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Valuing our Peatlands:

Natural capital assessment and investment appraisal of peatland restoration in Northern Ireland

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Cover image: Peatland restoration works on Garron Plateau (NI Water)

Executive Summary

Peatlands are an important asset in Northern Ireland, covering 12% of the land area, yet 86% are degraded and only about 1% of the peatland area has been restored over the last 30 years. As a result, the potential benefits of peatlands for people and nature in terms of water quality, natural flood management, and wild places for people to enjoy are compromised. Furthermore, the loss of soil carbon due to peatland degradation contributes to climate change. Thus, there is scope to align future peatland protection and restoration policy with other developments in the policy landscape, delivering multiple objectives. The Department for Agriculture, Environment and Rural Affairs (DAERA) is currently in the process of developing a peatland strategy for Northern Ireland, which will set the ambitions to protect and restore peatlands over the next 20 years and beyond. Peatland restoration offers a major opportunity to respond to the growing climate and biodiversity emergencies and at the same time support rural livelihoods.

This report presents a natural capital assessment and investment appraisal of two peatland restoration projects in Northern Ireland: the Garron Plateau, a large upland peatland, and Montiaghs Moss, a smaller lowland peatland. The project was commissioned by RSPB Northern Ireland and funded by DAERA. Using a natural capital framework, the project aimed to identify and assess existing natural capital assets, the flow of services from them, and the monetary value of the resultant benefits. A schedule of restoration works was prepared for both sites and the capital and maintenance costs were calculated. A cash flow was then created, taking into account the change in benefits as the sites were restored, and the costs of the works as they occurred, and projected over 50 years. The cash flow was summed to give the total net natural capital asset value and the cost benefit ratio. Impact on employment was also briefly assessed, and a stakeholder analysis and assessment of likely winners and losers was completed.

The **Garron Plateau** (SAC, SPA, ASSI, Ramsar Site) in Country Antrim contains the largest area of intact blanket bog in Northern Ireland. The peatland supports an array of flora and fauna, which include a number of rare and notable species, and a diverse upland breeding bird population. Prior to restoration commencing in 2010 the site was mostly in unfavourable condition. The total study area was 5,395 ha, including some surrounding coniferous forestry and farmland. The natural capital assessment confirmed that carbon, water services and biodiversity are by far the most important ecosystem services delivered by the site, along with some additional cultural services, such as educational and scientific value.

The benefits of restoration at the Garron Plateau greatly outweigh the costs (£50.1M v £12.8M over 50 years), with a net present value of £37.3M. For every £1 invested there will be £3.91 worth of benefits. In total, 92% of the monetised benefits are due to changes in carbon sequestration. Emissions will decline greatly as restoration proceeds and the site will move from being a major net emitter to a net sequester of carbon. A number of water-related benefits are also delivered by the restoration works, not all of which can be valued. This includes reduction in flood provision and erosion. Flood mitigation improved by 27% at the site, which translates to a 6.3% improvement across the catchment.

Montiaghs Moss (SAC, ASSI) is an area of lowland peatland in County Antrim, close to Lough Neagh. The site is an area of relic raised bog, primarily shaped by many years of traditional peat cutting, and consists of a mosaic of peat ramparts, trenches, pools and drains, interspersed with grassland, alder and willow carr, and tall hedgerows. The site supports a wide range of plants and animals, including many rare species. Most notable is the marsh fritillary butterfly (*Euphydryas aurinia*), with the site a major stronghold in the Northern Ireland context. It is 151 ha in size with a complex ownership pattern.

The assessment for Montiaghs Moss has shown that biodiversity benefits are by far the most important benefits being delivered by the site. Restoration of the site is focussed on this key objective, and aimed especially at improving conditions for the marsh fritillary. The benefits of restoration at Montiaghs Moss are less than the costs of doing the restoration (£1.37M v £1.54M over 50 years), with a net present value of -£172,000. Every £1 of investment will provide £0.89 worth of benefits. However, some of the costs are considered to be high, especially for fencing and creation of a boardwalk, and for staffing costs.

The assessments presented here do not attempt to value the biodiversity benefits, hence these amount to large additional benefits achieved by the site management works at both sites. Biodiversity benefits are partially captured by agri-environment payments, but these do not capture the true value. This is especially relevant for Montiaghs Moss, where the primary aim is to enhance the site for the marsh fritillary, rather than to maximise carbon sequestration or other ecosystem services. Perhaps an alternative way to describe the outcomes at Montiaghs Moss is that when money is spent on restoring the site for the marsh fritillary, a number of additional benefits can be delivered that are valued at almost 90% of the total costs.

At the Garron Plateau 92% of the monetised benefits relate to carbon, whilst at Montiaghs Moss the figure is 73%. This means that the assessments are strongly impacted by the price of carbon. We have used the UK Government non-traded carbon price, which is standard practice for these kinds of assessments and is a better reflection of the 'real' value of carbon sequestration than market prices. However, this is not the same as the voluntary carbon market price (or the traded carbon market price), which is where any investment would be likely to come from. For Garron, the breakeven point is reached using a carbon price set at 19.5% of the non-traded price, which would be about £15.15 per tonne in 2021. Note that the current price in the voluntary carbon market is slightly higher than this (£17.31 Woodland Carbon Guarantee third auction) and data from private voluntary markets indicates that prices have increased in the last year.

The Garron and Montiaghs Moss peatland projects have potential to impact on employment, directly through restoration activities and changes in land-based activities, and indirectly through related supply chains and the local economy. Results suggest that peatland restoration has potential to contribute to employment through changes in landscape management. While the farming sector could experience loss of employment due to reduced livestock production, actions can be taken to offset this by involving farmers in the restoration process and its activities, as well as alternative land uses consistent with restoration.

The findings described in this report are broadly applicable to other peatland sites across Northern Ireland (and in GB and Ireland). It is likely that in all cases, reducing carbon emission through restoration will provide substantial benefits. Enhancing biodiversity is also likely to be a major driver. A broad range of other benefits are also likely, especially focussing on water quality, water flow and flood risk, water supply, and a number of cultural benefits. In some locations, sites may also be important, or have the potential to support significant recreation and health and wellbeing benefits. It is clear that peatland restoration will lead to multiple benefits, and these will often have a value greater than the capital and maintenance costs of delivering the works. These values are most often public benefits, although rapid progress is being made at developing markets for carbon and other ecosystem service benefits. There is a growing opportunity to restore peatlands across Northern Ireland to achieve climate, biodiversity and other public policy aims, drawing in both public and private investment. In particular, obligations to commit to "UK net zero" climate policy, and growing awareness of the ecological crisis in the UK, present clear drivers for large-scale peatland restoration across Northern Ireland, which could deliver substantial emissions cuts and biodiversity gains.

The report ends by presenting recommendations, which include the need for accurate measurements and monitoring data, especially of peat depth across the Garron Plateau; a recommendation to calculate the benefits and costs of restoration for a wide range of peatland sites across Northern Ireland to support the 'business case' for peatland restoration and to help prioritise interventions; the need for refinements of the current agri-environment scheme to further reward the delivery of public goods; policies to promote the development of private carbon and other ecosystem services markets; work to enable payments for multiple benefits from the same parcel of land (stacking and bundling of benefits) and to enable both public and private investment in the same location; policy changes to make carbon and biodiversity offsetting mandatory; and embedding the natural capital approach in decision making across policy domains in Northern Ireland.

Contents

1. Introduction

In Northern Ireland, peatland soil covers around 12% of the land area. The raised bogs, blanket bogs and fens that make up peatland habitats are potentially amongst the most biodiverse landscapes in the country. After decades of drainage, overgrazing, peat extraction and afforestation, most are in a damaged and deteriorating state. Of the 242,000 hectares of peatlands in Northern Ireland, about 86% has been affected in some way by drainage or cutting. Similarly, pressures such as overgrazing, inappropriately sited forestry, burning and extraction also affect the health and function of peatland habitats in Northern Ireland.

Although a commitment was made to conserving peatlands in Northern Ireland in the early 1990s to arrest their degradation, only about 1% of the peatland area has been restored over the last 30 years[1]. As a result, the potential benefits of peatlands for people and nature in terms of water quality, natural flood management, and wild places for people to enjoy are compromised. Furthermore, the loss of soil carbon due to peatland degradation contributes to climate change. Thus, there is scope to align future peatland protection and restoration policy with other developments in the policy landscape, delivering multiple objectives.

Set in the context of increased awareness of the importance of peatlands, the Department for Agriculture, Environment and Rural Affairs (DAERA) is currently in the process of developing a peatland strategy for Northern Ireland to support the objectives of the IUCN sponsored UK Peatland Strategy[2]. The proposed Peatland Strategy for Northern Ireland will set the ambitions to protect and restore peatlands over the next 20 years and beyond. The targets for restoration are ambitious, especially in the light of the limited progress on previous statements of intent. However, peatland restoration now offers a major opportunity to respond to the growing sense of climate and biodiversity emergencies that characterises the new policy reality.

Here we present a natural capital assessment and investment appraisal of two peatland restoration projects in Northern Ireland; the Garron Plateau, which is a large upland peatland, and Montiaghs Moss, a smaller lowland peatland. The assessment of the Garron Plateau and Montiaghs Moss peatland sites are examples of restoration projects that can help support the case for peatland restoration, both within the Northern Ireland Peatland Strategy and the wider policy framework. The key aims of the project were to:

1. Carry out a natural capital assessment of the two sites, including an assessment of the existing natural capital stocks (asset register), the flow of benefits derived from this natural capital, and their value to society.
2. Assess how these change under a baseline (pre-restoration) scenario, compared to a restoration scenario.
3. Determine the capital and maintenance costs of restoring the sites to favourable condition.
4. Carry out an economic and investment appraisal to determine the cost-benefit analysis and return on investment of the proposed restoration works.
5. Calculate the job creation potential of the peatland restoration projects.
6. Examine the policy drivers influencing peatland restoration in Northern Ireland and the potential winners and losers of the restoration scenarios proposed for the two sites.

[1] Artz, R., Evans, C., Crosher, I., Hancock, M., Scott-Campbell, M., Pilkington, M., Jones, P., Chandler, D., McBride, A., Ross, K. & Weyl, R. 2019. The State of UK Peatlands: an update. IUCN.

[2] The UK Peatland Strategy was launched in April 2018 by the IUCN UK Peatland Programme. https://www.iucn-uk-peatlandprogramme.org/uk-strategy.

1.1 The natural capital and ecosystem services framework

The natural environment underpins our wellbeing and economic prosperity, providing multiple benefits to society, yet 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).

It is the stock of natural assets (e.g. soils, water, biodiversity) that produces a wide range of ecosystem services that provide benefits to people. These benefits include food production, regulation of flooding and climate, pollination of crops, and cultural benefits such as aesthetic value and recreational opportunities (Figure 1). Key attributes of natural capital are illustrated in Figure 2 (overleaf).

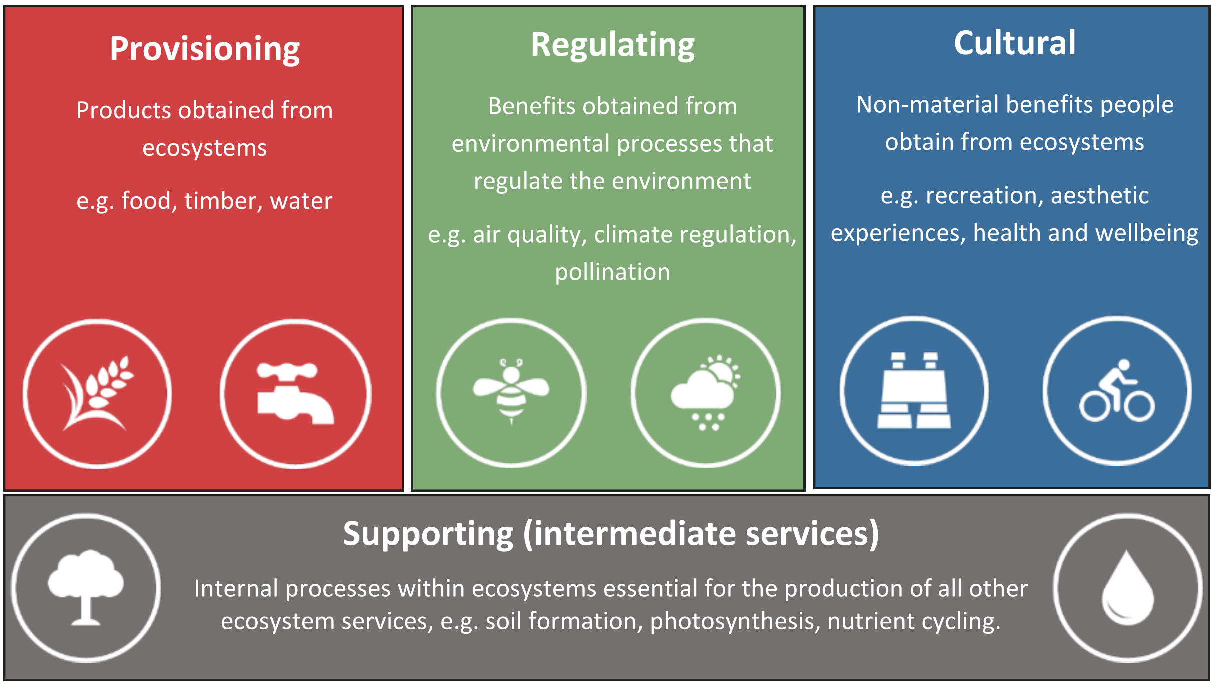

Figure 1 Key types of ecosystem services (based on MA 2005[3]).

The concepts of natural capital and ecosystem services are widely supported; the challenge, however, is in implementing the approach and embedding it in working practices, so that it becomes an integral component of decision making. One of the most important steps is to recognise and quantify ecosystem service delivery (the physical flow of services derived from natural capital). Through a natural capital assessment, it is possible to understand the extent and condition of natural capital assets, so the number and the flow of ecosystem service benefits from those assets can be established. These benefits can then be valued. Information on the condition and benefits derived from an asset enables better informed land management decisions to be made because of the transparency gained by recognising an asset's full, long term value. It provides an understanding of the consequences of land management change on the range of benefits that can be provided by a landscape. It can also highlight how specific changes can be tailored to enhance certain services or values, and how environmental change (e.g. climate change) may affect natural capital assets, their benefits and values. It can reveal

[3] Millennium Ecosystem Assessment (2005) *Ecosystems and human well-being: synthesis.* Island Press.

the value of both public and private benefits that come from managing landscapes, and it is key to identifying trade-offs and synergies between different ecosystem services.

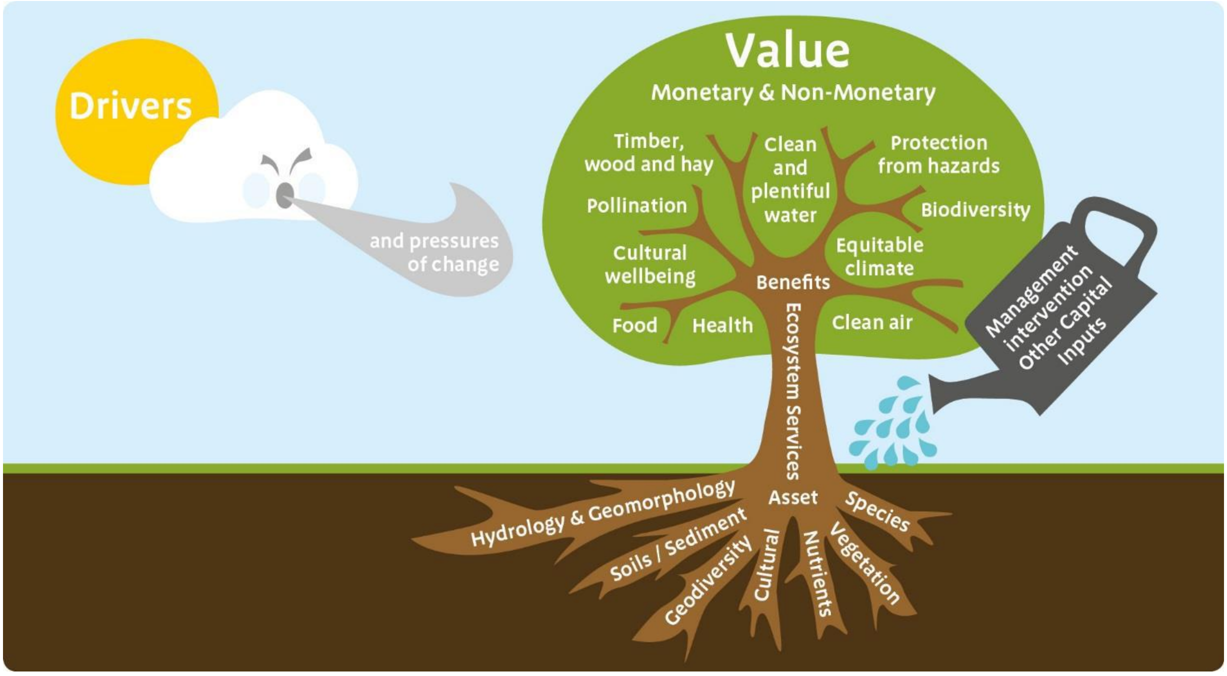

Figure 2 Key attributes of natural capital (from Natural England 2019[4])

1.2 Report structure and scope

It is important to set a natural capital assessment of peatland restoration within the policy context operating in Northern Ireland at present. Therefore, the report starts by presenting a summary of a policy review into peatland restoration in Northern Ireland in Section 2, with much more detail given in Annex A. We also present a conceptual framework for peatland restoration taking a natural capital perspective.

Section 3 presents a summary of the main methodological approach used in the assessment that follows. Sections 4 and 5 then present the key natural capital assessment and investment appraisals for the two sites: Garron Plateau (Section 4) and Montiaghs Moss (Section 5). Both assessments begin by describing and mapping the natural capital assets present across the study area and their condition, before summarising the proposed restoration works. A simple qualitative assessment of all ecosystem services provided by the sites and how these would change following restoration is then outlined, as this is able to capture a wider range of benefits than can be valued and highlights key ecosystem services. The following parts describe the physical and monetary flow accounts for the sites, and restoration costs. These costs and benefits are then brought together in an investment appraisal that considers the cash flow over 50 years and calculates net present value of the investment and the cost benefit ratio. Impact on employment is also briefly outlined.

A stakeholder analysis and assessment of likely winners and losers is presented in Section 6. The key findings and their implications are discussed in Section 7, including, implications for policy and support

[4] Sunderland, T., Waters, R.D., Marsh, D. V. K., Hudson, C., And Lusardi, J. (2019). Accounting for National Nature Reserves: A natural capital account of the National Nature Reserves managed by Natural England. Natural England Research Report 078.

for peatland restoration going forward, along with limitations and assumptions of the assessment. Recommendations are presented.

We have aimed to keep the main section of the report concise, with much additional technical information included in a number of Technical Annexes at the back, so please refer to those for much more detail. Please note that the assessment covers selected ecosystem services (natural capital benefits) for which information is available at the sites and which can be valued, and is not a complete assessment of all possible natural capital benefits and costs (although these are assessed qualitatively where possible). In particular, it should be noted that this is not a full biodiversity impact assessment and only uses data on habitats rather than species. We have not attempted to value biodiversity separately, as its different roles in ecosystem services are already embedded in the value of the ecosystem service flow, and this would risk double-counting.

2. Peatland restoration in Northern Ireland

2.1 Policy review

A review of policies affecting peatland management was undertaken, set in the context of increased awareness of the importance of peatlands for people and nature. This included links with the IUCN sponsored UK Peatland Strategy, the proposed peatland Strategy for Northern Ireland, the Land Strategy for Northern Ireland, and Northern Ireland's contribution to UK Net Zero. The links between peatland policy and other policy domains such as agricultural, rural and environmental policy, especially post Brexit, were also reviewed, alongside interactions with forestry, water resources and flood risk management. A brief summary of the key points emerging from the review is shown below, with the full review presented in Annex A.

Summary: key points

- **More than 80% of Northern Ireland's 242,000 ha of peatland are considered to be in a degraded state** due to decades of overgrazing, drainage and peat extraction. As a result, the potential benefits of peatlands for people and nature in terms of water quality, natural flood management, and wild places for people to enjoy are compromised.
- **A Peatland Strategy has been proposed to protect and restore peatlands** over the next 20 years and beyond. If this aligns with the IUCN Peatland Strategy it will set a target to place all degraded peatlands under sustainable management in order to secure their biodiversity and ecosystem functions for the benefit of people and nature.
- **Most peatlands in Northern Ireland, whether shallow organo- or deep peat soils, are used for livestock grazing or forestry.** Peatland land use is particularly influenced by agricultural and rural policy.
- **Leaving the European Union is perceived by DAERA to provide opportunities for greater regional discretion and flexibility in agricultural support.** The policy ambition is to achieve simultaneous improvements in the financial and environmental performance of farm businesses. In upland and disadvantaged areas, this is likely to involve special measures to help farmers to achieve sustainable returns from the assets at their disposal, including environmental assets.
- **The post-Brexit policy preference in Northern Ireland is broadly to maintain the status quo of direct farm income support and agri-environmental programmes, at least in the short term**. This contrasts with the English decision to phase out income support, replacing these with targeted farm development grants and an Environmental Land Management scheme (ELMs) that rewards farmers for providing public goods in the form of a range of ecosystem services.
- **Livestock farmers in Northern Ireland are extremely dependent on farm income support** and given current market, political and environmental uncertainties, are very vulnerable to any immediate policy change. In the medium to long term, however, it is likely that farmers will face greater policy or market driven incentives for High Nature Value farming. Peatland farmers are potentially well placed to benefit from these opportunities. Opportunities to incentivise and reward peatland restoration should be harnessed within Northern Ireland's future agriculture policy framework, which is currently being developed.
- **Peatlands have an important role in Northern Ireland's contribution to the UK obligation on climate change mitigation.** The 'Net Zero' target includes an ambition to restore all degraded

upland peatlands, and place a large proportion of lowland peat soils under sustainable management by 2045.

- **The restoration of peatland will play an important role in benefitting nature.** On both Garron Plateau and Montiaghs Moss, site restoration will provide benefits to a range of threatened priority species and habitats; the value of which is often difficult to accurately quantify. Biodiversity benefits are partially captured by current agri-environment payments, but these do not capture the true value.
- **Northern Ireland has 57 designated Special Areas of Conservation, the majority of which are in an unfavourable condition.** These include many peatland sites, including the Garron Plateau and Montiaghs Moss for which Conservation Management Plans are being prepared.
- **The Northern Ireland Peatland strategy may propose measures to prevent future tree planting and eventually remove existing coniferous forests on peat soils**. At present, half of Northern Ireland's commercial forestry of 75,000 ha occupies peatlands considered to have marginal agricultural value.
- **Peatland management can affect the supply of raw water quality, freshwater ecology and the control of flooding.** In this respect, peatland management interacts with key aspects of water policy and the responsibilities of associated regulatory bodies and service providers in the water sector. The Garron Plateau provides an example of these interactions.

2.2 Conceptual framework

The conceptual framework for this work is shown in Figure 3 (overleaf). It can be seen that pressures and policy drivers influence management practices in peatland areas. These management practices impact on peatland structure and function, which in turn affects the ecosystem services delivered and the benefits and values that are derived. The values placed on peatland services are ultimately determined by society, and changing attitudes and values lead to changes in policy drivers. Hence the process is cyclical, with impacts and feedbacks cascading through the system.

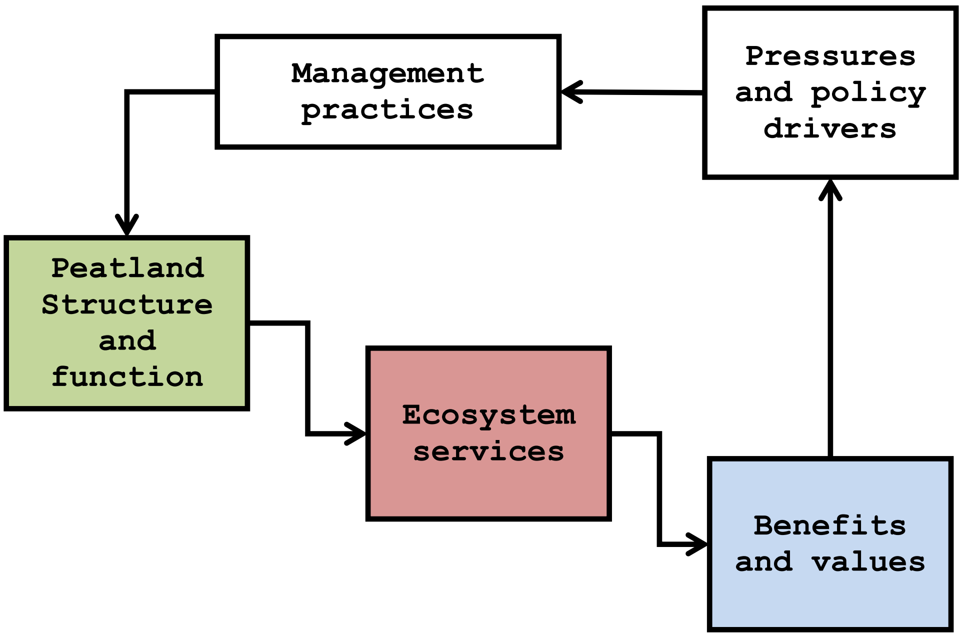

Figure 3 Conceptual framework, showing the management of peatlands and subsequent cascade of effects on peatland structure and function, ecosystem services, and the values and benefits derived (adapted from Potschin & Haines-Young 2011[5]).

[5] Potschin, M.B. & Haines-Young, R.H. 2011. Ecosystem services: exploring a geographical perspective. Progress in Physical Geography, 35: 575–594.

3. Outline of methodological approach

3.1 Scenarios

To assess the potential impact of peatland restoration, we developed two scenarios for each site, which are described below:

Scenario 1 – 2010 (pre-restoration)

This described the situation at the sites before restoration activities had taken place. For the Garron plateau this was assumed to be 2010, as a number of restoration activities have taken place since then. A condition assessment was carried out in 2010 and that was used to set the baseline condition for the habitats across the site, which were largely in unfavourable condition (see Section 4.1). For Montiaghs Moss the whole site was assumed to be in unfavourable condition, based on SAC condition assessment monitoring (Section 5.1).

For the Garron Plateau only, we also partially assessed the **2016** position, as this is the latest date from which condition data is available, and reflects a number of improvements in condition, following initial restoration works and grazing stock reductions. This is considered to be close to the current position at this site. We did not carry out a separate assessment for Montiaghs Moss as no significant restoration works have been undertaken to date.

Scenario 2 – 2045 (post-restoration)

The second scenario described the sites once restoration works have been completed, which was assumed to be 2045. This matches the timeline described in the policy analysis, by which all Northern Ireland's upland peatlands should be restored, and the majority of lowland peatland should be under sustainable management. For Garron Plateau, we are assuming that all habitats are in favourable condition by this point, coniferous woodland has been removed and blanket bog restored (see Section 4.2 for more details). For Montiaghs Moss it is assumed that the overall site will be in favourable condition (for marsh fritillary), but raised bog will not be restored (see Section 5.2).

3.2 Summary of methods

Full details of the methodology are provided in the Technical Annexes, with a brief outline of the approach described here and illustrated in Figure 4. The approach used, draws on the concepts of natural capital and economic valuation[6]. It also follows the broad approach to natural capital assessment outlined in "*How to do it: a natural capital workbook"* published by the Natural Capital Committee (2017).

The natural capital assets of the sites were first described and mapped. The condition of the habitats was determined based on SAC condition assessment monitoring for each site. The natural capital assets identified at each site deliver a range of ecosystem services, which provide benefits to people. Those that can be quantified and valued were assessed in the physical and monetary flow accounts (see below). However, there are still a number of ecosystem services that cannot be assessed in this way, hence a quantitative assessment (and a natural capital account) may not capture all the benefits provided by the site. A qualitative assessment was, therefore, conducted and is useful both as a

[6] Economic valuation quantifies the benefits that people gain as a result of the consumption of goods and services. It is based on welfare or well-being concepts where policy aims to maximise the welfare of society. The economic value of ecosystem services can be measured within the framework of 'total economic value' (TEV) (Defra 2007).

summary, and to provide a more comprehensive overview of the benefits provided by the natural resources in each area. It is also useful at drawing attention to key services and highlighting those that should be the focus of more detailed assessments. To do this, each ecosystem service was simply scored on a scale from 0-3, based on an expert assessment of the provision of each service at each site, determined using general principles and any data available. Note that these scores were separate to, and not used in, the calculation of the physical flows and monetised benefits of services used in the natural capital account and economic appraisal.

Next, indicators were used to measure the physical flow and monetary value of a number of ecosystem services. The services assessed are summarised in the short paragraphs below, with much more detail given in the Technical Annexes. Annual values were calculated for each service, as well as the present value (PV) of each service, which calculates the value of the flow of benefits over a 50-year period, using discount rates from HM Treasury. A detailed schedule of the restoration works already undertaken (at Garron) and those planned at both sites over the coming years, was prepared and the capital and maintenance costs were calculated. A cash flow was then created, taking into account the change in benefits as the sites were restored, and the costs of the works as they occurred, and projected over 50 years. The cash flow was summed to give the total net natural capital asset value and the cost benefit ratio.

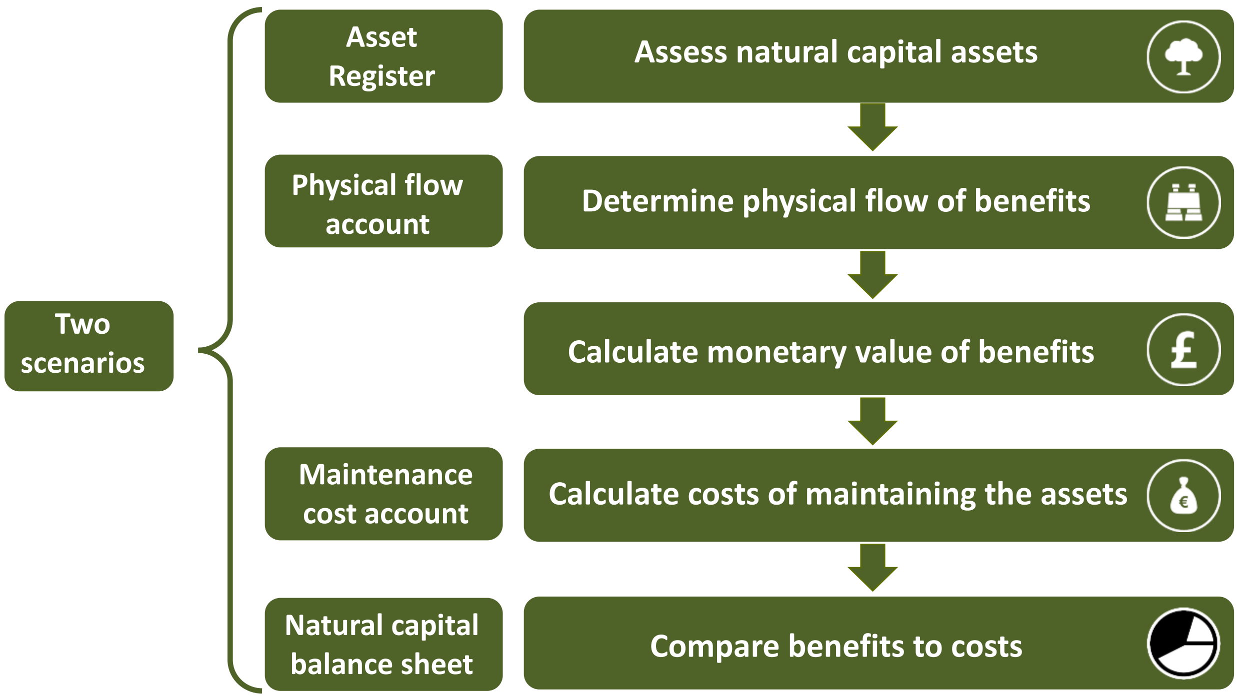

Figure 4 Outline of the assessment approach used for the Garron Plateau and Montiaghs Moss.

Carbon sequestration and storage

The carbon sequestration and greenhouse gas emissions (tCO_2e/ha/year) associated with the habitats at both sites was calculated, based on emissions factors taken from the scientific literature (see Annex B). Emissions differ, depending on whether the vegetation sits on deep or shallow peat. As this varies across the Garron Plateau, assumptions were made based on habitat type, following discussion with the steering group.

While carbon sequestration calculates the annual change in carbon balance at a site (an ecosystem flow that provides an annual benefit), carbon storage is concerned with the stock of carbon that is present (hence it is a natural capital stock, rather than an ecosystem service flow). Carbon storage calculations are based on estimates of bulk density, soil organic carbon concentration, and depth of peat. Given the number of uncertainties regarding peat depth and condition at the Garron, carbon storage has been estimated using three different methods at that site. Please see Annex B for further details of each method. At Montiaghs Moss, a single method could be used and the results expressed with greater confidence, as more studies have been carried out of lowland raised bogs in Northern Ireland than for blanket bogs (providing locally relevant parameter estimates), and peat depth was known with more certainty.

Carbon prices were based on BEIS carbon prices (£/tCO2 e) for the 2010-2100 period, expressed in 2018 prices, adjusted to 2021 prices using the ONS GDP deflators. The non-traded central price was taken as the base value for analysis, alongside the low and high non-traded price estimates. The impact on carbon benefits of using BEIS traded estimates were also considered, as well as the current Woodland Carbon Guarantee Auction price as an example of the current voluntary market value.

Water-related services

Viridian's HydroloGIS model was employed to understand how restoration of the Garron plateau would reduce flooding from local rivers, improve water quality and reduce erosion/siltation. The model investigates how water flows across the landscape and how these flows interact with soil and vegetation. The model considered the entire catchment areas for the Glenravel Water, the River Braid, Carnlough River, Glenariff River and the Black Burn, so that the benefits offered by restoring the Garron could be understood in terms of how the entire landscape functions.

The relative ability of the Garron to mitigate soil adsorbed pollution (such as phosphates), soluble pollution (such as nitrates) and particle export was calculated for the 2010 and 2045 scenarios. The model was run for the entirety of the river catchment in both scenarios, with the only changes between the two runs being the quality of habitats in the Garron. All other input data remained static for both runs. This identified the relative change in service provision that restoration will offer, which was then related to the reduction in phosphates and nitrates leaving the plateau due to restoration. Please refer to Annex C for further details.

The HydroloGIS modelling estimated the changes in water flow from the Garron Plateau associated with a change to favourable habitat conditions. To place a monetary value on this service, the impact of restoration on flows were phased according to the restoration schedule and were then moderated to assess likely changes in flood risk to properties within the 100-year flood event zone attributed to restoration activities. Change in the weighted average annual damage (WAAD) was then calculated, following the methods advised in the Multi-coloured (Flood and Coastal Erosion Risk) Manual[7] (Annex C).

Water treatment costs

Data on monthly volumes of treated water, raw water quality indicators and costs of selected treatment operating costs at Dungonnell WTW were provided by NIW. Data on chemical, energy and sludge disposal costs covered part or all of the period 2012 to 2020 during which phases 1 and 2 of the restoration works were carried out. An analysis explored the relationship between observed changes in water quality and unit costs (£/ML). The assessment was supported by a literature review and

[7] Penning-Rowsell, E., Priest, S., Parker, D., Morris, J., Tunstall, S., Viavattene, C., Chatterton, J. and Owen D. (2013) Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal, Routledge, Abingdon, Oxford

discussions with expert sources[8]. Estimates were derived of potential savings in treatment costs going forward. Full details of the methods, analysis and literature review are provided in Annex D.

Agricultural systems

Data was obtained from the Annual Farm Business Survey published by DAERA on the performance of livestock systems on lowland and uplands covering the period 2013/14 to 2018/19. Estimates were derived of key financial indicators in upland and lowland systems for less favoured and disadvantaged areas. Time series data were averaged using Agricultural Price indices to give 2021 values. Estimates were expressed in £/head and £/Livestock Unit. Changes in stocking rates (LU/ha) under different peatland management options were assessed and combined with £/LU to give changes in financial returns. The key indicator used was Net Margin £/LU, which included charges for selected so-called fixed costs at the farm scale. Land costs and income support were excluded, and a proportion of unpaid family labour was charged. Thus, the estimates indicate economic value added. Full details are provided in Annex E.

Agri-environment

Data was obtained from the site managers at the study sites on the type, areas and payment rates of environmental options taken up by land managers under the previous Countryside Management Scheme and the more recent Environment Farming Scheme. Predictions were made of likely future uptake in response to campaigns. Note, however, that some areas of the Garron Plateau are under Commonage, and these are areas which are not currently eligible for agri-environment scheme support.

Forestry

An assessment was made of the potential loss of value added, by prematurely removing coniferous trees in 'priority' areas. Two areas of forestry are located adjacent to the Garron Plateau and in each area a 'primary restoration opportunity area' had been identified, along with a larger 'policy opportunity area'[9]. The former areas were scheduled for early felling, while the latter areas were felled on maturity. Species mix, yield class and areas were obtained from the same report, and estimates were based on reported tree yield class, expected growth rate and current timber prices series, following Forest Research guidance[10]. See Annex F for further details.

Recreation

The value of recreational visits was assessed for Montiaghs Moss, but not for the Garron Plateau, due to the lack of any data on visitor numbers at the latter site and the assumption made by the steering group that it receives very few visits. Given the limited opportunities for spending at Montiaghs Moss we use recreational value derived by Sen et al. (2014) from a meta-analysis of just under 300 previous assessments of the value of outdoor recreational visits to different habitat types in Great Britain. The physical flow of the recreation service to sites (number of visits) was estimated by the site manager. The annual monetary flow for recreation was estimated by multiplying the number of visits by the per person per trip recreational value for moors and heathlands from Sen et al. (2014), inflated to 2021 prices. Note that this was derived from studies in Great Britain rather than Northern Ireland, but as Sen

[8] Dr Ray Flynn, Queen's University; Prof Peter Jarvis, Cranfield University; Prof Joe Holden, Leeds University; Rebecca Allen, NI Water; Roy Taylor, NI Water.

[9] Allen and Mellon 2015. Options for the restoration of afforested peatlands in Northern Ireland – a scoping study. Report for RSPB Northern Ireland.

[10] Matthews, R.W, Jenkins, T.A.R., Mackie, E.D., and Dick, E.C. 2016. Forest Yield: A handbook on forest growth and yield tables for British Forestry Commission, Edinburgh.

et al. (2014) is a meta-analysis of a large number of studies and there is no equivalent data from Northern Ireland, it was considered an appropriate source to use.

Peatland costs

An extensive review of peatland restoration costs was carried out involving a literature review and contact with organisations involved in restoration works, especially in the north of England. Recent UK wide reviews carried out under the Peatland Action Programme for Scotland were particularly useful[11]. Estimates were derived of capital costs, including design and supervision, for a range of restoration activities reflecting differences in context. Data on restoration capital costs were also available from the earlier phases of restoration works on the Garron Plateau. A range of estimates expressed in 2021 prices were derived for capital and annual maintenance costs, the latter distinguishing between recovery and favourable restoration conditions. Please refer to Annex G for the full literature review and cost details.

Appraisal method

Benefits and costs were estimated over a 50-year project life for the Garron Plateau and the Montiaghs Moss restoration projects. Constant 2021 prices were used throughout, inflation adjusted using ONS GDP deflators or agricultural prices series where required.

The Garron assessment covers the period 2010 to 2060 to include the works carried out in the earlier phases of the projects. The 2010 situation is the counterfactual (Scenario 1). The Montiaghs assessment begins 2021 through to 2071, against the 2020 counterfactual (Scenario 1). It is noted that the counterfactual is assumed to be fixed and constant. In the absence of the interventions, the counterfactual could be one of peatland degradation, especially under climate change. This would increase the expected performance of the restoration projects.

The assessment adopts an economic perspective, excluding taxes and subsidies. Land costs are excluded. Unpaid farm labour and volunteer time is charged at appropriate rates. Farm income support is excluded, EFS payments are used here to provide cost-based estimates of the environmental gains associated with agri-environment options taken up by farmers. It is recognised, however, that this grossly underestimates the additional value of biodiversity outcomes that are for the most part non-market, public goods that do not lend themselves to monetary valuation. Net Present Value and Benefit Cost Ratio are estimated at the Treasury Discount Rates, as well as Internal Rates of Return. A sensitivity analysis uses alternative price estimates and switch values.

[11] Glenk, K. Novo, P., Roberts, M., Sposato, M., Martin-Ortega, J., Shirkhorshidi, M., and Potts, J. (2020). The costs of peatland restoration. Analysis of an evolving database based on the Peatland Action Programme in Scotland. SEFARI report.

4. Natural capital account for the Garron Plateau

4.1 Site overview and natural capital asset register

The Garron Plateau in Country Antrim contains the largest area of intact blanket bog in Northern Ireland. The peatland supports an array of flora and fauna, which include a number of rare and notable plant and animal species, and a diverse upland breeding bird population. This includes critically endangered species such as breeding hen harrier, merlin and curlew and rare plants such as marsh saxifrage and bog orchid, many of which have declined in recent years. The upland area generally lies between 330 and 360m above sea level, with a maximum height of 440m. The site also holds the Dungonnell Reservoir and water treatment works, operated by NI Water, which supplies drinking water to approximately 14,000 homes in Ballymena and the surrounding area.

The Garron Plateau has been designated as an Area of Special Scientific interest (ASSI), Special Area of Conservation (SAC) a Wetland of International Importance (Ramsar site), whilst the site makes up a large proportion of the Antrim Hills Special Protection Area (SPA). The study area comprised the whole of the SAC/SPA, along with some additional adjoining areas of coniferous forestry and farmland. The total study area was 5,395 ha.

Table 1 Area and percentage cover of habitat types across the Garron Plateau study area

Habitat type	Area	% Cover
Blanket bog	2960.1	54.9
Purple moor grass and rush pasture and other wet grasslands	852.6	15.8
Wet heathland	718.4	13.3
Dry heathland	55.5	1.0
Transition Mire	13.2	0.2
Alkaline fens	10.9	0.2
Semi-natural dry grasslands	13.1	0.2
Oligotrophic standing water	37.7	0.7
Dystrophic standing water	21.7	0.4
Coniferous woodland	350.6	6.5
Farmland	360.6	6.7
TOTAL	**5394.5**	**100**

Detailed habitat information was provided by the site managers, which divided the site into 934 separate polygons. Within each polygon, the % cover of each habitat type present was recorded (usually multiple habitat types were present on each polygon). This was manipulated in GIS to determine the overall % cover of each habitat type across the Garron Plateau, and this is shown in the natural capital asset register (Table 1). The study area is dominated by blanket bog, accounting for 55% of the area. Purple moor grass and rush pasture (15.8%) and wet heathland (13.3%) occupy significant areas and the main bog area also contains a number of oligotrophic and dystrophic pools. Coniferous woodland blocks to the north and south of the main area (planted on deep peat) take up 6.5% of the study area, and farmland around the edges account for another 6.7%.

For statutory reporting of condition, the site has been divided into 31 units (the NI Water area is divided into 5 separate plots). By overlaying the condition assessment of each main habitat type within each management unit, with the detailed habitat information for each polygon described above, we tabulated information on the amount and condition of all habitats across the site. Table 2 shows that 94.5% of the site was assessed to be in unfavourable condition in 2010, with 5.3% considered to be unfavourable recovering and just 0.3% considered to be in favourable condition. Figure 5 shows habitat and its condition across the site in 2010, focussing on the dominant habitat in each of the 934 polygons.

Table 2 Condition assessment for the Garron Plateau in 2010, 2016 and projection for 2045, showing the overall percentage of the site in each condition category.

Condition (%)	2010	2016	2045
Unfavourable	94.5	43.5	
Unfavourable recovering	5.3	26.8	
Favourable	0.3	27.6	100
Unknown		2.2	

4.2 Restoration works and impact on condition

Restoration works at the Garron Plateau began after 2010, although there had already been a reduction in grazing in preceding years. The details are described more fully in Annex G, but included a significant reduction in stocking density across the site, drain blocking and the installation of 2,137 dams in the NI Water area. Some of this work was completed before 2016 and the impact on condition was already clear. Table 2 shows that by this date, 27.9% of the site had returned to a favourable condition, with a further 26.8% assessed as being in unfavourable recovering condition. Figure 6 shows the dominant habitats and condition in 2016 and the changes compared to 2010 (Figure 5) are clear.

Ongoing proposed restoration works, including the blocking of additional drains, and the removal of the coniferous forestry parcels and restoration of the blanket bog in their place, will occur over a number of years. A detailed schedule of works was developed and costed (Section 4.5). By 2045 the aim is to for the whole site to be in favourable condition.

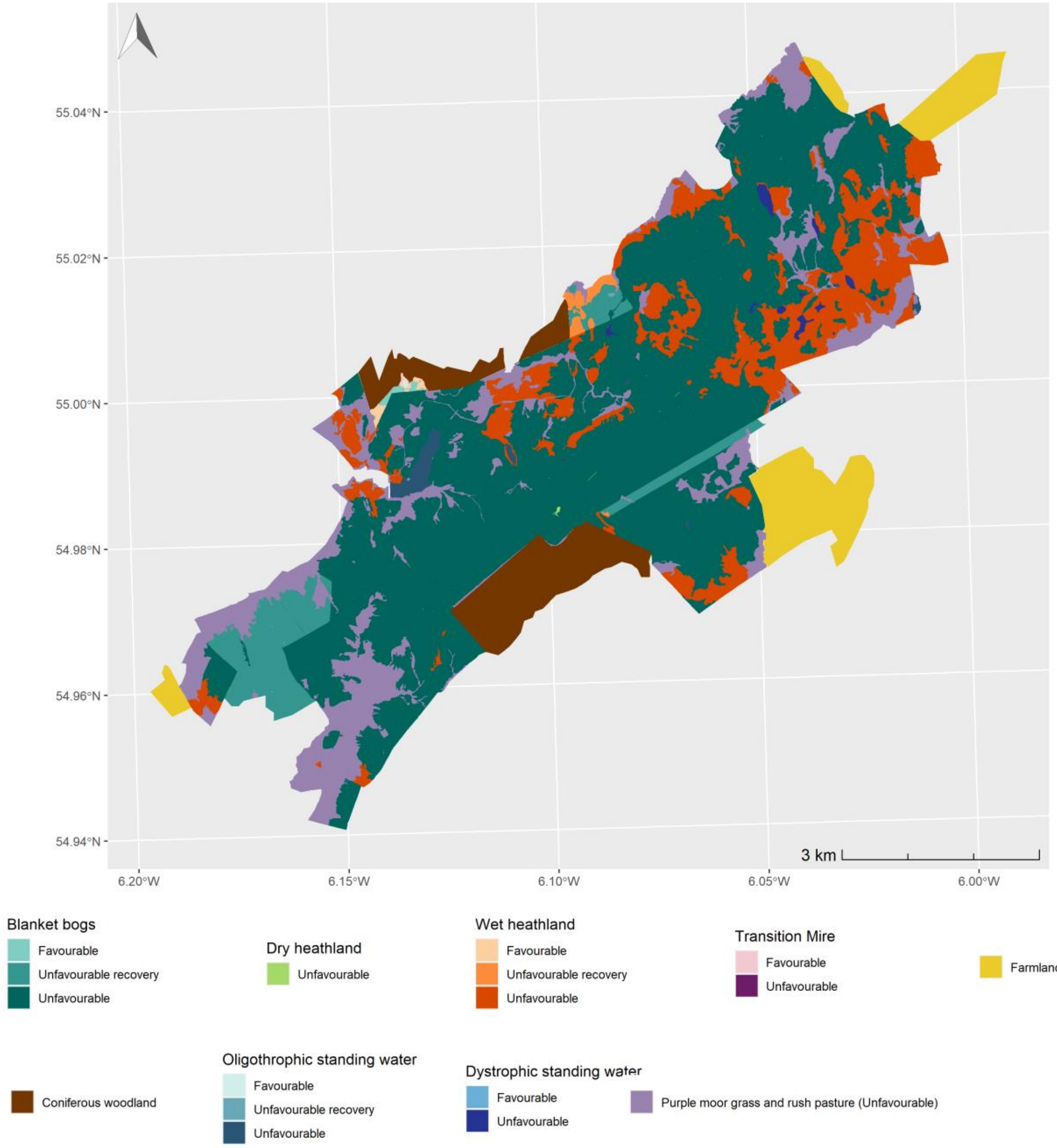

Figure 5 Habitats and condition across the Garron Plateau in 2010. The map shows the dominant habitat in each of 934 polygons, along with surrounding farmland and coniferous forestry areas.

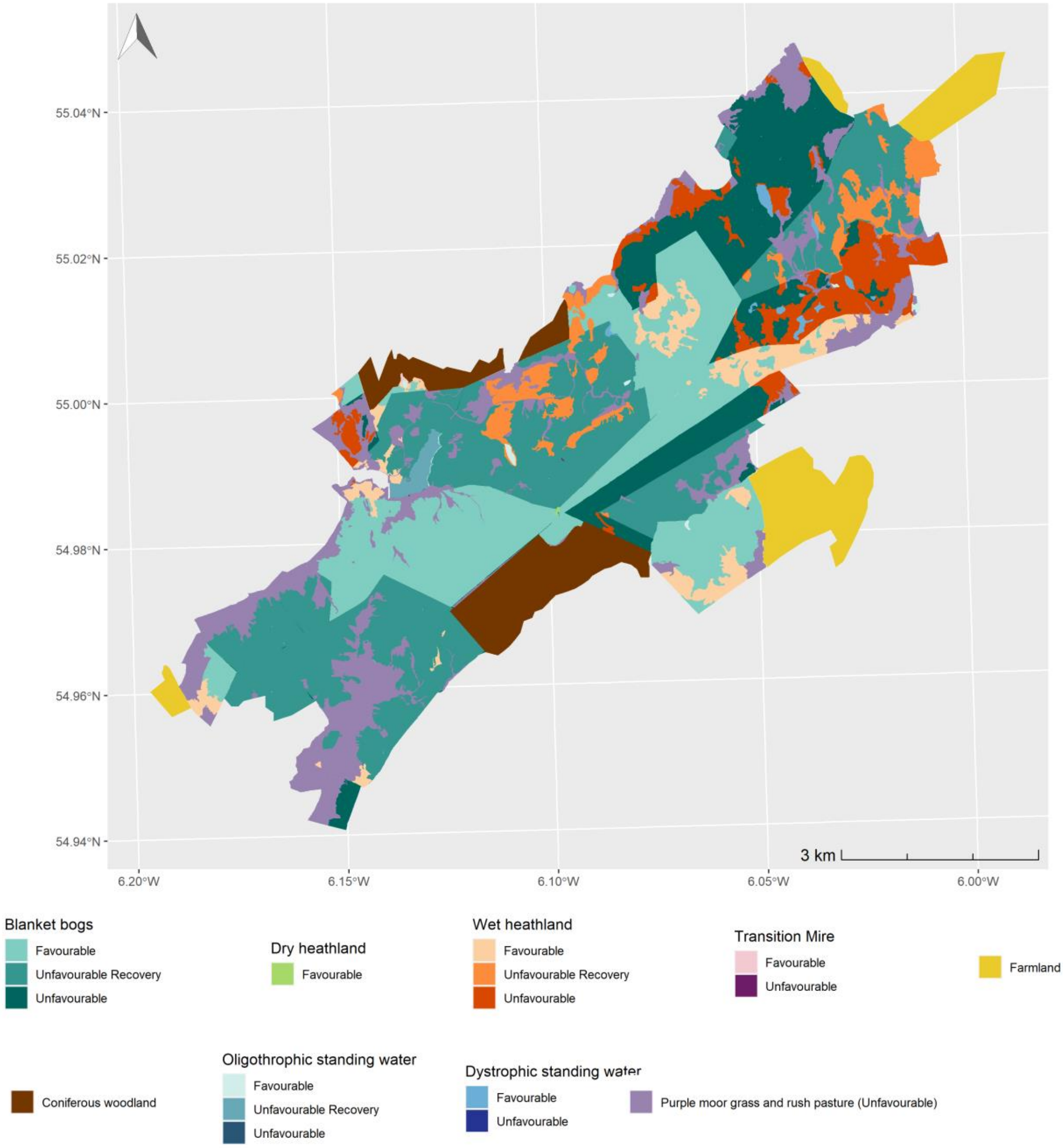

Figure 6 Habitats and condition across the Garron Plateau in 2016. The map shows the dominant habitat in each of 934 polygons, along with surrounding farmland and coniferous forestry areas.

4.3 Qualitative assessment of ecosystem service flows

The qualitative assessment of ecosystem services currently provided by Garron plateau is presented in Table 3. Provisioning services are relatively important at the site; it is a major source of drinking water via the Dungonnell Reservoir and there were also moderate levels of livestock (sheep) and wool production in 2010, although it is an upland low intensity system. Commercial forestry operations occur on the fringes, although some of these areas are particularly low in yield. Previously, the site had been used for peat cutting for fuel, but that practice no longer occurs. Livestock, fibre and timber production will fall under the 2045 (restoration scenario, but the site remains important as a drinking water source. There may be opportunities in future for new forms of biomass production under wet peatland conditions (paludiculture), including sphagnum farming.

Table 3 Estimated ecosystem service provision scores for Garron Plateau: 0 - no delivery; 1 – some delivery, 2 -significant delivery, 3 - very significant delivery. List of ecosystem services adapted from CICES v5.1.

Ecosystem service category	Ecosystem service	Estimated provision	
		2010	2045
Provisioning	Food: crop and livestock production	2	1
	Fibre and fuel (timber, woodfuel, wool etc.)	2	1
	Water (includes for drinking, agriculture & industry)	3	3
Regulating	Carbon sequestration and storage	2	3
	Local climate regulation	1	1
	Air quality regulation	1	1
	Water quality regulation and erosion control	2	3
	Water flow regulation	2	3
	Pollination	1	1
	Pest and disease control	1	1
	Noise attenuation	0	0
	Soil quality regulation	2	3
	Habitat and population maintenance (biodiversity)	2	3
Cultural	Aesthetic experiences	2	3
	Education, training and scientific investigation	2	3
	Recreation and tourism	1	2
	Health and well-being	1	2
	Characteristics and features of biodiversity that are valued (existence, option, bequest)	2	3
	Spiritual and cultural experiences	1	2

Most regulating services produce benefits at low to moderate levels in 2010. Blanket bogs and other upland habitats are significant at delivering water quality regulation, water flow regulation and soil quality regulation benefits, but due to the unfavourable condition of the site, these are not producing as many benefits as they could. These benefits will increase to very significant levels following restoration (2045). The habitats at Garron can provide some benefits in terms of local climate regulation and air quality regulations, but due to it's location, far away from any major settlement or main road, these benefits will be limited. Upland peatlands are a highly significant store of carbon, but the site will be performing badly for carbon sequestration in 2010, due to the unfavourable condition of the habitats. This will improve following restoration and is assessed in much more detail in the Section 4.3. Biodiversity benefits are considered to be significant at present, as the site is an SAC and supports a number of upland species, and this will increase further following restoration.

Cultural services at the site are generally moderate to low under the 2010 scenario. Those that rely on visitors (recreation, health and wellbeing, spiritual experience) are considered to be low in 2010, due to the low number of visitors, but those that rely less on visitors (aesthetics, characteristics and features of biodiversity that are valued) are considered to be of moderate significance in 2010. The Garron Plateau has been subject to a number of scientific studies, relating to hydrology, carbon, water quality and biodiversity, hence the site is moderately important for Education, training and scientific investigation. By 2045, most of these cultural services are likely to have increased and is likely to be moderately or highly significant for these services. It is likely that the site will remain relatively unvisited, although numbers may increase a bit, hence those services that rely on visitors will not achieve the highest scores. Biodiversity and aesthetic features are likely to be enhanced further and the restoration works and the monitoring put in place by NI Water and the RSPB, mean that the site will increase in importance for scientific research and education as an exemplar into the impact of peatland restoration on a large upland site.

4.4 Physical and monetary flow accounts

Carbon sequestration

All habitat types lying on deep peat emit carbon, although there is a large variation depending on both the type and condition of the habitats (Table 4). Drained and degraded habitats emit more carbon than undrained or restored habitats, and forestry on deep peat leads to particularly high emissions.

Table 4 Typical emissions from different habitats on deep peat soils

Land cover	Total GHG tCO_2e/ha/year
Degraded bog	-4.85
Rewetted bog	-0.81
Near natural bog	-0.01
Grass/heather-dominated undrained bog	-2.08
Grass/heather dominated drained bog	-3.40
Woodland	-9.91
Bare peat	-13.84

Source: Defra Peat Pilot (2020)[12] and Evans et al (2017)[13]

Before restoration (2010) the Garron Plateau was dominated by blanket bog in unfavourable (degraded) condition, hence it was a major emitter of carbon (Table 5). Peatland restoration activities performed to date, primarily through reductions in grazing and re-wetting of drains over parts of the area, has meant that significant areas of blanket bog can now be classified as rewetted or restored, leading to large reductions in the quantity and value of carbon emissions (Table 5). This process will continue as restoration is continued, with the Garron Plateau eventually moving from being a net emitter of CO_2 to a net sequester. Note that no areas of deep peat will sequester carbon, as even near natural bog emits carbon at a very low rate (this is the best performing habitat on deep peat), but heathland and other habitats on shallow peat on the Garron are able to sequester carbon and this more than compensates for the very low rates of emissions from the deep peat areas under Scenario 2. Removing coniferous woodlands and restoring blanket bog in these locations, will be particularly beneficial on a per hectare basis.

[12] Smart, T., Caporn, S., Field, C., Johnson, S., Rogers, K., Rowson, J., Thomas, P., Wright, A., (2020) Defra peat pilot - Greater Manchester.

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

Table 5 Total carbon sequestration across the Garron Plateau, mean per hectare, and change, for the three time periods. Negative scores indicate net emissions and positive scores indicate net sequestration.

Carbon sequestration	2010	2016	2045
Total emissions (tCO_2e/yr)	-16,772	-6,738	1,146
Mean per ha (tCO_2e/yr)	-3.11	-1.25	0.21
Change (tCO_2e/yr)		10,034	7,884
Overall change (tCO_2e/yr)			17,918

The monetary value of these reductions in emissions can be calculated, based on the UK Government non-traded carbon price (£77.41 per tonne in 2021 prices). Given the large size of the site and the large change in emissions, these values are very high (Table 6). However, estimates of the value of reduced carbon emissions are very sensitive to assumptions regarding future carbon prices, and this is investigated further in Section 4.5.

Table 6 Annual monetary value of carbon sequestration across the Garron Plateau, mean per hectare and change, for the three time periods. All values are in 2021 prices and are based on the UK Government non-traded carbon price (central estimate).

Carbon valuation (£2021)	2010	2016	2045
Total value (£/yr)	-£1,298,245	-£521,581	£88,733
Mean per ha (£/yr)	-£240.66	-£96.70	£16.45
Change (£/yr)		£776,664	£610,314
Overall change (£/yr)			£1,386,978

Assumes changes in carbon emissions valued at the carbon price for year 2021 not for the year of occurrence.

Carbon storage

Given the uncertainties in measuring carbon storage, particularly due to the lack of data from the Garron on peat depth and bulk density, we used three alternative methods. Results (Table 7) showed that very large quantities of carbon are stored at the site, ranging from 6.27M tonnes to 9.88M tonnes, depending on the method used. Even these alternative calculations were based on some major assumptions concerning peat depth, hence the results should be treated with caution, and should be seen as indicative rather than an accurate amount. The Lindsay (2010) approach was considered to be the most reliable given the condition of the peatland and data availability for the Garron, hence carbon storage of around 8.1 million tonnes is suggested, but with a high degree of error around that figure.

Table 7 Total carbon storage for the Garron Plateau and carbon storage per hectare, using three alternative calculation methods.

Caron storage calculation method	Total C stored (tonnes)	tonnes per ha
Cannell et al. (1993) Assuming a natural bog and multiplying by a standard cubic metre of peat	6.27M	1163
Lindsay (2010) Assuming that the moor has a disturbed upper (haplotelmic) layer and multiplying by a standard cubic metre of peat	8.14M	1509
Chapman et al. (2015) Applying bulk density from three peat depths to each hectare of the site	9.88M	1831

Water-related services

Figures 7 and 8 show how the relative provision of water-related ecosystem services change between 2010 and 2045, assuming that there is little change across the landscape other than restoration of the Garron. The darker blue colours show high service provision to mitigate flooding, soil adsorbed pollution, soluble pollution and erosion/siltation simultaneously; the pale buff colours show low provision of such services. These maps show the results for all four services combined. There is a clear and substantial improvement of service provision between 2010 and 2045, as quantified in Table 8, with full details of the results presented in Annex C.

Table 8 quantifies the changes in ecosystem service provision shown visually in the preceding maps. Every 5m-by-5m cell across these catchments was assigned a value for how well it was working to mitigate the water problems compared to all other pixels. These values were normalised due to the variety of biophysical attributes being calculated, but their scale between 1 and 0 retains meaning.

The numbers in the 2010 and 2045 columns are the sum of these normalised values across all cells. Their percentage change between 2010 and 2045 quantifies the relative change in service provision between these dates. Translating this relative change in flooding, pollution and erosion can only be translated into physical quantities through appropriate monitoring. This monitoring is only partially available for Garron, so various approximations and assumption have been used for the economic assessment.

Table 8 Normalised scores for water-based services, and relative changes in provision between 2010 and 2045.

Water based services	2010	2045	% Change
Flood mitigation	207,230	151,909	26.7
P analysis	185,264	163,364	11.8
N analysis	208,433	194,651	6.6
Erosion analysis	202,413	146,041	27.8

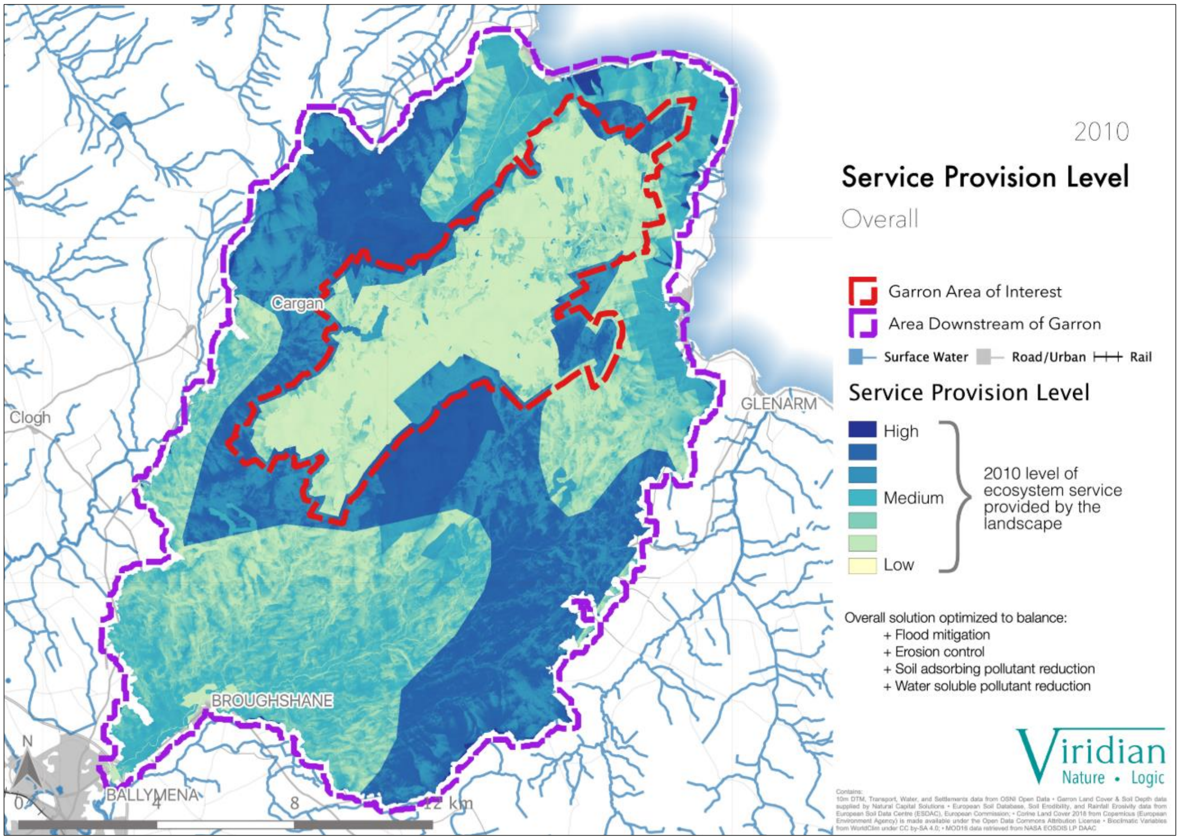

Figure 7 (above) Relative provision of water-related services in 2010.

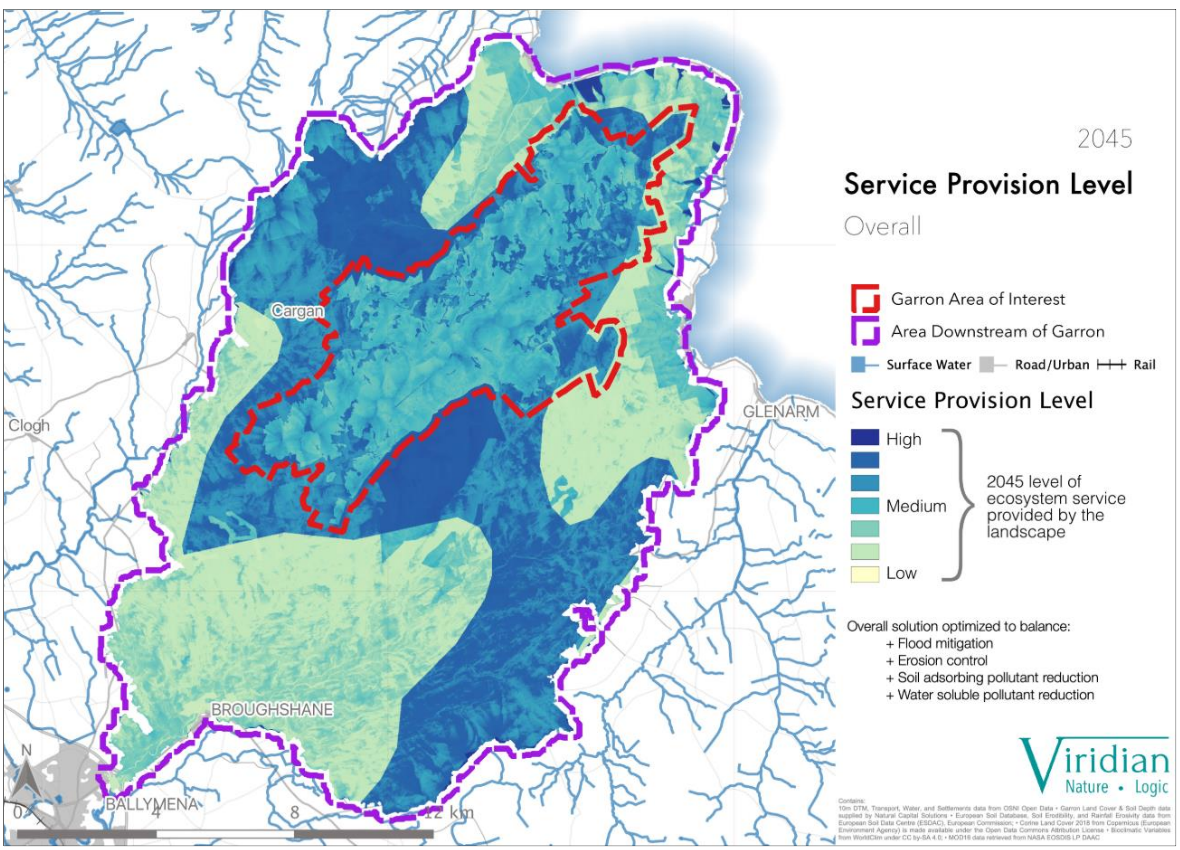

Figure 8 Relative provision of water-related services in 2045**.**

Table 8 shows the relative change in service provision for the Garron alone, but these values were also calculated for the entire rive catchment. The rivers are affected by drainage from the entire catchment, so changes made in the Garron will have a diluted effect on the river system as a whole. Restoration of the Garron will increase the ecosystem service provision across the entire river catchments to the following degree:

- Flood mitigation 6.3%
- Phosphate mitigation 2.8%
- Nitrate mitigation 1.5%
- Erosion mitigation 7.3%.

Reduction in water flows from the Garron Plateau due to land restoration have potential to reduce risks to properties in flood receptor areas. 180 residences were identified at risk for the 100-year flood event. The reduction in weighted average annual damage costs is £55,953 (Table 9) at full restoration (2045).

Table 9 Changes in annual flood related costs attributable to peatland restoration 2010 through to 2045 (full restoration), Garron Plateau.

Flood risk management	2010	2016	2045	Difference 2045 -2010
Reduction in Weighted Average Annual Damage (WAAD) £/yr	5,154	19,930	61,107	55,953

Water quality and water treatment costs

Although significant improvements in raw water quality are associated with the peatland restoration works to date (see Annex D), there is not yet conclusive evidence from available data to show that these have translated into reduction in water treatment operating costs, possibly due to other factors. It is expected that reductions in turbidity in particular can lead to reductions in chemical, energy and sludge management costs. Estimates are made based on evidence elsewhere of changes in treatment costs linked to turbidity applied to the cost profile of the Dungonnell WTW, pending further assessment (Table 10). The estimates are considered to underestimate potential benefit. See Annex D for a much more complete analysis of changes in water quality and impacts on water treatment costs at the Garron.

Table 10 Changes in annual water treatment costs attributable to peatland restoration 2010 through to 2045 (full restoration), Garron Plateau.

Water quality	2010	2016	2045	Difference 2045 -2010
Savings in water treatment costs (£)	0	0	4,158 (low) 8,663 (central) 17,325 (high)	4,158 (low) 8,663 (central) 17,325 (high)

Agriculture

Numbers of sheep and stocking rates (Livestock Units (LU)/ha) have reduced since 2010, and are expected to continue to do so (1 LU equals about 7 ewes and their lambs). This has been associated with restoration works and take up of agri-environment options, including agreements with NIW. The estimates of net margin presented here (Table 11) exclude direct farm income support, land costs and some farm scale fixed costs. Please see Annex E for much more information. Note that net margins for livestock systems in Northern Ireland (and elsewhere) are extremely low, with farmers relying on income support.

Table 11 Changes in agricultural production and annual value 2010 through to 2045 (full restoration), Garron Plateau.

Agricultural production	2010	2016	2045	Difference 2045 -2010
Livestock units	1,182	853	388	-794
Net Margin £/LU*	15.4	15.4	15.4	0
Total £ Net Margin	18,212	13,137	5,979	-12,235

*Net margin assumes partial fixed costs only excluding land.

Agri-environment (EFS)

Participation in agri-environment schemes has increased substantially since 2010, initially under Countryside Management Schemes (CMS and predecessors) and more recently under the Environmental Farm Scheme (EFS). Following promotion under the EFS going through to 2014, participation rates are approaching 50% of the eligible area. This is targeted to rise to 85% following campaigns to increase take up in communal grazing areas. This provides significant annual income for the Garron Plateau as shown in Table 12.

Table 12 Changes in take up and annual value of agri-environment schemes 2010 through to 2045 (full restoration), Garron Plateau.

Agri-environment	2010	2016	2045	Difference 2045 -2010
Area under schemes (ha)	900	2386	3895	2995 (+332%)
Average Payment £/ha *	41	41	45	4
Total payments £	36,780	113,160	196,300	159,520 (+433%)

* based on 2021 payment rates.

Forestry

Under the proposed restoration, coniferous forestry planted on deep peat to the north and south of the main site, will be cleared and the land restored to blanket bog. Hence the value of the forestry in those areas will drop to zero in 2045 (Table 13). However, only a small amount of the value of the forestry will actually be lost. Under the proposed restoration plan presented in this assessment, the areas of Cleggan and Glenariff forest identified as “primary restoration opportunity areas” will be felled early, but the larger “policy opportunity areas” would be felled on or close to maturity, meaning that the timber value would be extracted before the conversion to blanket bog. Furthermore, Glenariff is due to mature and be felled relatively soon, so the losses compared to normal felling would be minimal. It is only in the Cleggan restoration area that there would be some losses. Further details of the forest areas and the projected losses are provided in Annex F.

Table 13 Changes in annual timber volume and value 2010 through to 2045 (full restoration), Garron Plateau.

Timber	2010	2016	2045	Difference 2045 -2010
Annual volume of timber m^3	3,850	3,850	0	3,850
Annual value £	103,171	103,171	0	103,171

4.5 Restoration and maintenance costs account

An extensive review of peatland restoration work and costs across the UK and Ireland was carried out. In addition, details were obtained on the costs of the restoration works already carried out on the Garron Plateau. The review is included as Annex G. There was variation in the reported costs, due to variation in site conditions, restoration needs (as this affects required combinations of interventions), scale and management context, with conversion of forest to bog being the most expensive intervention.

From this review, estimates were derived for capital (Annex G, Tables G4) and annual maintenance costs (Table G6) for the Garron Plateau, which were used to calculate costs of the planned works over the project lifetime. A summary of the Present Value of these works, over 50 years, is shown in Table 14 in the next section.

4.6 Investment appraisal of peatland restoration on Garron Plateau

Over a 50 year period, 2010 to 2060, the central estimates of benefits and costs in 2021 prices for the Garron Restoration project give a Net Present Value of £37.3 million at the Treasury Discount rates and a Benefit Cost Ratio of 3.91 : 1 (Table 14). The Internal rate of Return is about 95%, reflecting the high benefit streams relative to costs in the early years of the Garron restoration project's appraisal period, notably prior to 2021, result in relatively high internal rates of return especially when high carbon prices are assumed. Thus, project feasibility is not sensitive to the discount rate.

Changes in carbon emissions (tCO_2e), valued at the Government’s non-traded price series for carbon (£/tCO_2e), account for about 92% of total benefits. About 6.5% of Present Value (PV) benefits are attributable to biodiversity benefits based here on agri-environment payments (the management costs of which included in project maintenance and operation costs). Flood risk management benefits account for about 1.5% of total benefits, while water treatment benefits account for 0.2%, although these are considered to be underestimated.

Regarding costs, over 63% of PV costs related to Maintenance and Operations, for the restoration recovery periods and subsequent maintenance of favourable conditions. Staff employment costs, and related costs including transport, materials, also volunteer time account for about 22%. No replacement capital costs for restoration works are assumed during project life in addition to those covered during ‘recovery’ and ‘favourable condition’ periods.

Table 14 Estimated Present Value of Cash Flows

50 Year Project Life, £$_{2021}$ prices. Summary Discounted Cash Flow	Present Value £ million	%	Switch values*
Benefits			
Carbon	46.26	92.4%	0.195
Agriculture	-0.20	-0.4%	ns
Forestry	-0.13	-0.3%	ns
Agri-environment	3.24	6.5%	ns
Flood Risk Management	0.77	1.5%	ns
Water treatment	0.12	0.2%	ns
PV Total Benefits at DR**	**50.06**	100.0%	
Costs			
Capital	1.45	11.3%	26
Extra Maintenance and Operations	8.01	62.6%	5
Extra Staffing and costs	2.79	21.8%	14
Contingency	0.54	4.2%	ns
PV Total Costs at DR**	**12.80**	100.0%	
Net Present Value (NPV) at DR (£M)	**37.27**		
B:C ratio	**3.91**		
Internal Rate of Return	**95%**		

* change in value of component to make NPV = 0 at the test discount rate**.** Ns = not significant

** discount rate (DR): years 1-30 at 3.5%, years 31-50 at 3%

Estimates of project performance were also obtained for low and high values for the main benefit and cost streams. Project performance is very sensitive to assumptions about the price of carbon. A switch in the carbon price equivalent to 19.5% of the central non-traded carbon price used would make the project break even at the test discount rate. The project is not very sensitive to other benefit streams considered individually.

Regarding costs, capital costs would need to increase by 26 times the base assumption to make the project cost more than the benefits delivered. Any need for replacement restoration capital works could be covered without prejudicing the project. Maintenance costs could rise by 5 times before the project would be compromised for the base assumptions. These switch values are within the range between high and low estimates for benefit and costs components.

Estimated project performance depends on the assumption of future carbon prices. The central estimate (indicated by 100% in Figure 9) is the BEIS non-traded central estimate (£77.4/t CO_2e for year 2021 in 2021 prices). The effect on NPV, Benefit Cost Ratio and IRR% of variations from this central carbon price is shown in Figure 9.

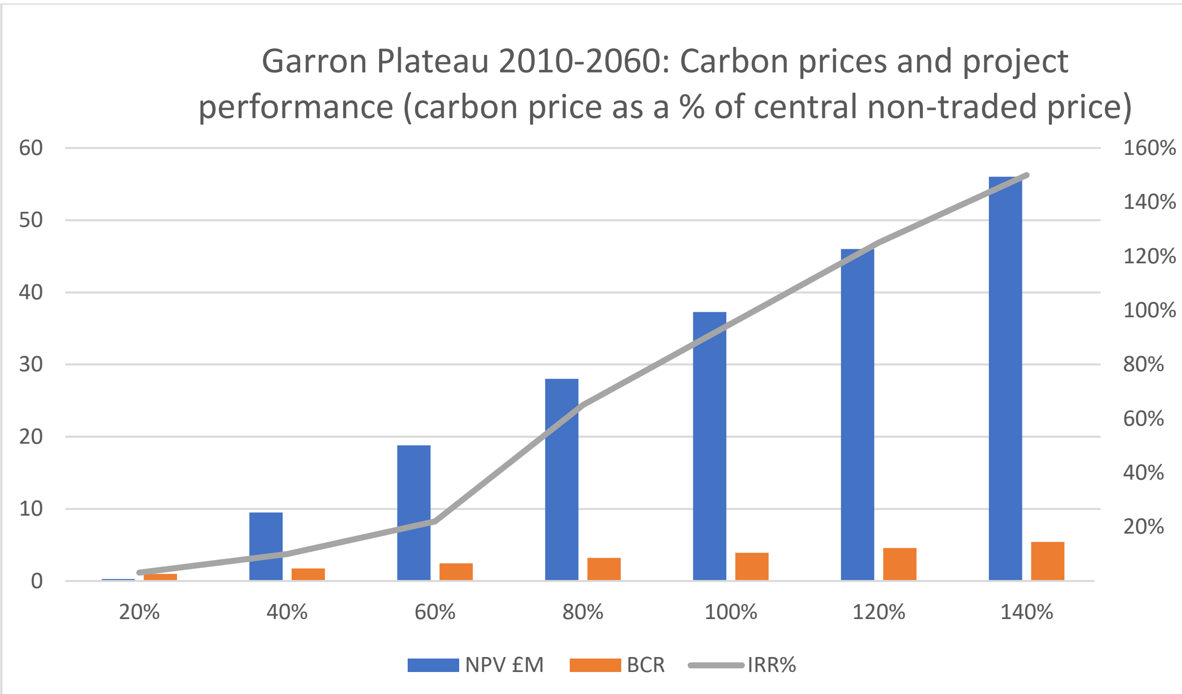

Figure 9 The effect of changes in carbon prices (£/tCO2e) on the performance of the Garron peatland Restoration Project. NPV = Net Present Value, BCR = Benefit cost ratio, IRR = Internal Rate of Return (right hand axis).

The effect on Benefit Cost Ration (BCR) of different carbon assumptions relative to the 2021 central price is shown in Table 15 (overleaf). The most recent trading price for the Woodland Carbon Guarantee third auction is £17.31, 22% of the 2021 central non-traded carbon price used here. The project just breaks even at this relative price. Traded and voluntary market prices are expected to rise in future as the market develops. The traded and voluntary market prices of carbon reflect the current ability to monetise the value of carbon, rather than the true social value of carbon which is captured in the BEIS non-traded estimate used above (see Section 7 for further discussion of carbon prices).

Table 15: The effect of alternative carbon prices (£/t CO2e) on the Benefit Cost Ratio for the Garron Plateau Peatland Restoration

Carbon prices 2021	% of central non-traded price	BCR at Test DR
Non-traded low	51%	2.1
Non-traded central	100%	3.9
Non-traded high	150%	5.7
Traded low	5%	-6.7
Traded central	28%	1.3
Traded high	151%	5.8
Woodland carbon	22%	1.2

4.7 Employment creation

The Garron Plateau restoration project has the potential to impact on employment, directly through restoration activities and changes in land-based activities, and indirectly through related supply chains and the local economy. For the restoration scenario, estimated Full Time Equivalent (FTE) employment increased by an average of 6.8 FTE/year (range 4.7 to 10.1 FTE) over project life after allowing for reduced employment from farm production. This increases to 16.3 FTE (range 11.3 to 24.2 FTE) using the Northern Ireland FTE multiplier for the agriculture and related sector. Further details of the analysis are presented in Annex H.

5. Natural capital account for Montiaghs Moss

5.1 Site overview and natural capital asset register

Montiaghs Moss is an area of lowland peatland in County Antrim, about 1 mile west of Lough Neagh. The site is an area of relic raised bog, and consists of a mosaic of peat ramparts, trenches, pools and drains, interspersed with grassland, alder and willow carr and tall hedgerows[14]. It has been primarily shaped by many years of traditional peat cutting, although these practices ended in the 1980s.

Montiaghs Moss supports a wide range of plants and animals, including many rare species. Most notable is the marsh fritillary butterfly (*Euphydryas aurinia*), with the site a major stronghold in the Northern Ireland context. The site is also notable for its invertebrate assemblage, including the Irish damselfly (*Coenagrion lunulatum*), water beetle assemblage, and aquatic heteroptera assemblage. It has been designated as an Area of Special Scientific interest (ASSI), and a Special Area of Conservation (SAC), the latter for the marsh fritillary. It is 151 ha in size with a complex ownership pattern.

Table 16 Area and percentage cover of habitat types across the Garron Plateau study area

Habitat type	Area	% Cover
Degraded raised bog	48.5	32.1
Active raised bog	0.8	0.5
Blanket bog	0.2	0.1
Acid flush / transition mire	0.8	0.5
Fen	0.0	0.0
Swamp	0.1	0.1
Standing water	1.8	1.2
Wet grassland	8.0	5.3
Neutral grassland	3.9	2.6
Improved grassland	1.1	0.7
Tall ruderal	0.04	0.03
Broadleaved woodland	30.5	20.2
Coniferous woodland	0.4	0.2
Dry scrub	1.6	1.1
Wet scrub	53.2	35.2
Buildings	0.01	0.01
Infrastructure	0.3	0.2
NA	0.1	0.1
TOTAL	**151.2**	**100**

[14] Northern Ireland Environment Agency. Protected Area Conservation Management Plan: Montiaghs Moss SAC/ASSI 2020-2030.

Detailed habitat information was available, dividing the site into 418 different polygons. Within each polygon, the % cover of each habitat type present was recorded (usually multiple habitat types were present on each polygon). This was manipulated in GIS to determine the overall % cover of each habitat type across the site, and this is shown in the natural capital asset register (Table 16). Montiaghs Moss primarily consists of three habitats: degraded raised bog (32.1%), broadleaved woodland (20.2%) and wet scrub (35.2%). Other notable habitats include wet grassland, neutral grassland, standing water and dry scrub, with a number of additional habitats occupying less than 1% of the site. Figure 10 shows habitat across the site under the pre-restoration scenario, displaying the dominant habitat in each of the 418 polygons.

The condition of the site is currently considered to be unfavourable. This was a single assessment covering the whole site (not for each habitat separately) and is based primarily on condition in relation to the marsh fritillary.

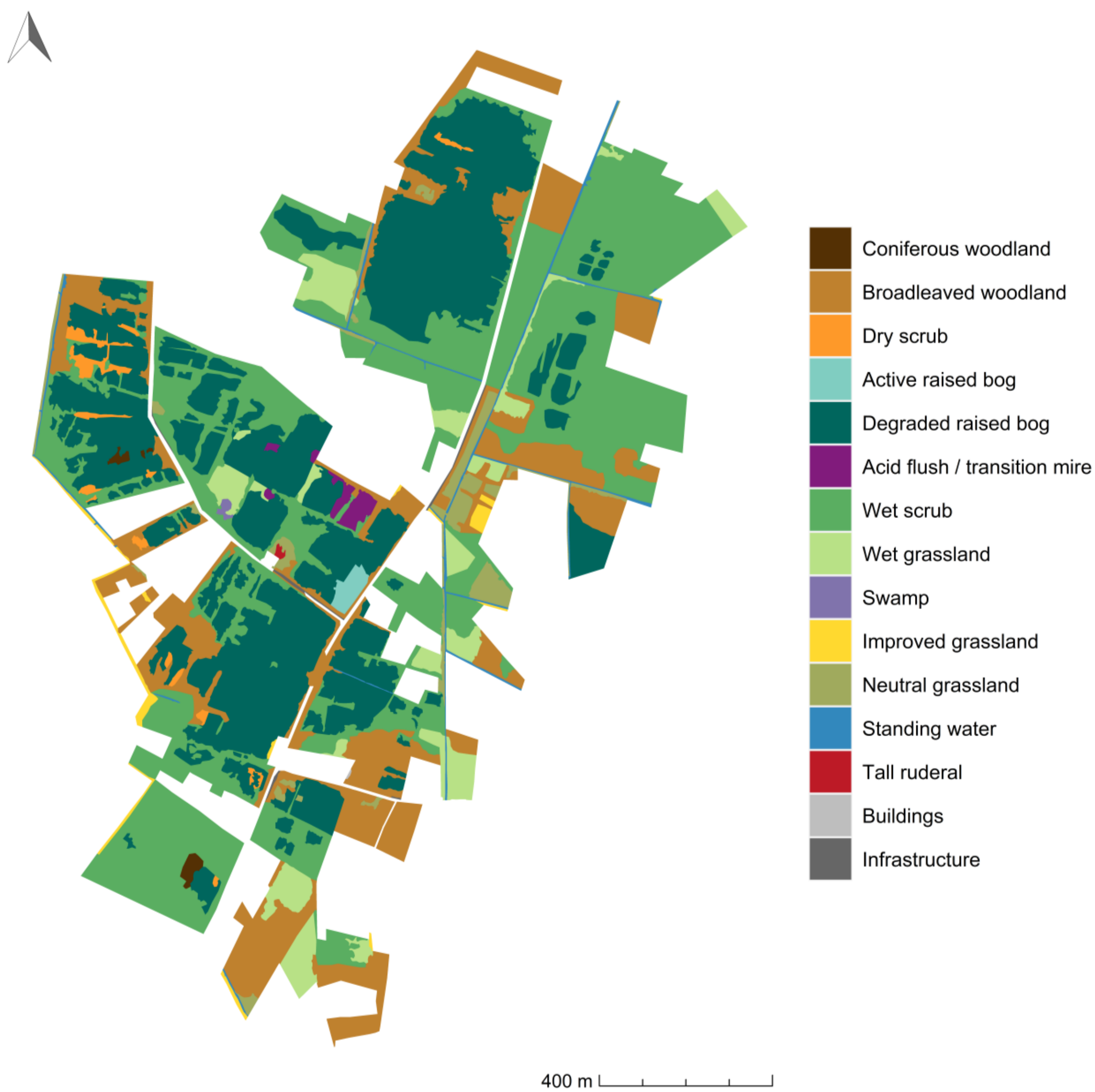

Figure 10 Habitats across Montiaghs Moss in 2010 (pre-restoration scenario). The map shows the dominant habitat in each of 418 polygons.

5.2 Restoration works and impact on condition

Restoration works at Montiaghs Moss are primarily concerned with creating suitable condition for the marsh fritillary, whilst maintaining the other important invertebrate assemblages. The habitat requirements of the marsh fritillary are based on that of its larval foodplant, Devil's-bit Scabious (*Succisa pratensis*). This is a species typical of damp, tussocky grassland and although it can be found on cutover raised bogs, it cannot survive regular inundation. The species typically requires light grazing and unshaded conditions. Hence management of the site is focussed around maintaining open wet grassland, rather than restoring the degraded raised bog. Planned management actions include removing scrub and areas of young woodland, instigating or maintaining light grazing (including installing fencing), rotational clearance of water bodies, and improving public access through the installation of a boardwalk and car park. The aim of these works are to restore the site to favourable condition (for the marsh fritillary) and this was the assumed end point under Scenario 2.

5.3 Qualitative assessment of ecosystem service flows

The qualitative assessment of ecosystem services currently provided by Montiaghs Moss is presented in Table 17. Provisioning services are not a significant feature of the site, with only some delivery of livestock production, woodfuel (potentially) and water and this will not change much under the proposals for the site. Peat has not been actively cut at the site for a number of years.

Most regulating services are either of little or moderate importance at the site, with little change following restoration. Water quality and water flow regulation delivered by the site are likely to be of moderate importance, although the site only impacts on a very small catchment. Local climate regulation and noise attenuation are of little importance due to the very rural location, while air quality regulation will decline a little following tree removal, although is again of relatively low importance as the site is not close to any major roads or built-up areas. The most important regulating service is undoubtably habitat and population maintenance (biodiversity), which is significant and will increase in importance assuming successful delivery of the management plan.

Montiaghs Moss currently has some value for aesthetic experiences and education / science and is the subject of regular wildlife monitoring and other scientific work. Recreation and tourism and health and wellbeing are currently both low due to the extremely low numbers of visitors, but will increase following the installation of visitor facilities (a boardwalk and car park), although will remain moderate. The site is important as a location with characteristics and features of biodiversity that are valued (existence, option, bequest) and this will increase further following restoration.

The qualitative assessment shows that biodiversity features are the most important ecosystem services delivered by the site, with most other services of moderate or low significance. Carbon also has the potential to be very significant, given that the site lies on deep peat and the next section evaluates the impact of the proposals on carbon in much more detail (along with other factors).

Table 17 Estimated ecosystem service provision scores for Montiaghs Moss: 0 - no delivery; 1 – some delivery, 2 – significant delivery, 3 - very significant delivery. List of ecosystem services adapted from CICES v5.1.

Ecosystem service category	Ecosystem service	Estimated provision	
		2010	2045
Provisioning	Food: crop and livestock production	1	1
	Fibre and fuel (e.g. timber, woodfuel, wool, peat etc.)	1	1
	Water (includes for drinking, agriculture and industry)	1	1
Regulating	Carbon sequestration and storage	2	2
	Local climate regulation	1	1
	Air quality regulation	2	1
	Water quality regulation and erosion control	2	2
	Water flow regulation	2	2
	Pollination	2	2
	Pest and disease control	2	2
	Noise attenuation	1	1
	Soil quality regulation	2	2
	Habitat and population maintenance (biodiversity)	2	3
Cultural	Aesthetic experiences	2	2
	Education, training and scientific investigation	2	2
	Recreation and tourism	1	2
	Health and well-being	1	2
	Characteristics and features of biodiversity that are valued (existence, option, bequest)	2	3
	Spiritual and cultural experiences	2	2

5.4 Physical and monetary flow accounts

Carbon sequestration

As all of Montiaghs Moss lies over deep peat, the site will inevitably emit carbon. However, the amount of emissions depend on the type and condition of the habitats. Under the current situation approximately a third of the bog is raised bog in unfavourable condition, but as the site is not eroded or dry, this has been classified as re-wetted bog, rather than degraded bog. Over 20% of the site has woodland cover, which leads to high emissions (Table 4), the extensive areas of encroaching scrub result in medium emissions, while a small area of improved grassland results in the highest emissions of all (per ha). Overall emissions at the site are therefore high (Table 18).

Under the 2045 restoration scenario there is an approximately 40% reductions in emissions, but the site remains a net emitter of CO_2 at a rate of over 2 tonnes CO_2e per hectare (Table 18). These reductions are achieved mainly through removal of some woodland, scrub removal and changes in grassland management. Further significant reductions would be possible through restoring the raised bog and by removing more of the woodland, but this is not planned as it would be incompatible with the conservation of the marsh fritillary and other site interest features.

Table 18 Total carbon sequestration across Montiaghs Moss and mean per hectare, for the start and end of restoration and the change. Negative scores indicate net emissions and positive scores indicate net sequestration.

Carbon emissions	2010	2045	Difference 2045 -2010
Total emissions (tCO_2e/yr)	-532	-314	217
Mean per ha	-3.52	-2.08	1.44

As for the Garron, a monetary value can be placed on theses emissions, based on the UK Government non-traded carbon price, with emissions falling by £16,800 per year (2021 prices) following restoration, but with the site still emitting CO2 valued at £24,300 annually (Table 19).

Table 19 Annual monetary value of carbon sequestration across Montiaghs Moss and mean per hectare, for the start and end of restoration and the change. All values are in 2021 prices and are based on the UK Government non-traded carbon price (central estimate).

Carbon valuation (£2021)	2010	2045	Difference 2045 -2010
Value (£/yr)	-£41,166	-£24,333	£16,834
Mean per ha	-£272	-161	111

Assumes changes in carbon emissions valued at the carbon price for year 2021 not for the year of occurrence.

Carbon storage

Unlike for the upland blanket bogs on the Garron Plateau, there have been a number of studies into carbon storage on lowland raised bogs in Northern Ireland, which we able to use for the current assessment. Peat depth is also considered to be relatively constant cross the site at 2.5-2.7m (see Annex B). Hence the estimates provided for Montiaghs Moss are likely to be more reliable than for the Garron Plateau, although should still be considered to be approximate. The stock of carbon stored at Montiaghs Moss is estimated to be about 139,000 tonnes, or 917 tonnes per ha (Table 20).

Table 20 Total carbon storage for Montiaghs Moss and carbon storage per hectare.

	Total C stored (tonnes)	tonnes per ha
Caron storage	139,000	917

Agriculture

The reduced area of improved grass under the 2045 scenario and controlled grazing, mainly by suckler beef, reduced stocking and the value of agricultural production (Table 21 and Annex E). The estimates here exclude direct farm income support, land costs and some farm scale fixed costs. The changes are small.

Table 21 Changes in Agricultural Production and value, 2010 through to 2045, Montiaghs Moss.

Agriculture	2010	2045	Difference 2045 -2010
Livestock units	46	32	-14
Net Margin £/LU*	14	14	14
Total £ Net Margin	640	448	-192

*Net margin assumes partial fixed costs only excluding land.

Agri-environment (EFS)

Full details of current agri-environment agreements need to be confirmed. However, following promotion to incorporate areas under fragmented ownership, a target to include 90% of the area in EFS type arrangements is proposed (Table 22), which will increase income significantly compared to the current situation.

Table 22 Changes in take up and value of agri-environment schemes 2010 through to 2045 (full development), Montiaghs Moss.

	2010	2045	Difference 2045 -2010
Area under schemes (ha)	39	131	92
Average Payment £/ha *	109	99	-9.4
Total payments £	4,267	12,953	8,686

* Based on 2021 payment rates.

Recreation

Current visits to the site are extremely low, hence the value of recreation is very low. Looking forward, the project includes the installation of facilities, such as a boardwalk and car park, to increase the annual number of visitors from the present 250 visits to 1500[15] over the next 5 years of project life, attracting visitors with particular ecological and educational interests (Table 23). Projected visit numbers and recreational value are still quite low and increased visits can be promoted beyond this period without compromising habitat management requirements.

[15] Aecom (2020) Montaighs Moss, Co. Antrim Proposed Boardwalk: Transport Assessment Form, used a lower and higher estimate of 8 and 17 visits per day respectively following installation, which is approximately 1000 and 2125 visits per year. Hence we chose a midpoint of 1500 annual visits for this assessment.

Table 23 Changes in number of visits and recreational value 2010 through to 2045 (full development) Montiaghs Moss**.**

Recreation	2010	2045	Difference 2045 -2010
Number of visits per year	250	1500	1250
Visitor value £/visit	6.31	6.31	6.31
Total £	1,578	9,465	7,888

* Assumes visits valued at 2021 prices, not for the year of occurrence.

5.5 Restoration and maintenance costs account

Restoration and maintenance costs were based on a review of peatland restoration works, described in Annex G, and on cost estimates from the site manager. Given the relatively small scale of the project, the identified costs are relatively high. This partly reflects investment in site infrastructure, notably fencing, livestock handling facilities and visitor facilities[16].

All of the capital and maintenance operations planned for the site were costed up over the project lifetime and a summary of the Present Value of these works, over 50 years, is shown in Table 24 in the next section.

5.6 Investment appraisal of restoration of Montiaghs Moss

Over a 50 year period, 2010 to 2060, the central estimates of benefits and costs in 2021 prices for the Montiaghs Moss restoration project give a Net Present Value of minus £172,000 at the Treasury Discount rates and a Benefit Cost Ratio of 0.89 : 1 (Table 24). The Internal Rate of Return is 2%.

The carbon related benefits are relatively small given the retention of bogs in a degraded condition to provide habitats for priority target species. Given the latter focus, the assessment of benefits here probably does not sufficiently include the value of the biodiversity benefits that are a critical intended outcome on this site. At the same time, the scope for carbon benefits is not taken up under the current habitat preferences.

Changes in carbon emissions (t CO_2e), valued at the Government's non-traded price series for carbon (£77.41/tCO_2e), account for over 70% of total benefits. About 15% of PV benefits are attributable to biodiversity benefits based here on agri-environment payments. This is probably an underestimate of potential benefits managed under high level and group EFS arrangements in future. Ecological recreation and associated educational and research benefits, have potential to be a significant benefit. Expectations of visitor numbers are modest. The proposed investment in visitor facilities would justify greater numbers, managed to avoid ecological damage.

Regarding costs, almost 50% of PV costs related to staffing, transport and related costs including volunteer costs. An additional full time project officer is assumed, appointed for four years, and a further 0.4 full time

[16] Some of the estimates of infrastructure costs provided by site managers were adjusted downwards to reflect likely lower out turn costs.

equivalent post after that relative to current staffing. Further information may modify the assumption on staffing costs. Some infrastructural replacements are assumed half-way through the project life.

Table 24 Estimated Present Value of Cash Flows for Montiaghs Moss.

50 Year Project Life, £$_{2021}$ prices. Summary Discounted Cash Flow	Present Value £000	%	Switch values*
Benefits			
Carbon	997.5	73%	1.2
Agriculture	-4.5	0%	ns
Agri-environment	198.9	15%	1.9
Recreation	179.6	13%	2.0
PV Total Benefits at DR**	**1371.4**	100%	
Costs			
Capital	379.6	25%	0.6
Extra Maintenance and Operations	340.4	22%	0.5
Extra Staffing and costs	749.8	49%	0.8
Contingency (5%)	73.5	5%	ns
PV Total Costs at DR**	**1543.3**	100%	
Net Present Value (NPV) at DR (£M)	**-171.9**		
B:C ratio	**0.89**		
Internal Rate of Return	**2%**		

* change in value of component to make NPV = 0 at the test discount rate**.** Ns = not significant

** discount rate (DR): years 1-30 at 3.5%, years 31-50 at 3%

Estimates of project performance were also obtained for low and high values for the main benefit and cost streams. Project performance is sensitive to assumptions about the price of carbon. A switch in the carbon price equivalent to a 20% increase on the central non-traded carbon price used would make the project break even at the test discount rate. Alternatively, breakeven would be achieved with a two-fold increase in either agri-environmental or recreational benefits.

Regarding costs, the project is particularly sensitive to assumptions on staffing costs and related costs. Volunteer time is charged at about £4/hour to reflect an average hourly opportunity cost between zero and the national wage: a zero value for volunteer time increases BCR to almost 1.0 at the test discount rate. The initial capital cost estimates for 30km of fencing totalling £300k, animal shelter at £20k (partly also covered in livestock net margins) and visitor boardwalks at £150k were reduced to £150k, £15k and £55k respectively to reflect scale related lower unit costs better attuned to the benefits obtained. Using these initial estimates reduced Project NPV to minus £450,000 and BCR to O.7.

Estimated project performance depends on the assumption of future carbon prices. The central estimate (indicated by 100% in Figure 11) is the BEIS non traded central estimate (£77.41/t CO_2e for year 2021 in 2021 prices). The effect on NPV, Benefit Cost Ratio and IRR% of variations from this central carbon price is shown.

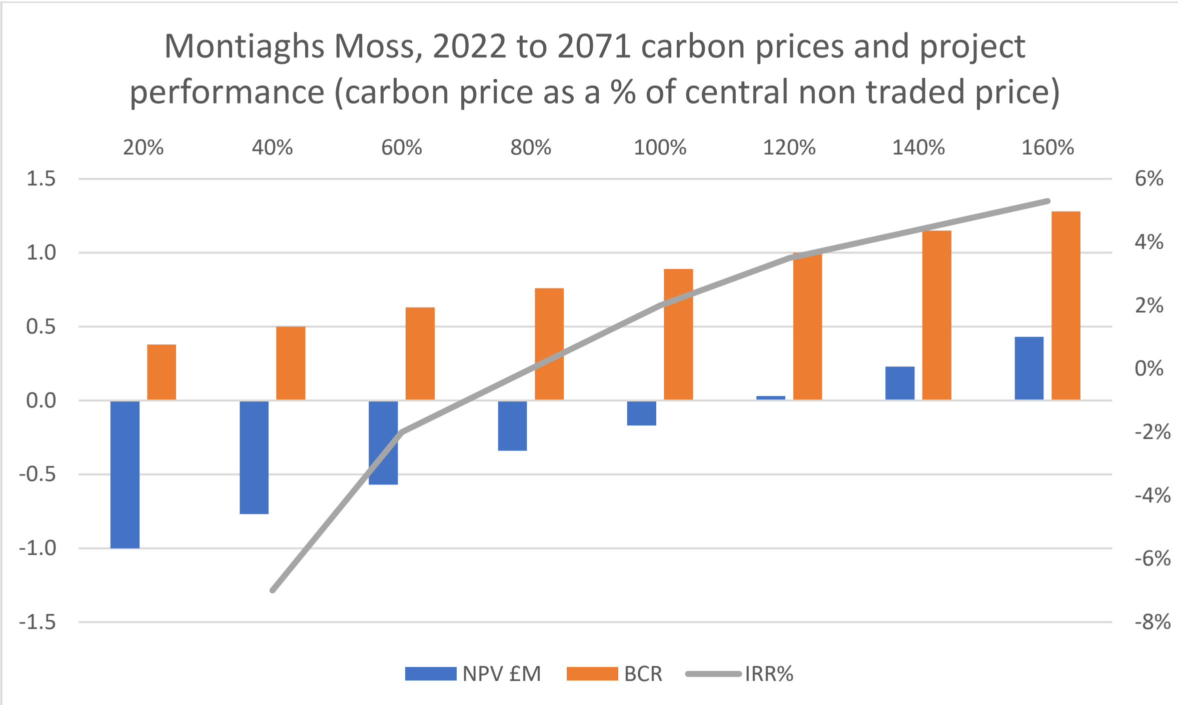

Figure 11 The effect of changes in carbon prices (£/tCO2e) on the performance of the Montiaghs Restoration Project. NPV = Net Present Value, BCR = Benefit cost ratio, IRR = Internal Rate of Return (right hand axis).

The effect on BCR of different carbon assumptions relative to the 2021 central price is shown in Table 25. The current voluntary market price for the Woodland Carbon Guarantee third auction is £17.31, 22% of the 2021 central non-traded carbon price used here. The project breaks even at the high traded and non-traded BEIS carbon prices, assuming everything else remains constant.

Given the marginal performance of the Montiaghs Moss project as currently identified, it is recommended to obtain more detailed information on project design and costs to enable a more confident estimate of project worth.

Table 25 The effect of alternative carbon prices (£/t CO2e) on the Benefit Cost Ratio for the Montiaghs Moss Peatland Restoration Project**.**

Carbon prices 2021	% of central non-traded price	BCR at Test DR
Non-traded low	51%	0.58
Non-traded central	100%	0.89
Non-traded high	150%	1.22
Traded low	5%	0.27
Traded central	28%	0.42
Traded high	151%	1.22
Woodland carbon	22%	0.38

5.7 Employment creation

Similarly to the Garron, the Montiaghs Moss restoration project has the potential to impact on employment, directly through restoration activities and changes in land based activities, and indirectly through related supply chains and the local economy. The restoration scenario is estimated to increase direct employment on Montiaghs Moss by about 1.2 FTE/year (range 0.9 to 1.5 FTE/year). Applying the FTE multiplier gives an estimate of 2.8 FTE /year including wider economy effects. Further details of the analysis are presented in Annex H.

6. Stakeholder analysis and winners and losers

The restoration projects at Garron Plateau and Montiaghs Moss are indicative of the type and magnitude of benefits and costs associated with peatland restoration projects in Northern Ireland in the upland and lowland sectors respectively. The Projects have potential redistributive effects with consequences for winners and losers. From a public policy viewpoint, there is a need to assess the distributive effects as these might influence the valuation of benefits and costs, the support of key stakeholders, and the overall feasibility and success of the projects, including actions to moderate negative impacts.

Three assessments were made here to assess distributive effects. First, the interactions between the peatland projects and key policy domains were explored. Second, the links between changes in ecosystem services and impacts on stakeholders were assessed. Third, an assessment was made of winners and losers for the two sites, with implications for the Northern Ireland Peatland Strategy.

Policy interaction

The review of peatland policy (see Section 2 and Annex A) identified the key interactions between the Peatland Strategy, within which Garron and Montiaghs would be subsumed, and key policy domains (Table 26). The projects clearly interact positively with climate change and biodiversity policies. They are directly congruent with the policy and institutional interests promoting these objectives, broadly under the commitments to 'Net Zero' and sustainable land, water and environmental management. Potential policy conflict may arise with an agricultural policy with an overriding focus to improve farming productivity and farm-based livelihoods. However, both the Garron and Montiaghs areas are of limited agricultural potential. Farm profits are currently low or negative and very dependent on income support. Under alternative reward systems for public goods, the impacts on food production are likely to be small, with increased benefit to the farming and environmental land management effort.

Table 26 Interactions with key policy domains indicated by the Garron and Montiaghs restoration projects.

Positive interactions	Relative strength*	Negative interaction	Relative strength*
Climate change mitigation and adaptation (G, M)	H	Food security: reliable nutritious food at affordable prices (G)	L
Nature conservation/biodiversity: target species and habitat (G, M)	H	Agriculture: constraints on intensity of production, reduction in agricultural incomes and impact on livelihoods (G, M)	L
Water resources: water supply and quality, drought management (G)	H	Forestry: Reversion of prior policies of afforestation on peatland areas considered marginal for agriculture (G)	L
Environmental Policy: public money for public goods (G, M)	H	Turbury: additional restrictions on peat extraction, especially for non-commercial usage (M)	L
Flood risk management: natural flood risk management and nature based solution (G)	H		
Land use planning: strategic assessment of needs and capacity in land sector, 'Soil health' as a policy target (G, M)	H		
Rural policy: enhanced livelihoods. diversification (G, M)	L-M		

Notes: G and M applicable to Garron and Montiaghs; *Strength of interaction H high, M medium, L low

Ecosystems services and stakeholder interests and impacts

There are a wide range of interactions between existing and potential future flows of ecosystem services and stakeholder interests and impacts on the two sites (Table 27). The distribution of services amongst stakeholders indicates potential winner and losers. The projects switch the importance from provisioning services associated with agricultural output and land use towards regulating and cultural services. Reflecting the high-level policy interactions referred to above, the projects serve the agenda of climate change, biodiversity, and water related organisations by enhancing mainly regulating service flows in the long-term public interest, including the attenuation of future environmental hazards. The interests of stakeholders in provisioning services historically associated with peatland sites, such as farming, turbury, and forestry are affected negatively. The projects switch the emphasis of output from 'traded' market goods such as agricultural products to non-traded public goods such as climate change mitigation and biodiversity. This transition requires that the reward and incentives for land managers are adjusted accordingly.

Winners and losers of peatland restoration

The preceding assessment points to the main winners and losers associated with peatland on the Garron Plateau and Montiaghs Moss sites.

Stakeholders may feel the impact of the restoration projects in a range of ways:

Impact = Δ (A + Y + E+ P + O + L + H + Q)

Where: Δ denotes changes in:

A: asset holdings, property rights and entitlements, and associated value
Y: income, expenditure and value-added
E: employment and livelihoods, including volunteering
P: policy purpose and objectives
O: organisational purpose and core mission,
L: leverage associated with advocacy, legitimacy and reputation
H: exposure to hazard and disruption
Q: quality of life, well being

Applying this framework to the stakeholders identified earlier provides a basis for identifying potential winners and losers (Table 28). Policy and organisational goals are key drivers of change and 'winning' outcomes. The main winners are those stakeholders whose policy and organisational objectives align with climate change mitigation and biodiversity conservation, serving the public interest. In the water sector in the Garron case, NI Water potentially benefits from reduced costs and reputational benefit associated with sustainable land management. Similarly, DoI benefits from cost-effective nature based solutions to flood risk. Winners also include farmers willing and able to respond to opportunities for payments for ecosystem services at the farm and landscape scale. The Increased value of peatland services can increase natural asset values for owners assuming reward systems are in place. Winners also include service providers involved in restoration and maintenance works.

The main losers appear to be farmers and allied industries whose assets, incomes and employment are negatively affected by reduced livestock production and the related demand for supplies and services. The extent and distribution of this impact depends on policy and market driven opportunities for substitute outputs and services linked to environmental management. The agricultural productivity of lowland and upland grazing systems on peatlands is generally low so the impacts on food security, sovereignty and cross border trade are also likely to be low.

In summary, the main winners are those associated with the achievement of key policy outcomes that serve the public interest. The main losers appear to be mainly linked to the constraints placed on livestock grazing on peatlands and consequences for farm incomes, as well as other restrictions placed on land use to achieve intended outcomes.

Moderating and communicating stakeholder impacts

A key constraint on peatland restoration may come from farmers and landowners and their representatives who fear that peatland restoration may compromise farm-based asset values, incomes and employment opportunities. Given the broad shift in agricultural and environment policy towards public money for public goods, perhaps more clearly evident in mainland Britain, there is need to explore targeted peatland options for environmental land management that can bring together environmental, social and economic objectives, especially at the local scale. Furthermore, one of the main constraints to sustainable land use in Northern Ireland is the fragmentation of land tenure and property rights where ownership of small parcels of land has become more important that land use and custodianship. Another constraint, not of itself undesirable, is that communal rights do not reward self-imposed limits on overgrazing. Thus, a key implication is to (i) develop environmental land management options suited to the peatland context that reward public goods in the place of subsidised agricultural output, (ii) encourage direct farmer participation in restoration works and management and (iii) supports collaborative group responses amongst those with fragmented entitlements to ownership and use. A communication strategy that engages with key stakeholders will be an important component of the peatland strategy going forward.

It is important to distinguish stakeholders according to relative interests and influence. Those with ‘interests’ may be affected in some way by the peatland proposals such as changes in ecosystem service flows. Second, those with ‘influence’ are positioned to affect decisions and outcomes. This latter group may or may not have well developed ‘interests’ in the peatland outcomes themselves, but are influential because they can exert critical control, for example associated with land ownership. From a peatland strategy and communications perspective, it will be important to devise a communication and engagement approach that in particular nudges or awakens those stakeholders with power to influence, whether through ownership of resources or the policy agenda, so that they develop a keen interest in the future Peatland Strategy.

Table 27 Existing and /or potential links between ecosystem services and stakeholder Interests on the Garron Plateau and Montiaghs Moss restoration projects

Service Flow:	Impacts	Stakeholder interests	Direction	Comments
Provisioning services				
Agriculture	Livestock production,	Farmers, owners, tenants, graziers, agricultural contractors and service providers, food industry operatives	**Negative:** Reduced livestock production, and agricultural inputs, potential income and employment effects, reduced farm viability, reduced food security and trade	Negative effects potentially offset by alternative farm income and employment for environmental services and diversification
Forestry	Timber production	NI Forestry, forest owners and contractors	**Negative**: Reduced timber production, premature felling, income and employment effects.	Removal of poor performing plantations
Water resources	Raw water supply and quality	NI Water, and public water operatives	**Positive:** Improved raw water quality, reduced treatment costs, reputational benefits **Negative:** Restrictions on extractions during drought periods	Potential increasing value with climate change
Biomass	Peat products /Turbury	Peat diggers and commercial extractors	**Negative**: Restrictions or moratorium of peat extraction for personal or commercial use,	Moratoria already apply, with proposals for buy out of turbary rights
Regulating services				
Climate change: soil carbon	Soil carbon storage and sequestration	Local and national government with CC obligations: carbon market participants	**Positive:** Cost effective contribution to Net Zero climate change obligations	Key policy target and development of new market-based instruments and finance models
Flood risk management	Flood damage costs	Property owners, Dept of Infrastructure (DoI), Insurance companies	**Positive**: Reduced flood costs using 'nature based solutions'	Important policy drivers towards natural flood risk management
Fire risk management	Fire damage costs	Emergency Services, Asset Owners, Local residents	**Positive**: managed and wetted sites reduce fire risk and associated damage	Increased climate change risk
Pollination	Beneficial insects	Nature Conservation organisations, Growers	**Positive:** habitats and refuge for beneficial insects and pollinators	Key biodiversity related target
Local air quality	Air quality indicators, dust, particulates,	NIAE, NHS, LGAs	**Positive:** clean air, reduced source of local emissions (peat blows, fires)	Linked to health impacts
Nutrient and sediment	Eutrophication, sediment	NI Environment Agency, DoI	**Positive:** Contribute to environmental water quality objectives, reduced river	Water Framework type objectives

control	deposition		maintenance	
Cultural services				
Recreation - Physical and mental health	Recreation activities and participation rates	NHS and caring services, Health-based organisations	**Positive**: health benefits of formal and informal outdoor recreation	Key wellbeing policy link
Education and research	Educational and research activities and outputs	Schools, colleges/ universities, vocational training, adult education	**Positive**: School, college and adult education, national and international research programmes	Environmental education to support behavioural change
Quality of place	National and local identity, landscapes, heritage assets	NI Government, Antrim local governments	**Positive:** Quality of place and character landscapes, linked to cultural identity, cultural offerings to support living and working	Quality of life and place interactions for wellbeing
Tourism	Number and types of visitors, visitor spend	Tourism NI, local service providers	**Positive:** Increased visitor spend, and eco-tourism based incomes and employment **Negative:** overuse, congestion and degradation of habitats, disturbance to wildlife	Support to diversified rural economy
Supporting Services				
Biodiversity	Habitat and species outcomes	NIEA, Ulster Wildlife, RSPB, conservation organisations	**Positive**: Delivery of key species and habitat targets on designated sites, delivery of core nature based organisational objectives	Fundamental delivery of habitat obligations
Soil health	Soil status and degradation risk	College and universities (Coleraine and Belfast)	**Positive**: Improved condition of peatlands as a key national soil health indicator	Growing awareness of soil quality and soil carbon
Hydraulic processes	Water quantities and quality	DoI, NIEA, Consulting Engineers	**Positive**: contribution to regulation of flows and flood and drought management	Critical link to climate change mitigation and adaptation

Table 28 Summary of potential winners and losers associated with Garron Plateau and Montiaghs Moss peatland restoration projects.

Winners	Positive Impacts*	Comment	Losers	Negative impacts*	Comment
Climate change advocates: National and Local Government Organisations	P, O	Restoration offers cost effective CC mitigation policy instrument	Farmers and landowners (production oriented)	A, Y, E, Q	Restrictions on production, reduced net income and land values
Conservation organisations: biodiversity and wildlife	A, Y, O, L	Restoration is 'core conservation business'	Agricultural industry supply and service agents	A, Y, E	Reduction in agricultural investment and expenditure
Land managers (conservation oriented)	A, Y, L, Q	Support for individual and group farm	Agriculture industry organisations and trade associations	O,L	Challenge to organisational farming purpose
Water industry (NIW); water resource managers	Y, L	Reduced treatment costs, high reputation value	Foresters and supply and service agents. NI Forestry Commission	A, Y, E	Reduced policy support, reduced plantations and product
Flood risk management organisations, insurance providers	Y, P, O, L	Sustainable, lower cost nature-based solutions	Ministry responsible for food security and sovereignty	P, L	Actual or perceived loss of food production
Corporate organisations	O, L	ESG corporate goals, 'social permits', reputational value	Neighbours: local residents and land owners	A, D, Q	Tourism congestion, countryside abuse. Potential effects of wilding and /or rewetting an adjacent land
Environmental financiers	Y,	Market development in environmental financial products and services			
Government departments	Y (fiscal), P, L	Target environmental outcomes, partnership funding			
Environmental service providers and contractors and consultants	Y, E	Specialist environmental product and service providers – design, build and manage			
Education, research organisations	P, O, Q	Educational services (multi), CPD, research programmes			
Conservation oriented farmers	Y, O, L, Q	Opportunity for alternative livelihoods			
Land owners (non-active farmers)	Y, L, Q	Opportunity to join environmental scheme while retaining ownership			

Cultural organisations and ‘artists’	O, Q	Northern Ireland landscapes and identity			
Volunteers and voluntary organisations	O, Q	Volunteering for wellbeing			

* Impacts: A: asset holdings, property rights and entitlements, and associated value, Y: income, expenditure and value-added, E: employment and livelihoods, including volunteering, P: policy purpose and objectives, O: organisational purpose and core mission, L: leverage associated with advocacy, legitimacy and reputation, H: exposure to hazard and disruption, Q: quality of life, well-being.

7. Conclusions

The benefits of restoration at the Garron Plateau greatly outweigh the costs (£50.1M v £12.8M over 50 years), with a net present value of £37.3M. For every £1 invested there will be £3.91 worth of benefits. In total, 92% of the monetised benefits are due to changes in carbon sequestration. Emissions will decline greatly as restoration proceeds and the site will move from being a major net emitter to a net sequester of carbon. A number of water-related benefits are also delivered by the restoration works, not all of which can be valued. This includes reduction in flood provision and erosion. Flood mitigation improved by 27% at the site, which translates to a 6.3% improvement across the whole catchment. The valuation and qualitative assessment have confirmed that carbon, water services and biodiversity are by far the most important ecosystem services delivered by the site, along with some additional cultural services, such as educational and scientific value.

The assessment for Montiaghs Moss has shown that biodiversity benefits are by far the most important benefits being delivered by the site. Restoration of the site is focussed on this key objective, aimed especially at restoring conditions for the marsh fritillary butterfly. The benefits of restoration at Montiaghs Moss are less than the costs of doing the restoration (£1.37M v £1.54M over 50 years), with a net present value of -£172,000 and an Internal Rate of Return of 2%. Every £1 of investment will provide £0.89 worth of benefits. However, some of the costs are considered to be high, especially for fencing and creation of the boardwalk (the latter is particularly high given the very low visitor numbers expected). Staffing costs may also be less than has been estimated here, although all these costs were reduced somewhat in this appraisal, compared to the figures supplied by the RSPB.

The vast majority of the benefits of restoration of both the Garron Plateau and Montiaghs Moss are in the form of public goods, rather than private goods that can be of direct benefit to the landowners. However, NI Water have recorded clear reductions in turbidity, colour and other water quality benefits at the Garron Plateau, which it is thought may lead to reductions in costs over time, as has occurred in similar cases in the UK. Reputational and CSR benefits have already been achieved and are continuing to be promoted. In addition, although returns from agriculture are reduced under the restoration scenarios at both sites, these reductions are small given the low margins typical of upland and low-intensity lowland livestock systems, and are made up for many times over by the increase in income from entering agri-environment schemes. Furthermore, new markets for ecosystem services are developing rapidly. The carbon market is the most established and is growing rapidly. But additional markets are also developing, for example around biodiversity, water flows (flood risk) and water quality. Indeed, the fact that NIW has restored a significant part of the Garron already, indicates that they were willing to pay (along with the EU and Northern Ireland Government) for the restoration. There is also growing interest in generating payments from multiple ecosystem services at the same site, in a process referred to as stacking, where services can either be sold bundled or unbundled. A key factor in setting up such projects is that they deliver "additionality", which means that only restoration works that have not been already undertaken or would not have occurred anyway can be funded and challenges remain around setting up stacked benefits that maintain additionality and avoid payments being made twice (or more) for the same work.

At the Garron Plateau 92% of the benefits relate to carbon, whilst at Montiaghs Moss the figure is 73%. This means that the assessments are strongly impacted by the price of carbon. We have used the UK Government (BEIS) non-traded carbon price, which is standard practice for these kinds of assessments and recommended by the UK Government[17], and is a better reflection of the 'real' value of carbon sequestration if it were to be exchanged, than market prices. Using the latter reflects the current institutional set up of carbon markets, rather than the true value of carbon sequestration. However, the non-traded carbon price is not the same as the voluntary carbon market price (or the traded carbon market through schemes such as ETS), which is where any investment would be likely to come from. For Garron, the breakeven point is reached using a carbon price set at 19.5% of the non-traded price, which would be about £15.15 per tonne in 2021. Interestingly, the current price in the voluntary carbon market is around £17.31 (Woodland Carbon Guarantee third auction[18]). This is a Government scheme and information from private voluntary markets indicates that prices have increased substantially in the last year, and were around £25 per tonne in March 2021[19], although these figures can be highly variable depending on the location, additional ecosystem services delivered and overall "narrative" of the project in question.

The assessments presented here do not attempt to value the biodiversity benefits, hence biodiversity benefits provide large additional benefits achieved by the site management works at both sites. Biodiversity benefits are partially captured by agri-environment payments, but these do not capture the true value. In particular, agri-environment payment rates are generally based on costs of interventions, or income forgone, rather than on payment by outcomes or on any attempt to value the biodiversity being enhanced. This is especially relevant for Montiaghs Moss, where the primary aim is to enhance the site for the marsh fritillary, rather than to maximise carbon sequestration or other ecosystem services. Indeed, as the planned works do not include restoring the raised bog (as this would be incompatible with conservation of the marsh fritillary), the site continues to be a net emitter of carbon dioxide, although at a lower rate than before the works. The benefits delivered at the site are not as high as the costs of restoration, but this does not fully account for the benefits for the marsh fritillary and other biodiversity features at the site. Perhaps an alternative way to describe the outcomes at Montiaghs Moss is that when money is spent on restoring the site for the marsh fritillary, a number of additional benefits can be delivered that are valued at almost 90% of the total costs.

The Garron and Montiaghs Moss peatland projects have potential to impact on employment, directly through restoration activities and changes in land-based activities, and indirectly through related supply chains and the local economy. The high-level estimates of employment effects presented in this report are indicative only of the direction of change. They suggest that peatland restoration has potential to contribute to employment through changes in landscape management. While the farming sector could experience loss of employment due to reduced livestock production, actions can be taken to offset this by involving farmers in the restoration process and its activities.

The conceptual framework underpinning this work (Figure 3) shows that policy and environmental drivers influence management practices, which in turn influence peatland structure and function, the ecosystem services provided, and hence the values and benefits derived by society. The system is cyclical, and as greater understanding of the key mechanisms and linkages in the system is gained, outcomes can be improved. Hence if society chooses to value certain ecosystem services more highly, or to recognise a wider range of benefits from peatlands, it is possible to alter the policy framework to influence certain management practices, enabling that goal to be achieved. Payments

[17] "BEIS values to be used rather than fledgling market values". Defra (2020). Enabling a Natural Capital Approach (ENCA).
[18] https://www.woodlandcarboncode.org.uk/woodland-carbon-guarantee
[19] Forest Carbon (pers comm)

for Ecosystem Services (PES) schemes provide one such policy mechanism, as these encourage an alteration of management by explicitly providing payment for ecosystem services that may have previously been unvalued or undervalued.

The findings described in this report are broadly applicable to other peatland sites across Northern Ireland (and in GB and Ireland). It is likely that in all cases, reducing carbon emission through restoration will provide substantial benefits. Enhancing biodiversity is also likely to be a major driver. A broad range of other benefits are also likely, especially focussing on water quality, water flow and flood risk, water supply, and a number of cultural benefits. In some locations, sites may also be important, or have the potential to support significant recreation and health and wellbeing benefits. It is clear that peatland restoration will lead to multiple benefits, and these will often have a value greater than the capital and maintenance costs of delivering the works. These values are most often public benefits, although rapid progress is being made at developing markets for carbon and other ecosystem service benefits. There is a growing opportunity to restore peatlands across Northern Ireland to achieve climate, biodiversity and other public policy aims, drawing in both public and private investment. In particular, obligations to commit to "UK net zero" climate policy, presents a clear driver for large-scale peatland restoration across Northern Ireland, which could deliver substantial emissions cuts. Peatland restoration presents a clear and relatively uncontroversial way to substantially cut emissions and go some way to delivering policy ambitions.

7.1 Data gaps, assumptions and limitations

Work is progressing rapidly on the calculation of physical and monetary flows of ecosystem services from natural capital assets, but it remains a developing area. A number of ecosystem services remain difficult to quantify and value. For example, a number of cultural services, such as aesthetic experiences, cultural heritage, and spiritual experience are difficult to even quantify, let alone value. It should, therefore, be borne in mind that the natural capital valuation and investment appraisal presented in this report place values on several key benefits, but these are necessarily incomplete.

For the services that have been included in the accounts, a range of assumptions have been made, and these are outlined when describing the methodology (see the Annexes). Valuation of ecosystem services is appropriate at indicating the magnitude of benefits, however, these results need to be interpreted with care, and in the knowledge that whilst the highest quality and most readily available data were used, there are limitations and assumptions that need to be borne in mind.

Of particular note, given the importance of carbon in the outcomes, was the lack of detailed information on peat depth across the Garron Plateau. This is a key factor when determining both carbon storage and sequestration and assumptions have been made based on habitat type and by extrapolating from measurements taken over only small parts of the site.

The water services calculated for the restoration of the Garron consider water exiting the Garron in all directions and no distinction has been made for the different river catchments. This means that some catchments are likely to experience a greater change in service provision and some less. NI Water also extract water from the reservoir within the Garron, which sits within its own sub-catchment. Again, the percentage changes in service provision to the reservoir are likely to be slightly different to the overall values produced during the study. It would be fairly simple to delineate this sub-catchment and use the existing modelling to calculate the change in service provision specific to the reservoir.

The VET-NFM tool was created for use with English data and has had to be repurposed for use in Northern Ireland. This may have introduced further uncertainty into the tool, but results are likely to remain within an order of magnitude to reality. This makes it comparable to more standard techniques that require far more intensive modelling.

The water quality monitoring data from NI Water could be used in conjunction with ongoing mapping of habitat restoration, so that accurate predictions of water quality and turbidity improvements could be calculated into the future. However, the current combination of modelling, estimations and approximations offer a good starting point.

7.2 Recommendations

- Given the importance of carbon to the outcomes, it is important that more accurate measurements of peat depth are obtained across the Garron. These could be obtained either through direct measurements taken at the same time as condition assessment monitoring, or, if technically feasible, through remote sensing.
- The Garron Plateau in particular, has the potential to be a showcase of peatland restoration in Northern Ireland, hence it would be beneficial if the current monitoring programme could be continued and expanded. Many impacts of restoration have been estimated in the current assessment, based on limited data and examples, so a site where data was collected to monitor changes in response to restoration would be invaluable, both in Northern Ireland and in the wider UK and Ireland contexts. Continuing collecting information on the response of the habitats to restoration is a key first step. But it would also be useful if the monitoring can be extended to included carbon flux, water flow and additional water quality information.
- Visits to the natural environment can deliver substantial recreation and health and wellbeing benefits. At present these are largely untapped at both the Garron Plateau and Montiaghs Moss, which receive very low visitor numbers. There is potential to increase his considerably, whilst still keeping numbers below those that would cause disturbance. Facilities are being enhanced at Montiaghs Moss, through the installation of a boardwalk and car park, at relatively high costs compared to the predicted increase in visitor numbers. It may therefore be worthwhile to enhance numbers further, by publicising the sites and other activities that would promote visitors.
- The natural capital approach demonstrated here for the Garron Plateau and Montiaghs Moss cases could be developed to support the design and implementation of the new Peatland Strategy for Northern Ireland. The benefits and costs of restoration and management options could be assessed for the wide range of peatland sites, recognising important differences in context, scale, policy alignment, funding opportunities and potential outcomes as these influence feasibility and impact. Such an approach would support the 'business case' for peatland restoration as well as help prioritise interventions in line with stakeholder interests.
- Widespread uptake of peatland restoration is likely to require Government support in a number of ways. Whilst the rest of the UK have all made multiannual funding commitments towards peatland restoration, no such commitment has been made in Northern Ireland. To successfully deliver its objectives, a Peatland Strategy with ambitious targets for restoration must be matched with commensurate levels of funding. Additionally, new agri-environment options that support restoration and encourage high nature value farming and farming for ecosystem services are particularly important. In England, Defra is developing the new Environment Land

Management scheme (ELMs), which has at its heart the concept of paying "public money for public goods", and similar schemes are being developed in Scotland and Wales. Such a scheme would be highly beneficial in Northern Ireland and would encourage farming practices that promoted carbon sequestration, water quality and flow regulation and other public benefits (as well as biodiversity). Note, also that it would be beneficial if agri-environment support was extended to Commonage areas, which are ineligible under current schemes.

- As well as public investment, there is huge opportunity for private carbon and other ecosystem services markets to develop in Northern Ireland, but these may require some promotion to enable them to take off. For example, intermediaries such as land advisors to identify potential buyers and sellers, publicity to raise awareness of these types of schemes, and potentially underpinning government policy to encourage it.
- Stacking, bundling and the issue of additionality requires some further attention. At present it is relatively straightforward to receive payment for habitat creation / restoration for one single benefit (e.g. carbon), but it remains complicated when attempting to promote and receive payments for multiple benefits for the same patch of land. The requirement for additionality makes these schemes difficult. Yet payment for one benefit may not make the scheme financially viable, whereas it is likely that multiple additional benefits will be delivered, which if taken into account would make the scheme financially worthwhile for the landowner. Linked to this is the need to allow both public (through agri-environment schemes) and private investment in the same area of land. This whole subject requires further work and the development of new schemes and payment mechanisms to allow such approaches.
- Further policy changes in Northern Ireland would enable much greater take up of peatland restoration options. For example, if all businesses were obliged to offset their carbon (not just heavy industry), it would unlock a potentially vast market of investors, which would go some way to helping Northern Ireland achieve its net zero ambitions. In addition, launching a mandatory requirement for biodiversity offsetting for all new developments, could unlock funds for peatland restoration focused on biodiversity benefits.
- Natural capital assessments, valuation and accounting are an ideal way to identify and present the benefits of peatland restoration schemes (and other assessment of the natural environment) and the approach should be further embedded in decision making in Northern Ireland. This may require the development of a new policy framework to encourage the wider use of natural capital approaches. Natural capital approaches should be integrated into Strategic Planning, Local Development Plans, Environmental Impact Assessments (EIAs), and other appraisals as an integral component of decision making, and also encouraged in the private sector. Such assessments are more complete as they consider a wider range of costs and benefits than traditional economic analyses and reveal values and benefits that may otherwise remain hidden. It is hoped that this will lead to more joined up and sustainable decision-making.

Annex A: Northern Ireland Peatland Policy Review

Peatland Strategy

The Department for Agriculture, Environment and Rural Affairs (DAERA) is currently in the process of developing a peatland strategy for Northern Ireland to support the objectives of the IUCN sponsored UK Peatland Strategy[20]. The latter seeks to place 95% of UK peatlands that currently support semi-natural vegetation under relevant local, national and/ or international designations. Along with sustainable land management, this will help secure the future of peatland biodiversity and ecosystem functions, and contribute to climate change mitigation[21].

A Peatland Strategy for Northern Ireland will set the ambitions to protect and restore peatlands over the next 20 years and beyond. If targets for restoration are ambitious, this will be welcomed, especially in the light of the limited progress on previous statements of intent. However, peatland restoration now offers a major opportunity to respond to the growing sense of climate and biodiversity emergencies that characterises the new policy reality. The assessment of the Garron Plateau and Montiaghs Moss peatland sites are examples of restoration projects that can help support the case for peatland restoration, both within the Northern Ireland Peatland Strategy and the wider policy framework.

The commitment to sustainable peatland management needs to be seen in the broader context of land resource management. Reflecting the interests of a coalition of sectoral interests, a proposed Land Strategy for Northern Ireland 2015[22] sought to guide the management of land and landscapes for the benefit of people's wellbeing and prosperity, making best use of opportunities for multifunctionality. An important guiding principle, of particular relevance for the management of peatlands, is that where land is highly suitable for a key primary function, whether food production, flood management, tourism and recreation, or carbon storage, this function should be recognised in decision-making. The strategic review also noted that the short term 'conacre' land tenure system, along with a strong individual attachment to land that emphasised ownership rather than use, acted as a constraint on potentially beneficial land use change.

Public funding for Peatland Restoration

Sufficient public investment in peatland restoration will play an important role in meeting ambitious targets under the peatland strategy. To date, the vast majority of funding for restoration works in Northern Ireland has been delivered through agri-environment schemes and EU funding for specific projects. However, this has been significantly less than what is required to deliver peatland restoration at the sufficient scale. In the rest of the UK, multiannual funding commitments for peatland restoration have been made, as set out in Table A1 overleaf. Northern Ireland should follow suit and ensure that any restoration targets are backed up with a similarly ambitious programme of public funding.

[20] The UK Peatland Strategy was launched in April 2018 by the IUCN UK Peatland Programme. https://www.iucn-uk-peatlandprogramme.org/uk-strategy

[21] Evans, C., Artz, R., Moxley, J. & Renou-Wilson, F. 2017. Implementation of an Emissions Inventory for UK Peatlands. Centre for Ecology and Hydrology. ONS. 2019. UK Natural Capital: peatlands. Office of National Statistics.

[22] NI Land Matter Task Force. 2015. Towards a Land Strategy for Northern Ireland. https://www.nienvironmentlink.org/cmsfiles/Towards-a-Land-Strategy-for-NI_2015-Main-Report.pdf

Table A1 Public funding commitments for peatland restoration in the other counties of the UK.

Country	Funding commitment	Restoration target
Scotland[23]	£250 million to 2030	250,000 ha by 2030
Wales[24]	£ 1 million to 2025	600-800 ha per year
England[25]	£50 million to 2025	35,000 ha by 2025

Peatland and Agricultural Policy

The realignment of agricultural and rural policy following the UK's withdrawal from the European Union and membership of the Common Agricultural Policy will have an important role to play in meeting ambitions within the proposed Peatland Strategy. Agricultural policy is a devolved matter and preferences vary considerably amongst the administrations. In all cases, however, there is recognition to reconcile the conflicts between agricultural and environmental outcomes of the previous policy regime.

It appears that the current stated preference in Northern Ireland is broadly to maintain the status quo of income support and the existing framework of agri-environmental programmes, at least in the short term. This contrasts with the approach in England, for example, where the intention is to phase out direct income support (referred to as the Basic Payment Scheme (BPS)) to farmers over the period 2022 to 2028. Here, BPS will be replaced with targeted grants and payments to improve the sustainability of farming and achieve environmental outcomes.

In a 2018, a Stakeholder Engagement on a future agriculture policy framework for Northern Ireland DAERA outlined four proposed principles that will guide future agriculture policy. These centre around increased productivity, resilience, environmental sustainability and an integrated supply chain. However, to date it is unclear how they will be implemented as part of a future policy and what balance will be struck between each of these objectives. To date, the response post Brexit has been to maintain the status quo regarding the balance of income support and agri-environment payments. Along with continued income support, the Northern Ireland Government has continued to deliver an Environmental Farming Scheme (EFS) that provides funding for farmers to carry out environmental works on their farms primarily related to biodiversity, climate change and water quality. EFS operates at three levels, namely 'Wider' for land outside designated areas, 'Higher' mainly for designated sites and a 'Group' pilot to support farmers working together in specific areas[26].

Although no detailed policy changes have been proposed, the new post-CAP policy framework sets the likely direction of travel in the UK as a whole, evident in Wales and Scotland that have indicated a hybrid approach. Perhaps learning from the experience in England of the roll out of the

[23] Source: https://soils.environment.gov.scot/resources/peatland-restoration/#:~:text=The%20Scottish%20Government%27s%20Climate%20Change%20Plan%20sets%20targets,habitat%2C%20improving%20water%20quality%20and%20reducing%20flood%20risk.

[24] Source: https://naturalresourceswales.gov.uk/about-us/strategies-and-plans/national-peatland-action-programme-2020-2025/?lang=en

[25] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/987859/england-peat-action-plan.pdf

[26] DAERA, 2021. Guide to the Environmental Farming Scheme For agreements commencing 01 January 2022,

Environmental Land Management scheme[27] over the next 5 years or so, it is likely that a proportion of direct income support to farmers in Northern Ireland will in time be replaced by payments for public goods delivered at the farm and/or or landscape scale. Indeed, rural policy within the European Union is likely to move in this direction in due course, while still supporting the vitality of rural areas and businesses[28].

The implications for changes in agricultural and environment policy are particularly important for the non-dairy livestock sector and for peatland farmers in Northern Ireland's agriculturally 'Less Favoured Areas'. The beef and sheep sectors are highly dependent on direct farm income support. In 2018/19 for example, average Farm Business Income (FBI), a measure of profitability that excludes charges for unpaid family labour, was about £14,400 and £12,300 for LFA and lowland cattle and sheep farms respectively[29]. This included £28,900 and £21,600 of direct income support respectively. Thus, FBI in the absence of direct income support was minus £14,500 and minus £9,300 for the two farm types. On average, off farm employment and pensions provided about £11,400 in 2018/19 on LFA livestock farm. Put simply, beef and sheep production is not profitable on the majority of non-dairy livestock farms that would be rendered non-viable without income support.

In the longer term, any switch away from direct income support would do two things. First, it would expose farm inefficiencies hidden by dependency on high levels of income support. Hence the importance of improving farm profitability and business resilience. Second, it would increase the incentives to take up environmental options, perhaps under an extended and a better targeted EFS, assuming options are priced appropriately.

On the first point, while there may be some scope for productivity improvements in the LFA livestock sector, it is not clear whether these in themselves will be sufficient to compensate for loss of income support (ADAS, 2019[30]). Furthermore, farms located solely within Severely Disadvantaged Areas may find making significant increases in productivity extremely challenging[31]. On the second point, switching to lower input: lower output systems with reduced livestock densities could not only be more profitable now but also enable the greater future take-up of environmental management options for which farmers could be rewarded (Silcock et al, 2012[32]; Clark et al, 2019[33]). This will require farmers to embrace the new opportunities provided by new EFS options as they emerge, possibly drawing on the English LFA experience. The mechanisms to achieve this, while maintaining

[27] Under the mantra of 'public money for public goods', ELMs in England seeks to provide incentives and rewards to farmers and land managers for the provision of 'ecosystem' services that benefit people and nature. The scheme will involve three main components (i) ***Sustainable Farming Incentive*** to improve environmental outcomes at the farm scale. (ii) ***Local Nature Recovery*** initiatives aimed to deliver locally targeted, mainly habitat-based, outcomes and (iii) ***Landscape Recovery*** with a focus on long term landscape scale and land-use change projects. This will involve collaborations amongst land managers. The ELMs proposals are the subject of National Trials 2021-2024, with a view to roll out of the scheme over the period 2022-29, phased with the withdrawal of direct income support. This includes piloting proposals in Less Favoured and Disadvantaged Areas, including the uplands that may provide evidence suited to the Northern Ireland context.

[28] EU CAP - https://ec.europa.eu/info/news/future-rural-social-objectives-next-cap-2019-feb-15_en

[29] DAERA, 2020. Farm Incomes in Northern Ireland. Department of Agriculture, Environment and Rural Affairs Policy, Economics and Statistics Division, Belfast.

[30] 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.

[31] https://www.cumulus-consultants.co.uk/documents/The-potential-impacts-of-Brexit-for-farmers-and-farmland-wildlife-in-UK-23.10.17.pdf

[32] Silcock, P., Brunyee, J. and Pring, J. 2012, Changing livestock numbers in the UK Less Favoured Areas – an analysis of likely biodiversity implications. Report for Royal Society for the Protection of Birds. Cumulus Consultants Ltd, Broadway.

[33] 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.

viable farm businesses, remain to be put to the test (Rayment, 2019[34]). A synthetic upland case in northern England constructed from actual farms showed, for example, that net revenues from environment related options would need to increase by two to three times to plug the income gap left by the withdrawal of income support (Holt and Morris, 2020[35]).

Agricultural policy in Northern Ireland in the next five years is likely to focus on improving the productivity and viability of its mainly livestock farms to better cope with future market and environmental challenges and opportunities. In the meantime, however, there is likely to be a growing appetite to embrace the opportunities provided by new policy initiatives and markets in land-based ecosystem services. Peatland farmers are potentially well placed to benefit from these opportunities, with support.

Peatland and Climate

Peatlands have an important part to play in the UK's commitments to reducing emissions of greenhouse gases. Northern Ireland's contribution to "UK Net Zero" will require a reduction of 82% compared to 1990 levels as a minimum by 2050. In the absence of intervention, emissions from degraded peatland in Northern Ireland could add around 9% to Northern Ireland's total emissions. The Northern Ireland Government is committed to the development of Climate Legislation under the New Decade New Approach (2020) agreement in line with the Paris Agreement. The UK Climate Change Committee CCC[36] has identified a range of peatland restoration scenarios, reflecting different levels of ambition, all of which include the restoration of all upland peatland and between 25% and 40% of lowland croplands rewetted and sustainably managed by 2045/2050, including areas of organo-peat soils. For its part, RSPB[37] argue that the most effective way to minimise further emissions is to fully restore peatlands to favourable condition.

Protected Sites Network legislation & Site Management Plans

Northern Ireland has 58 areas designated as Special Areas of Conservation (SAC) covering terrestrial, freshwater and marine habitats. Many of Northern Ireland's SACs are not in good health. Individual Conservation Management Plans for 57 SACs are currently being prepared. These include Montiaghs Moss and the Garron Plateau.

Forestry & Woodland expansion

Forestry expansion has been identified as a key component of the UK Net Zero land use strategy. However, there is a need to ensure trees are planted in the right place. Most commercial forestry in Northern Ireland is managed by Forest Service Northern Ireland, with an estate extending to 75,279 hectares, of which 35,810 hectares occupies peat soils with a depth greater than 50 cm, although 7,389 hectares of this is unplanted[38].

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[34] Rayment, M. (2019). Paying for public goods from land management: How much will it cost and how might we pay? A report for the RSPB, the National Trust and The Wildlife Trusts, Rayment Consulting Services Ltd, Plymouth.

[35] Holt, A. and Morris, J. (2020) Plugging the income gap: Assessing environmental options for upland farms: A case study in Pendle Hill, Lancashire, Report to Pendle Hill Landscape Partnership, Natural Capital Solutions Ltd, December 2020.

[36] Thomson, A, Evans, C, Buys, G, Clilcerd, H. 2020. Updated quantification of the impact of future land use scenarios to 2050 and beyond. Report to the Climate Change Committee Centre for Ecology & Hydrology. Wallingford.

[37] RSPB. https://storymaps.arcgis.com/stories/fe3455a345bf45ce9b72d70ae75f933b

[38] Mellon, D and Allen, D. (2015) Options for the restoration of afforested peatlands in Northern Ireland – a scoping study. Forestry Northern Ireland

Whereas in the past Northern Ireland's Forestry policy encouraged conifer afforestation on peat soils considered marginal for agricultural purposes, there is growing recognition that tree planting should only occur on shallow organo-mineral soils if nature and carbon benefits can be demonstrated[39]. Tree planting will be prevented on deep peat soils in future. This should involve the avoidance of restocking plantations on deep peat soils as this has a negative effect on both biodiversity and the long-term net greenhouse gas balances[40,41,42]. Furthermore, there are opportunities within the Peatland Strategy to enable the removal of existing conifer plantations on deep peat soils. A number of sites, including part of the Glenariff and Cleggan Forests adjacent to the Garron area have been identified for forest removal[43], although the timing of this with respect to tree maturity would need to be agreed.

Peatland, Water Resources and Flooding

Peatlands have important implications for the quality and resilience of raw water, for freshwater ecology and for the control of potential flood waters. Water supply is managed by Northern Ireland Water (NIW), which has statutory responsibility for water resource planning, including drought management[44]. NIW operate the Dungonnell WTW that takes raw water from the Garron Plateau catchment. As explained elsewhere, NIW has undertaken a number of peatland restoration and land management actions to improve water quality from the Garron in order to improve operational and cost efficiency.

Environmental water quality is regulated under arrangements previously transposed from the EU Water Framework Directive. River Basin Management Plans (RBMP) to protect and improve all aspects of the water environment including rivers, lakes, estuaries, coastal waters and groundwater are currently under review. Peatland management, including the management of fens, mires and bogs, is strongly linked to environmental water quality targets, both inland and coastal water, especially where affected by nutrients or sediments transported from agricultural land.

Flood risk assessment is the responsibility of the Department for Infrastructure that follows the framework previously operated under the EU Floods Directive. DoI identify and estimate the potential damage to areas at risk of flooding, prioritising risk management measures accordingly[45]. Of particular interest here, DoI recognise the potential contribution of natural flood risk management interventions involving land use change that slow the movement of water through the landscape in order to protect people and property. Such nature-based solutions can be more cost effective than structural measures, although they do require strong engagement with, and incentive for land owners to participate. The options for peatland restoration in the Garron in particular can help to reduce flood risk in the lower catchment, as explored here.

[39] RSPB. https://storymaps.arcgis.com/stories/1ea3da7bc65847ddb087bb17121c2a91
[40] Peatland & Trees position statement released | IUCN UK Peatland Programme (iucn-uk-peatlandprogramme.org)
[41] RSPB, 2020. Repairing nature's carbon store. [online] ArcGIS StoryMaps. Available at: https://storymaps.arcgis.com/stories/fe3455a345bf45ce9b72d70ae75f933b
[42] Crane (2020) Woodland for Climate and Nature
[43] Mellon and Allen, as above
[44] NIW. 2020. Water Resources and Supply Resilience Plan, March 2020. Northern Ireland Water, Belfast
[45] DoI. 2018. Northern Ireland Flood Risk Assessment. December 2018. Department for Infrastructure, Belfast.

Annex B: Carbon storage and sequestration

Carbon storage

Three methods were used to calculate the carbon storage of the Garron Plateau. This approach was adopted as there is no consensus on the best way to make such estimates and there are a lot of uncertainties around peat measurements on the Garron.

The area of deep peat and shallow peat was estimated from habitat data, following discussion with the project steering group. Dry heathland and purple moor grass and rush pasture habitats were assumed to be on shallow peat, with all other habitats (blanket bog, alkaline fens, transition mires, wet heathland, and coniferous woodland) assumed to occur over deep peat. It is acknowledged that this is a crude approximation, but was the best option given the lack of comprehensive data.

Peat depth data for the Garron was derived from two different data sources[46]. In total, this amounted to 135 peat depth measurements, but these were taken over a small part of the site, all within the NI Water land holding. As a consequence, it was necessary to estimate the areas of deep peat associated with the depths recorded in the field. Based on the peat depth data we assigned an equal area to each of the peat depths (1.5, 3.0 and 5.0 metres).

The standard equation for the estimation of carbon storage is:

$$C = bd \times SOC \times h$$

C = carbon density (Mg C or t C), *bd* = bulk density (g cm^{-3}), *SOC* = soil organic carbon concentration (as a proportion), *h* = depth of peat (cm).

In order to estimate the carbon density of the Garron we used either the volume of peat estimate or the data on peat depth. We did not have field measurements for bulk density or soil organic carbon, so estimates for typical upland peat bog soils in the UK were taken from the scientific literature. The value of bulk density used can greatly influence the carbon storage estimate, and there is little data on the bulk densities of non-natural bogs, or on how bulk density varies with depth past 1 m. Upland blanket bogs are generally considered to have a bulk density of around 0.1 g cm^{-3} (Heinemeyer et al. 2010)[47].

The first method used was Cannell et al. (1993)[48], which assumes that the bog is in a natural state, and uses the bulk density for a standard cubic metre of peat. Here, the bulk density of the upper acrotelm layer is 0.06 g cm^{-3} with an SOC of 0.54 up to a depth of 15 cm. The lower catotelm (85 cm depth) has a bulk density of 0.12 g cm^{-3} and an SOC of 0.54.

The second uses the standard cubic metre of peat for a haplotelmic bog following Lindsay (2010)[49]. This assumes a disturbed upper layer of peat (25 cm depth) called the haplotelm, with a bulk density of 0.15 g cm^{-3} (a higher value than in Cannell et al. due to the exposed and disturbed peat layer), with an SOC of 0.54. The catotelm layer underneath (75 cm depth) has a bulk density of 0.11 g cm^{-3} and the same SOC as the upper layer.

[46] Dr Ray Flynn, Queen's University Belfast and RSPB (2018) Garron Plateau vegetation survey.
[47] Heinemeyer, A., Croft, S., Garnett, M.H., Gloor, M., Holden, J., Lomas, M.R., Ineson, P. (2010) The MILLENNIA peat cohort model: predicting past, present and future soil carbon budgets and fluxes under changing climates in peatlands. Climate Research 45:207–226.
[48] Cannell, M.G.R., Dewar, R.C. and Pyatt, D.G. (1993) Conifer plantations on drained peatlands in Britain: a net gain or loss of carbon? Forestry 66: 353-369.
[49] Lindsay, R.A. (2010) Peatbogs and Carbon: A Critical Synthesis. Royal Society for the Protection of Birds, Edinburgh.

The natural standard cubic metre of peat contains 47kg of carbon, and the haplotelmic cubic metre contained 61kg. These were both multiplied by the volume of peat on the Garron.

The third method used the Chapman et al. (2015)[50] data on bulk density for three soil depths, and applied this to the soil depths for each hectare of the Garron, rather than calculating from the peat volume estimate. The bulk density estimates are from a project that collated data on bulk density of peatlands in Scotland. After a review of the literature and the identification of a gap in the data on bulk density for blanket bogs in Northern Ireland, this seemed the most suitable data available to apply to an upland blanket bog in Northern Ireland. As this method applies the bulk density and SOC estimates to each depth of peat individually, it should be a more accurate approach than the other two.

The peat depth of the Montiaghs lowland raised bog was estimated to be a uniform depth of 2.5-2.7 metres[51]. We used a depth of 2.6 m to estimate the carbon density of this bog. We used this and the area of the bog to calculate the peat volume. Data on bulk density and SOC were taken from a study of four lowland raised bogs in Northern Ireland[52]. The standard equation (see above) was used to calculate the carbon density of the site.

All of the methods used to estimate carbon density for both the study sites come with their caveats, and the overall carbon density figures for the Garron and Montiaghs should be considered to demonstrate the approximate magnitude of carbon storage, rather than the exact storage.

Carbon balance

The carbon sequestration and greenhouse gas emissions (tCO_2e/ha/year) associated with the habitats on peat soils was calculated. The emissions factors were taken from Evans et al. (2017)[53], Natural England (2010)[54] and RSPB (2017)[55]. The Evans et al. report is considered to be the most comprehensive and up to date source of emission factors for habitats on peat soils and has been used in the most recent Defra Peat Pilot project[56]. The condition of the habitats across the Garron varied as restoration progressed, which meant that the emissions factors applied changed over time. For example, unfavourable, unfavourable recovering and favourable blanket bog were assumed to be eroded, rewetted and near natural bog respectively, with different emissions factors. For Montiaghs Moss, the degraded raised bog was assumed to be equivalent to rewetted bog, and this remained the same across the project timeline as the bog is not restored. Emissions across the site do change as scrub and woodland is removed and habitats changed. These emissions factors were multiplied by the area of each habitat on the Garron and Montiaghs Moss and summed to provide an estimate of the overall balance between emissions and sequestration for the baseline and restoration periods.

[50] Chapman, S.J. Artz, R.R.E. and Poggio, L. (2015) Determination of organic carbon stocks in blanket peat soils in different conditions – assessment of peat condition. The James Hutton Institute.
[51] RPS 2018. Hydrological survey of Montiaghs Moss SAC & ASSI. Report for CAAB and RSPB
[52] Tomlinson, R.W. & Davidson, L. (2000) Estimates of carbon stores in four Northern Irish lowland raised bogs. *Suo* 51(3):169-179.
[53] Evans, C., Artz, R., Moxley, J., Smyth, M-A., Taylor, E., Archer, N., Burden, A., Williamson, J., Donnelly, D., Thomson, A., Buys, G., Malcolm, H., Wilson, D., Renou-Wilson, F. (2017). Implementation of an emission inventory for UK peatlands. Report to the Department for Business, Energy and Industrial Strategy, Centre for Ecology and Hydrology, Bangor.88pp.
[54] Natural England (2010) England's peatlands: carbon storage and greenhouse gases (NE257). Natural England.
[55] The RSPB. (2017) Accounting for Nature: A Natural Capital Account of the RSPB's estate in England. Annex 7.
[56] Smart, T., Caporn, S., Field, C., Johnson, S., Rogers, K., Rowson, J., Thomas, P., Wright, A., (2020) Defra peat pilot - Greater Manchester.

Annex C: Water services and flood risk management

HydroloGIS Model

The supply of ecosystem services for water were modelled using HydroloGIS. This is a novel GIS planning tool, developed to mitigate dangers to the water supply in river landscapes using nature-based solutions. The scientific research underpinning HydroloGIS has been collated from hundreds of papers by the Natural Capital Project and University of Leeds.

The engine at the core of HydroloGIS is the 'Resource Investment Optimisation System' or RIOS. RIOS was created by the Natural Capital Project to account for biophysical, social and economic data when designing cost-effective investments in watershed services in Latin America. HydroloGIS transposes and extends the functionality of RIOS to UK river catchment/subcatchment regions, and is weighted towards using biophysical optimisation to improve ecosystem services provided by those regions.

Landscape issues are interpreted as a combination of up to four HydroloGIS objectives. It works by grid-based map analyses of the risk factors associated with each objective. These objectives are:

1. *Erosion control:* preventing soil particles from being washed into streams.
2. *Reduction of soil adsorbing pollutants:* preventing chemicals such as phosphates from being washed into streams. Soil adsorbing chemicals adhere to the surface of soil particles and so this objective is often linked to erosion control, although with important differences.
3. *Reduction of water soluble pollutants*: preventing chemicals such as nitrates from being washed into streams. Soluble chemicals dissolve in water and so can be highly mobile.
4. *Flood mitigation:* preventing excessive water entering streams and causing downstream flooding.
5. *Overall provision:* the most efficient ways to meet the above four objectives by creating single interventions. The results are a compromise to simultaneously reduce erosion, soil adsorbed pollution, soluble pollution and flooding.

The risk factors are calculated from a range of datasets, including landscape characteristics, weather and ecosystems. The risk factors are indexed and all locations within the catchment of interest are ranked by appropriately combining each indexed (and appropriately weighted) risk factor. Simultaneously, HydroloGIS models hydrological transport through the landscape, with all risk factors analysed along entire flow paths over the whole landscape.

The Garron forms part of several river catchments, since water flows from the plateau in all directions. The entirety of all these river catchments were divided into 5m-by-5m cells or pixels, and the above calculations were undertaken for every cell along all the flow paths across these catchments. HydroloGIS performs many calculations involving multiple biophysical parameters, so all values were normalised.

The modelling assigned each cell a value between 0 and 1 that quantified the degree of service provision relative to all the other cells in the catchments. This allowed every cell to be ranked for how effective it is at mitigated flooding, soluble pollution, soil-adsorbed pollution, erosion/siltation and all these simultaneously.

Biophysical Modelling Approach

The provision of the four services were calculated for the Garron and contiguous catchment in their 2010 state and in their 2045 state. It was assumed that the wider catchments experienced no appreciable change during this period, with land cover being that of the 2018 Corine habitats in functional condition. The only change between 2010 and 2045 was therefore the restoration of the Garron habitats.

The change in service provision values for the Garron cells therefore identified the relative improvement in service provision provided by restoration. The normalisation of the cell values means that the service improvements were presented as percentages relative to 2010 values.

These percentage values are internally robust but do not provide a measure of physical quantities. This conversion would need a number of local monitoring results across similar habitat changes (restoration or degradation) to properly quantify change in physical quantities at receptors (such as flood depths or phosphate concentrations).

There is some monitoring data for this region, but not sufficient to allow a robust conversion. There were therefore various approximations and assumptions used to include water services in the financial account.

Table C1 HydroloGIS Results for Flooding

Sum cell values flood provision layer 2045 whole catchment	819426.90
Sum cell values flood provision layer 2010 whole catchment	874768.21
Sum cell values flood provision layer 2045 Garron area only	151909.02
Sum cell values flood provision layer 2010 Garron area only	207229.91
Sum cells 2010 minus 2045 Garron area only	55320.89
Sum cells flood provision layer 2010 outside Garron only	665071.38
Sum cells flood provision layer 2045 outside Garron only	665048.23

Baseline service provision % 2010	23.69

Change in service provision of Garron area between 2010 and 2045 (%)	
relative to whole 2010 current provision layer	6.32
relative to 2010 Garron only current provision layer	26.70

These figures show that variation in service provision from areas outside of Garron between 2010 and 2045 was negligible

Table C2 HydroloGIS Results for Phosphates

Sum cell values phosphates provision layer 2045 whole catchment	756027.97
Sum cell values phosphates provision layer 2010 whole catchment	777931.93
Sum cell values phosphates provision layer 2045 Garron area only	163364.08
Sum cell values phosphates provision layer 2010 Garron area only	185264.03
Sum cells 2010 minus 2045 Garron area only	21899.95
Sum cells phosphates provision layer 2010 outside Garron only	592667.90
Sum cells phosphates provision layer 2045 outside Garron only	592663.88

Baseline service provision % 2010	23.81

Change in service provision of Garron area between 2010 and 2045 (%)	
relative to whole 2010 current provision layer	2.82
relative to 2010 Garron only current provision layer	11.82

These figures show that variation in service provision from areas outside of Garron between 2010 and 2045 was negligible

Table C3: HydroloGIS Results for Nitrates

Sum cell values nitrate provision layer 2045 whole catchment	883110.51
Sum cell values nitrate provision layer 2010 whole catchment	896893.50
Baseline service provision % 2010	23.24
Sum cell values nitrate provision layer 2045 Garron area only	194650.71
Sum cell values nitrate provision layer 2010 Garron area only	208432.90
Sum cells 2010 minus 2045 Garron area only	13782.20
Change in service provision of Garron area between 2010 and 2045 (%)	
relative to whole 2010 current provision layer	1.54
relative to 2010 Garron only current provision layer	6.61
Sum cells nitrate provision layer 2010 outside Garron only	688460.60
Sum cells nitrate provision layer 2045 outside Garron only	688459.80

These figures show that variation in service provision from areas outside of Garron between 2010 and 2045 was negligible

Table C4 HydroloGIS Results for Erosion

Sum cell values erosion provision layer 2045 whole catchment	715662.13
Sum cell values erosion provision layer 2010 whole catchment	772066.89
Baseline service provision % 2010	26.22
Sum cell values erosion provision layer 2045 Garron area only	146041.26
Sum cell values erosion provision layer 2010 Garron area only	202412.71
Sum cells 2010 minus 2045 Garron area only	56371.44
Change in service provision of Garron area between 2010 and 2045 (%)	
relative to whole 2010 current provision layer	7.30
relative to 2010 Garron only current provision layer	27.85
Sum cells erosion provision layer 2010 outside Garron only	567943.22
Sum cells erosion provision layer 2045 outside Garron only	567909.91

These figures show that variation in service provision from areas outside of Garron between 2010 and 2045 was negligible

Estimating Flood Damage Costs Avoided

The future reduction in fluvial flood damage costs due to restoration of the Garron was estimated using VET-NFM. This tool has been specifically created for nature-based interventions and considers the response of the catchment to different levels of flooding; the position of NFM features within a catchment; and the correlation between these elements and the damage costs to property.

The damage costs to property are based on a desktop use of the Multi-Coloured Manual (MCM) to give estimated Annual Damage (EAD). The estimation process is broken into different elements, which can be revised independently of each other if better information becomes available for some elements but not others.

It can be presented as:

$$\text{EAD saved through NFM} = \text{NFM location efficiency factor} \times \text{NFM extent factor} \times \text{catchment response factor} \times \text{calibration factor} \times \text{£ EAD}$$

The catchment response element was taken as the difference in the number of people affected by flooding in Q100 (1% probability) and Q1000 (0.1% probability) flood events. This acted as a proxy for how much additional flooding would be caused by an increase in river height, accounting for all biophysical processes in the catchment.

The NFM effect on flooding, considered the proportion of the catchment covered by the NFM features (extent factor), as well as how effectively they are located (efficiency factor). The latter was taken from the HydroloGIS prioritisation values.

An empirical calibration factor was then applied to convert these biophysical numbers into financial metrics, which were used to inform the economic assessment (see below). The results of VET-NFM are shown in Table C5.

Table C5 VET-NFM results showing flood damage costs avoided.

Q100 numbers Broughshane	
People Affected	Cost squares sum (£)
255	1550000

Q1000 numbers Broughshane	
People Affected	Cost squares sum (£)
820	3310000

Q100 approx. no. houses flooded	
Broughshane	90
Martinstown	9
Waterfoot	32
Carnlough	49

Scaling factor of Broughshane figures to account for other flooded areas	= whole catchment/broughshane = 180/90 = 2

Q100 numbers Whole Catchment	
People Affected	Cost squares sum (£)
(255 x 2)	(1550000 x 2)
510	3100000

Q1000 numbers Whole Catchment	
People Affected	Cost squares sum (£)
(820 x 2)	(3310000 x 2)
1640	6620000

Notes: (1) lower boundary of Cost Squares figures used; taken from https://dfi-ni.maps.arcgis.com/apps/Compare/index.html?appid=fe513432bd3e4e538f360c9a1011f2f1

(2) Cost Squares and People Affected available for Broughshane alone. A linear relationship was assumed between these figures and the number of houses in the Q100 flood zone, so the number of houses within the flood zone of other villages in the catchment were counted and thereby included in the calculations.

Garron area 2010 flood provision raster cells above 0.3	
36048 cells of 100sqm per cell	
3.6048	sqkm

Garron area 2045 flood provision raster cells above 0.3	
420445 cells of 100sqm per cell	
42.0445	sqkm

Calibration Factor (for Total average annual damage costs (£))
(100-baseline)/10
=
(100-23.7)/10
=
7.64

		Location Factor		Catchment response factor		NFM Extent factor		Calibration factor		Financial factor		Results	
	Yearly Avg NFM benefit =	NFM location	x	(1- People affected Q100 / People affected Q1000)	x	(Area of NFM interventions / Area of catchment)	x	calibration factor	x	Expected damage costs (£)	=	Total value of NFM damage costs avoided (£)	% of total average damage costs avoided
Year	Location												
2010	Garron area Cell values <0.3	0.25	x	0.689	x	0.01422573	x	7.64	x	1550000	=	29018	2
2045	Garron area Cell values <0.3	0.25	x	0.689	x	0.165921468	x	7.64	x	1550000	=	338456	22

Flood Alleviation Benefits from Restoration on the Garron Plateau

The restoration of peatland and related habitats on the Garron Plateau has potential to reduce run off from land and the costs of flooding in receptor areas. Estimates were derived by modelling the change in water flows from the Garron due to land use and management change. This was equivalent to a reduction of 7% in the current baseline flow at full development. Adjustment factors were derived (Table C6) to assess the change in flood risk exposure to downstream assets, allowing for location and catchment response.

Using NIEA data[57], 180 properties were identified in the 1% medium flood risk flood areas potentially affected by Garron water. Following the MCM methods[58], weighted average annual damages were derived accordingly, extrapolated to include the 200-year event (Table C6).

Land use change on the Garron Plateau has potential to reduce flood risk to about 190 properties against the 200-year event (180 against the 100 year event, 155 against the 50 year event, and so on) by about 12% in downstream unprotected areas, particularly in the villages of Broughshane, Martinstown, Waterfoot and Carnlough. The increment in WAAD is estimated at about £56,000/year, assumed to be phased in accordance with the achievement of favourable habitat conditions as a result of restoration carried out since 2010 (Table C7).

There could be flood alleviation benefits on lowland grassland sites, particularly at the confluence of the Clough and main rivers. These are not thought to be substantial, especially if these sites are already managed to accommodate frequent flooding: they have not been included here.

No allowance is made for possible climate change effects on flood generation, or on possible increases in the number or value of properties at risk. These can be considered in sensitivity analysis.

Table C6: Estimated Weighted Average Annual Damage (WAAD) for the 200-year flood for residential properties potentially affected by flood water from the Garron Plateau.

return period	exceed-ence	weighted £ cost/residence (MCM)	% Of 100 year event cost	prob of interval	mean £ ann interval damage	Ann interval damage £	Nr of properties by flood interval (MCM)	Nr properties (based on 1% flood zone)	£ damage cost for flood interval
2	0.50	0							
				0.30	5286	1586	5%		15346
5	0.20	10572	31%					10	
				0.10	15217	1522	11%		29452
10	0.10	19862	58%					19	
				0.06	20902	1254	27%		60683
25	0.04	21942	64%					48	
				0.02	26427	529	86%		81838
50	0.02	30912	90%					155	
				0.01	32637	326	100%		58747
100	0.01	34362	100%					180	
				0.01	34362	172	108%		33254
200	0.005	34362	100%					194	
			WAAD per residence			5388		Total WAAD	279321

57 https://dfi-ni.maps.arcgis.com/apps/Compare/index.html?appid=fe513432bd3e4e538f360c9a1011f2f1

58 Penning-Rowsell, E., Priest, S., Parker, D., Morris, J., Tunstall, S., Viavattene, C., Chatterton, J. and Owen D. (2013) Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal, Routledge, Abingdon, Oxford

Table C7: Estimated change in weighted average annual flood damages (WAAD) for the Garron Plateau with and without habitat restoration.

			Basline pre rest'n	Future with rest'n
	Year		2010	2045
	Modelling results			
a	Location factor		0.25	0.25
b	Catchment response factor		0.69	0.69
c	Restoration extent		0.014	0.166
d	Calibration factor		7.64	7.64
abcd = e	weight		0.02	0.22
	Flood risk estimates			
f	WAAD for 200 yr event	£/year	279321	279321
ef	Reduction in WAAD	£/year	5154	61107
	Increment in WAAD	£		55954

Annex D: Water treatment costs and peatland restoration

Context

The potential benefits for the supply and treatment of raw water for public use is a key driver of peatland restoration on the Garron Plateau. Degradation of the peat due to loss of vegetation cover, due to overgrazing and drainage, has reduced the reliability and quality of raw water to the Dungonnell Reservoir. This has reportedly increased the costs of water treatment to remove colouration and materials in suspension from the peat-stained water. A high organic content also increases the risk of contamination by disinfection by-products.

Peatlands in favourable condition provide high quality raw water that is potentially cheaper to treat for public supply. Degraded peatlands release higher concentrations of organic carbon into the water causing 'brown water', which has to be removed at high cost.

Water quality Issue on the Garron Plateau

In collaboration with RSPB and NIEA, NIW undertook to restore the 1,937 hectares of the Garron Plateau ASSI owned by NI Water. The interventions involved ditch and drain blocking, small dam construction, and management agreements with farmers to reduce stocking densities (Table D1). Two phases of works have been carried out: first in 2013/14 under the Futurescapes Project, and second in 2018/209 under the 'Cooperation Across Borders for Biodiversity' (CABB) INTERREG VA project, covering a total of 567 ha at an outturn cost of works only at about £130,000, about £225/ha (about £260/ha in 2021 prices). The estimates are thought to underestimate full costs including design, supervision and other implementation costs (See Annex G: Peatland restoration costs).

Table D1: Peatland Restoration Works carried out on the Garron Plateau, 2013-2019.

Date	*Project*	*Contractor*	*No of dams constructed*	*Area of bog restored*
Nov 2013 – Feb 2014	Futurescapes Project	Euro Services	799 peat dams	74 ha
			208 Timber dams	
			82 Plastic dams	
			31 stone dams	
Jan 2018 – Feb 2019	CABB Project	DLG Water	781 peat dams	493 (target 444 ha)
			143 Timber dams	
			93 Stone dams	
38,473 metres of drains blocked in total				

Source: Allen, R, 2021[59]

Raw water quality for the Dungonnell WTW catchment area

Data on the turbidity, colour and Total Organic Carbon of raw water supplied to the Dungonnell WTW for the period 2008 though to (February) 2021 were analysed by Allen (2021), comparing estimates of mean values before the initial restoration works (2008 to 2013) and afterwards (2014-2021) (Table D2). Results show that raw water colour, TOC and turbidity have generally improved since the first phase of restoration was completed (March 2014). Mean raw water colour reduced by 3%, together with a decrease in the range of observed values. Mean turbidity decreased by 4% between the two periods, but a number of outlying results increased the range of values. Mean raw

[59] Allen, R. 2021 Garron Plateau Peatland Restoration Works: A Review. March 2021. NI Water

water TOC reduced by 4% between the periods, with a reduction in the reported range. The considerable variations about the means however suggest that the mean estimates may not be significantly different (at P<0.05).

Table D2 Raw water quality indicators at Dungonnell WTW 2008-2021.

	Pre-restoration		***Post-restoration***		
	2008-2013		***2014-2021***		***% difference***
Colour (mg/l Pt/Co)	Mean	109.0	Mean	105.8	-3.04
	Range	310.2	Range	200.0	-55.10
	Minimum	1.00	Minimum	38.0	97.37
	Maximum	311.2	Maximum	200.0	-55.60
Turbidity (FTU)	Mean	2.45	Mean	2.36	-4.02
	Range	115.44	Range	129.60	10.71
	Minimum	0.56	Minimum	0.40	30.00
	Maximum	116.00	Maximum	130.00	10.77
TOC (mg C/l)	Mean	13.36	Mean	13.02	-4.26
	Range	30.17	Range	26.90	-12.27
	Minimum	0.21	Minimum	6.20	96.77
	Maximum	30.37	Maximum	33.10	8.16

Source: Allen, R. 2021. NIW

The restoration works were considered to have a beneficial effect on the recharge rate of the Dungonnell Reservoir following the dry summer of 2018: blocked drains enabled the bogs to remain relatively saturated, releasing water when precipitation resumed[50].

Raw water quality and water treatment costs

A subset of the above data on water quality covering the period 2012 to 2020 inclusive was used to explore possible variation with the energy and chemical costs of water treatment. This covers the period prior to Phase 1 of the restoration works (period A in Table D3), the period between the completion of Phase 1 and the completion of Phase 2 (period B) and the period post Phase 2 (period C).

Table D3 Estimated Mean Values for raw water quality indicators by observation periods Dungonnell WTW 2012-2020

		Turbidity (NTU)		TOC (mgC/l)		Colour mg/l Pt/Co	
	Period	mean	variance	mean	variance	mean	variance
A	2012-2013	3.41	10.89	12.7	20.2	111.5	1807
B	2014- 2018	2.00	5.20	12.8	20.3	105.8	1312
C	2019-2020	1.22	1.06	12.9	20.0	100.4	1594
B + C	2014 -2020	1.82	4.39	12.8	20.2	104.4	1385
Significance at P<0.001							
A v B		s		ns		ns	
A v C		s		ns		ns	
B V C		s		ns		ns	
A V B+C		s		ns		ns	

s= significant at p<0.05, ns not significant. Source: derived from data provided by NIW, 2021.

Raw Water and the cost of treatment

The observed significant reductions in turbidity during the period might be expected to result in reductions in water treatment costs, other things being equal. Data from the Dungonnell WTW on raw water throughput (ML/day) (for the period 2009 to 2020 inclusive), and chemical kg by type/month) (2012-2020) and energy (kWh/month) (2009 to 2020) inputs and costs were provided by NI Water (Allen, R). Energy and chemical prices were assumed at constant £2021 values. For the purposes here, outliers have not been modified. Some variation may be attributable to recording practices, especially regarding allocation of stock materials.

Energy and chemical costs might be expected to vary with raw water quality, involving the use of coagulants to clean water and extra energy use for centrifuge and filtration processes. Poor water quality may also produce more sludge that requires handling and disposal.

Monthly raw water throughput averaged about 250ML/month over the period 2009 to 2020 with some indication that seasonal variation has moderated in recent years (Figure D1)

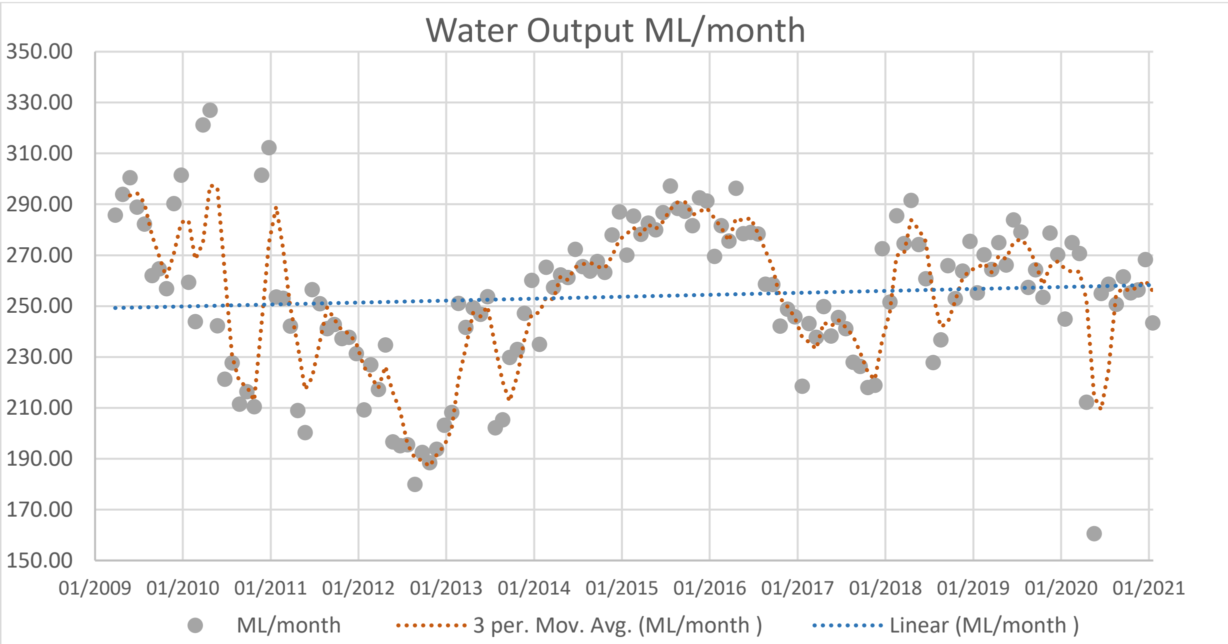

Figure D1 Treated Water Output from Dungonnell WTW 2009-2020.
Source: Derived from data provided by NIW, 2021

Water throughput (ML/month) and combined total energy and chemical costs (£/ML/month) are positively correlated (r=0.29, p<0.05). Average combined energy and chemical costs £/ML for water treatments remained constant in real terms over the period at about £46/ML in 2020 prices (Table D4 and Figure D2). However, energy and chemical costs appear to be negatively correlated over the period, but the relationship is not significant (at p<0.05). Mean £/ML energy costs have reduced (Figure D3) while unit chemical costs (£/ML) have risen (Figure D4). The significant changes have occurred since December 2018.

Table D4 shows the change in mean values for energy and chemical costs during the periods for which data were available.

Table D4 Mean Energy and Chemical treatment costs for the Dungonnell WTW, 2009 to 2020.

Mean values by period			
	Energy	Chemical	Water
Period	£/ML	£/ML	ML/month
A: up to Dec 2013	30.5	16.2	241.7
B: Jan 2014 to Dec 2018	29.4	16.9	
C: Jan 2019 onwards	25.1	20.8	
D (B&C) Jan 2014 onwards			261.9
Difference in means		significance p<	
A v D	0.000	0.277	0.000
A&B together v C	0.000	0.015	
B v C	0.000	0.023	
A v C			

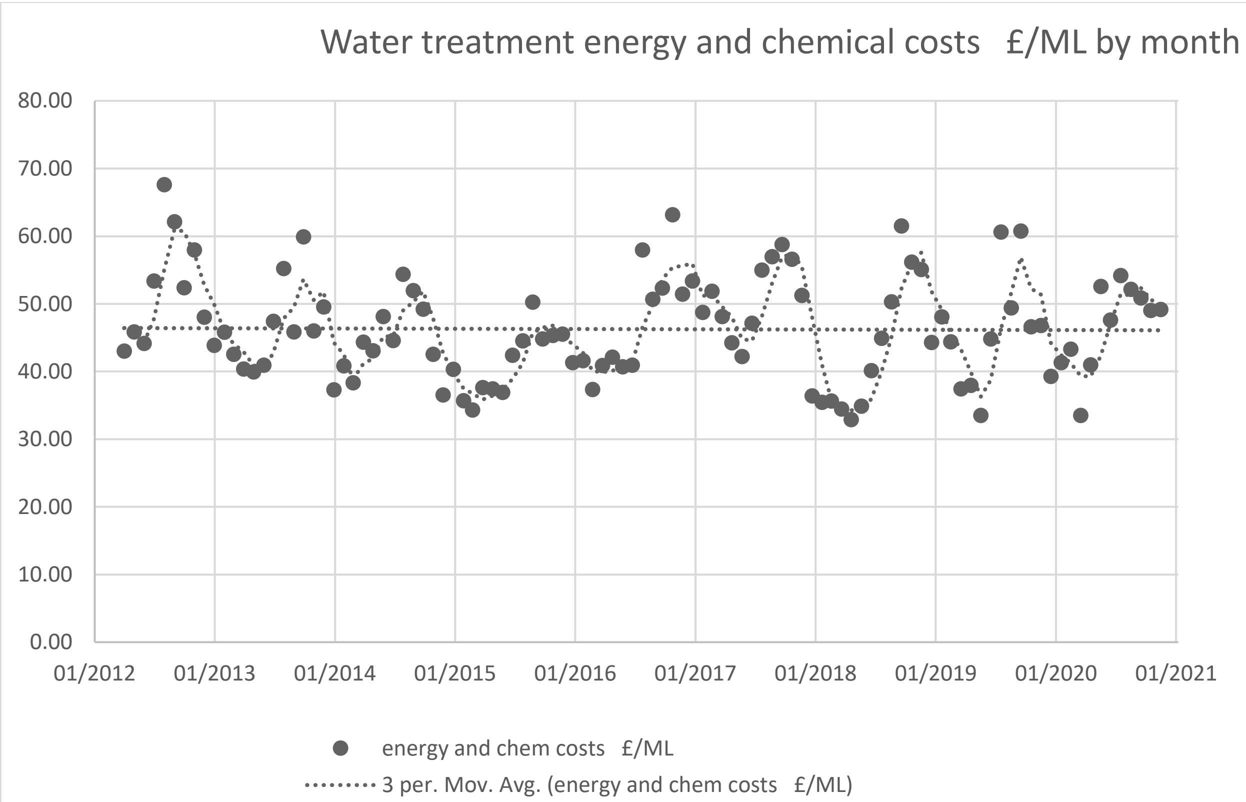

Figure D2 Water treatment energy and chemical costs £/ML for the Dungonnell WTW, 2009 to 2020.

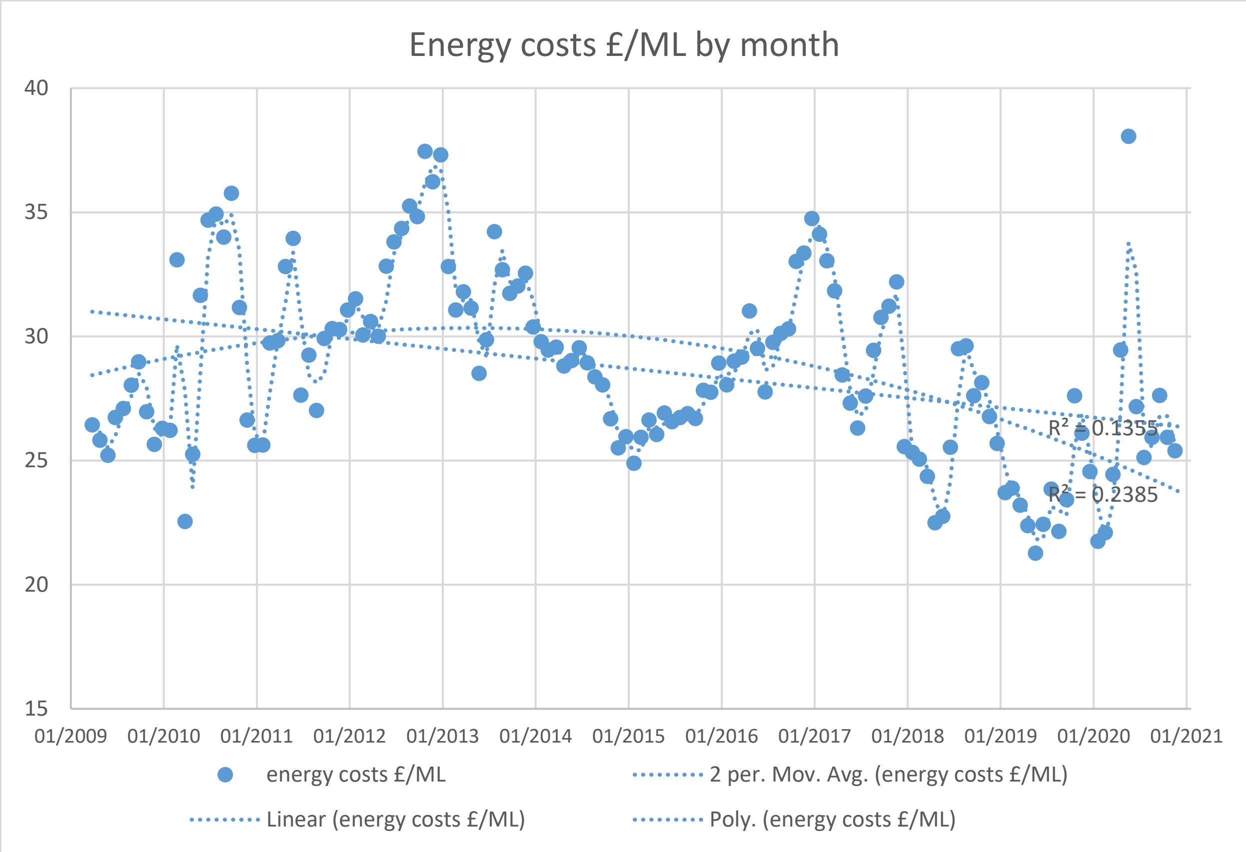

Figure D3 Energy Costs £/ML at Dungonnell WTW.

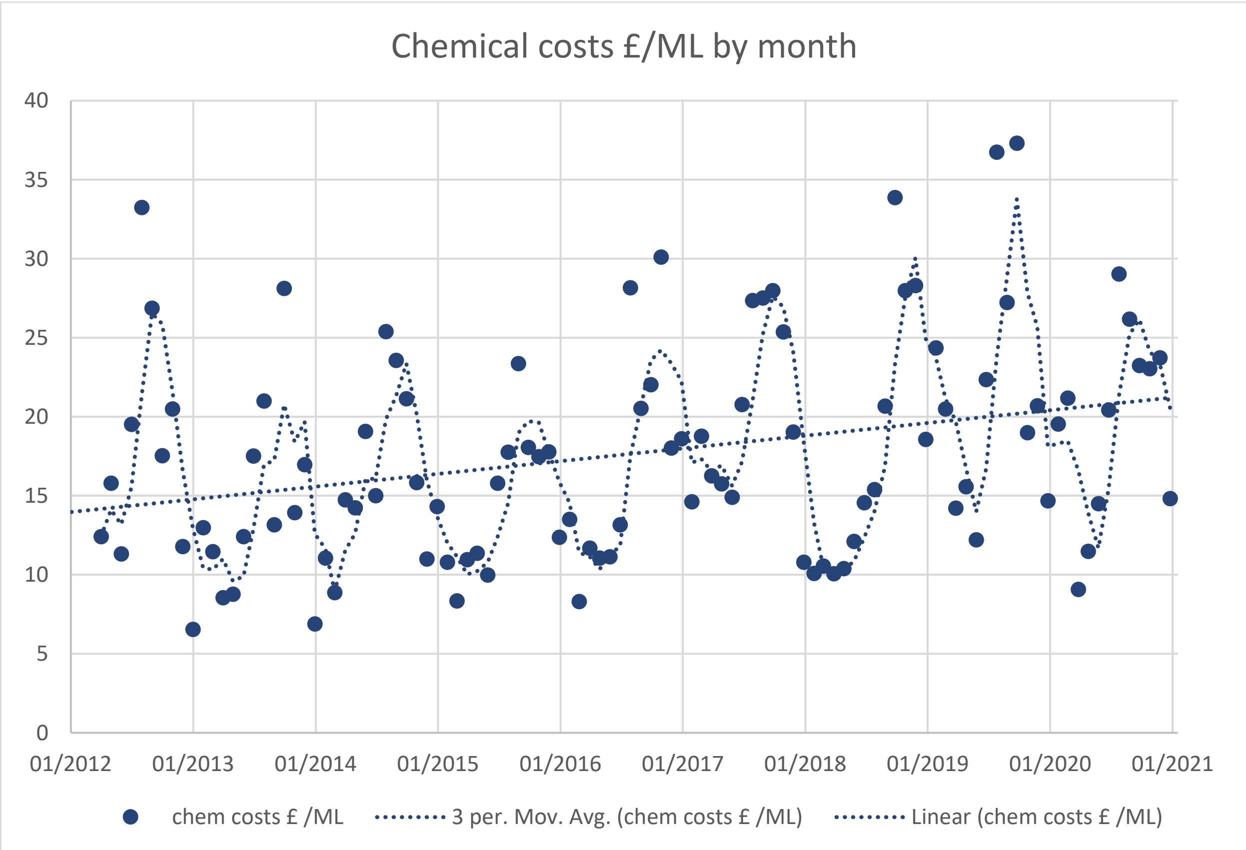

Figure D4 Chemical Costs £/ML at Dungonnell WTW.

Sludge costs

Data were obtained on the monthly quantities and costs of disposal of sludge by contractor from Dungonnell WTW over the period 2017 to 2020 inclusive. Given the reductions in observed turbidity, it might be expected that sludge quantities and disposal costs would fall per ML. Monthly sludge quantities and costs rose during the 2017 to 2020 period, in line with increased raw water throughput. A preliminary assessment (pending further analysis to allow for lagged effects) did not show a significant positive correlation between monthly sludge costs and ML throughput, nor between sludge and energy costs. Sludge quantities and costs £/ML are, however, positively correlated (R^2 = 0.31, $P < 0.001$) with chemical costs during the period, both of which are associated with the removal of material in raw water. However, these observed increases in chemical and sludge costs occurred during a period of reduced turbidity, and to a lesser extent colouration.

Conclusion

While there is evidence to show that raw water quality has improved over the period of observation and this could be attributed to the extent and timing of peatland restoration works, it is not possible to show that this is associated with, or responsible for, reductions in water treatment costs.

Average £/ML chemical and sludge disposal costs have risen during the latter part of the observation period following the-completion of Phase 2 of the peat restoration works. This is surprising as turbidity was observed to decline significantly. There have however been reductions in energy use and costs (£/ML), possibly due to other factors, that have kept mean £/ML reasonably constant in real terms during the period. Further analysis is required to determine whether other factors, yet to be identified, can help to explain the relationship between peat restoration, raw water and treatment costs.

The above results do not show a clear link between changes in water quality parameters, notably in turbidity and water treatment costs during pre and post restoration periods. Variations in energy and chemical costs could be attributable to unidentified factors, such as variation in operating conditions, practices and processes, including possible plant refit. The post 2018 period was characterised by considerable variation in seasonal conditions, notably hot dry summer periods.

Estimating potential benefits from clean raw water

Within the limits of the current data available and time for analysis, it is not possible to draw firm conclusions at this stage on the savings in treatment costs associated with improved raw water quality on the Garron Plateau.

Obtaining data to value the water quality benefit of peatland restoration has generally proved elusive. While Martin-Ortega et al., (2014)[60] suggest there are potential financial benefits of peatland restoration for utility companies associated with improved raw water quality, their review of scientific and grey literature was not able back this up with evidence. They attributed this to limited data availability due to confidentiality issues and other contextual factors affecting costs.

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[60] Martin-Ortega, J., Allott. T. E. H., Glenk, K. and Schaafsma, M. 2014. Valuing water quality improvements from peatland restoration: Evidence and challenges. Ecosystem Services, 9, 34–43

There are, however, some limited data on which to estimate the responsiveness of water treatment costs to raw water quality due to the variations in water plant operating procedures and conditions. United Utilities and Yorkshire Water (reported in Bain et al (2011)[61] estimated that an increase of one Hazen (water colour unit)/ML of daily throughput of water treated could result in an increase in treatment costs of between 10p to 20p/ML. Deriving estimates based on data from 12 treatment plants in the USA, Dearmont et al., (1998)[62] suggested a 1% increase in turbidity was associated with a 0.27% increase in chemical treatment costs, although average cost saving declined with greater throughput.

Using values transferred from elsewhere, at mean chemical costs of about £18/ML, it might be expected that a 1% reduction in mean turbidity levels would generate a saving of about £0.05/ML. This would equate to about £0.20/ML at the 4% reduction observed by Allen for the pre and post 2013 periods, and over £2/ML assuming a linear response over the reduction in mean turbidity observed between pre 2013 and the post 2018 restoration periods.

Energy cost have reduced by an average £5/ML during these two periods. It is not possible to attribute a proportion of this saving to observed reductions in turbidity in the absence of further information.

For the purpose here, indicative values for savings in selected water treatment costs have been derived, assuming a central estimate of a 25% reduction in turbidity. This is compatible with the range of observed values in Table D5. Indicative response to turbidity is assumed for chemical, energy and sludge costs in Table D6 (overleaf). That gives a central estimate of 4% savings in selected operating costs, equivalent to about £2.9/ML, and an annual saving of about £8,700/year (about £4/ha across 2000 ha managed by NIW, and £14/ha over the 600 ha restored by 2019. This is a cautious estimate of expected benefit, set at the current relatively low turbidity levels. In the absence of the restoration project, raw water quality would deteriorate and the potential to save water treatment costs will rise. These very cautious estimates are used here pending further assessment.

Table D5 Estimated Costs of Water Treatment at Dungonnell WTW.

ML throughput (2015-2020)	ML /year	3000
Dungonnell WTW		
Ops costs 2015-2021		
Chemical treatment	£/ML	21
Sludge	£/ML	25
Energy	£/ML	25
Total	£/ML	**71**
Total	£/m3 (1000l)	0.07
Total /year	£	213,000

Based on NIW data

[61] Bain, C.G., Bonn, A., Stoneman, R., Chapman, S., Coupar, A., Evans, M.,Gearey, B., Howat, M., Joosten, H., Keenleyside, C., Labadz, J., Lindsay, R.,Littlewood, N., Lunt, P., Miller, C.J., Moxey, A., Orr, H., Reed, M., Smith, P.,Swales, V., Thompson, D.B.A., Thompson, P.S., Van de Noort, R., Wilson, J.D.& Worrall, F. (2011) IUCN UK Commission of Inquiry on Peatlands. IUCN UK Peatland Programme, Edinburgh

[62] Dearmont,D., McCarl, B.A., and Tolman, D.A. .(1998) Costs of water treatment due to diminished water quality: A case study in Texas. Water Resources Research, VOL. 34, 4, 849-853

Estimates of % reductions in sediments and in N and P constituents transported by water, potentially to the freshwater environment were derived from modelling. However, the base loads are not known. N and P rates and the potential costs of damage are thought to be low under current land use and have not been considered further.

Table D6 Indicative savings in water treatment costs associated with reduction in peat related raw water turbidity at Dungonnell WTW.

		low	central	high
Potential reduction in turbidity	%	12%	25%	50%
Turbidity to cost response factor				
Chemicals	%	25%	25%	25%
Sludge	%	20%	20%	20%
Energy	%	10%	10%	10%
Potential savings in costs				
Chemical treatment	£/ML	0.6	1.3	2.6
Sludge	£/ML	0.5	1.1	2.1
Energy	£/ML	0.3	0.5	1.1
Total	£/ML	1.39	2.89	5.78
Reduction in total selected ops costs	%	2%	4%	8%
Total savings	£/m3	0.001	0.003	0.006
Total saving for throughput	£/year	4,158	8,663	17,325

Annex E: Farming systems

Context

Agricultural land use in Northern Ireland is dominated by the dairy, beef and sheep livestock sectors, occupying mainly improved grassland. Peatland areas, comprising either lowland wet grasslands or upland moors, are utilised for extensive grazing of beef and sheep. The non-diary livestock sector generally, and in agriculturally Less Favoured and Disadvantaged Areas particularly, is highly dependent on farm income support. Post Brexit, political uncertainties in Northern Ireland probably mean that prevailing arrangements for agricultural support will remain in the short term. In the medium to long term there is likely to be a shift towards paying farmers for environmental goods and services (see Annex A: Northern Ireland Peatland Policy Review: Peatland and Agricultural Policy). In this respect, farmers occupying peatland areas where productivity is naturally constrained are vulnerable to withdrawal of direct income support, but simultaneously may benefit in future from greater incentives and rewards for High Nature Value Farming.

Approach and estimates

For the purposes here, an assessment was made of the physical and financial performance of livestock farming systems typically occupying lowland and upland peatland areas. Data were obtained from the Annual Farm Business Survey published by DAERA[63] on the performance of livestock systems on lowlands and uplands, covering the period 2014/15 to 2019/20. Estimates were derived of Gross Output, Gross Margins, Fixed Costs and Net Margins for upland and lowland systems including less favoured and disadvantaged areas. Time series data were adjusted using Agricultural Price Indices to give 2021 values. Gross Margins (£/head) for suckler beef and sheep are given in Table E1.

Table E1 Estimated Gross Margins for beef and sheep systems in Northern Ireland, 2015/16 to 2019/20**.**

Gross Margins £/head	2015/16	2016/17	2017/18	2018/19	2019/2020	Average current	Average 2021 prices
Suckler Cows							
Non LFA	217	239	280	246	255	247	258
Disadvantaged Area	184	252	195	163	169	193	201
Severely Disadvantaged Area	189	218	182	140	145	175	183
Breeding Ewes					0		
Non LFA	51	55	59	53	55	55	57
Disadvantaged Area	40	51	46	36	37	42	44
Severely Disadvantaged Area (Cross-Bred Flocks)	36	40	37	32	33	36	37
Severely Disadvantaged Area (Hardy Hill Breeds	17	22	19	16	17	18	19

Using data on farm sizes and stock numbers, average stocking densities (Livestock Units per ha, LU/ha) were derived by agricultural designation (Table E2). (One LU is the equivalent of a dairy cow obtaining a maintenance diet from grass energy, about 7 ewes and their lambs, or 1 sucker cow and its progeny until fully weaned). The average stocking rates hide the considerable variation between land types within and between farms according to potential carrying capacity of the land.

[63] DAERA, 2020. Farm Incomes in Northern Ireland. Department of Agriculture, Environment and Rural Affairs Policy, Economics and Statistics Division, Belfast, and earlier editions.

Table E2 Areas and stocking rates for livestock farms by agricultural designation in Northern Ireland.

	SDA	DA	LFA	NON LFA
Utilised agricultural area per farm	95	64	82.5	62.4
Adjusted forage area per farm	65.6	60.1	63.3	58.2
Total cow equivalents per farm	80.3	86.4	82.8	90.1
of which cattle	47.1	65	54	72
of which sheep	33.3	22	29	17
Stocking rate (cow equiv/ha)	1.2	1.4	1.3	1.5

Estimates of fixed costs for livestock (beef and sheep) farms were obtained from DAERA sources[64] for 2017/18 and 2018/19 and expressed in 2021 prices using the ONS Agricultural Price Indices for agricultural inputs (Table E3). There is less variation between years in fixed costs compared with Gross Margins. Fixed costs were expressed in terms of average £/LU based on the stocking rates in Table E2.

Table E3 Estimated full and partial fixed costs for non-dairy livestock farms by agricultural designation, Northern Ireland, 2021 prices.

Agricultural Area	SDA		DA		LFA		NON LFA	
£/ha	Full	Partial	Full	Partial	Full	Partial	Full	Partial
Fixed costs (excluding labour)								
Conacre rent	38	0	55	0	43	0	74	0
Depreciation of fixed capital expenditure	40	12	81	24	53	16	81	24
Depreciation of machinery and equipmer	74	22	126	38	91	27	141	42
Upkeep and running costs of machinery	90	90	143	143	106	106	148	148
Farm fuel	6	6	9	9	7	7	11	11
Rates	6	0	17	0	10	0	15	0
Building repairs	37	15	46	18	40	16	59	24
Miscellaneous	25	10	43	17	30	12	51	20
Total Fixed Costs (excluding labour)	316	155	520	250	380	184	580	270
LABOUR								
Farmer and spouse	268	80	423	127	316	95	431	129
family	44	13	102	31	63	19	148	44
hired	2	1	16	5	6	2	15	5
Total Labour	314	94	541	162	385	116	594	178
Fixed Costs incl labour	630	249	1061	412	765	300	1174	448
Summary per LU								
Fixed costs (excluding labour)	263	129	371	178	292	142	387	180
Total Labour	262	79	386	116	296	89	396	119
Fixed Costs (incl land and labour)	525	208	758	294	588	231	783	299
Fixed Costs (incl labour, excl land)	493	208	719	294	555	231	733	299
Fixed costs excl land and labour	232	129	332	178	259	142	337	180
Employment per LU								
Employment days	4.1	1.2	6.0	1.8	4.6	1.4	6.2	1.9

Based on DAERA Sources

Net Margin £/LU was used as the key indicator of the change in agricultural output attributable to changes in grassland management. However, not all fixed costs at the farm scale change when there is a change in livestock numbers. For this reason, a distinction was made between full and partial

64 DAERA, 2020. Farm Incomes in Northern Ireland. As above

fixed costs (sometimes referred to as semi-fixed costs) where the latter are considered to change almost linearly with changes in output (this partition is based on evidence from the Regional Farm Business Surveys on the estimation of marginal costs). Table E3 provides estimates of full and partial fixed costs (£/LU) by agricultural designation. Land costs and income support were excluded and only a proportion of unpaid family labour was charged. Thus, the estimates indicate economic value added and are suitable for economic cost benefit analysis.

Combining estimates of gross margins and fixed costs, expressed as £/LU, generated net margins (£/LU) after partial fixed costs for Sheep (Table E4) and Beef (Table E5). It is noted that net margins after full fixed costs are removed are negative for sheep and beef in all cases, reflecting the observation that these systems are unprofitable if full fixed costs, including a value for unpaid family labour, are charged. Here the 'average' farm business is kept going by income support and off-farm earnings, including pensions. Net margins after partial fixed costs, an appropriate indicator to assess marginal changes in livestock numbers, are either low or negative.

Table E4 Estimated performance indicators for sheep enterprises by agricultural designation in Northern Ireland.

		DA	SDA X bred	SDA Hardy	LFA	Non LFA
Gross Output	£/head	108	101	75	112	115
Gross Margin	£/head	44	37	19	48	57
LU/head		0.14	0.14	0.12	0.14	0.15
GM/LU		314	267	158	343	380
Farm scale LU/ha		1.4	1.2	1.2	1.3	1.5
Fixed Costs (farmscale)						
Full incl labour (exc land)	£/LU	719	493	493	555	733
Partial incl labour excl land	£/LU	294	208	208	231	299
Net Margin £/LU						
full incl lab	£/LU	-404	-227	-336	-213	-353
Partial incl labour excl land	£/LU	20	59	-50	112	82

Table E5 Estimated performance indicators for suckler beef enterprises by agricultural designation in Northern Ireland, 2021 prices.

		DA	SDA	LFA	Non LFA
Gross Output	£/head	390	370	415	430
Gross Margin	£/head	201	183	220	258
LU/head, incl calf		1.00	1.00	1.00	1.10
GM/LU		201	183	220	235
Farm scale LU/ha		1.4	1.2	1.3	1.5
Fixed Costs (farmscale)					
Full incl labour (exc land)	£/LU	719	493	555	733
Partial incl labour (excl land)	£/LU	294	208	231	299
Net Margin £/LU					
full incl lab	£/LU	-517	-310	-335	-499
Partial incl labour excl land	£/LU	-93	-24	-11	-64

Estimates, based on a simple grassland model and literature[65] [66], were derived of typical stocking rates (LU/ha) by grassland management options found in lowland and upland peatland areas (Table E6). For example, uncontrolled grazing on moorland stocked at around 0.22 LU/ha to 0.25 LU/ha is known to result in severe habitat damage. Stocking rates at around 0.1 LU/ha or less are required to support moorland natural habitats[67,68]. The management agreements on Garron Plateau aim to limit stocking to 0.07Lu/ha. This was used as a target stocking rate for the restoration project for moorland habitats. In this way, changes in stocking rates (LU/ha) under different peatland management options were assessed and combined with £/LU estimates to give changes in economic returns, excluding subsidies and land costs.

Table E6 Indicative stocking rates by grassland management

	moor low stocking	moor moderate stocking	rough wet or bracken	Purple moor grass	dry heather moor	Unimproved/semi natural		Improved zero to moderate N				
kgN/ha	0	0	0	0	0	0	50	0	25	50	75	100
tDM/ha	0.31	0.46	0.93	1.10	1.08	2.76	3.56	3.09	3.94	4.74	5.51	6.25
Graze	1	1	1	1	1	1	0.55	0.55	0.55	0.55	0.55	0.55
Cutt	0	0	0	0	0	0	0.45	0.45	0.45	0.45	0.45	0.45
UME	2426	3639	7277	8641	8490	21608	28782	25037	31853	38376	44606	50543
LU/ha *	0.07	0.11	0.22	0.26	0.25	0.65	0.86	0.75	0.95	1.15	1.34	1.51

Note: moorland stocking at about 0.1 LU/ha is required for sustained moorland habitat management

Assumed beef and sheep combinations

The relative numbers and types of livestock vary according to peatland context. Moorland grazing involves a mix of hill cross and purebred sheep. Lowland peatlands have mixed, mainly suckler beef systems. This mix effects the estimates of average £/LU for the peatland study sites (Table E7).

Table E7 Estimated livestock combinations and Net Margins by peatland study areas.

(a) Garron Plateau

Sheep Type	Hill X	Hill Pure	Weighted
Mix % by total LU	60%	40%	100%
	£/LU	£/LU	£/LU
Gross output	721	625	683
Gross Margin	267	158	223
Net Margin (partial fixed costs)*	59	-50	15
Net Margin (full fixed costs) *	-227	-336	-270
* excl land costs			
LU/head, incl lambs	0.14	0.12	0.13

[65] Holt, A. and Morris, J. (2020) Plugging the income gap: Assessing environmental options for upland farms: A case study in Pendle Hill, Lancashire, Report to Pendle Hill Landscape Partnership, Natural Capital Solutions Ltd, December 2020.
[66] Martin, D., Fraser, M.D., Pakeman, R.J. & Moffat, A.M. 2013. *Natural England Review of Upland Evidence 2012 - Impact of moorland grazing and stocking rates.* Natural England Evidence Review, Number 006.
[67] Martin, D.,et al, 2012, as above
[68] McKnight, G.. 2014. Moorland Grazing - guidance for upland grazing management. Technical Note TN659, SRUC Ediburgh.

(b) Montiaghs Moss

Livestock	Sheep	Beef	Weighted
Mix	20%	80%	100%
	£/LU	£/LU	£/LU
Gross output	800	415	492
Gross Margin	343	220	245
Net Margin (partial fixed costs)*	112	-11	14
Net Margin (full fixed costs) *	-213	-335	-311
* excl land costs			
LU/head	0.14	1.00	0.83

Annex F: Forestry

Forestry Options

Options for the restoration of afforested peatlands in Northern Ireland were review by Mellon and Allen, (2015) [69]. They identified 20 sites occupying peatlands as potential areas for deforestation and restoration of natural peatland habitats. Restoration options vary according to site conditions including tree species and degree of maturity as this determines revenue from commercial felling.

Two sites on or adjacent to the Garron Plateau were identified, namely:

- **Glenariff Forest** contains a small area of poor quality (Yield Category (YC 2)) lodgepole pine of about 7 ha that offers a Primary Restoration Opportunity. The remainder, 93.5 ha of sitka spruce (YC 10-14), offers a Policy Opportunity for early removal before the expected maturity dates between 2026 and 2037.
- **Cleggan Forest** contains a large uniform plantation of predominantly sitka spruce bordering Garron Plateau, part of which serves the Dungonnell catchment. Felling schedules are set for between 2040 and 2046. There is a Primary Restoration Opportunity on 53 hectares along the northern fringe of the plateau and the remaining area is classed as a Policy Opportunity on 194.7 hectares (YC 10-12).

For the purposes here, it is assumed that the Primary Restoration Options are taken up on the Glenariff and Cleggan Forests areas over a three-year period, beginning 2026. Costs of deforestation and peatland restoration are charged to the project, with an assumed loss of future added value where forests are harvested before maturity. Estimates of forests yields are based on Yield Class and Maximum Incremental Yield by tree species[70], allowing for intermediate thinning. Timber Prices are based on the Forestry Commissions Price Indices, March 2021.

Some timber materials and brash can be used for restoration works. It is assumed that Policy Priority areas are restored to peatland habitats on the commercial maturation of the forest coupes, with no additional benefit or cost to the Peatland restoration project. Annual carbon emissions are estimated for the forest management options as they apply.

Table F1 (PTO)

[69] Mellon, C and Allen, D (2015). Forestry Northern Ireland. Options for the restoration of afforested peatlands in Northern Ireland – a scoping study. Final Report to RSPB Northern Ireland May 2015. Forest Research

[70] Matthews, R.W, Jenkins, T.A.R., Mackie, E.D., and Dick, E.C. 2016. Forest Yield: A handbook on forest growth and yield tables for British Forestry Commission, Edinburgh

Table F1 Loss of remaining values of standing forests at Garron Plateau if harvested early. Note that only the Priority areas are felled early in the schedule assessed for this project (hence with loss of value), Policy areas included for interest.

Forest stands at Garron Designation		**Priority**	**Policy**
Glenariff	areas ha	6.9	93.5
Species		pine	sitka
Yield category		4	12
mature yield at 2027-2036		240	720
Schedule harvest year (mean)		2032	2032
Early Harvest year (mean)		2028	2028
Loss of production years		4	4
Production loss £		429	1286
Remaining value (after thinnings)		**343**	**1029**
Cleggan	areas ha	95	195
Species		sitka	sitka
Yield category		12	14
mature yield at 2040	2040-2046	720	840
Schedule harvest year (mean)		2044	2044
Early harvest year (mean)		2028	2028
Loss of production years		16	16
Production loss £		5146	6003
Remaining value (after thinnings)		4116	4803
Years to maturity (YC 12-14) mean			60
Value of standing plantation £/m^3 (OB)			£/m^3
central (assumed here)			26.8
low			21.4
high	£/m4		32.2

Annex G: Peatland restoration costs

Approach

A review was carried out of peatland restoration work and costs. A number of organisations involved in peatland restoration works in the UK and Ireland were contacted. The review confirmed that the costs of restoration vary considerably according to context such that generalisations are difficult.

Peatland Restoration Activities

The costs of peatland restoration vary according to the type of peatland, the degree of degradation and context, particularly as this determines site accessibility and management.

There are significant differences between upland mainly blanket bogs and lowland mainly raised bogs, in terms of peatland ecology, land use pressures, processes of degradation and options for restoration. The depth of remaining peat and the severity of the processes and state of degradation are important factors affecting the choice and cost of restoration options. Accessibility to site, the need for low ground pressure vehicles and possibly of helicopters to deliver materials, can significantly affect the cost of restoration works. Furthermore, costs per hectare of restoration can vary according to scale, enabling the costs of design and supervision to be spread over larger areas in some cases.

Broadly, restoration involves three components that vary according to circumstances:

1. **Hydraulic Restoration** involving measures to control peat soil-water and associated water levels, including processes of rewetting. These include slowing down and retaining water through:
    - Blocking existing grips (surface drains) and underground field drainage pipes
    - Barrier dams, whether stone, timber or other materials
    - Modifying channel profiles (cross sections and gradients)
    - Erosion control measures including gulley blocking and filling, conservation bunding, and re-vegetation measures.

2. **Vegetation Restoration** involving re-establishment of peat forming vegetative cover, including:
    - Reseeding of vegetation cover in eroded areas- seed and feed
    - Coverage of bare peat to alleviate wind and water erosion, using brash or heather coverage
    - Biodegradable mattings and membranes
    - New plantings of sphagnum plugs
    - Relocation of plantings from adjacent sites
    - Reprofiling of gulley ridges and relaying vegetative cover
    - Conservation bunding
    - Regeneration or scrub control
    - Planting of indigenous tree species to provide erosion control.

3. **Land Management Interventions** involving controls on land use and access, including:
    - Discontinuation of arable farming, where relevant,
    - Controlled or avoided grazing, specifying livestock type, stocking rates, grazing seasons,
    - Controlled public access, to avoid further degradation, including recently restored sites,
    - Restrictive access measures, including livestock fencing, footpath and signage infrastructure,
    - Removal of inappropriate plantings, including coniferous forestry.

Peatland Restoration Costs

Broadly, the costs of restoration vary according to the above components, with variations according to the intensity of degradation, site conditions, notable access, and scale.

A review of the costs and benefits of peatland restoration in Scotland (Artz et al, 2018) assessed the cost effectiveness of alternative restoration techniques. With respect to hydraulic restoration, similar techniques were observed in upland blanket bogs and lowland raised bogs. Installation of barrier dams, repacking trenches and gullies, and membrane techniques were found to be hydraulically effective, although rehabilitation of structural measures require ongoing maintenance, and possible replacement. In forested areas, tree felling and drain blocking achieved water table recovery over time.

Vegetation restoration techniques vary a lot according to context, using a variety of reseeding methods, geotextile and other membrane to stabilise peat profiles, and measures to slow water flow and erosion.

Average costs were derived for 26 restoration interventions, and showed reasonable convergence of costs for most interventions except for erosion control where unit cost varied greatly according to context. Variation in the scale and intensity of peatland degradation, and in the type, intensity and spatial spread of intervention measures made it difficult to assess the area restored by and hence the average costs of individual intervention measures and restoration costs as a whole. Although interventions appeared effective immediately after installations, limited ongoing monitoring prevented evaluation of measures in the long term.

Artz et al (2018)[71] collected cost information from 19 restoration projects, involving total outturn costs that ranged between £3,600 and £191,000. Data from 17 sites showed average costs ranged between £800 to £3,000 per 'unit' of restoration, where the latter refer to hectares of restored peatland or km of restoration for channel works. They concluded that It was difficult to assess the relative cost effectiveness of the options chosen, either because the 'no intervention' counterfactual is difficult to assess, or there were many options that could be used on any situation. Responses from project managers suggested the effectiveness of restoration interventions was immediate and sustained for at least one year, but all were perceived to require further work to maintain effectiveness over the longer term.

Drawing on literature and interviews covering 59 restoration sites across the UK, Okumah at al. 2019[72] reviewed the cost of peatland restoration in the UK. They conclude that restoration costs comprise three main components: the direct cost of restoration works (89% of total costs), internal staff cost involved in project management and supervision, and other costs associated with specialist services for design and operations.

Reported costs per ha of restoration techniques vary considerably, although as noted by Artz et al, 2019, it proved difficult to attribute costs to areas of restoration. Furthermore, intervention techniques are used often in combinations across restoration sites according to needs and suitability. Techniques vary in average costs from about £300/ha for damming drains with peat material up to

[71]Artz, R, Faccioli,M. RobertsM, and Anderson, R. (2018) Peatland restoration – a comparative analysis of the costs and merits of different restoration methods. The James Hutton Institute, University of Exeter and Forest Research, Final Report, March 2018.

[72] Okumah, M., Walker, C., Martin-Ortega, J., Ferré, M., Glenk, K. and Novo, P. (2019). How much does peatland restoration cost? Insights from the UK. University of Leeds -SRUC Report.

over £5,000/ha for damming with imported stone material, Okumah et al. estimated average costs at about £1200/ha of restored peatland compared with £880/ha suggested by Artz et al (2019).

Peatland restoration costs were reported to vary according to site characteristics such as site altitude, restoration history, and depth of remaining peat, although differences in mean costs were not statistically significant. ‘Low altitude’ sites (below 349 m AOD) showed average costs of £1,242/ha compare with ‘high altitude sites’ (350 m and above) at £1,011/ha. Scale was not identified as a source of variation in unit costs. The need on some sites for detailed site surveys, analysis, design and tendering costs is however likely to offer economies of scale on larger sites.

With regards to factors affecting average costs, practitioner identified location as an important factor. Location was associated with distance, remoteness and accessibility, interacting with site conditions as they determine the need for specialist vehicle to transport materials. Location also affected the availability of contractors and quotation costs. Land ownership was reported to affect restoration costs associated with obtaining necessary agreements and consents. Public consultations may be required where changes in land use or access are involved. Consultations and consents generally take longer on common land where entitlements are held by many different users.

Commenting on the gaps in available information, Okumah at al. (2019) identify data requirements for a comprehensive analysis of restoration costs. It is apparent however, that while reasonable estimates of individual interventions may be feasible, the considerable variation in site conditions, restoration needs (as this affects required combinations of interventions), scale and management context make generalisations difficult, and potentially misleading.

Glenk et al report evidence on the restoration costs from the Peatland Action Programme in Scotland[73], drawing on 90 projects and 166 sites and data from project applications and final reporting documentation. Restoration activities were broadly categorised into five main categories: A) Ditch (grip) blocking; B) Hag, gully and bare peat restoration; C) Bunding; D) Forest to bog restoration; and E) Scrub removal (Table G1).

Table G1 Estimated cost of peatland restoration activities in the UK (taken from Glenk et al 2020)

		Design Estimate* £/ha		Actual Cost** £/ha		Nr of
Code	Intervention	mean	median	mean	median	sites**
A	Ditch Blocking and Dams	580	525	1100	1000	6
B	Hag, Gulley & Bare Peat Restoration	620	535	560	440	4
C	Bunding and Profiling	2140				0
DE	Forest to Bog Rest (D) & Scrub removal (E)	5230	4610	1850	1600	16
A&B	1750	1750	1170	830	580	31
B&C		3040	2970	1410	750	3
A, D&E		2830	2830	1140	1070	10
DE absent		1540	990	880	630	44
DE present		3540	3810	1580	1410	26
Overall average		1980	1160	1240	960	

Source: Glenk et al, 2020

excludes management and supervision

* at proposal stage ** after works completion , costs rounded to nearest 10

73 Glenk, K. Novo, P., Roberts, M., Sposato, M., Martin-Ortega, J., Shirkhorshidi, M., and Potts, J. (2020). The costs of peatland restoration. Analysis of an evolving database based on the Peatland Action Programme in Scotland. SEFARI report.

Based on costs estimates at the project application stage, the mean estimate of restoration cost per hectare is £1976 (median: £1157). The corresponding estimate across all 'final reporting' projects is considerably lower at £1227 (median: £955). Glenk et al. 2020 attribute this difference to i) overestimation of measures needed for restoration; ii) overestimation of restoration costs for specific measures; and iii) changes in the area under restoration. Excluding very small and very large values, the mean costs for reported restoration is £1061 per hectare (median: £955).

Median project management costs were about 6% of total restoration costs, with mean values for oversight services by Peatland Action equivalent to between 6% and 12% of total restoration costs (3% -9% median value). It was observed that restoration costs on forest to bog restoration were twice as high as non-forested sites. Costs were significantly higher where peat is actively eroding, and removal of scrub and forest is involved. A regression function was derived to explain variation in restoration costs (R^2 = 0.47). Forest to bog restoration and scrub removal accounted for the biggest source of variation. The intercept value indicating costs when no other independent factors are included was £708/ha.

Generic Habitat Management

Estimates of peatland and related habitat management are also available from the Environmental Management Farm Level Costing Tool Costing produced by NT, RSPB and the WLT that are included here for reference (Table G2).

Table G2 Estimated Habitat management costs for selected peatland related habitats

	Creation	**Restoration**	**Maintenance**
$£_{2020/21}$	**£/ha**	**£/ha**	**£/ha/year**
Purple Moor Grass & Rush Pastures	660	690	185
Lowland Fens	1,100	760	45
Reedbeds	1,800	1,100	100
Lowland Raised Bog	1,100	650	190
Blanket Bog	-	660	50

Source: NT/RSPB/WLT, 2019

Reported Restoration Costs from the Garron Plateau Peatland Projects

Two phases of peatland restoration works, mainly to modify hydraulic process, have been carried out to date (Table G3), alongside changes in sheep grazing regimes. Drains were blocked to raise the water table, together with the installation of peat, timber, stone and plastic sheet dams. No replanting or transfer of bog vegetation was undertaken during these phases. The total number of dams installed was similar for both phases (1,120 for phase 1 and 1,017 for phase 2), but the area covered including areas containing blocked drains differed considerably between the phases, as did average unit costs in £/ha.

Average costs for the works carried out by contractor including materials was about £260/ha in 2021 prices. The works were carried out under the auspices of ongoing development projects, supported by organisational staff. Full costs, including design and supervision, additional materials, and volunteer inputs would probably be twice the reported contractor costs, but details are not known. This would give an estimate of about £520/ha in 2021 prices. This adjusted estimate is similar to the design stage median estimate in 2019 prices of £525/ha (£570/ha in 2021 prices) reported by Glenk et al 2020, excluding design and management (Table G1). It is much lower than the actual median cost of £1,100/ha reported by Glenk et al. for ditch and dams works.

Table G3 Peat bog restoration and costs on the Garron Plateau 2013-2019

Date	***Project***	***No of dams constructed****	***Area and costs of restoration*****
Nov 2013 – Feb 2014	Futurescapes Project	799 peat dams 208 Timber dams 82 Plastic dams 31 stone dams	74 Ha £26, 850 £362/ha £440/ha in 2021 prices
Jan 2018 – Feb 2019	CABB Project	781 peat dams 143 Timber dams 93 Stone dams	493 ha £100, 860 £205/ha £230/ha 2021 prices

*plus 38.5 km of blocked drains in the two phases ** cost of contracted out works only.

Estimated Peatland Restoration Capital and Maintenance Costs for Study Sites

For the purpose of project appraisal, estimates were derived from the above sources for capital (Tables G4 and G5) and annual maintenance costs (Table G6) for the Garron Plateau and Montiaghs Moss sites, expressed in £/ha in 2021 prices.

Table G4 Estimated capital cost for peatland restoration and related works on the Garron Plateau.

	Low £/ha	central £/ha	high £/ha
Blanket Bog Restoration (mixed works)	850	1100	1500
Blanket Bog Restoration (drain and dams)	560	700	1100
Conif to BB	1500	2100	2700
Scrub clearance	1350	1500	1700
Wet heathland : BB	280	560	700
Purple more to BB	280	350	550
Dry heathland restored	250	400	600
Semi Natural Dry Grassland	175	250	325

Table G5: Estimated capital cost for peatland restoration and related works on Montiaghs Moss.

	Low £/ha	central £/ha	high £/ha
Woodland (BroadL) clearance	1550	1850	2400
Scrub clearance	1250	1400	1650
Establish neutral grassland	350	500	650
Degraded raisewd bog ex Broad/l wood	1550	1850	2400
Defraded raised bog ex conif	1500	2100	2700
Degraded raised bog ex dry scrub	1350	1500	1750
Degraded raised bog wet scrub	1350	1500	1750
Neutral grass ex improved grass	350	500	650
Neutral grass ex wet grassland	350	500	650

Table G6 Annual costs of maintenance of peatland restoration site for Garron Plateau and Montiaghs Moss sites £/ha

Maintenance during	% of capital works	Low	central	high
Recovery period	15%	£/ha	£/ha	£/ha
Favourable condition	10%			
Garron Plateau				
Blanket Bog Restoration (mixed works)		128	165	225
Recovery		85	110	150
Favourable				
Blanket Bog Restoration (drain and dams))				
Recovery		84	105	165
Favourable		56	70	110
Wet heathland : BB				
Recovery		42	84	105
Favourable		28	56	70
Purple more to BB				
Recovery		42	53	83
Favourable		28	35	55
Dry heathland restored				
Recovery		38	60	90
Favourable		25	40	60
Conif to BB				
Recovery		84	105	165
Favourable		56	70	110
Lowland Montiagh's Marshes				
Maintenance of lowland bog (degraded)		75	90	105
Semi Natural Dry Grassland				
Recovery		53	75	98
Favourable		35	50	65

Annex H: Employment generation and peatland restoration

Context

The peatland projects in the study areas have potential to impact on employment. The effects can be direct in terms of the number of types of jobs generated through the project of peatland restoration and subsequent operations and maintenance. Indirect employment effects arise due to changes in land based activities as well as knock on effects on employment though related supply chains and the local economy[74 75 76].

Approach

The potential impact of changes can be assessed by comparing estimated labour requirements for the with and without restoration options. A very high-level assessment is made here of selected employment effects of the Garron Plateau and Montiaghs Moss Projects based on project expenditures and the proportion likely to be associated with employment costs. The impacts on farm employment due to reduced stocking are considered. A broad estimate of the employment created in the wider Northern Ireland economy is also made using employment multipliers[77]. For the purpose here, the assessment is indicative of the direction of employment generation only and is not regarded as a reliable absolute estimate of the employment effects of the two projects.

Average employment costs per FTE are estimated at about £24,000 in the nature conservation sector across a range of employee grades (Table H1).

Table H1 Estimated average costs of employment of FTE equivalent, all grades in the nature conservation sector, Northern Ireland.

Grade	£000/yr empl cost	ratio nr	ratio %	£000/yr cost weighted
Professional	48	1	4%	2.1
Technical	34	4	17%	5.9
Skilled	25	6	26%	6.5
Unskilled	18	12	52%	9.4
Av employment cost / person		23	100%	23.9

Estimated Employment Effects: Garron Plateau

Estimates were made of the proportion of total costs by main component that comprise employment costs (Table 2) based on information of similar types of land based activities, including estimates from the farming sector. These proportions were applied to total undiscounted costs (over 50 years) for the Garron Project to derive employment expenditure by the main project costs components. Dividing by the average cost £/FTE gave the total equivalent FTE of 552 FTE years over

[74] Rayment, M and Dickie, I. 2001. Conservation Works for Local Economies in the UK, RSPB, Sandy
[75] Mills, J. 2002. More than Biodiversity: The Socio-economic Impact of Implementing Biodiversity Action Plans in the UK Journal of Environmental Planning and Management, 45:4, 533-547,
[76] RSPB. 2012. Natural Foundations: conservation and employment in the UK. RSPB, Sandy
[77] NISRA. 2021. NI Economic Accounts: NI Supply-Use Tables and Multipliers, NI Statistics and Research Agency.

a 50 year project life, or an average 11.0 FTE equivalents per year (with a range between 8.9 and 14.3 FTEs for low and high assumptions respectively (Table H2).

Table H2 Estimated employment costs and FTE equivalents for the Garron Peatland Restoration Project

	Costs at outturn 50 years £000	estimated % labour expenditure			Estimated employment expenditure £'000			Employment Full Time Equivalents Years		
		low	central	High	low	central	high	low	central	high
Capital	2438	25%	35%	50%	610	853	1219	25	36	51
Ops & maintenance	16318	35%	45%	60%	5711	7343	9791	239	307	409
Staffing and costs	6347	60%	70%	85%	3808	4443	5395	159	186	226
Contingency	1133	40%	50%	60%	453	567	680	19	24	28
Total FTE over 50 years								443	552	714
Average FTE per year								8.9	11.0	14.3

The reduction in livestock numbers on the Garron Plateau could reduce the demand for farm labour. Livestock units (LU) decrease by an estimated 708 LU at full development. At an average 1.3 days direct labour time per livestock unit[78] and 220 work days/year this gives 4.2 FTE/year of agricultural labour at full development (708 x 1.3/220). On this basis, the reduction in farm employment associated with sheep farming is offset by the employment created by the peatland project. Part of the peatland maintenance and land management activities will be carried out by farmers by arrangement and linked to EFS and other payments. In this way, employment losses in the farming sector are likely to be small.

Employment and associated income and expenditures generated the Garron Project has potential to increase employment in the wider Northern Ireland economy. The Type 1 employment multiplier in 2016 for the Industry Group A01 Crop and Animal Production, Hunting and Related Services for Northern Ireland was 2.4 (NISRA, 2021) (The UK equivalent multiplier was 1.7 (ONS, 2021)). Applying this to the crude estimate of net employment gain of 6.8 FTE/year above (11 - 4.2), gives an estimate of 16.3 FTE/year additional employment per year, including impacts across the wider Northern Ireland economy (about 11.3 FTE/year for the low estimate in Table 2). This estimate is crude and serves only to indicate the direction of change rather than provide a robust prediction of employment effects.

Unpaid 'employment' is also generated through volunteering. An allowance is made for this above in the form of some nominal volunteer costs. Volunteering could involve the work of about 2 FTE/year on the Garron.

Estimated Employment Effects: Montiaghs Moss

Using the approach outlined above, Table H3 shows for the central estimate an average increase of 1.3 FTE/year attributable to the Montiaghs Moss restoration project over its life, with a range of 1.1 FTE/year to 1.6 FTE/year. Estimated stocking rates decline by 13.7 LU, associated with a decline in farm labour equivalent to about 0.1 LU/year (13.7 x 1.3/220). The net increase is thus about 1.2 FTE/year.

[78] It is noted in the Annex E on Agricultural Economics that average total labour inputs are about 4 .4 units labour /LU. However, about 30% of this average is considered to change directly with livestock numbers at the farm scale.

Table H3 Estimated employment costs and FTE equivalents for the Garron Peatland Restoration Project

	Costs at outturn 50 years £000	Estimated % labour expenditure			Estimated employment expenditure £'000			Employment Full Time Equivalents Years		
		low	central	High	low	central	high	low	central	high
Capital	496	0.25	0.35	0.50	124	173	248	5	7	10
Ops and Mai	710	0.35	0.45	0.60	249	320	426	10	13	18
Staffing and	1390	0.60	0.70	0.85	834	973	1181	35	41	49
Contingency	130	0.40	0.50	0.60	52	65	78	2	3	3
					Total FTE over 50 years			53	64	81
					Average FTE per year			1.05	1.28	1.62

Applying an FTE multiplier of 2.4 as above, gives an estimate of about 2.9 FTE/year including employment effects in the wider Northern Ireland economy (about 2.3 FTE for the low estimate in Table H3). During the early restoration phase, volunteering could account for a further 1 FTE/year. This estimate of employment effects of the Montiaghs Moss restoration is crude and serves only to indicate the direction of change rather than provide a robust prediction of employment effects.

Conclusion

In conclusion, the above estimates are indicative only of the direction of change. They suggest that peatland restoration has potential to contribute to employment through changes in landscape management. It is important that actions are taken to involve farmers in the restoration process and its activities, to ensure that farm businesses are rewarded for the public goods they provide as a result of peatland restoration.