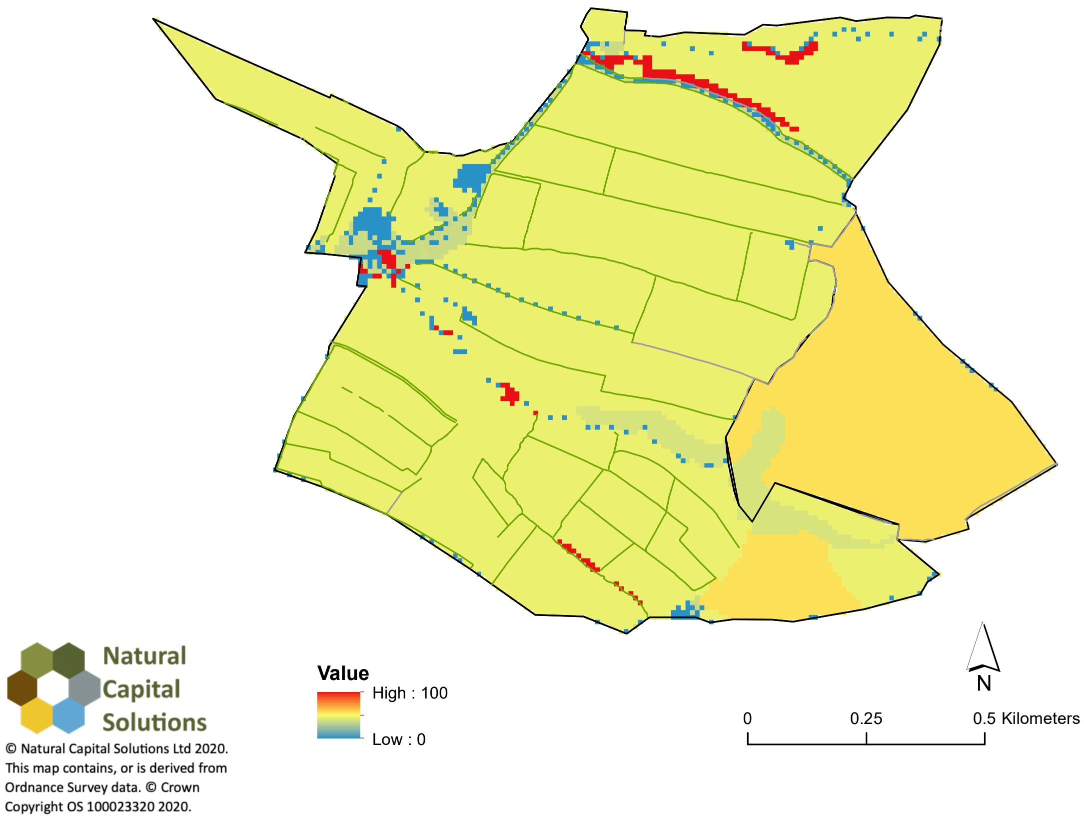

Figure 2.2.1 The capacity of the natural capital assets of Pen Farm to store carbon.

Noise regulation

The map (Figure 2.2.2) demonstrates that the wooded areas of Pen Farm have the highest capacity to deliver noise regulation services. The grasslands of the farm have a medium capacity (yellow) to deliver the service, with sealed surfaces and buildings offering no provision of this service (blue). In areas of low to medium provision, structural vegetation such as trees could be used to increase the provision of this service.

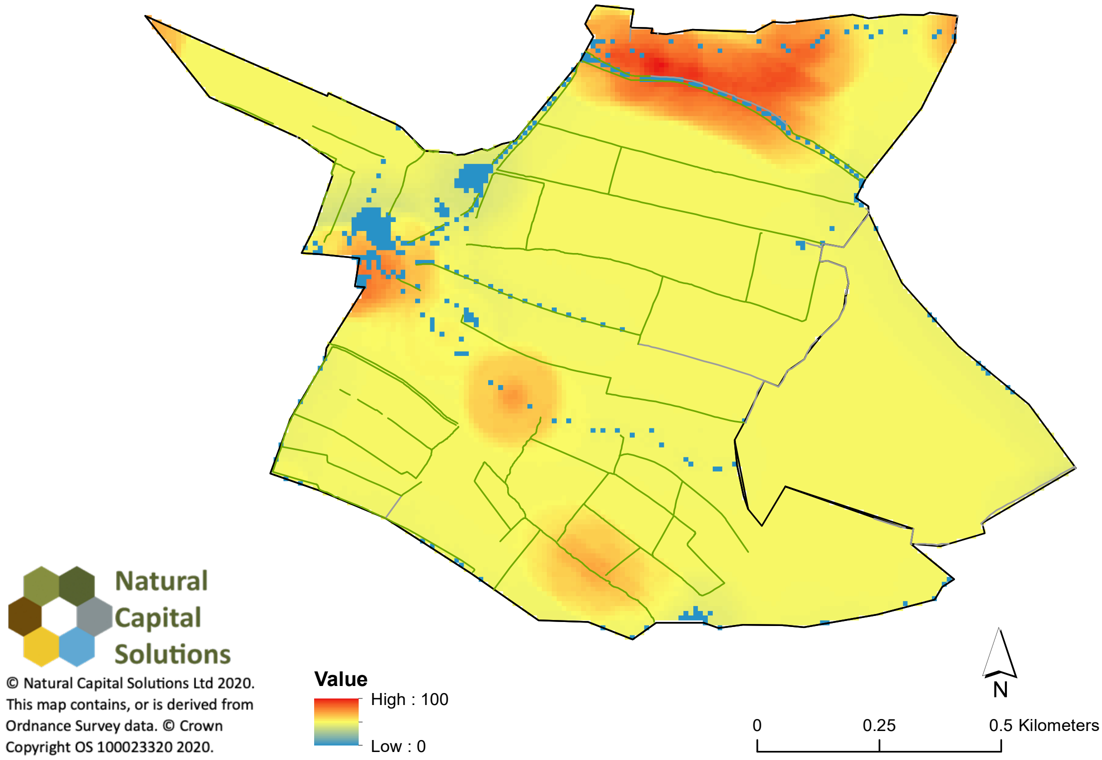

Figure 2.2.2 The capacity of the natural capital assets of Pen Farm to regulate noise.

Air pollution regulation

Again, the woody areas of Pen Farm have the highest provision score (Figure 2.2.3, in red), as the large surface area of tree canopy allows the uptake of pollutants. The grassland habitats also play a role, but to a much lesser extent. The provision of this service does depend on there being air pollution. In rural areas such as this it is likely not to be a significant problem. The areas of the farm that offer a low to medium provision of this service provide opportunities for planting woodland and hedges that can increase the provision of this service.

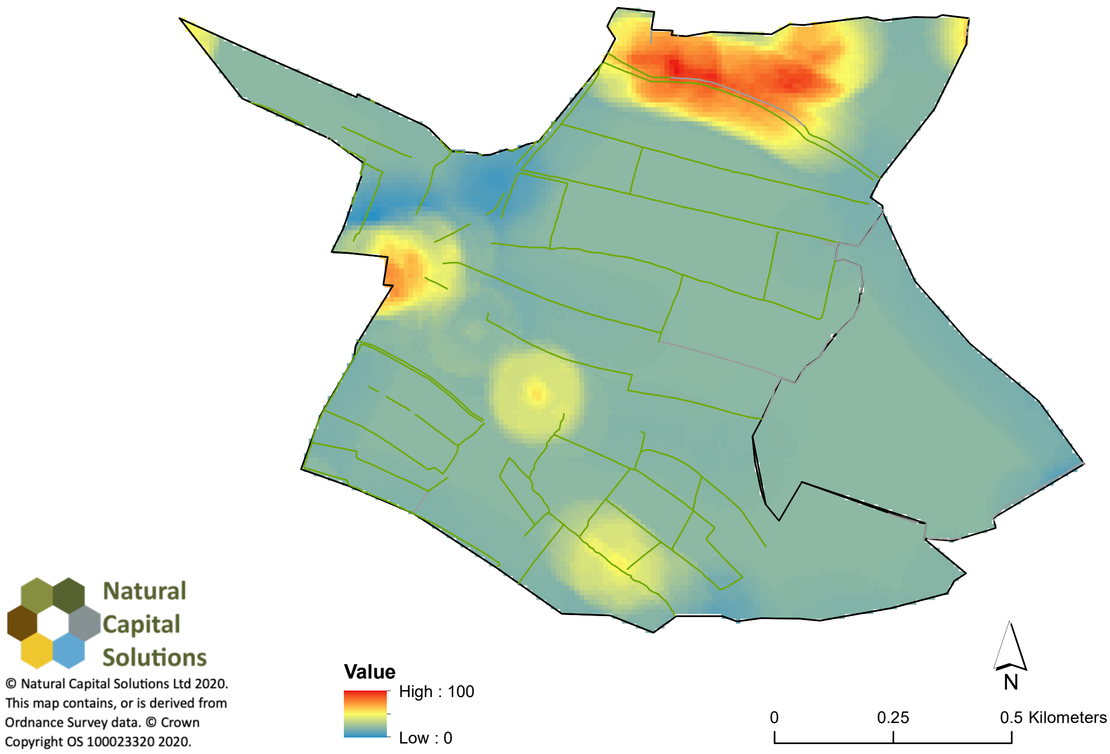

Figure 2.2.3 The capacity of the natural capital assets of Pen Farm to regulate air quality regulation.

Agricultural production

Agricultural production models the capacity of the land to produce food under current farming practices. The capacity for agricultural production at Pen Farm (Figure 2.2.4) is low (grey/blue) in the SDA of the farm on the higher slopes, it is medium (yellow) in the DA of the farm, and high (red) on the section of the farm out of the LFA designation with higher grade more productive agricultural land. The model is based on agricultural land class, and so reflects that much of the land on the farm is of low quality for arable food production.

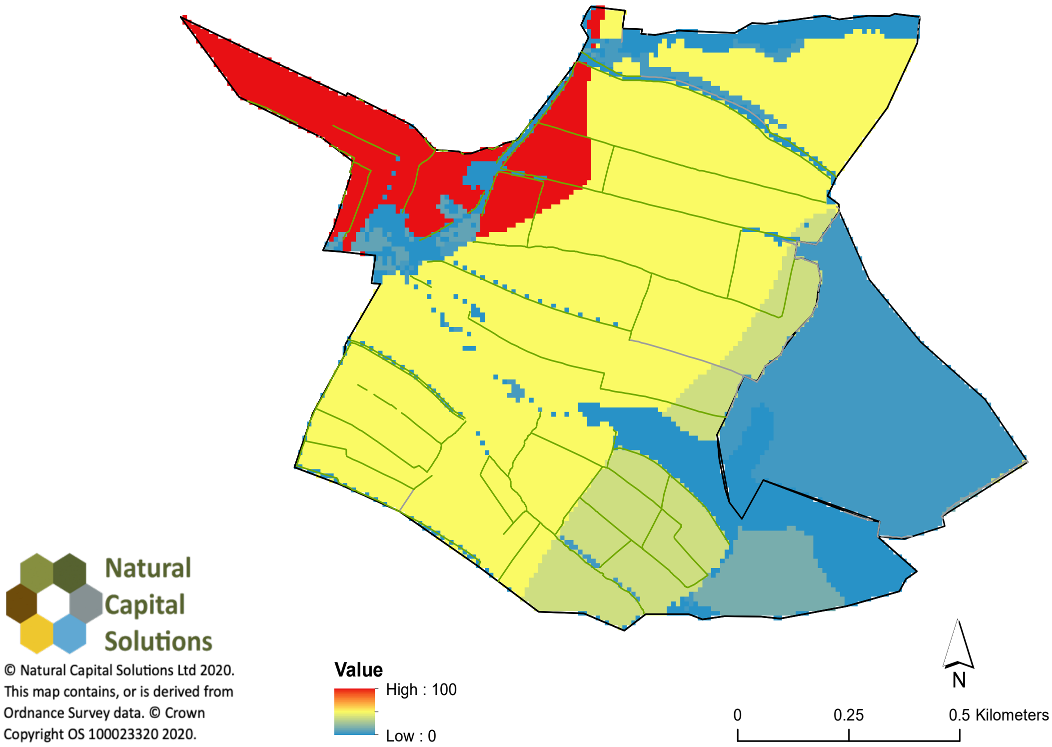

Figure 2.2.4 The capacity of the natural capital assets of Pen Farm to provide agricultural production.

Water flow regulation

The areas of Pen Farm with the highest capacity to soak up run-off are shown in red (Figure 2.2.5). These areas occur where there is more structure to the vegetation (e.g. in the semi-improved rough grassland), but also in flatter areas with soil that can allow the percolation of water. The improved grasslands provide less vegetation structure and also occur on the high elevations, so show medium to low provision of this service. The blue areas of no provision are sealed surfaces and water. Area of low to medium provision of this service offer opportunities for interventions that will slow the flow of water through the farm. More complex vegetation than short grass, such as hedges and woodland, on slopes and offline or online ponds will help to slow the flow of water through the farm.

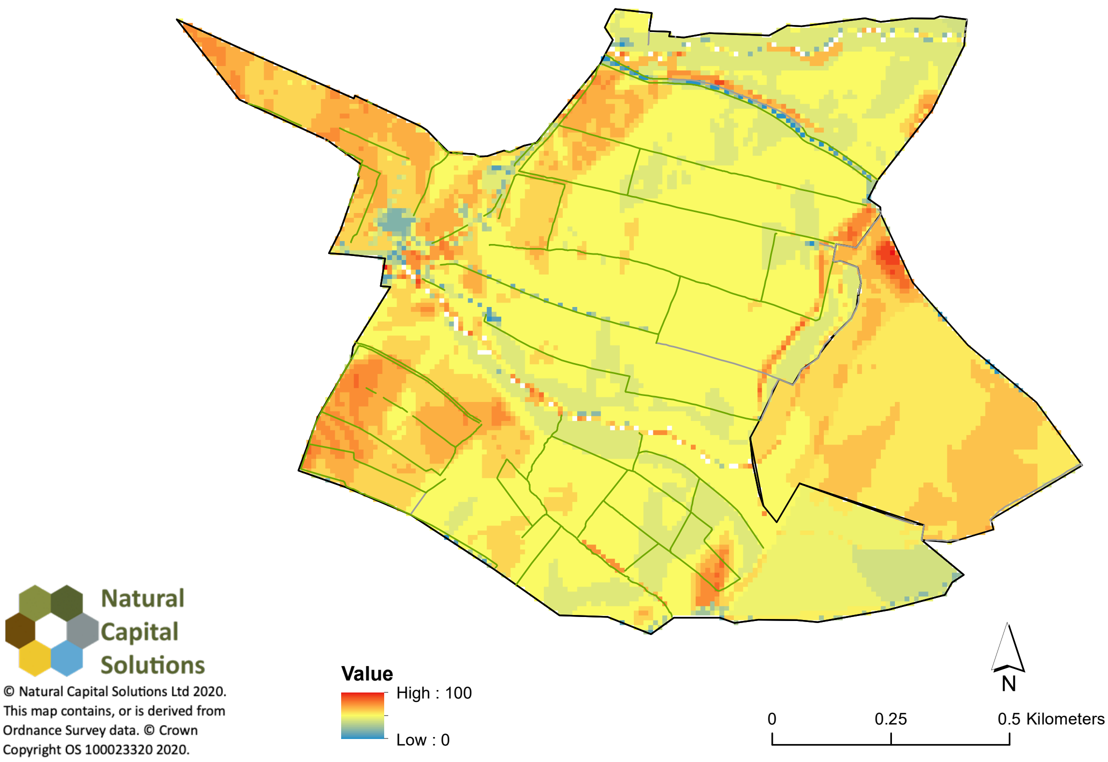

Figure 2.2.5 The capacity of the natural capital assets of Pen Farm to regulate water flow (run-off).

Accessible nature

Pen Farm has an area of high provision (Figure 2.2.7, in red) of the accessible nature service in the east of the farm on the higher rough grassland area. This land is open access (so publicly accessible) and scores more highly in terms of naturalness, therefore providing higher well-being benefits than in habitats that are less natural. The footpath from the village up the hill is considered to be a low provision of this service because it runs through largely improved grassland habitats, which have a low score for naturalness, but the provision increases as the footpath runs up hill into more natural habitat. Restoration of heathland and bog habitats, and an increase in woodland on the farm will increase naturalness on the farm, and, therefore, overall accessible nature scores.

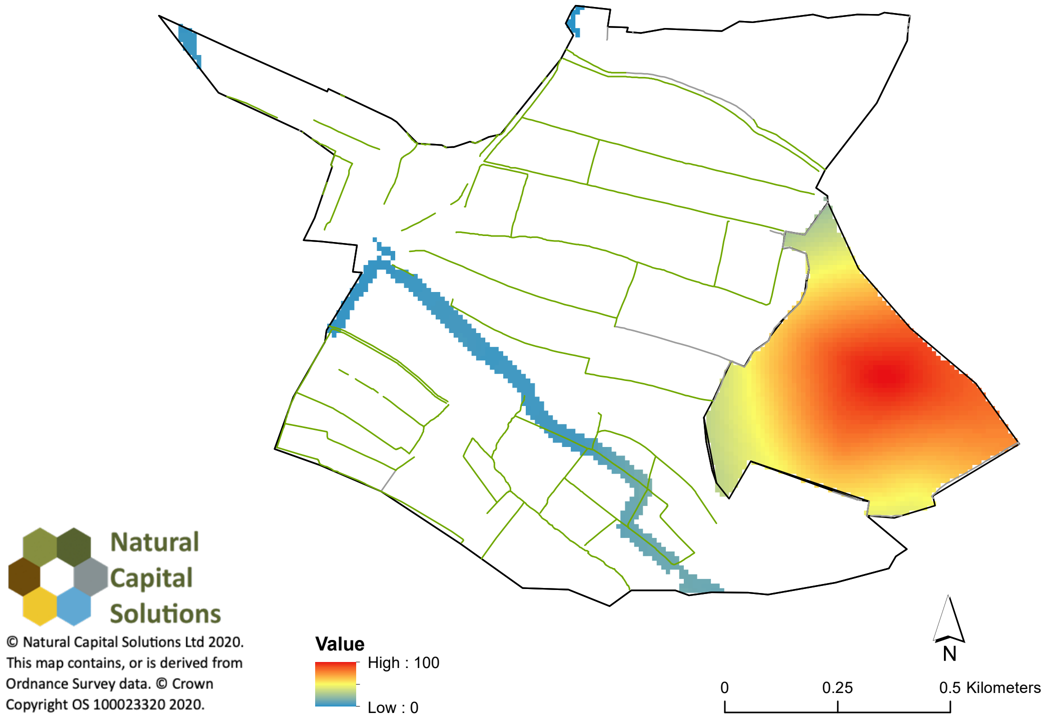

Figure 2.2.7 The capacity of the natural capital assets of Pen Farm to provide access to nature.

2.2.3 Mapping limitations and future tools

As discussed in the main report, these maps are not able to take account of livestock density and the impacts of the application of fertilizers on the farm. This is important as grazing intensity, compaction of soil from livestock and the fate of nitrates and phosphates have significant impacts on the condition of the natural capital assets, and their ability to supply ecosystem services. An accurate baseline of Pen Farm is, therefore, not possible to quantify. However, this baseline is good enough to illustrate the main trends in ecosystem service provision from agricultural land covers and identify areas that are potential opportunities for on-farm interventions to enhance benefits such as increased water quality, reduce flood risk and enhance carbon sequestration.

This mapping approach can also be very powerful when extended to explore the impact of interventions, such as natural flood management on reducing flood risk. The difference in the level of provision before and after these interventions can be compared. This is particularly important in the context of ELMs, as payments are likely to be for results (at least in Components 2 and 3). However, we were not able to do this here as it was beyond the resources of the project.

In the future this approach could be the basis of a tool that works both at the farm and the landscape scales, that quantifies the provision of ecosystem services on the basis of habitat information (including hedgerows and buffer strips), as well as data on livestock densities and chemical inputs. Hydrological-based models would also be essential for understanding the placement of interventions in order to maximise the water quality and flood risk benefits, without unintended consequences. A tool of this nature is required for delivering Farm Plans, to understand baselines, opportunities for enhancing services, and to ensure that interventions will deliver intended results.

2.2.4 Valuation of ecosystem service benefits – sensitivity analysis

The results of the ecosystem service valuation for the baseline and ELMs scenario are outlined in Sections 4.2.2 and 6.1 of the main report. Here we present a sensitivity analysis of the monetary values, to demonstrate the range of uncertainty in these estimates. The low and high estimates of Present Value around the central value presented in the main report (Table 4.5) are outlined in Table 2.2.2 below for the baseline and ELMs scenario.

Table 2.2.2 Sensitivity analysis showing low, central and high estimates of Pen Farm benefits under the baseline and ELMs scenario.

Ecosystem service benefits	Baseline PV £2020 (50 years)			ELMs PV £2020 (50 years)		
	Low	Central	High	Low	Central	High
Carbon sequestration trees and hedges	19,134	41,045	62,955	148,687	318,943	489,199
Carbon sequestration grass	48,275	103,553	158,831	315,630	677,047	1,034,201
Air quality regulation	17,767	84,620	251,454	195,441	889,790	2,765,994
Timber production	2,029	2,705	3,381	19,275	25,700	32,125
Agriculture production	-231,162	-288,953	-346,744	-840,755	-1,050,944	-1,261,133
GHG emissions (agriculture)	-444,129	-3,539	-1,454,160	-315,981	-677,803	-1,034,580
GHG emissions (deep peat)	-236,986	-508,351	-775,935	-105,327	-225,934	-344,860

Annex 3: Pen Farm: Farming System and Business Aspects

This Annex considers the farm business aspects of the Pen Farm Case. It describes the farming system and financial performance for the baseline situation, including existing take up of agri-environment options. It then, drawing on the results of the natural capital assessment, considers the financial implications for the farm business of taking up ELMs type interventions. It considers the extent to which income from new ELMs option can plug the income gap due to the withdrawal of BPS.

3.1 Land use and farming system

Pen Farm, located alongside Pendle Hill, near Clitheroe, Lancashire, is a beef and sheep farm. It has been held under an agricultural tenancy for 2 generations. The total area of the farm is 146 ha (360 acres) of which 139 ha is useable for agriculture (denoted as 139 'ha ua') (Table 3.1.1). There are about 100 ha of improved grassland mainly within the Disadvantaged Area (DA) designation, about 10 ha of which is managed under agri-environment agreements. The remainder, lying within the Severely Disadvantaged Area (SDA) designation, involves a range of less agriculturally productive land at higher elevations. Allowing for the latter gives a total adjusted agricultural area of about 111 ha (denoted 111 'ha adj')[65]. There is an additional shared area of about 30 ha common hill land that supports seasonal grazing.

Table 3.1.1 Areas of land type and cover and adjusted agricultural area for Pen Farm.

Land type and cover	Agric Area ha	Agric Adj factor	Agric Adj ha
PP Improved	89.6	1.00	89.6
PP Improved zero N	2.7	1.00	2.7
PP Species rich grass	7.5	1.00	7.5
Grassland: rushy	4.4	0.25	1.1
Semi -improved grassland	11.5	0.50	5.7
Semi natural rough grazing (bracken)	4.1	0.25	1.0
Semi natural rough grazing (moorland)	19.1	0.15	2.9
Adjusted ha	**138.9**	**0.80**	**110.5**
Moorland common	30.0	0.10	3.0
Adjusted ha incl common			**113.5**

The farm type is classed as LFA Beef and Sheep (Table 3.1.2). The sheep enterprise comprises 500 lowland/upland of mainly lowland/upland cross bred ewes and a cohort of pure hill ewes (85%:15% ratio) lambing in spring, producing about 1.4 lambs per ewe overall. Lambs are mostly sold off grass in the autumn, with about a quarter carried over as 'gimmers' to produce ewes for breeding in the following

[65] The terms ua and adj are used in the case study to denote useable agricultural areas and adjusted areas respectively. The former indicates actual land area committed for agricultural use. The latter adjusts the estimate of useable agricultural area to reflect the equivalent livestock carrying capacity of land, expressed relative to that of improved pasture, in accordance with the methods used in the Farm Business Survey.

year. A small herd of beef suckler cows produce calves in spring that are carried over the following winter to be finished on grass in summer.

Table 3.1.2 Estimated Stocking Rates for Pen Farm**.**

		Baseline		
Stock type	LU/hd	nr	LU	% of LU
Ewe and lamb	0.12	500	57.7	60%
Breeding ewe lambs	0.06	185	11.1	11%
Rams	0.08	10	0.8	1%
Beef cows incl calf	0.9	17	15.3	16%
Beef cattle sold as stores	0.5	22	11.0	11%
Bull	0.65	1	0.65	1%
Total LU			96.6	100%
Land Areas			ha	
Total utilised agricultural area ha (excl common)			138.9	
Adjusted agric area ha (excl common m'land)			110.5	
Common Moorland			30.0	
Adjusted common moorland			3.0	
Adjusted farm area incl moorland ha			113.5	
Adjusted farm LU/ha (113.5 ha)			0.85	

LU = Grazing Livestock Units

Sheep and beef are mainly grass fed, with supplementary bought concentrate feed and some bulk feed for the cattle. On agriculturally improved pastures, about 75-80kgN/ha of chemical fertilizer is applied where grass is cut for silage, and about 50-60 kg N/ha where grazed only. Otherwise, fertilizer use follows stewardship prescriptions, whether zero or reduced applications of chemical and/or organic fertilizer

There is the equivalent of 97 Livestock Units (LU) on Pen Farm of which about 72% are sheep and 28% are beef. The overall average stocking rate is about 0.85 LU/ha (Table 3.1), similar to an average of 0.86 LU/ha for LFA Beefs and Sheep farms in England.

The Total Full Time Equivalent (FTE) employment is 1.6, provided by family labour (farmer, spouse and son), with occasional casual labour. Some agricultural contracting services are provided to neighbouring farms.

3.2 Farm business revenues and costs

The farm generates an estimated annual Gross Output of about £70,000 from beef and sheep production and a Gross Margin, after deducting variable costs, of about £30,000 (£269/adjusted ha) (Table 3.2.1). Fixed costs including rents and a charge for unpaid family labour attributable to agricultural activities total about £71,300 (£645/ha adj), made of up of 46% labour charged at agricultural wage rates (£300/ha), 24% machinery and contractors (£155/ha), 13% general (£85/ha) and 16% rents and interest (£105/ha, see also Table 3.15 below). These revenue and cost estimates are consistent with the estimates for the 'average' LFA Beef and Sheep Farm in England (Harvey and Scott, 2020)[66].

Table 3.2.1 Estimated Annual Gross Output and Gross Margin from Agricultural production on Pen Farm for 2020.

	Head	Gross Output		Variable Costs		Gross Margin	
	nr	£/head	Total £	£/head	Total £	£/head	Total £
Ewe and lamb	500	85	42500	48	24000	37	18500
Breeding ewe lambs	185	55	10175	28	5180	27	4995
Beef cows incl calf	17	291	4947	265	4505	26	442
Beef store cattle	22	544	11968	280	6160	264	5808
Total			69590		39845		29745
£/Ha (adjusted)			630		361		269

Table 3.2.2 contains key business indicators for Pen Farm. The main sources of Farm Business Income are shown, namely: Agriculture, Agri-environment Schemes (AES), Diversification and the Basic Payment Scheme (BPS)[67]. Total Farm Business Income is about £21,000/year (£190/ha adj), with agricultural making a negative return at about minus £9,500 (minus £86/ha adj). Charging for unpaid labour at £32,000/year (for 1.6 FTE) (£290/ha adj) makes Farm Corporate Income about minus £11,000/year (minus £100/ha adj), Net Farm Income, showing income to the family household, is about £22,900/year (£207/ha adj). After charges for unpaid labour, the return to the farm's managerial effort and capital invested in the business (Management and Investment Income) is about minus £5,950/year (about minus £54/ha adj).

In summary, the agricultural activities on the farm fail to breakeven before charges for unpaid family labour but would result in losses of about £370/ha if such charges are made. Net contributions (after estimated costs) from other farm-based sources, notably AES and BPS, are not sufficient to cover the estimated cost of unpaid family labour at 1.6 FTE.

[66] Harvey, D. and Scott C. 2020. Hill Farming in England, 2018/19. Farm Business Survey. Rural Business Research (RBR). Newcastle University, Newcastle. (and previous years)

[67] This classification follows the methods used by the Regional Farm Business Survey. The Survey is a national programme that assesses the performance of farming in the UK on behalf of Government in support of policy. It uses a number of indicators of business performance. **Farm Business Income** is a commonly used indicator to show the annual return to all unpaid labour and capital invested in the farm, including land and buildings. **Farm Corporate Income** takes the former and deducts charges for unpaid family labour. **Farm Investment Income** shows the return to all capital invested in the farm business, after charges for unpaid labour and interest charges. **Net Farm Income** indicates the return to the farm household on their labour and tenant type capital. **Management and Investment Income** shows the return to the farm business's management inputs and capital invested (having deducted charges for unpaid family labour).

Table 3.2.2 Summary of Key Farm Business Indicators: Pen Farm.

	Agriculture		AES		Diversification		BPS		Total	
	£/farm	£/ha	£/farm	£/ha	£/farm	£/ha	£/farm	£/ha	£/farm	£/ha
Total Ouput	69590	630	7500	68	3315	30	27421	248	107826	976
Variable Cost	39845	361	31	0	167	1	0	0	40044	362
Total Gross Margin	29745	269	7468	68	3148	29	27421	248	67783	613
Fixed Costs	39233	355	1543	14	3050	19	27421	36	71248	645
Total costs	79078	716	1575	15	2089	20	4113	36	86855	786
Farm Business Income	-9488	-86	5925	53	1227	10	23308	212	20972	190
Unpaid Labour	30350	275	366	3	1284	12	0	0	32000	290
Farm Corporate Income	-39838	-360	5559	50	-57	-2	23308	212	-11028	-100
Interest payments	1326	12	65	1	61	1	122	1	1574	14
Farm Investment Income	-38511	-348	5624	51	3	-1	23430	213	-9454	-86
							Inputed rent		0	0
							Ownership charges		3000	27
							Directors remun		500	5
							Unpaid labour		28800	261
							Net farm income		**22846**	207
							M&I Inc		**-5954**	-54

The proportions of Total Gross Output (Revenue) and Farm Business Income [68] attributable to different sources are shown in Table 3.2.3. BPS alone accounts for 25% of Gross Output by value and 111% Farm Business Income, a measure of farm profitability before payments for unpaid family labour are charged. Existing take up of AES options provides 7% of Total Output and 28% of Farm Business Income.

Table 3.2.3 Sources of Income as % of Gross Output and Farm Business Income: Pen Farm.

		Agric	AES	Div'n	BPS	Total
Pen Farm						
% of	Output	65%	7%	3%	25%	100%
% of	Farm Bus Inc	-45%	28%	6%	111%	100%
Average for LFA Grazing Livestock Farms (2015-2018)						
% of	Output	62%	12%	4%	22%	100%
% of	Farm Bus Inc	-50%	47%	11%	92%	100%

3.3 Farm Business Type Performance

Table 3.3.1 shows key financial results for Pen Farm relative to the average for LFA Grazing Farms. The differences between Pen Farm the average for LFA Beef and sheep farms mainly reflect differences in the structure and treatment of fixed costs, noting that Pen Farm is entirely tenanted and almost completely dependent on unpaid family labour. By comparison the ‘average’ LFA beef and sheep farm, which in reality does not exist, is part owned, employs regular labour and is larger in area.

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68 The Farm Business Survey is a national programme that assesses the performance of farming in the UK on behalf of Government in support of policy. It uses a number of indicators of business performance. **Farm Business Income** is a commonly used indicator to show the annual return to all unpaid labour and capital invested in the farm, including land and buildings**.** **Farm Corporate Income** takes the former and deducts charges for unpaid family labour**.** **Farm Investment Income** shows the return to all capital invested in the farm business, after charges for unpaid labour and interest charges. **Net Farm Income** indicates the return to the farm household on their labour and tenant type capital. **Management and Investment Income** shows the return to the farm business’s management inputs and capital invested (having deducted charges for unpaid family labour).

Table 3.3.1 Estimates of Financial Indicators for Pen Farm and the Average Less Favoured Area Grassland Farm in England.

	Pen Farm	LFA Beef and Sheep *
Utilsable agric area (ha)	131	215
Adjusted agric area (ha)	111	146
% of area tenanted	100%	45%
Stocking rate GLU/ha	0.85	0.85
	£/ha	£/ha
Total Ouput	976	1024
Variable Cost	362	407
Total Gross Margin	613	617
Fixed Costs	645	470
Total costs	786	876
Farm Business Income	190	148
Unpaid Labour	290	225
Farm Corporate Income	-100	-77
Interest payments	14	30
Farm Investment Income	-86	-48
Net farm Income	207	69
Management & inv income	-54	-105
* 2018/19 average (Farm Business Survey)		

3.4 Importance of BPS and AES income

The financial viability of farm business is dependent on about £35,000/year of income support, of which AES contributes about £7,500 (£5,900 after costs including labour) and BPS contributes about £27,400 (about £23,300 net after costs).

On this basis, to retain current levels of Farm Business Income and Net Farm Income, Gross Income from Agri-environment agreements would need to increase by almost 4 times to compensate for the loss of annual BPS.

3.5 Environmental activities and future options

A range of environmental options have already been taken up on Pen Farm (Table 3.5.1). These mainly include field and habitat management options, hedgerow management and refurbishment of traditional buildings[69]. Current Countryside Stewardship agreements generate about £7,500/year income.

[69] A map of baseline interventions for Pen farm is given in Figure 4.3 of the Main Report

Table 3.5.1 Baseline AES agreement and revenues for Pen Farm.

Field and habitat management	unit	areas	£/ha	£/year	C ref
Legume rich pastures	ha	7.5	309	2318	GS4
Grassland rushy (wet)	ha	4.3	134	576	GS5, SP6, GS16
Grassland semi improved	ha	5	132	660	UP2, GS17
Grassland enclosed rough grazing (moorland)	ha	19.1	83	1585	UP1, GS17
Semi-natural (bracken)	ha	4.1	83	340	UP1, GS17
PP very low inputs (non SDA)	ha	3	95	285	GS2
Subtotal		43		5764	
Other					
Management of existing trees	ha	1.64	100	164	WD2
Managing hedgerows	m	3729	0.16	597	BE3
Traditional buildings maint	m2	3.25	300	975	HS1
Subtotal				1736	
Grand total				**7500**	
£/ha ua (139)				54	
£/ ha adj (111)				68	

Future environmental options for Pen farm include interventions for woodlands, woodland pasture with the equivalent of 10% plantings of trees by area, field and habitat management, water quality and regulation, improved public access and amenity[70].

The proposed interventions are listed in Table 3.5.2, together with estimates of revenues and costs. Existing CS rates are used provisionally as a guide to payment rates noting that a new regime, yet to be announced, will operate under future ELMs. ELMs conditions and payment rates are yet to be announced and will be subject to the findings of the Test and Trials programme. Early feedback from the programme indicates that the payments rates under CS, based as they are on 'income foregone plus costs' are not regarded to provide a sufficient incentive for ELMs uptake (See Annex 1.3).

The options assumed here are likely to apply under the different ELM Components. There is some uncertainty for example about the promotion of silvopasture as a mainstream land use, both in the lowlands and uplands. It has potential to integrate agricultural and environmental outcomes: it is anticipated that the current CS Wood Pasture creation option (WD6) will continue in some form under ELMs and will include options for upland silvopasture. [71]

Potential revenue of is estimated at about £33,000 (before costs), equivalent to about £240/ha over the 139 ha of ha of existing woodland and usable agricultural land.

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[70] A map of baseline interventions for Pen farm is given in Figure 6.1 of the Main Report

[71] Currently CS WD6 Wood Pasture (creation) can be managed under grazing or cutting (hay/silage) regimes, usually with limits on fertiliser use and stocking rates, and in some cases favouring natural grass swards. There is no standard specification. WD6 has been mainly supported where woodland is a historic or priority habitat. Defra are about to begin a Test and Trial project on agroforestry that includes a farmer focussed upland silvopasture component (pers. Comm: Woodland Trust, October 2020).

Table 3.5.2 ELM-type environmental options and estimated annual receipts for Pen Farm.

Option Types	units	nr	£/ha or m	£/year	CS ref*
Woodlands					
New woodland	ha	8.5	200	1700	WD1
Creation of woodland pasture	ha	33	409	13497	WD6
New woodlands: trees on slopes	ha	1.8	200	360	WD1 var
Woodland improvement	ha	1.64	100	164	WD2
Field Management					
Improved grass converted to species rich	ha	15	309	4635	GS4
Semi natural grassland restoration : bracken/scrub	ha	4.11	83	341	UP1, GS17
Semi natural grassland restoration (rushy/wet grass)	ha	4.43	134	594	GS5, SP6, GS16
PP very low inputs non SDA	ha	1	95	95	GS2
Semi improved grass SDA	ha	8.5	132	1122	UP2, GS17
Moorland habitat (sole use)	ha	19	83	1577	UP1, UP6
Moorland habitat (common)	ha	30	83	2490	UP1, UP6
Hedgerows management	m	3720	0.16	595	BE3
Take field corners out of prod	ha	1	365	365	GS1
Water quality, resources and regulation					
Riparian Buffer strips (excl woodlands)	ha	1.6	440	704	SW11
Ponds and swales (temp water storage)	ha	2	256	512	SW16
Leaky barriers /dams (temp water storage)	nr	2	256	512	SW16
Fencing off streams (water quality/erosion)	m	1083	0.08	87	FG1 (maint)
Livestock infrastructure					
Livestock feeding, drinking, yarding	m2	0	0	0	RP/LV
Cultural				0	
Archeological features grassland	ha	0	30	0	HS5
Improved public access	m	2,200	0.50	1100	new
Maintenance of Trad Buildings	m2	300	3.25	975	HS1
Stone wall maintenance	m	1720	0.50	860	BN12 (maint)
Educational visits	visit	3	290	870	ED1
Total revenue		£/year		33155	
		£/ha ua (139 ha)		239	
		£/ha adj (111 ha)		300	

*CS: Countryside Stewardship reference for types of options

Some options are associated with preparatory or establishment capital works that are fully or partially grant aided (Table 3.5.3). Estimated capital costs for 'major' items, net of grants, are about £167,000, mainly for woodland creation (31%), wood pasture (19%) and stone wall restoration (13%). This gives a total equivalent annual cost of about £20,500/year (amortised over 10 years at 4%) and £148/ha ua/year for the farm's useable agricultural area of 139 ha. After grant aid at assumed rates, the cost to the farmer is about £2,400/year (£17/ha ua, £21/ha adj). Provision is made to charge for these extra capital costs. Adequate funding of additional capital costs and the costs of maintenance of existing assets was identified as a topic for concern in the design of ELMs (Annex 1.3).

There are also other minor capital expenditures mainly associated with habitat creation and restoration field, such as bracken clearance and grass reseeding. These cost an annual equivalent of £1,650, about£12/ha ua, £15/ha adj. These costs are assumed to be covered in the normal operational costs of environmental options (costs are currently about 20% of annual AES revenues), as explained below, and no additional provision is made for these minor capital costs.

Table 3.5.3 Estimated total and equivalent annual costs for capital investments associated with ELM-type options for Pen farm.

Major capital items assumed eligible for grant aid

	CS ref*	Units	nr of units	Estimated cost £/unit	Total capital costs	Total Equiv Annual cost (10 yrs at 4%)	Assumed grant rate	Equiv Annual cost after grant £
Woodlands								
New woodland	TE4	ha	8.5	6000	51000	6273	90%	627
Creation of woodland pasture	TE4 variant	ha	33	975	32175	3958	90%	396
New woodlands: trees on slopes	TE4 variant	ha	1.8	6500	11700	1439	90%	144
Field management		0						
Hedge restoration	BN9	m	1790	5	8950	1101	75%	275
Hedge planting	BN11	nr	980	13	12740	1567	90%	157
Water quality, resources and regulation								
Ponds and swales (capital)	RP11, RP12, RP7	nr	2	4500	9000	1107	90%	111
Leaky barriers /dams (capital)	RP32	nr	4	512	2048	252	90%	25
Fencing off streams (capital)	FG1	m	1083	6.0	6498	799	70%	240
Cultural								0
Improved public access		m	2200	5	11000	1353	90%	135
Stone wall restoration (capital)	BN12	m	860	25	21500	2645	90%	264
£ total					166611	20493		2374
£/ha (139 ha)					1200	148		17
£/adj ha (111 ha)					1507	185		21

Other minor capital expenditure for habitat restoration /establishment assumed covered by annual payments

	Units	nr of units	Estimated cost £/unit	Total capital costs	Total Equiv Annual cost (10 yrs at 4%)	Assumed grant rate	Equiv Annual cost after grant £
Improved grass converted to species rich	ha	15	250	3750	461	0%	461
Semi natural grassland restoration : bracken/scrub	ha	4.11	200	822	101	0%	101
Semi natural grassland restoration (rushy/wet grass)	ha	4.43	200	886	109	0%	109
Semi improved grass SDA	ha	8.5	200	1700	209	0%	209
Moorland habitat (sole use)	ha	19	120	2280	280	0%	280
Moorland habitat (common)	ha	30	120	3600	443	0%	443
Riparian Buffer strips (excl woodlands)	ha	1.6	250	400	49	0%	49
£ total				13438	1653		1653
£/ha (139 ha)				97	12		12
£/adj ha (111 ha)				122	15		15

*CS: Countryside Stewardship reference for types of capital items

3.6 Implications of new environmental options for grassland management and stocking rates

The adoption of ELMs options to generate public goods will require changes in grassland management and the number and possibly type of livestock carried on the land. The latter is largely determined by soils, climate and topography. Stocking rates (Livestock Units/ha) are also influenced by grassland management, notably the application of artificial fertiliser and the choice of grazing and grass cutting regimes. Stocking rates on grassland also depend the use of supplementary feeds as this affects the proportion of an animal's diet that is provided by grass.

Drawing on research evidence [72,73,74.75], a simple grassland model was used to estimate dry matter (tDM/ha) and energy production (Mj/ha) from grassland according to nitrogen use, grazing /cutting, and grass growth class, assuming upland grassland and livestock management regimes. This was used, supported by field observation and discussions with farmers in the study area, to estimate the carrying capacity and hence financial performance of grassland under different managements options

Figure 3.6.1 shows estimated stocking rates (LU/ha) and associated Gross Margins (£/ha revenue less livestock and grassland variable costs) for the range of grassland practices observed in the Pendle Hill area. The estimates have been used, for example, to assess the effects on farm level livestock numbers and gross margins of changes in grassland management associated with the take up of environmental options. For example, a switch from improved pasture with about 75-80 kgN/ha to 0 kgN/ha, or to a semi-improved condition of herb rich pasture is associated with a halving of stocking rates and gross margins, assuming livestock feeding regimes remain unchanged.

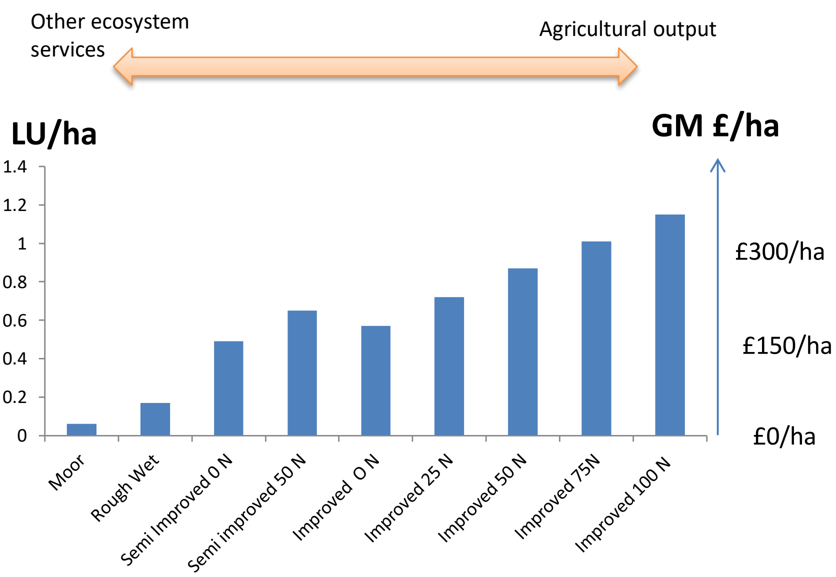

Figure 3.6.1 Estimated livestock stocking rates and gross margins by grassland type and management practices.

[72] Qia, A., Murray, P.J. and Richter, G.M. 2017. Modelling productivity and resource use efficiency for grassland ecosystems in the UK. European Journal of Agronomy 89 (2017) 148–158

[73] Jackson, M. and Williams, T. 1979. Response of grass swards to fertilizer under cutting or grazing. J Agricultural Science, 92 (03), S49-S62

[74] Qi, A., Holland, R.A., Taylor, G,, and Richter, G.M. 2018. Grassland futures in Great Britain – Productivity assessment and scenarios for land use change opportunities. Science of the Total Environment 634 (2018) 1108–1118

[75] Ruelle, E., Hennessy, D. and Delaby, L. 2018. Development of the Moorepark St Gilles grass growth model (MoSt GG model): A predictive model for grass growth for pasture based systems. European Journal of Agronomy 99 (2018) 80–91

There may be scope to improve the profitability of upland livestock farming by increasing the proportion of the total livestock diet provided by grass and simultaneously reducing inputs of relatively expensive fertiliser and bought feeds and other inputs (See Annex 1.5). Such changes could be taken up for the baseline situation. The incentive to seek efficiency gains by changing to mainly grass based diets with reduced fertiliser use is likely to increase after the withdrawal of BPS, although much depends on the relative cost of purchased feeds.

3.7 Estimated impact on Farm Business Income

At full development, new environmental options generate an estimated £23,900 annual revenue after deductions for estimated annual costs compared with existing AES agreements at £5,900, an increase of £18,000/year, helping to offset the net loss of £23,300 from BPS. (Table 3.7.1). Thus, after allowing for changes in costs, there remains a shortfall of about £5,400 in net income assuming take-up of new environmental options (valued at current CS rates), before adjustments for impacts on income from agricultural activities. Annual costs for existing AES options are assumed to be 21% of revenue for Upland beef and Sheep farms, based on Harvey and Scott (2020)[76]. This cost estimate increases to 28% of revenue under the new environmental options in order to cover charges for additional capital costs referred to above (including additional labour costs).

Table 3.7.1 Estimated changes in Net income from new environmental options to offset BPS loss on Pen Farm.

		£/farm/year			£/ha adjusted*			£/ha ua*
		Revenue	**Costs**	**Net**	**Revenue**	**Costs**	**Net**	**Net**
Total new AES options	a	33155	9283	23871	300	84	216	172
Current annual receipt AES	b	7500	1575	5925	68	14	54	43
AES Change	a-b	25655	7708	17946	232	70	162	129
BPS	c	27421	4113	23308	248	37	211	168
new AES - BPS	a-c	5734	5170	563	52	47	5	4
Extra AES - BPS	(a-b)-c	**-1766**	3595	**-5362**	-16	33	-49	-39

* adj adjusted 111 ha, ua usable agricultural 139 ha, excluding shared moorland

Total costs of existing AES as % of revenue	21%
Total costs of new AES options as % of revenue (incl extra capital costs)	28%
Total cost for BPS as % BPS revenue	15%

The new environmental options on Pen Farm impact on agricultural activities and outcomes, especially with respect to land-take and reduced stocking rates. The estimated net reduction in livestock at the farm scale is 21.5 LU (Table 3.7.2), about 22% of the existing total. Assuming this applies across the range of livestock activities, this results in a reduction in Gross Output of £15,500 (£141/ha ua, £112/ha adj) and in Gross Margin (inclusive of grass and forage costs) of £6,600 (£48/ha ua, £60/ha adj) (Table 15). Most of the reduction in agricultural output is attributable to reduced stocking on land converted from improved grassland to wood pasture with reduced inputs (about 25kg N/ha) [77] and to sole woodland. (If no

[76] Upland Livestock Farming in England, 2018/19, FBS, Newcastle University. 2020 ref to come

[77] It is assumed that woodland land taken for plantings will be 10% of pre -grassland area, and that stocking rates per ha of woodland pasture will be 10 % lower than for sole grassland assuming grassland management practices otherwise remain unchanged. Evidence from Upland Agroforestry demonstration projects show pre-agroforestry

chemical N fertiliser is applied on wood pasture, total farm stocking would fall by an estimated 25.7 LU, equivalent to a 27% reduction overall, and a loss of Gross Margin of about £7,930/year, £72/ha adj).

stocking rates can be maintained with approximately 10% tree cover in poplar plantations. It is assumed that inputs on improved grassland are reduced from about 75kgN/ha to 25KgN/ha under wood pasture, from 1.10 LU/ha to 0.72 LU/ha. Wood pasture stocking rates are thus assumed at 0.65 LU/ha (0.72 x 0.9). Revenues from wood fuel and biomass are considered separately.

Table 3.7.2 Impact of environmental options on agricultural production, gross output and gross margin net income for Pen Farm.

	Existing ha	New ha	Extra ha	Stocking LU/ha before Lu/ha	after LU/ha	Reduced LU/farm	Reductions in Gross output £	Goss margin £
Wood pasture on improved grass	0.00	31.00	31.00	1.01	0.65	11.34	8173	3493
Wood pasture on semi improved gras	0.00	2.00	2.00	0.65	0.59	0.13	94	40
Woodland	1.64	10.14	8.50	0.57	0.00	4.84	3486	1490
woodland plant/ slopes	0.00	1.84	1.84	0.65	0.00	1.20	868	371
Hedgerows on improved grass	0.00	0.20	0.20	1.01	0	0.20	146	62
Moorland habitat (sole use)	19.10	19.20	0.10	0.08	0.08	0.00	0	0
Buffer strips	0.00	1.60	1.60	1.01	0.57	0.71	513	219
Water structures	0.00	4.00	4.00	0.65	0.65	0.00	0	0
Improved grass converted to species	7.50	15.00	7.50	1.01	0.57	3.34	2404	1028
Semi natural grassland rest'n bracken	4.11	4.11	0.00	0.17	0.19	-0.10	-73	-31
Semi natural grassland rest'n rushy	4.43	4.43	0.00	0.17	0.19	-0.11	-79	-34
Take field corners out of prod	0.00	1.00	1.00	0.51	0.10	0.41	292	125
Totals		94.52	56.74			**21.5**	**15531**	**6639**
Average per ha ua (139)						0.16	112	48
Average per ha adj (111)						**0.19**	**141**	**60**

The reduction in agricultural activities and output associated with the adoption of some environmental options will enable reductions the cost of inputs. Pro rata reductions can be achieved in the use of inputs directly linked to livestock output and the so called 'variable costs' of feed and forage costs. These 'savings' are accounted for in the reduced Total Gross Margin for the farm as a whole. There is also scope to achieve reductions in agricultural inputs that are conventionally classified as 'fixed' costs but are known to vary with output. These include the costs labour and machinery (that together account for over 70% of total fixed costs on Pen Farm). Pro rata, a 22% reduction in fixed costs would be equivalent to about £15,900 (£71,000 x 22%) (Table 3.7.3). A 'safe' assumption is that savings of about 11% (that is at half of the 22% rate of reduction livestock numbers and gross margin) can be achieved in selected fixed costs that tend to vary with output, namely labour, machinery operating costs, contractors, and water and electricity[78] (Table 3.7.3). On this basis, total savings in fixed costs are about £5,300/year, equivalent to about 7% of current total fixed costs. It is noted that 67% of this saving is associated with reduction in 'unpaid' family labour on agricultural activities, valued at an equivalent cost of employment. (It is also noted that increased labour inputs are required for the new environmental options). Further savings in fixed costs may be possible, for example in machinery depreciation, general expenses and possibly rents.

It is possible that further 'savings' can be achieved by reducing and/or adjusting livestock and management systems on Pen Farm. There may be scope, for example to reduce inputs of purchased concentrate feed, carrying reduced stock numbers on grass-based diets only. Changes in grassland management and livestock husbandry practices, such as controlled grazing regimes, breed selection, livestock breeding finishing schedules, and veterinary practices could improve the financial performance of agricultural activities[79]. Although many of these changes are feasible under current conditions, the withdrawal of BPs and the incentives provided by ELMs will, however, provide a stimulus for their adoption.[80]

[78] There is probably scope for larger reductions in fixed costs. Average fixed costs (£/ha adj) were about 18% lower and Gross Margins 20% higher in the high performing LFA farms compared with medium performing LFA farms in 2018/19 (Harvey and Scott, 2020), although the former were larger (195 ha adj cf 106 ha adj), suggesting economies of scale.

[79] Clark, C. Scanlon, B. and Hart, K. 2019. Less is More: Improving profitability and the natural environment in hill and other marginal farming systems. Report to RSPB, WLT and NT. November 2019

[80] The review reported in Annex 1 shows that for the 'average' LFA farm agriculture makes a negative contribution to Total Farm Business Income suggesting that a reduction in agricultural output would, of itself, not necessarily lead to a reduction in Total Farm Business Income, providing that costs can be simultaneously reduced.

Table 3.7.3 Estimated reductions in fixed costs associated with reduced agricultural production under new environmental options on Pen Farm.

Reduction in Farm Total Gross Margin a	Fixed cost reduction factor b	% Reduction in fixed costs c =a x b
22%	50%	11%

Fixed cost categories	Total fixed costs £/year	Alternative savings assumptions at 11% reduction £/year: All fixed costs	Excluding rent and interest	Labour, Machinery running, W&E,	Excluding unpaid labour and General
Regular labour paid	0				
Regular labour unpaid	32000	3571	3571	3571	
Casual labour	1105	123	123	123	123
Total Labour	33105	3694	3694	3694	123
machinery Depreciation	7736	863	863		
Machinery Running	6631	740	740	740	740
Contract	2763	308	308	308	308
Total Machinery	17130	1912	1912	1048	1048
Farm maintenance	2210	247	247		
Water and Electricity	4973	555	555	555	555
General	2210	247	247		
Total Other	9394	1048	1048	555	555
Rent (adj area)	11052	1233			
Interest	553	62			
Rent & Interest	11604	1295			
Total Fixed costs	**71233**	**7949**	6654	**5297**	**1727**

* used as the best estimate

For the assumptions made, the combined effect of changes in AES, BPS and in agricultural production, gives an estimated change in net income of about minus £6,700/year, equivalent to £48/ha ua and £61/ha adj annually. (Table 3.7.4). Thus, the introduction of the package of new AES ELM-type options does not fully fill the met income gap left by BPS withdrawal. [81]

As noted earlier, the revenue estimates for new environmental options are based on the legacy rates of the existing CS agreements. These mainly use the principle of

[81] If, as referred to above, Zero kg N is applied on grass within woodpasture,, the total change in net income in Table 3.7.4 would be minus £6,970, that is minus £63/ha adj. This is a relatively small (4%) increase in 'loss' for a further 19% reduction in stock numbers at the farm scale, for the assumptions made. It is possible that ELMs payments for woodpasture may vary according to stocking rates.

'compensation' for income loss plus costs set in the context of broader farm income support, namely BPS. In future, in the absence of BPS, it is likely that payment rates will be more closely attuned not only to the costs but also the benefits of delivering the intended environmental outcomes in the farmed landscape. (Note, a distinction has not been made here between options that might apply at different ELMs Tier levels).

Table 3.7.4 Changes in AES, Income Support and Agricultural Net Income under new with environmental options for Pen Farm.

Change in AES and BPS support		£/year	£/ha (adj)*	£/ha (ua)**
Extra net income from AES	a	17946	162	129
Loss of net revenue from BPS	b	23308	211	168
Subtotal	a-b =c	-5362	-49	-39
Change in Agricultural Net Income				
Change in Agricultural Gross Margin	d	-6639	-60	-48
Savings in Fixed costs ***	e	5297	48	38
Subtotal	d-e=f	-1341	-12	-10
Total Change in Net Income	c+f	-6703	-61	-48

* adj adjusted 111 ha, ** ua usable agricultural 139 ha, excluding shared moorland
*** includes savings in unpaid family labour valued at employment cost
*** savings as % of total fixed costs = 7%
Av Stocking rate LU/ha (adj) 0.66 original 0.85 reduction 22%

Table 3.7.5 summarises the overall financial impact of the above changes on key financial indicators for Pen Farm. For the assumptions made, Farm Business Income (before charges for unpaid labour) falls by about £8,500/year (£61/ha ua, £77 /ha adj) to £12,400/year. This is a measure of financial profitability representing the return to all unpaid family labour (1.5 FTE equivalent) and the capital invested in the business. Corporate Income, after charges for unpaid labour, fall by about £6,700 (£48/ha ua, £61/ha adj).

No changes in net revenue from Diversification activities are assumed, other than educational services that are included in agricultural income. There may be scope for farm based recreational services such as seasonal visitor accommodation, catering and bike hire, and letting of commercial workspace.

Table 3.7.5 Estimated changes in financial indicators by income source for Pen Farm with new environmental options.

	Agric	AES	Divers'n	BPS	Total	
	£	£	£	£	£	£/ha (adj)
Total Ouput	-15531	25655	0	-27421	-17298	-157
Variable Cost	-8893	598	0	-4	-8299	-75
Total Gross Margin	-6639	25057	0	-27417	-8999	-81
Fixed Costs (excl unpaid lab)	-1727	5379	0	-4109	-457	-4
Total costs	-10619	5977	0	-4113	-8756	-79
Farm Business Income	-4912	19678	0	-23308	-8542	-77
Unpaid Labour	-3571	1731	0	0	-1839	-17
Farm Corporate Income	-1341	17946	0	-23308	-6703	-61
Interest payments	0	1500	0	0	1500	14
Farm Investment Income	-1341	19446	0	-23308	-5203	-47

minor rounding errors

Table 3.7.6 shows the revised account for Pen Farm after adjustments for the above changes. Net Farm Income, a standard measure used to allow comparisons between farms with different combinations of family/hired labour and land tenure, falls by £6,800 to about £16,000.

Table 3.7.6 Summary of revised financial indicators for the whole Pen Farm business.

	Existing		Change		Revised	
	£/farm	£/ha	£/farm	£/ha	£/farm	£/ha
Total Ouput	107826	976	-17298	-157	90529	819
Variable Cost	40044	362	-8299	-75	31745	287
Total Gross Margin	67783	613	-8999	-81	58784	532
Fixed Costs (excl unpaid lab)	71248	645	-457	-4	70791	641
Total costs	86855	786	-8756	-79	78099	707
Farm Business Income	20972	190	-8542	-77	12429	112
Unpaid Labour	32000	290	-1839	-17	30161	273
Farm Corporate Income	-11028	-100	-6703	-61	-17731	-160
Interest payments	1574	14	1500	14	3074	28
Farm Investment Income	-9454	-86	-5203	-47	-14657	-133
Inputed rent	0	0	0	0	0	0
Ownership charges	3000	27	0	0	3000	27
Directors remuneration	500	5	0	0	500	5
Unpaid labour*	28800	261	0	-15	27144	246
Net farm income	22846	207	-6858	-62	**15988**	145
M&I Inc	-5954	-54	-5203	-47	**-11157**	-101

Minor rounding errors. *excluding National Insurance payments

3.8 Agro-forestry and wood pasture options

Agroforestry options have potential to generate revenues net of costs from the future sale of wood products [82, 83; 84)]. These have not been included in the estimates of changes in net income above, partly due to the longer term and uncertain payoff involved. None the less they are potentially an important additional source of net income

Rotational woodpasture could generate sales of standing timber in approximately 12-year cycles for wood fuel and woodchip products., equivalent to an average annual value of £68/ha, about £2,200/year on 33 ha (Table 3.8.1). (Annual maintenance costs of woodland pasture were included in the annual costs). There is also scope for sales of woodchip from hedgerows[85] cut every year on a 15-year cycle, generating about £400/year[86]. Including these sources would reduce the estimated annual deficit in net income (as defined in Table 17) from £6,700/year to about £4,500/year (Table 19).

Table 3.8.1 Potential net revenue from sales of agroforestry products.

Years	Biomass m3/tree	Fuel wood £/ha	Wood chippings £/ha	Future value (weighted) £/ha	Annual equiv * £/ha
10	0.33	891	297	713	59
12	0.47	1269	423	1015	68
15	0.77	2079	693	1663	83
30	2.67	7209	2403	5767	103

*Assumes real discount rate of 4%
Wood pasture: 10% tree cover: 150 trees/ha, poplar/hazel
Prices (standing): wood fuel: £18/m3, wood chippings £6/m3
Ratio fuel wood to wood chippings : 70%:30%

3.9 Sensitivity and risk analysis

There is considerable uncertainty associated with estimates of the physical and financial variables on which the estimate of changes in net income are based. Upland farms have generally shown greater variation in Farm Business Income over the last 10 years or so than farms generally, mainly due to variations in agricultural performance associated with volatility in livestock yields and prices, and exposure to increased input prices[87]. Table 3.9.1

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82 Graves AR, Burgess PJ, Liagre F, Terreaux JP, Borrel T, Dupraz C, Palma J, Herzog F (2011) Farm-SAFE: the process of developing a plot-and farm-scale model of arable, forestry, and silvoarable economics. Agroforestry Systems 81: 93-108

83 Giannitsopoulos. M.L., Graves, A. R., Burgess, P.J., Duran, J.C., Moreno, G., Herzog, F., Palma, J.H.N., Kay, S., and García de Jal, S. (2020). Whole system valuation of arable, agroforestry and tree-only systems at three case study sites in Europe 2020 Journal of Cleaner Production. 269 (2020) 122283

84 Raskin, B and Osborn, S (eds). 2019. The Agroforestry Handbook: Agroforestry for the UK. 1st Edition. Soil Association Limited, Bristol

85 Smith, J, Westaway, S., Mullender, S., Giannitsopoulos, M. and Graves, A. (in preparation) Making hedgerows pay their way: the economics of harvesting hedges for bioenergy. Special issue of Agroforestry Systems

86 Hedgerows for wood chipping: 0.25m^3/m length, 3,700m on 15 year cycle, 62m^3 /year at £66/m^3 for wood chippings, or bought home fuel biomass replacement at £18/m^3: £400- £1,100/year.

87 Harvey and Scott. 2020, as referred to above

shows the relationship between selected important variables considered separately and the *change in net income* arising from the replacement of BPS with increased ELM-type uptake.

The estimate of the change in Net Income change is particularly sensitive to estimates of Agricultural Gross Output, that is Yields (stocking rates) and or livestock prices, and the revenue and payment rates for the new AES (ELM-type) options. A rise in Agricultural Gross Output by 20% for example would increase the net income gap by 46%. A rise in new AES (ELM-type payment rates) by 20% would reduce the net income gap by 71%, indicating strong sensitivity to this estimate.

Table 3.9.1 also shows the switch in the estimated value of a selected variable required to close the net income gap (make net income = 0). A fall in Agricultural Gross Output of 43%, whether by livestock numbers or prices, would close the gap. A prior fall in the profitability of farming makes new ELM-type options relatively more attractive and reduces the income gap. This would in itself, however, reduce overall farm profitability.

A 28% rise in ELM-type payment rates (currently based on CS rates) would remove the net income gap for the assumptions made. It was noted (in Annex 1.5) that there has been a call to increase future payments rates to reflect benefit (output) rather than cost (input) based pricing.

Changes in variables can be considered together: for example, a simultaneous 20% fall in commodity prices, a 20% increase in savings in agricultural fixed costs and a 20% increase in ELMs payment rates above those assumed here would together result in a 133% rise in net income, moving from a loss of £6,700 to a gain of £2,200/year.

Table 3.9.1 Sensitivity of estimated net income to changes in selected variables for Pen Farm.

	Relationship: between variable and estimated Net Income Gap	Response value : +/-% change in estimated Net Income for +/- 20% change in variable	Switch Value: % change to make estimated Net Income zero *
Agricultural			
Gross Output, stocking rates, output prices	-ve	46	-43
Variable Costs, agric input usage, input prices	+ve	27	+75
Gross Margins (GO-VC)	-ve	20	-100
Savings in Fixed Costs	+ve	16	+125
BPS and AES			
BPS revenue lost	-ve	70	-29
AES (existing) revenues	-ve	18	-115
AES (ELMS type)) revenue, payment rates	+ve	71	+28
AES (ELMS type)) costs	-ve	28	-73

3.10 Closing Remarks

The Pen Farm case illustrates the potential synergies and trade-offs between agriculture and new ELM-type options as upland farmers seek to maintain the financial viability of their businesses in the face of post Brexit policy reform.

Extrapolating from this case to farm LFA farms generally suggest that upland farms face a BPS income gap of between £150/ha and £180/ha after costs. In many cases this will require a three-fold increase in net income from new ELM-type options compared to the current take-up of Countryside Stewardship agri-environment agreements. Substantial and comprehensive take-up of environmental options will be needed alongside reductions in the intensity of agricultural management practices, as we have demonstrated in this generic case.

Photo Appendix: Images from Pendle Hill, February 2020