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Will environmental land management fill the income gap on upland-hill farms in England?

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ABSTRACT

The decision by the UK Government to withdraw from the European Union has prompted a major review of Agricultural and Environmental Policy. Focussing on upland farms in England, we explored the implications of switching from direct income support to 'public money for public goods'. We posed two questions: (i) what public goods can upland farms provide? and (ii) can the rewards for environmental land management options fill the income gap due to loss of income support? Working with three volunteer upland farms, we combined the methods of a map-based natural capital and ecosystem services assessment with those of financial farm business appraisal. From this we produced a synthetic 'Pen Farm' Case to demonstrate the methods, produce indicative results and help support decisions by policy makers and practitioners during policy transition. We conclude that plugging the income gap could require a threefold increase in net income from environmental options. This will, however, require resetting the relationship between agricultural and environmental outcomes, particularly involving changes to livestock and grassland management. Furthermore, as environmental services become a core business function, payments by results must provide sufficient return on effort and assets to maintain the viability of the upland farm business. We also conclude that the integration of natural capital and farm business accounting is critical to support decision making at the farm and landscape scales as the transition to environmental land management is implemented.

1. Introduction

1.1. Context

Heightened global concern about the mounting pressures on natural resources and the continuing degradation and loss of the natural environment (IRP, 2019; IPBES, 2019) has increased the recognition of the importance of a healthy natural environment for human wellbeing and prosperity (UNEP, 2019). It has also highlighted the vulnerability of agricultural production systems to climate change (IPCC, 2019, 2021), raising fundamental questions about the future relationship between farming and the natural environment. While Governments contemplate these challenges, there is also justifiable concern about the welfare of communities whose land-based livelihoods critically depend on the interplay of Government policy and uncertain market conditions (FAO, 2017; Defra, 2020a).

Indeed, these challenges are posing real questions to policy makers and practitioners alike. Furthermore, the legacy of a previous policy and practice often makes change and adaptation to new priorities and circumstance more difficult. Common themes in the call for policy reform are the phasing out of distorting producer support, targeting income support where it is needed, and investing in public goods (Bateman and Balmford, 2018; OECD, 2021,).

In this respect, the decision by the UK Government to withdraw from the European Union, and with it the EU Common Agricultural Policy, has prompted a major review of Agricultural and Environmental Policy (Defra, 2018). The stated purpose is to balance the objectives of food security, sustainable farming and livelihoods, and a healthy natural environment. Although responses vary between the devolved UK administrations, direct income support to farmers under the Basic Payment Scheme (BPS) will be reduced or removed and replaced over time. In the English case, this involves a new Environmental Land Management scheme (ELMs) scheduled for implementation during the period 2022–2028 (Defra, 2020b). Accordingly, it is intended that taxpayer subsidies for inefficient farm production that simultaneously cause environmental damage can be redirected towards value for money

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provision of environmental and other public goods by farmers (Bateman and Balmford, 2018).

In England ELMs is proposed as a key element of the 'Path to Sustainable Farming' (Defra, 2020a). This recognises the need to protect natural capital such as land and soils, air, water and biodiversity that are not only essential for the supply of food but also for a wide range of other ecosystem services such as carbon sequestration, air pollution regulation, flood alleviation, water quality regulation, pollination and recreation. Alongside other initiatives to support farming, ELMs contains three components (Defra, 2020b). The first provides *sustainable farming incentives* to simultaneously deliver efficient farming and environmental outcomes. The second focusses on *local nature recovery* that targets habitat recovery, restoration and management. The third addresses *landscape recovery* through larger scale, often multi-farm nature restoration projects. The programme is currently under review through a programme of Test and Trials (Defra, 2020c) supported by a National Pilot scheme.

Early trialling, points to the need for financial incentives for ELMs take-up that go beyond the 'costs plus income foregone' principle that applies to existing agri-environment schemes, notably Countryside Stewardship (CS) (Defra, 2020d). Trialling participants identified the need for payments to cover initial capital and ongoing maintenance costs, with payments ahead of delivery of long-term outcomes in some cases. Opportunities for supplementing ELMs payments with revenues from parallel markets such as carbon and biodiversity off setting credits have also been called for.

More recently, much of the agriculture-environment policy debate has been framed in terms of natural capital: those elements of nature that produce value for people by generating a range of ecosystem services (UKNEA, 2011; Natural Capital Committee, 2017; Defra, 2020e). Indeed, ELMs has the concept of natural capital at its core, particularly for aligning management interventions with opportunities and needs, and for monitoring and evaluating outcomes (Lusardi et al., 2018). Simultaneously, the approach requires innovative tools to support decision making and policy impact assessment (Defra, 2020b).

The proposed withdrawal of BPS has particular resonance for the upland Less Favoured Area[1] (LFA) grazing livestock sector (NFU, 2014; Wallace and Scott, 2018; Arnott et, al, 2021). Farm Business Survey data (Harvey and Scott, 2019; RBR, 2020) for the period 2013–2018 shows that the average LFA Grazing Livestock farm (170 ha) in England earned about 62% of its annual gross revenue from agricultural activities, 12% from Agri-environment schemes (AES), 4% from non-farming diversification activities, and 22% from the BPS direct income support. If BPS income support and/or existing agri-environment income are stripped away, total Farm Business Income (FBI), a measure of profit before charging for unpaid family labour, is either near zero or negative (Fig. 1). Most English LFA farms 'in their present form' would not be commercially viable without public payments (Harvey and Scott, 2019). A similar situation prevails in Wales (Arnott et, al, 2021).

Policy vulnerability was evident in the findings of a farmer led Upland Nature Partnership study (ADAS, 2019) that concluded that productivity improvements and opportunities to generate income from both on and off-farm diversification were unlikely to be sufficient to make good the gap arising from the loss of direct income support. In response, Clark et al. (2019) argue for a new business model for upland farms based on a switch 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. (2019) showed, however, that this switch would not be sufficient in most cases to achieve agricultural profitability in the absence of income support. It could, however, enable the greater take-up of environmental management options and the achievement of environmental outcomes for which farmers could be rewarded: the change of form implied by Harvey and Scott (2019).

Hence the challenge: many upland farms face a BPS income gap of between £ 150/ha and £ 180/ha (Euro 180 – 220) after costs. A three-fold increase in net income from new ELMs-type options will be required in many cases compared with the current take-up of Countryside Stewardship agreements.

1.2. Aim and objectives

Set in the vicinity of Pendle Hill, an upland area in the northwest of England, we aimed to assess whether the newly proposed ELMs could deliver sustainable agriculture by combining habitat restoration and management with commercially viable farm businesses. Specifically, our objectives were 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 make up for the loss of direct income support under the Basic Payment Scheme?

In addition, we aimed to show how the methods of natural capital assessment can be combined with farm business management techniques to support decision making, especially at the farm scale. Following this introduction, we explain the methods used to address the study objectives, including the development of a generic case study based on a sample of real farm cases. The results of the generic case are presented, followed by a discussion on the implications for policy and practice. The findings are of potential interest to practitioners and policy makers attempting to balance farming and environmental objectives during a period of major policy change.

2. Methods

2.1. The study area

The study was carried out within the Pendle Hill Landscape Partnership (PHLP) area (120 km^2) as part of a series of projects to explore the value of upland landscapes (https://www.pendlehillproject.com). Pendle Hill (**OS grid:** SD804414) is an isolated and steep sided hill rising to 557 m within the Forest of Bowland Area of Outstanding Natural Beauty in east Lancashire, northwest England. It is largely treeless with peat on high elevations. Mean annual rainfall is 1200 mm.

The Pendle Hill area Photo 1 contains about 125 farm businesses designated as 'Less Favoured Area' farms, with land classed either as competitively 'Disadvantaged' or, for higher altitudes, 'Severely Disadvantaged'. These designations are used to set the payment rates for BPS income support. The average farm size is 86 ha, supporting mainly sheep, and sheep and beef cattle farming systems, and a reducing number of dairy farms. The land consists of upland grass moor, rough grazing, and lower lying 'in-bye' grasslands of varying levels of agricultural improvement, managed as an integrated system (Appendix A).

Adopting a natural capital approach is a key principle of the Forest of Bowland Area of Outstanding Natural Beauty (AONB) Management Plan (FOB AONB Unit, 2019). This recognises that natural capital underpins the local society and economy, including benefits to those living and working within the Area. A key aim is to promote the value of the AONB's natural capital and the public benefits it provides. The farmed landscape of Pendle Hill provides a range of benefits alongside food production, including recreational and other cultural opportunities. Current upland-hill farm management practices are, however, often associated with a relatively low provision of regulating services such as carbon, water quality and water flow regulation. We explore how these

[1] LFA - a European Union designation to provide special measures to support farming in areas where production is difficult.

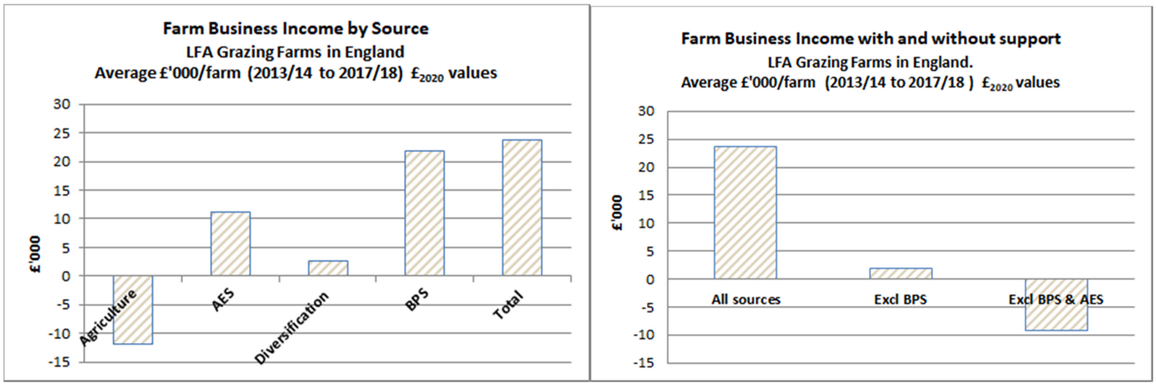

Fig. 1. Annual Farm Business Income for Less Favoured Area Grazing Livestock farms in England by income source and effect of income support (2013/14-2017/18). AES: Agri-environment Scheme receipts.
BPS: Basic Payment Scheme direct income support. Source: based on Rural Business Research data.

benefits can be enhanced in the context of ELMs.

2.2. Case study farms

Three volunteer farms, selected by the PHLP to represent the main types of upland farming systems in the area, were used to explore the challenges and opportunities for the upland sector. The farms were classed as Less Favoured Area Grazing Farms: one mainly sheep, one sheep and beef, and one mainly dairy with sheep. The farms all had lower slopes and valley bottoms of improved grassland for grazing and forage making, mostly classified as Disadvantaged Areas. All had a proportion of their farm categorised as a Severely Disadvantaged Area, mainly occupying higher ground consisting of upland heath, blanket bog and acid grassland used as rough grazing. The farms had access to specified common grazing rights on adjacent moorland 'hill' areas. Two farms were about 150 ha and one over 500 ha, adjusted to allow for land of different productivity. They included tenant and owner occupancy. All farm businesses were heavily reliant on the Basic Payment Scheme (BPS). They also received agri-environment income from management agreements under the Countryside Stewardship (CS) scheme.

A group meeting was held with the participating farmers to explain the purpose of the study, namely, to produce a generic case drawn from real world situations. At least two visits were made to each farm, plus follow-up telephone conversations. The farmers kindly agreed to provide information about their farms to enable the study methods to be applied at the individual farm scale. In return, they were provided with individual farm reports on the results of the analysis. It was agreed that the latter would remain confidential to the farmer concerned.

2.3. Constructing a generic case

Drawing on the methods used, and the data obtained from the three farm cases, the synthetic Pen Farm case was constructed to represent a typical Pendle Hill farm. It is based on an actual location and site conditions within the study area but not on any one existing farm business. Pen Farm was constructed to show the use of the natural capital approach at the farm scale to support the selection and assessment of ELMs type options, addressing the research questions referred to earlier. Thus, the Pen Farm case was a key output of the work: an important part of the research method and the main vehicle for communicating results. A requirement of the work was to draw on information provided in confidence (and subject to non-disclosure) by volunteer farmers to produce a synthetic but realistic, illustrative and non-prescriptive case to create a general awareness of issues, challenges, and possible ways forward in the context of considerable policy change. The Pen Case is, therefore, an example of moving from confidential farm specific cases to a generic case that can support wider engagement (Cochet, 2015).

2.4. Natural capital assessment

A variety of approaches were used to assess the baseline natural capital assets and physical flows of ecosystem services from each of the three case study farms. This enabled the identification of on-farm ELMs-type interventions to create new habitats and enhance the quality of existing ones. (We refer to 'ELMs-type' here because the details of the ELMS offering have not yet been announced). This baseline was also used as a comparator to test whether the ELMs-type interventions could deliver against the main themes of the ELMs and for the grants and payments that were likely to be available. Having tested the approach on the three real farm cases, the method was applied to the generic case of Pen Farm, based on an actual location in the study area.

The study drew on a habitat base map created earlier at the landscape scale for the Forest of Bowland Area of Outstanding Natural Beauty (AONB). This used EcoServGIS (Winn et al., 2018), a toolkit developed by the Wildlife Trusts, with bespoke modifications. Ordnance Survey MasterMap polygons were used as the underlying mapping unit. A series of different data sets were then used to classify each polygon to a detailed habitat type together with a range of additional data for each polygon. Polygons were classified into Phase 1 habitat types and into broad habitat groups, based on a comprehensive Phase 1 ground survey of the Pendle Hill Partnership Area completed in 2016. These data were prioritised in the classification process. Upon initial completion, the base map was checked and manual alterations were made where necessary.

Base maps for each volunteer farm and for the Pen Farm case were clipped from the AONB maps. The farmers viewed the farm base maps and any discrepancies were raised and corrected. An asset register was created for each farm, identifying the type and area of habitat. These base maps were later adapted to illustrate the ELMs-type interventions for Pen Farm.

Qualitative and quantitative approaches were used to assess the on-farm generation of ecosystem services. A qualitative approach identified a wide range of ecosystem services provided by habitats whereas quantitative approaches were applied to selected services for which data and estimation methods were available. For the former the Common International Classification for Ecosystem Services (CICES) (Haines-Young and Potschin, 2017) was used to create a list of ecosystem services provided by the habitats of the farms. The ecosystem services were associated mainly with grassland habitats as the dominant on-farm habitat type, using Bengtsson et al. (2019) as a guide. The generation of each service was qualitatively assessed for the baseline condition and the ELMs-type intervention scenario. One stock item, carbon stored in soils and vegetation, and seven ecosystem services were mapped using available models from the EcoServ-GIS software (Winn et al., 2018, with the scientific basis for each model referenced therein), and other indicators from the scientific literature (further details are provided in Supplementary Data). These services were carbon sequestration for woodland, air quality regulation, noise regulation, agricultural production, water flow, water quality and accessible nature (a combined indicator of publicly accessible green space and its level of naturalness). In all cases, the models used were applied at a 10 m-by-10 m resolution to provide fine scale mapping across the farm. The models are based on the detailed habitat information determined in the base map, together with a variety of other external data sets (see below). Carbon emissions for peat soils were assessed but not spatially mapped because they occur on shared common land beyond the farm boundary.

It is noted that many of the models used here, except for carbon storage and sequestration, provide relative scores for site-based ecosystem services showing that particular areas have higher capacity to provide services than others, such as potential for water flow and water quality regulation. The final capacity score was calculated for every 10 m by 10 m cell across the study area and was presented on a 0 (no ecosystem service delivery) to 100 (maximum ecosystem service delivery) scale relative to values present within the mapped area. It was not possible within the resources available to undertake process-based mathematical models, such as hydrological or nutrient transport modelling, which could generate absolute values for services. This is, however, identified as a possible future refinement. (The modelling methods are explained in more detail in Supplementary Data).

A natural capital accounting approach was used to quantify the annual and discounted present monetary value of selected ecosystem services using the valuation and appraisal techniques advised by Government (ONS, 2017; HMT, 2018). The value of net carbon flux associated with trees and hedges, grassland, peatland and agricultural activities was estimated, as well as the change in $PM_{2.5}$ absorption by trees and hedges.

Carbon values (£/tCO_2e) were based on Government policy appraisal prices 2010–2100 for traded emissions (DBEIS, 2019) to reflect the values that farmers might obtain from participation in carbon markets. Values for particulates (£/t$PM_{2.5}$) were based on Defra (2019) guidance on air quality damage costs for rural areas. The average reported level of $PM_{2.5}$ pollution for the Pendle Borough Council is 6.04 μg m^{-3} (Defra, 2021a), similar to some of the more urbanised areas in the region and confirming the scope for air quality improvement.

Subsequent to the analysis here and reflecting changes in the policy context and refinement of estimation methods, the Government published new Net Zero policy consistent prices (£/tCO_2e) for carbon emissions (DBEIS, 2021). These remove the distinction between traded and non-traded values for carbon and give higher values for carbon than previous estimates. Revised estimates have also been issued for air quality damage (Defra, 2021b) that reduce unit prices for particulates (£/t $PM_{2.5}$) to about 45% of their previous values for rural areas. (Further explanation is given in Supplementary Data). The implications of these recent revisions are considered in the results and sensitivity analysis.

Agricultural and timber production were valued in market prices net of subsidies (see below). The accounting approach was used to compare the Pen Farm baseline with the ELMs-type intervention scenario to assess the change in the output and value of services, supported by a sensitivity analysis of key assumptions.

Using the natural capital assessment at Pen Farm, opportunities for a range of possible environmental interventions were aligned with the main themes of ELMs. At the time of the assessment, the ELMs options and payment rates had not been announced. Hence, legacy annual payments rates and capital grants under the Countryside Stewardship (CS) medium and higher tiers were used as a guide, the implications of which are discussed later.

2.5. Farm business assessment

Following the approach applied to the three farm cases, an assessment was made of the change in net income on Pen Farm where:

$$\Delta \text{ Net Income} = \Delta \text{ AgricEnv}_{net} - \Delta\text{BPS}_{net} + \Delta \text{ Agriculture}_{net} + \Delta \text{ Diversification}_{net}$$

A steady state 'before and after' comparison was made between the existing pre-ELMS situation and the adoption of ELMs-type options at full development. The additional revenues attributable to ELMs-type options were based on CS legacy payment rates. Annual maintenance costs for the prior CS were assumed at 21% of the payments received based on reported mean estimates (RBR, 2020). The estimate for ELMs was set at 28% of receipts based on the upper range for the aforementioned reported costs and the expectation that maintenance costs will be higher under the outcome-oriented ELMs. The capital costs net of grants to derive contributions by farmers were amortised over 10 years at a commercial interest rate of 6% for secured funds, adjusted by inflation at 2% to give a real discount rate of 4%. Minor works, such as reseeding, where not covered by grants, were included in the annual maintenance costs. The annual BPS for Pen Farm was based on the standard rates according to land designations, net of annual costs based on RBR (2020) data.

The financial performance of Pen Farm was assessed using the conventions of Gross Output, Gross Margins (after variable costs) and Net Margins (after total costs) drawing on data from the completed accounts of the case study farms for the period 2017/18–2019/20 and data for upland farms over the period 2013/14–2017/18 from RBR (various years). Allowing for inflation effects (ONS, 2020) and the observed variation between years, output and input quantities and prices, stock numbers and performance were derived for Pen Farm to represent a reasonable basis for forward budgeting (Redman, 2019). Unit prices, revenues and costs were expressed in constant 2020 values. Unpaid family labour was valued at average agricultural wage rates. These assumptions were tested in sensitivity analysis to identify likely ranges in the best single estimates.

The adoption of ELMs-type options involves changes in land use as well as changes in livestock and grassland management. Drawing on research evidence (Jackson and Williams, 1979; Qi et al., 2018; Ruelle et al., 2018), a simple grassland model was constructed to estimate dry matter (tDM/ha) and energy production (Mj/ha) from grassland according to nitrogen use, grazing/cutting practice, and grass growth class, assuming upland grassland and livestock management regimes. Supported by observations from the three farms, Fig. 2 shows estimated stocking rates (LU/ha) and associated Gross Margins (£/ha revenue less livestock and grassland variable costs) for the main grassland types and management practices observed in the Pendle Hill area.

An agro-forestry option with woodland and low input grassland

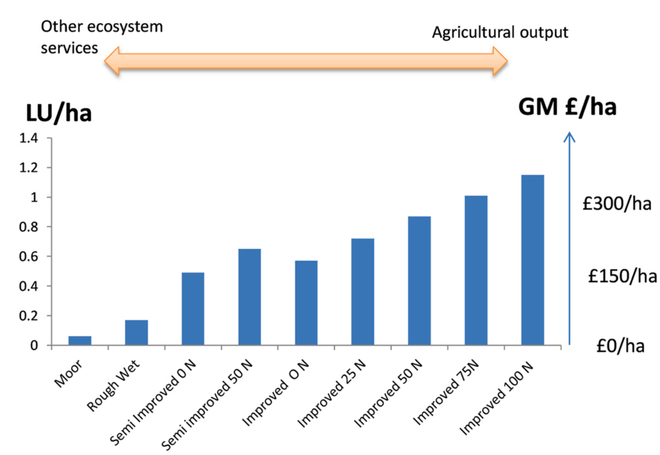

Fig. 2. Estimated livestock stocking rates per ha (LU/ha) and gross margins per ha (GM/ha) by grassland type and management practices (N kg/ha applied) for Pen Farm.

accounting for 15% and 85% by area respectively was included as an ELMs-type option, offering revenue potential from woodland products (Graves et al., 2011; Raskin and Osborn, 2019; Giannitsopoulos. et al., 2020).

Diversification options on Pen Farm mainly involved renewable energy and contracting services. No changes in net revenue from Diversification activities are assumed, other than educational services that are included in agricultural income. There is scope for farm based recreational services such as seasonal visitor accommodation and services, and the letting of commercial workspace.

At the farm scale, the changes in net income from AES were first assessed against the loss of BPS to indicate the change in payment for public goods under ELMs-type options. The impact on agricultural net income was then considered, allowing for changes in outputs and in variable costs such as feeds and fertilisers as these affect Gross Margin. Informed by the three real farm accounts and RBR (2020) data, it was estimated that every 1% reduction in Gross Margin was potentially associated with a 0.5% reduction in selected 'fixed costs' known to vary with output, such as labour, machinery operating costs, use of contractors and energy consumption, and that the latter accounted for about 60% of average total fixed costs. Thus, it was assumed that the reduction in Farm Gross Margin of 22% associated with reduced livestock production would enable a 'saving' of about 7% in total fixed costs ($0.22 \times 0.5 \times 0.6$). It is noted here that about 60% of this saving is associated with reduction in 'unpaid' family labour on agricultural activities, much of which is offset by increased labour inputs and costs for the new environmental options. Further savings in fixed costs may be possible, for example in machinery depreciation, general expenses and

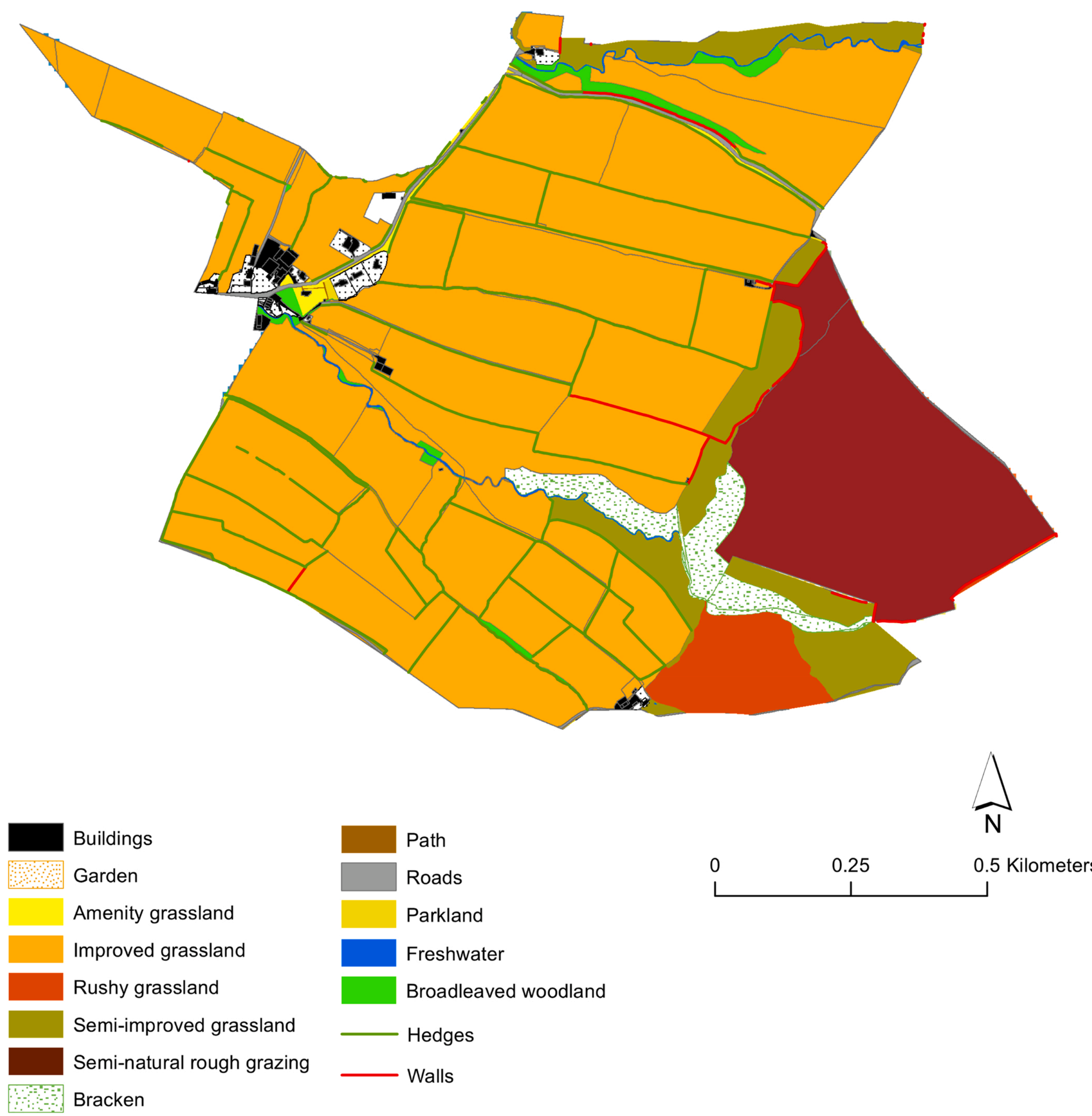

Fig. 3. Baseline natural capital assets of Pen Farm.

possibly rents.

3. Results

This section presents the results of the Pen Farm Case, including the list of ELMS-type interventions, the changes in the natural capital register and physical and monetary ecosystem service flows, and the financial consequences for the farm business.

3.1. Pen farm baseline

The total area of Pen Farm is 146 ha (360 acres) of which 139 ha is useable for agriculture and held under an agricultural tenancy. The Natural Capital Asset Map (Fig. 3) and the Asset Register (Table 1) show that the Pen Farm in the baseline scenario mainly consists of improved grassland habitat (68% of the farm area) and a range of semi-improved and semi natural grasslands (22%).

About 100 ha of improved grassland lies mainly within the Disadvantaged Area (DA) designation, about 10 ha of which is managed under agri-environment agreements. The remaining 39 ha, lying within the Severely Disadvantaged Area (SDA) designation, involves a range of less agriculturally productive land at higher elevations. Allowing for the different livestock carrying capacity of different land and habitat types expressed as permanent pasture equivalent (Harvey and Scott, 2020), gives a total 'adjusted' agricultural area of about 111 ha. There is an additional 30 ha of shared common hill land that supports seasonal grazing, equivalent to 3 adjusted ha, giving a total of 114 adjusted ha. This compares with 136 adjusted ha for the national 'average' LFA Beef and Sheep farm (Harvey and Scott, 2020). Thus, in terms of area, Pen farm lies between this and the study area average of 86 adjusted ha.

Pen Farm is a beef and sheep farm with 500 lowland/upland of mainly lowland/upland cross bred ewes and a cohort of pure hill ewes (85%:15% ratio). 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 year. A herd of about 17 beef suckler cows produce calves in spring that are carried over the following winter to be finished on grass in summer. Total grazing livestock units (LU), a measure to express different types of stock in dairy cow equivalents, are 97 LU giving a stocking rate of 0.85 LU/ha, similar to the LFA Beef and Sheep sector average of 0.86 LU/ha.

Like most upland farms, Pen Farm has existing Countryside Stewardship options (Fig. 4). To the east of the farm, within the SDA, areas of semi-natural rough grazing have lenient grazing options, some managed specifically for birds. An area of semi-natural grassland is under low inputs with cattle grazing and rush control. Outside the SDA, some hillside fields in permanent grassland have very low inputs and at lower elevations to the west, some grassland fields are managed to provide legume and herb rich swards. Hedgerows (3700 m) are managed and maintained, along with 1.6 ha of broadleaved woodland. A traditional farm building is also being maintained.

Table 1
Natural capital asset register for the Baseline and ELMs-type scenarios for Pen Farm.

Broad habitat	Baseline		ELMs-type scenario		Difference
	Area (ha)	% Cover	Area (ha)	% Cover	Area (ha)
Improved grassland	99.8	70	44.3	30	-55.5
Wood pasture, silvo-pastoral system	0	0	33.0	22	+ 33
Semi-natural grassland and rough grazing (restored to heather moorland)	19.1	13	20.6	14	+ 1.5
Semi-improved grassland (includes legume and herb rich pastures)	11.5	6	24.5	17	+ 13
Broadleaved woodland and hedges	1.6	1	12.4	8	+ 10.8
Rushy grassland	4.4	3	4.4	3	0
Bracken/scrub	4.1	3	2.5	2	-1.6
Other (incl built areas)	5.9	4	5.9	3.9	0
Total area	146	100	147	100	-1

Minor errors in totals due to rounding and small boundary differences on GIS layers

Pen Farm's baseline natural capital assets supply a broad range of ecosystem services under existing land management practices (Table 2). Under the baseline scenario, with an emphasis on agricultural production, the scores for provisioning services are high relative to regulating and cultural services, reflecting the trade-offs under existing land use and management regimes.

The generation of ecosystem services varies spatially across Pen Farm (Fig. 5), showing areas of low delivery where interventions could generate additional services. For example, carbon sequestration by woodland and storage capacity are generally low across the farm (Fig. 5a&b), water quality regulation is low near the water courses in the north and the south of the farm (Fig. 5e), water flow regulation is low on improved grassland in the middle of the farm (Fig. 5f). The lack of footpaths across semi-natural habitats on the farm currently limit the quality and accessibility of nature benefits for people (Fig. 5h) in an area with considerable visitor potential.

Table 3 shows the estimated annual physical and monetary flows of selected ecosystem services on Pen Farm under the baseline situation. The return to livestock production is negative for reasons explained earlier. The annual flows and values of carbon sequestration are low, especially relative to the emissions from agriculture and peatland degradation. Pen Farm is currently a net emitter of carbon at about 350 t CO_2e/year including the common moorland area.

3.2. Pen farm ELMs-type scenario

A suite of ELMs-type options on Pen Farm have the potential to achieve the intended outcomes of ELMS themes and fill the income gap left by the withdrawal of BPS (Table 4).

The extent and spatial location of ELM-type interventions on Pen Farm are shown in Fig. 6, including peatland conservation on the eastern higher elevations, woodlands to the north, wood pasture in the centre of the farm, and conservation grassland to the south. A range of water management inventions at higher elevations and along the major watercourse slow water flow and protect water quality. A network of new and restored hedgerows and shelterbelts with trees, provides shelter for livestock, habitat for wildlife and slow the flow of water.

The selected ELM-type interventions change the type and quality of natural capital assets and ecosystem services on Pen Farm (Table 1 above). Intensively managed grassland decreases by 56 ha, from 68% to 30% of the total farm area, semi-natural and conservation grasslands increase by 15 ha, and broadleaved woodland by 11 ha. New habitats of wood pasture and areas of natural scrub are created. The profile of ecosystem service provision changes (Table 3 above), reducing the capacity for livestock production by about 22% while increasing the supply of timber products and a range of regulating services. The estimated PV benefits attributable to changes in air quality and net carbon emissions exceed the estimated losses from agricultural production. The recent Government revisions for air quality damage costs and carbon prices halve the PV values for air quality improvement and double the PV value of changes in carbon emissions respectively, increasing the margin over agricultural losses. Unquantified cultural services associated with education, recreation, and health and well-being benefits are also enhanced, as well as the supporting services of biodiversity and improved soil health.

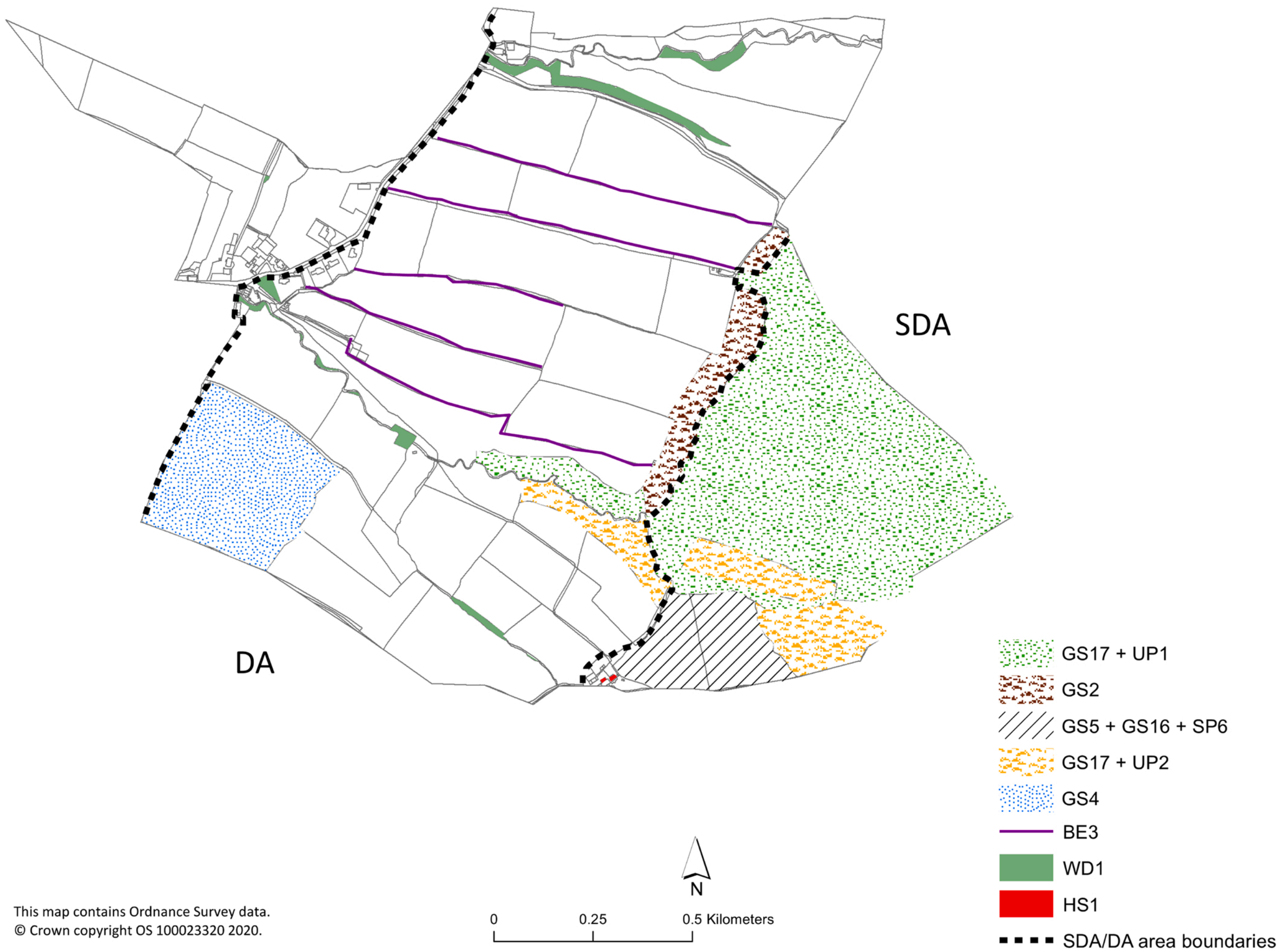

Fig. 4. Baseline take-up of Countryside Stewardship options on Pen Farm.: GS17 + UP1 - Enclosed rough pasture with lenient grazing; GS2 – Permanent grassland with very low inputs (non-SDA); GS5 + GS16 + SP6 = Very low input grassland (SDA) and cattle grazing and rush control; GS17 + UP2 – Management 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.

3.3. Farm business impacts

The estimated annual value of Total Output and Farm Business Income from Pen Farm for the pre-ELMs baseline situation is £ 108,000 and £ 21,000 respectively in 2020 prices, respectively. AES and BPS account for 7% and 25% of Gross Output, and 30% and 110% of Farm Business Income respectively, reflecting the net losses from agriculture. Once the estimated cost of unpaid family labour at £ 32,000 is deducted, the return on own capital invested in the business, to risk and entrepreneurship', becomes a negative £ 11,000 (£21,000- £32,000). These indicative estimates generally accord with the national 'average' for LFA Grazing Farms shown in Fig. 1. They compare well in terms of £ /ha output and costs with the national average for the category of LFA Beef and Sheep farms (Harvey and Scott, 2020). Indicating the order of change required, the value of Gross Output at the farm scale as determined by commodity prices or yield would need to increase by more than one third to compensate for the loss of BPS, assuming everything else, including inputs costs, remains unchanged. Alternatively, total annual costs would need to reduce by about 30%.

At full development, new environmental options (Table 5) generate a best estimate of £ 23,900 annual revenue after deductions for estimated annual costs. This compares with existing AES agreements at £ 5900, an increase of £ 18,000/year, helping to offset the net loss of £ 23,300 from BPS. Thus, after allowing for changes in costs, there remains a shortfall of about £ 5400 in net income before adjustments for impacts on income from agricultural activities. (Table 6).

The ELMs-type 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 numbers at the farm scale is equivalent to 22 LU, about 22% of the existing total. Gross Margin (inclusive of grass and forage costs) falls by about £ 6600 (£60/ha) (Table 5). Savings in costs that are conventionally regarded as 'fixed' are conservatively estimated at £ 5300/year. Additional costs savings could be achieved by further changing grassland and livestock management practices and reducing the reliance on purchased feeds and fertilisers. For the assumptions made, changes in environmental related net revenue, farm income support and agricultural production together result in an estimated change in net income of minus £ 6700/year (£61/ha annually) (Table 5). This implies that the assumed ELMS-type payments rates would need to rise by about 25–30% above the assumed Countryside Stewardship legacy rates to maintain income levels. Alternatively fixed costs savings would need more than double (to 15% of current total fixed costs) to fill the remaining income gap on Pen Farm. There is a high degree of inherent uncertainty in the estimates as shown by the possible ranges in Table 5. While there is certainty that BPS in its present form will be withdrawn, the relatively high uncertainty attached to the other income and expenditure estimates means that the final estimate of the change in net income is likely to be more than + /- 50% of

Table 2
Qualitative estimation of the level of ecosystem service delivery from Pen Farm natural capital assets for the baseline and proposed ELM-type options. (0 no delivery through to 3 high delivery).

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

the best estimate.

No allowance is made here for future revenues from rotational coppicing of wood pasture, with a possible annual net income of £ 2200. There is also income potential from carbon trading or biodiversity offsetting credits. Carbon credits from woodland sequestration, for example could be worth about £ 1186/year valued at the UK Government's 2020 traded price of £ 14/tCO_2e.

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

4. Discussion

Addressing the study objectives, we have found it necessary to make many simplifying assumptions that bely the real-world complexities of upland-hill farming systems and the uncertainties faced by this policy dependent farming sector. We have used three real cases to build a grounded generic case located on a real farm site that inevitably loses the subtleties and richness that make upland hill farms so varied and appealing in features, context, motivations, activities and outcomes. Nonetheless, we feel able cautiously to draw observations that can help to inform the wider policy challenge. We discuss these in turn.

The case of Pen Farm, and the three real cases from which it is derived, shows that the adoption of ELMs-type options on upland farms can deliver multiple public benefits across a range of environmental themes. The case shows the synergies and trade-offs between agriculture and environmental options as upland farmers seek to maintain financial viability in the face of the major policy reforms. Upland farmers will need to take up a wide-ranging package of ELMs-type options to plug the income gap left by the withdrawal of income support, probably requiring a three-fold increase in net revenue from environmental options compared with the current situation.

The Pen Case shows that the transition to ELMs in the upland sector will require an improved understanding of the relationship between agriculture and intended environmental outcomes (Bateman and Balmford, 2018; Arnott et al., 2021). Livestock stocking rate, and associated grassland management, is the defining 'pivot' that balances agricultural and environmental outcomes. The transition will require significant reductions in current livestock numbers and stocking rates, less intensive grassland management practices and reduced use of artificial fertilisers, and possibly a switch to conservation-oriented breeds. It also requires new learning (or re-learning) to support the knowledge, skills, and motivations to successfully combine farming and environmental objectives, especially where this involves innovative solutions.

The withdrawal of farm income support will expose many of the inefficiencies and hidden losses of existing upland livestock systems. The Pen Case shows there is scope to move to lower input, higher added value agricultural systems that can simultaneously deliver agricultural and environmental benefits. Here, we identified potential savings associated with reduced fertilisers use and greater dependency on grass energy, as well as cautious estimates of reductions in farm level fixed costs. Discussions with our participating farmers confirmed opportunities for further farm-specific efficiency gains in line with the 'Less is More' observations by ADAS (2019) and Clarke et al. (2019). 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, environmentally beneficial but less production-driven upland systems. Indeed, the setting of sustainable farming incentives and ELMs payments may be viewed in the broader context of driving structural reform in the upland sector to reduce the cost to the public purse in the longer term.

The future success of ELMs depends on farmer participation and uptake, with farmers as 'suppliers' of ecosystem services. The Pen Case shows that payments based on the previous 'cost and income foregone' regime may not be sufficient to incentivise and provide the 'normal profits' necessary to secure the delivery of environmental outcomes and the viability of the farm business. This issue has been reinforced in recent ELMs Test and Trial reporting (Defra, 2021c). For ecosystem services to become a core business function, a much better understanding is required of the real costs of environmental actions, of investment planning and the return on assets necessary to keep farms in business. ELMs also implies the move towards demand driven benefit pricing for public goods, including context specific valuation and benefit-based reward systems. Benefit pricing tends to favour a competitive bidding amongst efficient suppliers who know their costs and margins. As the Pen case implies, the absence of income support, the success of ELMs will probably require a much closer connection between land managers and their financial accounts (Clark et al., 2019). Understanding how the business and other motivations of land managers combine to shape their responses to new and different incentives will be critical (Vliet et al., 2015).

Benefit-based rewards will also favour multi-farm collaborations to deliver outcomes at the larger landscape scale, such as joint action to improve catchment water quality, alleviate flooding and help restore habitats that contribute to Nature Recovery Networks and Strategies. Pen Farm and the supporting farm cases confirm the opportunities for joint and collaborative working with cumulative environmental effects that can exceed individual actions. It will, however, be important to support the preparation of such initiatives, including incentives to cover the additional cost and risk of collaboration, as well as aligning funding from multiple sources (Ozdemiroglu, 2019; Defra, 2021c). Energised by the opportunity for policy reform and with the purpose of maximising the benefits from natural capital, there is scope and need to strengthen existing and create new systems of governance that bring together the interests and resources of the wide range of national and local stakeholders at the landscape scale (Dwyer and Hodge, 2016; Gawith and Hodge, 2019).

It is apparent from our generic and supporting farmer cases that ELMs may affect land values, rents and tenure arrangements. Long term options for upland peatland restoration, and the expansion of woodland and agri-forestry may not suit current tenancy agreements: special financial

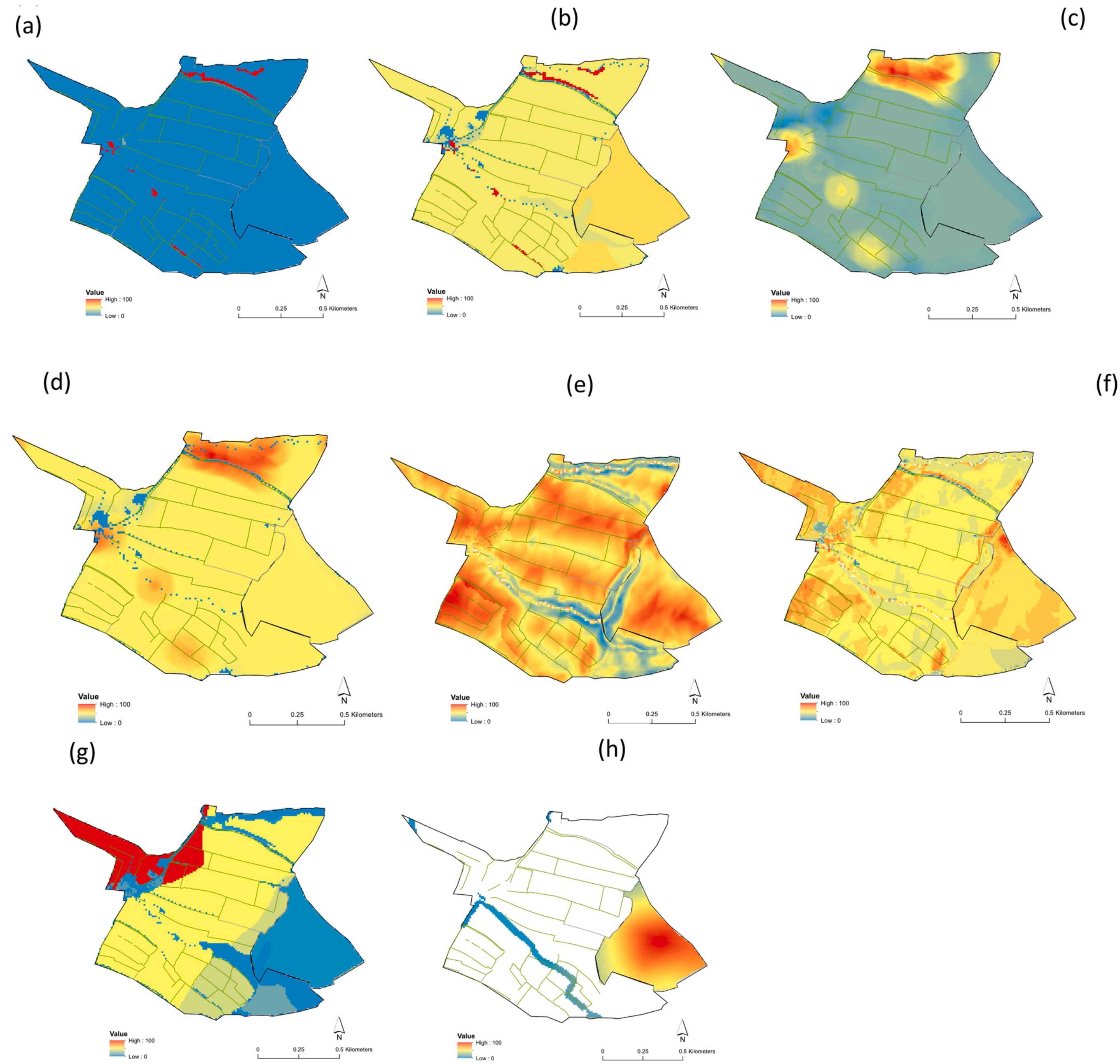

Fig. 5. The capacity of the natural capital assets of Pen Farm to provide (a) carbon sequestration by woodland, (b) carbon storage, (c) air pollution regulation, (d) noise regulation, (e) water quality regulation, (f) water flow regulation, (g) agricultural production and (h) accessible nature. The capacity score was calculated for every 10 m-by-10 m cell across the study area and is presented between 0 (blue- no delivery) to 100 (red -maximum deliery) relative to values present within the mapped area.

and legal arrangements to suit the needs of landlords and tenants. Indeed, landlords may see advantage to implement restorative options directly as landowners, particularly at the landscape scale. Termination of tenancy agreements could be an unintended consequence.

The natural capital approach as applied here for Pen Farm can help to support the design, selection and management of ELMs interventions. It can provide both qualitative and quantitative assessments of the current and potential future state of natural capital assets and flows of ecosystem services and environmental outcomes. In particular, the map-based assessment and reporting methods suit 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.

The Pen Farm case confirms the need to refine the natural capital approach at the farm scale. It was not possible here to assess, for example, the beneficial impact of specific control measures on flooding or freshwater quality in receptor environments. There is potential to do this, however, by more detailed modelling, set within an assessment of environmental risks at the relevant scale. There is also a need to strengthen the assessment of services that impact on human health and wellbeing, including air quality improvements in rural areas: something that may be worthy of further policy scrutiny. Looking forward, a farm-based version of the natural capital approach is needed that is attuned to field scale conditions and practices such as soil type, topography, grazing regime and stocking density, fertilizer and agrochemical application, and woodland and hedgerow management, with links to the array of services generated in the local context. Such an assessment tool must be relatively easy to use, supported by locally relevant data, and

Table 3
Physical and monetary (£2020) flows* of selected ecosystem services provided by the natural capital of Pen Farm for the baseline and ELM-type options.

Ecosystem service	Baseline		ELMs-type		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)
Agricultural production *Livestock Units*	97	-11,322† (−288,953)	78	-41,179† (−1050,944)	-19	-29,857 (−761,991)
Timber production *m^3per year*	6.6	106 (2705)	61.0	1007 (25,700)	+ 54.4	+ 901 (22,995)
Air quality regulation (trees, hedges and grass)[1] *$tPM_{2.5}$ per year*	0.03	2289 (84,620)	0.33	24,069 (889,790)	+ 0.3	+ 21,780 (805,170)
Carbon sequestration (trees and hedges)[2] *tCO_2e per year*	10.9	153 (41,045)	84.7	1186 (318,943)	+ 73.8	+ 1033 (277,898)
Carbon sequestered by grassland *tCO_2e per year*	27.5	385 (103,553)	179.8	2517 (677,047)	+ 152.3	+ 2132 (573,494)
GHG emissions from agriculture* *tCO_2e per year*	253	-3539 (−952,683)	180	-2522 (−677,803)	+ 73	+ 1017 (274,880)
Carbon emissions from peat habitats *tCO_2e per year*	135	-1890 (−508,351)	60	-840 (−225,934)	+ 75	+ 1050 (282,417)

* Central price estimates: low and high estimates for PV values are − 50% and + 50% of central estimates for carbon flows respectively, and − 75% and + 300% for air quality respectively. Annual monetary value flows apply 2020-year prices.
[1] Revised guidance on estimating rural air quality damage costs, issued in 2021, reduce unit costs by about 55%, giving baseline and ELMS type annual flows of about £ 1030 and £ 10,830 respectively, and a difference of £ 9800/year, with proportionate reductions in PV values.
[2] Carbon values here are based on UK Govt modelling prices for traded carbon (in $£_{2020}$) set at £ 14/tCO_2e in 2020 rising over time, for example to £ 87/tCO_2e in 2030, to converge with non-traded policy prices. Revised guidance on carbon valuation issued in 2021 advises the use of a single series of 'policy consistent' prices. The central estimates for the latter are £ 241/tCO_2e for 2020 and £ 280/tCO_2e for 2030 for example (in $£_{2020}$ prices). The estimated PV added value of carbon flows over 50 years (shown in brackets) increases by a factor of 2.1 using these revised prices, from a PV of £ 3770/tCO_2e to £ 7990/tCO_2e over 50 years.

Table 4
ELM-type options for Pen Farm and links with ELMs themes and intended outcomes.

ELMs Outcome Themes Intervention and outcomes	CC* Carbon sequestration	CPW Water quality	HAZ Flood alleviation	CA Air pollution regulation	TPW Pollination	TPW Habitat restoration/ creation	BHE Recreation Health and well-being	BHE Cultural heritage
Woodland	✔	✔	✔	✔			✔	
Wooded shelterbelts	✔	✔	✔	✔	✔	✔		
Riparian woodland/ grassland buffer with scrub	✔	✔	✔	✔	✔	✔	✔	
Ponds and swales		✔	✔			✔		
Woody debris dams		✔	✔			✔		
Fenced watercourses		✔						
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						✔		
Maintenance of traditional farm buildings								✔
Maintenance of stone walls								✔
Improved public access							✔	
Educational visits								✔

*Note: 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.

capable of guiding the selection of ELMs options to achieve both environmental and financial outcomes. The environmental contributions from individual farms could then be aggregated and considered against local environmental targets and values, such as reduced flood risk, improved water quality and cultural and health benefits. This would support the implementation of ELMs Nature and Landscape Recovery components. The scope for developing such a decision-support tool could be explored by aligning the ongoing ELMs Test and Trial Programme with the Farming Innovation Programme (UKRI, 2022).

The Pen Farm case shows the advantage of integrating the natural capital assessment with farm business accounting methods, helping land managers to assess the financial implications of ELM-type options, including long term viability. 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. Set in the broader context of agricultural transition, integrated environmental business support can also help prepare land managers to participate in new markets as joint or supplementary 'blended' funding options come on stream, linked for example to carbon, flood risk or biodiversity net gain credits, and nature-based tourism and recreation (Bateman and Balmford, 2018). This will require forward visioning of what makes a viable

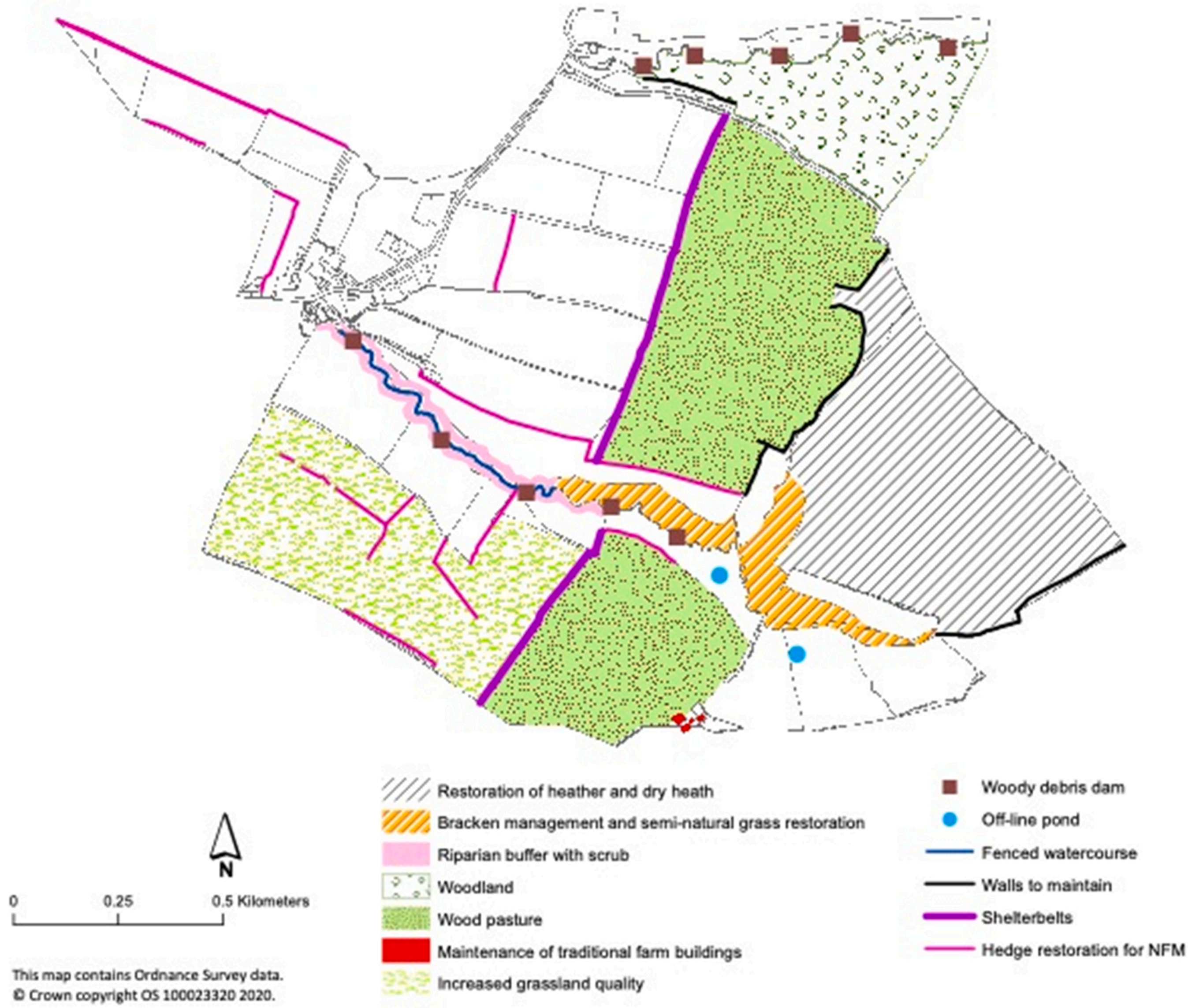

Fig. 6. ELMs-type interventions on Pen Farm.

Table 5
Estimated changes in annual net income from ELMs-type options to offset BPS loss on Pen Farm.

		£ /farm/year			£ /ha*		
		Revenue	Costs	Net	Revenue	Costs	Net
ELMs-type options	a	33,155	9283	23,871	300	84	216
Current AES	b	7500	1575	5925	68	14	54
Change (ELMs-AES)	a-b	25,655	7708	17,946	232	70	162
BPS	c	27,421	4113	23,308	248	37	211
ELMS-type - BPS	a-c	5734	5170	563	52	47	5
Extra (ELMs-AES)- BPS	(a-b)-c	**1766**	**3595**	**-5362**	**-16**	**33**	**-49**

* £ /adjusted ha at 111 ha

upland farm, 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.

As alluded to earlier, the methods used and the results obtained inevitably have some limitations, discussed here with implications for policy and practice. First, there is our use of a generic case. It is assumed that the considerable observed variation in actual farm circumstances and practices can be conflated into a meaningful synthetic case. We argue that the Pen Farm case has served our purpose for methods development and demonstration, helping to identify key issues, challenges and responses. We see advantage in further developing this farming systems approach through exemplar cases to test policy and practice options, while recognising the inherent contextual variation. Furthermore, the generic case can provide a focal point for learning and stakeholder engagement.

Second, there are questions of scale, granularity and content. Our modelling of natural capital assets and ecosystem services used methods initially applied in the study area at the broad landscape scale. These were subsequently adjusted to suit the three supporting cases and the synthetic generic case. The methods do not therefore include the detailed process modelling required to support comprehensive site-specific estimates of, for example, overland water flow or pollution transport, and of flood risk or freshwater quality impacts in receptor

Table 6
Changes in total annual farm net income under new ELMs-type options for Pen Farm.

		£ /year	£ /ha *	Relative uncertainty rating** and possible range of estimate
Change in environmental and income support				
Extra net income (ELMs-AES)	a	17,946	162	M: + /- 25–50%
Loss of net income from BPS	b	23,308	211	L: < +/- 24%
Subtotal	a-b =c	-5362	-49	
Change in agricultural net income				
Change in Agricultural Gross Margin	d	-6639	-60	M: + /- 25–50%
Savings in Fixed Costs***	e	5297	48	M: + /- 25–50%
Subtotal	d-e=f	-1341	-12	H: > +/- 50%
Total change in farm net Income	c+f	**-6703**	**-61**	**H: > +/- 50%**

* £ /adjusted ha at 111 ha.
** L: Low, M: Medium, H: High.
*** includes imputed savings in unpaid family labour

areas. Neither, given data and resource limitations, did we quantify potential changes in cultural services such as outdoor recreation that can deliver high-value physical and mental benefits. As we have discussed earlier, there is scope and advantage to develop natural capital decision-support tools that can operate at the farm and farm-group scale, including the valuation of off-farm-effects, supported by generic demonstration cases and guidance.

Third, we note the high degree of uncertainty in the estimates of agricultural financial performance, not least because of the year-to-year variation in agricultural yields and commodity prices, but also because details of the key ELMs policy instrument have yet to be announced. Risk and sensitivity analyses are critical in this respect. Again we argue that the generic case helps to support an understanding of uncertainty, supported by scenario analyses of key policy and market drivers and possible practitioner responses.

Fourth, with regard to testing policy and practice options, we did not seek here to maximise the returns from environmental options or determine a theoretical optimum uptake for Pen Farm. Rather we set a direction and magnitude of change that was deemed potentially feasible and appealing, drawing on the detailed and interactive assessments in our supporting real cases. We recognise, however, the potential advantage of using the generic case to explore alternative 'objective-oriented' gradients of take-up of agricultural and environmental options and outcomes, underpinned by policy and market drivers, and farmer responses.

Despite these shortcomings, we feel that our methods were appropriate for the available data and resources, and for the production of a grounded generic case to illustrate the approach, the issues arising, and how these limitations can be addressed in future.

5. Conclusions

Using confidential assessments on three actual farms, we constructed a synthetic generic case to explore the implications for upland grazing livestock farms of the proposed policy reform to switch from direct income support to payment for public goods.

We conclude that while upland farms are vulnerable to the withdrawal of income support, they are well placed to provide a wide range of public benefits aligned with the key themes of the proposed Environmental Land Management scheme. Although multiple benefits can be delivered at the farm scale, it is at the wider landscape scale that greatest impact will be achieved, suggesting the need for strong collaborative action amongst farmers.

We conclude that it is feasible for upland farmers to plug the income gap but for many farms this will probably require a threefold increase in environmental services as source of income. Feasibility, however, depends on two conditions. First, it will require resetting the relationship between agricultural and environmental activities and outcomes. This transition will involve reduced livestock numbers and changes to livestock and grassland management. Second, as environmental services become a core business function, payments by results must provide sufficient return on effort and assets to maintain the viability of the upland farm business. The technical and economic feasibility of high nature value upland systems are correctly a focus of the ongoing Test and Trials programme. They should also be a target for advice and technical support.

We also conclude that the integration of natural capital and farm business accounting is critical to support decision making as the proposed ELMs is implemented. Mapped-based assessments of environmental opportunities, aligned with local priorities and feasibility can support decisions at the farm and landscape scale, as well as monitoring and evaluation. Again, this is something worthy of attention in the Test and Trials Programme as innovative and enduring solutions are sought to the upland challenge. The insights here for the English upland sector are relevant in other regions facing new policy futures in the United Kingdom and beyond.

Conflict of interest

The authors declare that there is no conflict of interest or restriction on the publication of the work: permissions have been obtained and due acknowledgements made.

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Appendix A

Land use in the Pendle Hill study area

Appendix B. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2022.106339.

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