The costs of peatland restoration in Scotland – considerations for data collection and systematic analysis

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Summary

This report serves as a basis of reference regarding ongoing research on peatland restoration costs within the Scottish Government Rural Affairs and the Environment Portfolio Strategic Research Programme 2016–2021, RD 1.1.4 (Soil management). It lays the foundation for data collection and subsequent analysis to enhance our understanding of restoration costs and their variation across measures, peatland condition, and location of restoration sites. The report summarises existing evidence on cost-effectiveness analysis of restoration, potential indicators of the effectiveness of peatland restoration and types of peatland restoration costs. It also proposes an initial framework for collecting and analysing peatland restoration cost data.

There is a lack of information on cost-effectiveness analysis for peatland restoration that takes into account different restoration measures and analyses underlying reasons for costs and effectiveness variation. Literature on cost-effectiveness analysis of habitat or ecosystem restoration in general remains scarce, with most studies focusing only on ecological outputs and future scenarios. Existing costs estimates typically include materials and labour but rarely maintenance costs. Similarly, use of discounting is rarely considered and measures and time frames considered are highly varied. Most of the spatial optimisation for cost-effectiveness focuses on the spatial variation of costs and not on effectiveness as well.

Using reductions in greenhouse gas emissions is most straightforward considering a range of potential indicators of effectiveness of peatland restoration; several proxy indicators such as vegetation classes have been identified to overcome some of the challenges associated with measuring emissions. Peatland restoration costs may include capital costs, recurring costs such as those related to maintenance and monitoring, administrative costs and opportunity costs. Depending on a wide range of circumstantial and site-specific factors and restoration techniques implemented, a large variation in costs can be expected. An on-going challenge is the consideration of opportunity costs as a potentially considerable cost component.

Efforts are needed to systematically collect data on costs and assess the factors explaining variation in costs, including spatial factors. The Peatland Action scheme grant process offers an opportunity to collect detailed restoration cost data that can enable a more nuanced analysis of variation in cost across different spatial scales and restoration activities. The framework proposed in this report summarises the information entailed in the data sources and identifies appropriate statistical methods to be used for data analysis.

1. Introduction

1.1. *Background*

Peatlands are an important part of Scotland's natural capital. Following periods of historic degradation, the restoration of peatlands has received increasing attention by policy makers due to its potential to contribute to greenhouse gas mitigation, to the regulation of water quality and quantity and to meet biodiversity conservation targets (Glenk and Martin-Ortega 2018; Glenk et al. 2014; Martin-Ortega et al. 2014).

In its recent Draft Climate Change Plan[1], the Scottish Government specifies targets to restore 20,000 hectares of peatlands each year over the next 15 years, at least initially supported through restoration grants available to land managers. There has been a pledge by the Scottish Government to commit £8 million in 2017/18 to fund restoration activities through the voluntary Peatland Action scheme, administered by Scottish Natural Heritage (SNH)[2]. Between 2013 and 2016, grants through the Peatland Action programme resulted in the restoration of about 10,000 hectares (2013-2016).

To ensure that current and future investments in restoration activities represent 'value for money', knowledge on the costs and benefits of peatland restoration is needed (Glenk et al. 2014). Initial social cost-benefit analyses suggest that benefits of restoration will likely outweigh costs (Moxey and Moran 2014; Glenk and Martin-Ortega 2018). While this provides economic justification for public support for restoration at a national scale, it is unclear if all individual restoration projects pass a cost-benefit test. Knowledge on where restoration will yield the greatest net benefits in terms of welfare, and in terms of biophysical ecosystem service delivery including greenhouse gas mitigation, will become increasingly important as restoration efforts are scaled up to meet the ambitious targets laid out in Scotland's Draft Climate Change Plan. Spatially explicit information can serve to support greenhouse gas emission reporting ("carbon accounting") and the development of alternative private or public/private, market-based funding mechanisms for restoration, for example in line with the Peatland Code[3].

Based on information gathered in the initial phase of Peatland Action, there is a large variation in implementation and maintenance costs depending on restoration methods and other site-specific factors. Regarding opportunity costs to land managers (in terms of income forgone), some land managers reported to benefit from restoration, for example through reduced mortality of grouse chicks (Byg and Novo 2017). Overall, however, there is a paucity of data on costs and their spatial distribution, and knowledge on how they relate to ecosystem service benefits is limited. Therefore, efforts are needed to systematically

[1] http://www.gov.scot/Resource/0051/00513102.pdf
[2] http://www.iucn-uk-peatlandprogramme.org/news-and-events/news/scottish-government-sets-peatlands-route-recovery
[3] http://www.iucn-uk-peatlandprogramme.org/peatland-code

collect data on costs and assess the factors explaining variation in costs, including spatial factors. This will underpin the following types of analyses:

- Cost-effectiveness analysis (CEA): costs can be compared to indicators of effectiveness related to ecosystem service delivery or other project outcomes. CEA may be used to target restoration efforts if information on the spatial variation in costs and effectiveness is available. It may also be used to gauge budget requirements for achieving given targets, for example regarding greenhouse gas mitigation.
- Marginal abatement cost curve (MACC) analysis: MACC curves are based on CEA of individual measures to reduce the concentration of a pollutant (e.g. greenhouse gas emissions). They therefore require detailed information on costs and effectiveness of individual restoration measures, as well as on their potential to be implemented given constraints in the natural environment and in management. MACC curves thus help policy makers identify restoration measures with the greatest potential to abate pollutants in a cost-effective manner.
- Social cost-benefit analysis (CBA): both at project or at programme level, CBA may assist in defining whether investment represents good value for money. Benefits here represent benefits to society as a whole while, in the case of peatland restoration, costs are mainly borne by private land owners implementing restoration.

1.2 *Brief overview on existing cost data for peatland restoration*

Peatland restoration comes at a cost to private land managers. Costs comprise of upfront capital costs needed to implement restoration practices, recurring costs associated with maintenance and monitoring of the restoration sites, and transaction costs. Private land managers also face an opportunity cost in terms of income forgone from alternative land uses.

Restoration can be achieved by implementing various restoration techniques including, for example, blocking grips, drains and gullies, re-profiling of peat, or stabilisation of bare peat through reseeding or the use of jute mats. In case a peatland is being used for forestry, trees need to be removed before preparing the area for restoration. Costs of implementation vary greatly depending on the technique used and the associated need for machinery, labour and materials as well as costs associated with accessing the restoration sites. Furthermore, appropriate restoration techniques and hence costs of restoration vary depending on the ecological condition of peatlands, which is associated with current land use and management. For example, restoring a peatland that is currently used for forestry will require a different set of measures compared to a peatland that has been drained to allow upland sheep grazing. Highly eroded areas with large patches of bare peat will have to be restored with a different degree of effort compared to areas with shallow ditches and continuous vegetation cover. Data on actual implementation costs is mainly anecdotal at present. Moxey and Moran (2014) refer to an indicative range of £200/ha to £10,000/ha.

As mentioned above, about 10,000 hectares of peatland restoration have been implemented since 2013 through Peatland Action. Unfortunately, the application and reporting process was not specifically designed up to derive per hectare values of restoration costs, broken down by restoration technique, and did not systematically relate restoration activities to peatland condition. According to the SNH Peatland Action manager (A. McBride, pers. comm.), indicative per hectare costs including implementation and management costs vary greatly and span from about £300/ha for restoration of dry heath peatlands to about £5,000/ha for restoration of sites of peat extraction, or where bare peat dominates. Including all project management costs and a wide range of restoration activities including expensive forest to bog and bare peat restoration, the average cost per hectare over the 3 years of the Peatland Action scheme is reported to be about £830 per hectare for all types of restoration.

Recurring costs may also vary greatly. Moxey and Moran (2014) use a range of £25/ha (minimal monitoring costs and no management and opportunity costs) to £400/ha (substantial opportunity costs and/or high costs of management and monitoring) for aggregate average annual on-going costs. The opportunity costs of restoring peatlands can vary greatly, depending on the individual context of restoration sites vis-à-vis business needs and objectives, and may only become evident over time through collecting detailed information on management changes from individual land managers (Moxey 2016). Profitability of livestock grazing and grouse management as two prominent land use options on peatlands may typically lie in the range of £20/ha to £140/ha. Gross margins of upland farms may actually be negative (Moxey 2016; Smyth et al. 2015). Furthermore, early restoration action may not be representative of opportunity costs of large scale restoration since initial restoration areas may be allocated to areas of low productivity. Opportunity costs will also be likely affected by potential changes in policy support following Brexit.

1.3 *Report aims and objectives*

This report serves as a basis of reference regarding ongoing research regarding peatland restoration costs within the Scottish Government Rural Affairs and the Environment Portfolio Strategic Research Programme 2016–2021. It lays the foundation for data collection and subsequent analysis to enhance our understanding of restoration costs and their variation across measures, peatland condition, and location of restoration sites.

The specific objectives of this report are as follows:

- To provide a brief review of existing data and studies on cost-effectiveness of habitat and ecosystem restoration;
- To identify potential indicators of effectiveness and associated data sources;
- To identify elements of costs to be considered and ways to measuring them;
- To develop an initial framework for analysing cost data to understand (spatial) variation in costs.

2. Costs and cost-effectiveness analysis of habitat and ecosystem restoration – an overview of the literature

Literature on cost-effectiveness analysis of habitat or ecosystem restoration remains scarce, with most studies focusing only on ecological outputs. Where cost-effectiveness has been considered, modelling of future scenarios is more common than reporting on completed projects. Overall costs typically include only materials and labour, with maintenance costs accounted for more rarely. We found only three examples of opportunity costs being explicitly incorporated into calculations, either accounted using payment levels from agri-environment schemes (Newton et al., 2012) or through declines in production (Birch et al., 2010; Gren, Baxter, Mikusinski, & Possingham, 2014). The use of discount rates was rare, and where used ranged from 2% (Wada et al., 2017) to 10% (Newton et al., 2012). Measures of effectiveness are highly varied, including area restored (Grand-Clement et al., 2015), measures of actions taken (e.g. area cleared of invasive plants (Lindenmayer et al., 2015; McConnachie, Cowling, van Wilgen, & McConnachie, 2012), avoidance of damage by action (Black, Turpie, & Rao, 2016; Pinjuv, Daugherty, & Fox, 2000) and ecological (DEFRA, 2008; Gren et al., 2014; Macmillan, Harley, & Morrison, 1998; Petty & Thorne, 2005; Powell, Ellsworth, Litton, Oleson, & Ammondt, 2017; Rose, Heard, Chee, & Wintle, 2016; Wada et al., 2017) or social (Birch et al., 2010; Newton et al., 2012) changes. The majority of studies concentrate on a single spatial scale, and time frames range from one (Grand-Clement et al., 2015) to 100 (Macmillan et al., 1998; Schuster & Arcese, 2015) years (Table 1).

Cost-effectiveness analysis of peatland restoration has previously been carried out in the shallow peatlands of Exmoor National Park, UK (Grand-Clement et al., 2015). This study focused on ditch blocking carried out within the National Park, comparing methods using peat, wood, and plastic dams. Costs were measured through direct expenditure over a single year, excluding land purchase or monitoring. Outcomes were measured against a 2.5 year baseline of water quality, quantity, biodiversity, gaseous emissions, peat depth and drain density, with effectiveness measured as area considered restored after one year. Overall costs varied from £473-£811/ha, depending on location. The study did not detail costs by restoration action, nor did it consider the reasons for the varied costs at different sites (Grand-Clement et al., 2015). Overall cost-effectiveness (or cost-benefit) of peatland restoration for carbon sequestration has also been measured at the Scottish (Chapman, Thomson, & Matthews, 2012) and UK (Moxey, 2011) scale. Both studies used average costs, and were not concerned with comparing actions or locations, but assessing the viability of peatland restoration as a method for tackling CO_2 emissions. These studies show large variation in cost estimates, ranging from £800/ha at the Scottish scale (Chapman et al., 2012) to £1500/ha, or £29/tCO_2e, at the UK scale (Moxey, 2011). In 2008 a study by DEFRA estimated costs of UK peatland restoration to be £1600/ha, including land purchase costs, but again did not differentiate by action (DEFRA, 2008).

We identified four additional papers which measure cost-effectiveness of past actions. Three of these studies were concerned with invasive plant removal, in Australia (Lindenmayer et al., 2015), South Africa (McConnachie et al., 2012) and Hawaii (Powell et al., 2017). The forth study compared actions for the removal of small diameter ponderosa pines in the USA (Pinjuv et al., 2000). Only one study considered the ecological response of the system as the measure of effectiveness (i.e. recovery of native vegetation (Powell et al., 2017)). Other studies measured actions taken (i.e. reduction in invasive plant cover (Lindenmayer et al., 2015; McConnachie et al., 2012), or compared actions based on the amount of damage caused to remaining vegetation (Pinjuv et al., 2000). All studies included material and labour costs, with only Powell et al. (2017) incorporating maintenance costs.

Spatial optimisation for cost-effective restoration has largely relied on spatial variation in costs of actions and has not considered spatial variation in effectiveness. Indeed, the importance of considering the spatial variation in costs has been well identified in the global conservation literature (Evans et al., 2015; Naidoo & Ricketts, 2006; Wilson, McBride, Bode, & Possingham, 2006). In the context of peatland restoration, Glenk et al (2014) provide an overview of the importance, and associated challenges, of spatial variation to achieving spatially optimal peatland restoration. Benefits of peatland restoration not only vary with the biophysical characteristics of the site, but must also take account of the spatial variation in beneficiaries. This includes local population, as well as accessibility and availability of substitute sites. Benefits of restoration may be impacted by the biophysical characteristics outwith the immediate restoration area, and indeed may accrue over larger spatial areas, dependent on the hydrological connectivity between sites. While costs also vary between peatland sites due to accessibility and biophysical characteristics, they do not necessarily vary over the same spatial scales as benefits. Indeed benefits themselves may apply to varied spatial scales (e.g. greenhouse gas emissions reduction is a global benefit, while improvements in landscape are seen only at a local scale) (Glenk, Schaafsma, Moxey, Martin-Ortega, & Hanley, 2014).

The WISE tool for peatland restoration (Artz, Donnelly, Aitkenhead, Balana, & Chapman, 2013) was developed to start considering spatial variation in restoration *potential*. Site selection is based first on expert multi-criteria analysis (to identify important attributes impacting peatland restoration), and secondly on availability of data, to identify peatland within Scotland with the highest potential for restoration. These choices are based on spatially varied criteria including current rate of physical degradation, peat type and depth, and current land use. Though the authors urge caution not to discount those sites with low scores, the tool provides a starting point for spatial optimisation of peatland restoration (Artz et al., 2013).

Despite the identified importance of considering spatial variation into cost benefit analysis of restoration, only one of the studies into past actions considers spatial variation in any measure (variation of cost by stand type for ponderosa pine removal (Pinjuv et al., 2000).

Spatial variation is more common in the modelling studies we present. Effectiveness of actions may be varied by spatial features such as vegetation type (Macmillan et al., 1998) or elevation (Wada et al., 2017). As the functioning of ecological systems is also highly spatial, the effectiveness of an action may be determined by the actions occurring elsewhere in the landscape. Models may therefore incorporate target patch sizes (Gren et al., 2014; K. A. Wilson et al., 2011) or connectivity (Blackwood, Hastings, & Costello, 2010; Rose et al., 2016) as measures of effectiveness.

Table 1. Studies on cost-effectiveness analysis of habitat restoration

Cost data considered	Discounting	Effectiveness measure	Spatial analysis	Time scale	Measured/ Modelled	Study site	References
Material and labour	No	Area of peatland restored.	No	1 year	Measured	Exmoor National Park peatlands	(Grand-Clement et al., 2015)
Material and labour. Opportunity cost of land incorporated through negative impact on effectiveness, related to current land designation	Yes, 3%, equivalent to rate of return on Government bonds.	100ha of old deciduous forest with $20m^3$/ha deadwood in area of 500ha for lowest cost.	Some. Model accounts for number of locations as well as area, but not connectivity.	60 years	Modelled	Deciduous forest, Sweden	(Gren et al., 2014)
Expert estimated cost/ha, as a function of action, desired habitat type, and slope.	No	Function of change in degradation state, likelihood of success, and stochastic event probability.	Restoration areas clustered by watershed.	20 years	Modelled	Irvine Ranch Natural Landmark, southern California.	(Wilson et al., 2011)
Materials, labour and land purchase. Survey of peatland restoration projects.	No	Staff grading of percentage estimate of success. Including hydrological condition, carbon sequestration, biodiversity and proportion of intact peat.	No	Varied, generally projects ongoing	Measured	UK peatland restoration	(DEFRA, 2008)
Material and labour costs.	No	Avoidance of adverse impacts when removing small diameter trees.	Costs and effectiveness varied by stand type.	Unknown	Measured	Ponderosa pine stands at urban-wildland interface, Arizona	(Pinjuv et al., 2000)

Table 1 ctd. Studies on cost-effectiveness analysis of habitat restoration

Cost data considered	Discounting	Effectiveness measure	Spatial analysis	Time scale	Measured/ Modelled	Study site	References
Costs covered per ha under the Woodlands Grants Scheme, no actual costs measured.	No	Estimated restoration potential as a function of: Genetic integrity, species composition, tree density and patchiness, precurser vegetation, method of deer control, area of new woodland, area of surrounding natural woodland, distance to surrounding woodlands, number of surrounding woodlands, area of associated habitat, area of adjacent habitat.	No	10 to 100 years (length of time grant scheme runs for)	Modelled	UK woodlands	(Macmillan et al., 1998)
Capital costs, including road construction. Annual maintenance also included.	No	Effectiveness of restoration for brook trout habitat, as an indicator of good water quality. Function of basin area, stream alkalinity, and stream buffering capacity.	No	20 years	Modelled	Trout streams, West Virginia, USA	(Petty & Thorne, 2005)
Materials and labour	2%	Ground water recharge as a function of rainfall, fog interception and evapotranspiration, which varies with land cover. Landscape flammability, as a function of land cover, climate and weather variables.	Varied by elevation	50 years	Modelled	Dry forest, Hawaii	(Wada et al., 2017)
Materials and labour. Opportunity costs incorporated through declines in livestock costs.	5%	Net social benefit as a function of change in carbon sequestration, livestock production, non-timber and timber forest products, and tourism. Market values	No	20 years	Modelled	Dry forest, Latin America	(Birch et al., 2010)
Materials and labour from budget records	No	Cover of live and dead invasive vegetation, native vegetation and crown cover.	No	7 years	Measured	Australia	(Lindenmayer et al., 2015)

Table 1 ctd. Studies on cost-effectiveness analysis of habitat restoration

Cost data considered	Discounting	Effectiveness measure	Spatial analysis	Time scale	Measured/ Modelled	Study site	References
Materials and labour from budget records	No	Change in invasive plant cover.	Project and site level measures	6 years	Measured	South Africa	(McConnachie et al., 2012)
Materials, labour and maintenance from budget records	No	Survival and cover of native plants.	Three spatial scales considered	3 years measured, modelled for 30 years	Both	Dry forest, Hawaii	(Powell et al., 2017)
Unclear	No	Number of locations predicted to be occupied by focal species.	Meta-populations with habitat connectivity	30 years	Modelled	Frog habitat, Australia	(Rose et al., 2016)
Estimated from habitat type for capital and maintenance costs. Agri-environment scheme payments used for opportunity costs.	0% to 10%	Economic value of arable crop production, livestock production, carbon storage, and timber production. Non-market values for flood risk, flood mitigation, aesthetics, recreation and culture.	No	10 or 50 years	Modelled	River Frome, Dorset, UK	(Newton et al., 2012)
Estimated from population size and amount of removal.	Varied	Number of invasive remaining, and associated dis-benefit costs.	Patch based model with inter-patch heterogeneity and species movement.	NA	Modelled	Unspecified model	(Blackwood et al., 2010)
Property cost, plus 15% for management costs.	No	Likelihood of focal species occurrence.	Only in terms of achieving diversity targets	100 years	Modelled	Georgia Basin, SW British Colombia	(Schuster & Arcese, 2015)

3. Potential indicators of the effectiveness of peatland restoration

Indicators for the effectiveness of peatland restoration have largely focused on reductions in greenhouse gas emissions, following the inclusion of peatlands into the voluntary reporting section of the Kyoto protocol (Bonn et al., 2014; DEFRA, 2008). Additional measures of the effectiveness of peatland restoration in the UK include biodiversity and hydrological condition (DEFRA, 2008). Although greenhouse gas emissions are the main focus of the majority of peatland restoration schemes, direct measurements are complex, expensive, and resource and labour intensive (Bonn et al., 2014; Joosten & Couwenberg, 2009). As such several proxy indicators have been identified (Table 2). The Greenhouse Gas Emissions Site Types (GEST) categorise peat condition based on water level class, C:N ratio, pH, and vegetation type, and are compared to a number of study sites to estimate greenhouse gas emissions (Couwenberg et al., 2011). GEST vegetation classes are used by peatland restoration PES schemes in the UK (Peatland Code) and Germany (MoorFutures) (Bonn et al., 2014). Focusing on vegetation has further advantages as vegetation indicates changes in biodiversity and hydrological condition, and is relatively easy and cheap for monitoring by landowners (Couwenberg et al., 2011; DEFRA, 2008; Joosten & Couwenberg, 2009; Mazerolle et al., 2006).

In addition to vegetation monitoring additional biodiversity indicators can be useful to measure peatland restoration success. Peatland restoration sites within the UK and elsewhere have monitored birds and invertebrates (DEFRA, 2008; Mazerolle et al., 2006; Ramchunder, Brown, & Holden, 2009), while Canadian studies have also shown partial recovery in amphibian populations in restored bog pools (Mazerolle et al., 2006). However recovery of biodiversity is not consistent across restored sites (Ramchunder et al., 2009), and differences in responses of wading bird species to peatland degradation in Scotland illustrate the importance of carefully selecting indicator species (J. D. Wilson et al., 2014). As biodiversity is a secondary result of peatland restoration, and is also impacted by other site characteristics, such as pool depth, water colour or erosion rate (Ramchunder, Brown, & Holden, 2012), these indicators also have a long time lag following restoration action, and may vary independently of peatland restoration success.

Measuring direct water characteristics, such as colour or dissolved organic carbon (DOC), can provide a more direct measure of peatland restoration, and is also directly related to greenhouse gas emissions (Couwenberg et al., 2011; Joosten & Couwenberg, 2009; Worrall, Armstrong, & Holden, 2007). In addition water colour and DOC is of particular interest to water companies, as both are requirements for potable water in Scotland, as well as impacting biodiversity (Ramchunder et al., 2009). Blocking of drains has been recorded to decrease DOC and improve water colour at the catchment scale 4 years after drain blocking (Wallage, Holden, & McDonald, 2006), and similar results were found through a UK wide survey (Armstrong et al., 2010). However though a general trend for declining DOC and improved water colour was observed within this study, this did not hold for all sites

(Armstrong et al., 2010). The short term impacts of drain blocking on DOC and water colour also showed no impact at the catchment scale in sites in northern England, and actually showed increases at the drain scale over this time period (Worrall et al., 2007).

As discussed above, restoration of peatlands is impacted by, and has impacts on, areas beyond the direct restoration effort (Glenk et al., 2014). At the catchment scale stream macroinvertebrates have been observed to improve (Ramchunder et al., 2012), while hydrological conditions can also be impacted at this scale (Wallage et al., 2006). Indicators of peatland restoration success must therefore take account of these wider spatial impacts to fully account for the impacts of peatland restoration.

Table 2. Indicators of peatland ability to deliver ecosystem services.

Indicator	Ecosystem services addressed	Advantages of indicator	Disadvantage of indicator	Time scale	Spatial scale	References
Vegetation – including cooccurrence of species	GHG emissions Biodiversity Hydrological function	Relates to water level in immediate and long term, nutrient availability, soil pH and land use history, which all impact GHG emissions. Relatively simple to assess.	Impacted by many factors not linked to GHG emissions (e.g. competition). Slow to react to environmental change. Needs to be calibrated to local context.	Changes over multiple years.	Suitable for within and between patch heterogeneity.	(Couwenberg et al., 2011; DEFRA, 2008; Joosten & Couwenberg, 2009)
Direct emissions – chamber method	GHG emissions	Immediate response observed. Most accurate as no need for proxy data.	Very time and labour intensive, not suitable for project monitoring.	Real time, but multiple years needed to observe changes due to restoration.	Existing datasets are averaged over global scales. Measurements at m^2 level.	(Bonn et al., 2014; Joosten & Couwenberg, 2009)
Mean annual water level	GHG emissions Hydrological function	Accurate long term data, less cost and labour intensive that direct emissions monitoring. Related to all GHG emission types.	Requires frequent and dense monitoring of water levels. High initial investment.	Annual	Patch level.	(Couwenberg et al., 2011; Joosten & Couwenberg, 2009)
Subsidence of peat	GHG emissions Hydrological function	Simple to assess. Most dominant cause is reduction in water level. Potential for LiDAR to be applied for large areas.	Depends on peat type, fire history and fertiliser regime. Most effective for tropical peatlands. More suited to estimating loss from degradation than gains from restoration.	Multi-year	Patch level	(Couwenberg et al., 2011; Joosten & Couwenberg, 2009)
% condition for carbon storage	GHG emissions	Simple to assess and compare to baseline.	Low accuracy, relies on individual assessment.	Annual	Patch level	(DEFRA, 2008)
% area target biodiversity covers	Biodiversity	Simple to measure, can be applied easily by land managers.	Biodiversity may be impacted by factors other than peat health. Indicators must be carefully chosen. Percentage cover does not account for variation in health.	Multi-year	Within patch	(DEFRA, 2008)

Table 2 ctd. Indicators of peatland ability to deliver ecosystem services.

Indicator	Ecosystem services addressed	Advantages of indicator	Disadvantage of indicator	Time scale	Spatial scale	References
Invertebrates	Biodiversity	Indicative of health across ecosystem. Simple to monitor.	Removed from peat condition through relationship to vegetation. May have long time lag to show impacts.	Multi-year	Patch level	(DEFRA, 2008)
Birds	Biodiversity	Indicative of health across ecosystem. Simple to monitor.	Removed from peat condition through relationship to vegetation. May have long time lag to show impacts.	Multi-year	Patch level	(DEFRA, 2008)
Score hydrological status	Hydrological condition	Simple to apply.	Large opportunity for error.	Annual	Patch level	(DEFRA, 2008)

4. Types of peatland restoration costs

While the benefits of peatland restoration are mainly social, costs are typically incurred by private land managers (owner or tenant) and public funds if they are in place to cover, for example, administrative costs associated with grant processes and monitoring. An upfront capital investment is often required to implement appropriate restoration practices, depending on site characteristics, including ecological condition, and techniques. Frequently applied techniques include, for example, blocking grips, drains and gullies, re-profiling of peat, or stabilisation of bare peat through reseeding or the use of jute mats. Restoration of peatlands under forestry often requires tree removal even for younger stands with little commercial timber value. Rewetting would slowly result in die-offs of trees, but would increase susceptibility of trees to tree pests and diseases, thus increasing the risk that pests spread to neighbouring stands. Furthermore, dead trees are likely to find little acceptance among land managers concerned about their image as good stewards of the land, and among members of the public affected by the visual disamenity of dead trees. Costs of implementing the different techniques, at different levels of intensity, can be expected to vary greatly. Factors that are likely to affect implementation costs include types of machinery required and labour intensity, both also in association with variation in the accessibility of restoration sites and the availability of expertise. There is little information on restoration costs available in the UK. An indicative range of £200/ha to £10,000/ha is reported by Moxey and Moran (2014). Grossman and Dietrich (2012) estimated total project expenditure for wetland restoration based on the expenditures for 21 large-scale lowland wetland restoration projects in the Elbe River Basin, Germany. They estimate an average total expenditure of €3,193/ha (£2,792/ha) with a range from €826-8,783/ha (£722-7,679/ha). Estimates include expenditures for planning and project implementation, the purchasing of land and for the removal of water regulation and drainage infrastructure and embankments. In most cases, the purchasing of land represented the largest share of the total project expenditure.

Apart from capital costs of implementing peatland restoration, there may be recurring costs associated with the maintenance and monitoring of restoration sites, and transaction costs associated with information search for restoration solutions and suppliers as well as preparing grant application for public funding schemes (if applicable). It is currently unclear under which conditions maintenance costs are relevant. For example, maintenance efforts may be required to make sure that dams installed in gullies or drains remain effective. Monitoring and administrative costs, including transaction costs, are not considered for the purpose of this work, although it could be argued that monitoring efforts may also come at a cost to land managers, and that land managers face some costs associated with grant application and administration. If required (for example for benefit-cost assessments of restoration grant schemes), such costs can be added based on experience and staff time allocations. It is also worth noting that in some cases administrative costs might be shared across different public funds or programmes. For example, as noted in Byg and Novo (2017)

Peatland Action officers often provided support in applying for agri-environmental schemes under the Rural Development Programme.

About 10,000 hectares of peatland restoration were funded by Scottish Government since 2013 through its Peatland Action scheme administered by Scottish Natural Heritage (SNH). Based on the judgement of SNH's leading peatland officer (A. McBride, pers. comm.), there was a large variety in costs ranging from about £300/ha for restoration of dry heath peatlands to about £5,000/ha for restoration of sites of peat extraction, or where bare peat dominates. The average cost per hectare is reported to be about £830 per hectare for all types of restoration. This includes all project management costs and a wide range of restoration activities.

A potentially important element of overall restoration costs are potential opportunity costs that private land managers face. These recurring costs represent the benefits of the next best land use alternative, often assumed to be the land use under a business as usual scenario or the current land use; i.e. they represent income forgone by implementing restoration. Opportunity costs of restoration are difficult to assess since they are highly context dependent. For example, even within a single land use type (e.g. rough sheep grazing), there will be a large variation in gross margins per hectare for different businesses, including negative gross margins. Opportunity costs may be higher for field sports such as grouse management compared to livestock (sheep) grazing. Across land use types, opportunity costs will also vary depending on size of land ownership and thus marginal productivity of the land to be restored within a single farm business (or land holding). Opportunity costs of initial hectares enrolled in a restoration scheme are likely lower than those associated with enrolling additional hectares. Opportunity costs will also depend on potential changes in capitalised land value and how this is influenced by direct payments under the Common Agricultural Policy (CAP), and on whether current and future payments will allow for consideration of restored peatland areas to be eligible for inclusion in payment calculations. An opportunity cost (of the reduced agricultural productivity) estimate of €200/ha (£175/ha) is provided by Grossmann and Dietrich (2012) based on the payments offered under agri-environmental schemes and taking into account average income losses, transaction and risk costs. Finally, it should be noted that there is anecdotal evidence that restored sites also yield benefits to land managers, for example due to reduced mortality rate of grouse chicks after restoration (Byg and Novo,2017).

A question may be how restoration costs 'evolve' over time as efforts to restore peatlands increase in scale. On the one hand, increasing restoration may mean that the supplier base offering restoration services increases, thus reducing per hectare restoration costs. On the other hand, however, and as mentioned above, opportunity costs both within and between land holdings may increase.

Table 3 summarizes the main cost types and provides a brief overview of how to measure the different elements, challenges associated with measuring them and what their likely contribution to overall costs will be based on own judgment.

Table 3. Overview of cost types

Cost type	Ways of Measurement	Challenges and ease of measurement	Likely contribution to overall costs
Implementation cost (upfront)	• Recording of reported (actual) costs/expenses, including time/labour	• Accuracy issues due to recall if ex post recording • Mismatch between ex ante (expected) costs and actual costs • Uncertainty about actual area affected by restoration to derive per hectare costs • Valuing time/labour contributions of land managers is difficult	Large
Maintenance cost (recurring)	• Recording of reported (actual) costs/expenses, including time/labour	• Accuracy issues due to recall if ex post recording • Mismatch between ex ante (expected) costs and actual costs • Uncertainty about actual area affected by restoration to derive per hectare costs • Valuing time/labour contributions of land managers is difficult • Unclear how maintenance costs would evolve over time	Small to medium
Administrative/ transaction costs (recurring)	• Administrative data on scheme administration costs • Time costs or costs of consultants to prepare and administer grant	• Data on scheme administration costs may not be available by funder • Accuracy of self-reported time commitments unclear • Willingness or limited possibility for land managers to reveal costs of consultancy • Valuing time/labour contributions of land managers is difficult	Small
Opportunity costs (recurring)	• Natural and field experiments (e.g. auctions or surveys) • Association of land use with gross margins in agricultural accounting data • Association of land use with gross margins reported in literature • Potential benefits may be at least qualitatively captured through land manager surveys	• Difficulty to find funding for field experiments; if auctions concerns about lack of competitiveness; if surveys concerns about hypothetical bias and strategic behaviour • Measurement error (e.g. due to reporting issues) of profitability estimates for land use types based on accounting data • Using gross margins of particular land use types risks oversimplification due to using averages • Unclear how to 'value' reported benefits	Small to large

5. Initial framework for collecting and analysing cost data

As part of the Scottish Government's Rural Affairs and the Environment Portfolio Strategic Research Programme 2016–2021, RD 1.1.4 (Soil management), data on costs will be collected through the Peatland Action grant process. In particular, data will be collected in a systematic manner in the application form, and changes to planned action will be recorded in the final reporting form[4]. While this (still) represents us with challenges and relies to some degree on self-reporting, this process has the advantage that i) data is collected when relevant to land managers, i.e. not in the form of an additional, burdensome survey; ii) data can be used for both research and administrative purposes; iii) data collection will be ongoing as long as funding is allocated to peatland restoration in this way, thus potentially creating interesting longitudinal data.

Once collected, data will have to be entered into spreadsheets and checked for errors. We anticipate that each line in the spreadsheet will represent a single restoration site; where one grant (and thus business) can include several sites simultaneously. The same spreadsheet will capture data from the initial grant application process and the final reporting, thus allowing to assess differences and ease integration across the two data sources. Once the database is established, it can be linked to other sources of information. For example, since restoration sites will be geocoded, they can be linked to information available through geographical information systems, for example concerning altitude or access to road networks and markets. Additionally, we ultimately hope to be able to link this information to peatland and peatland condition mapping work conducted by researchers of the James Hutton Institute.

Information on variables that can be obtained from both forms can be found in Appendix 1 (application form) and Appendix 2 (final reporting form). The application form is structured into five different sections. The first section covers key personal details. The second section focuses on project details and gathers information on planned site based restoration activities, e.g. planned meters of ditch blocking per site, and planned restoration activities which are not linked to specific sites. Sites are identified both with an id number and a central grid reference. Planned restoration costs are recorded in the third section. Restoration costs include cash costs per site id and project cost description and cash costs that are non-site specific. Planned costs are broken down per financial year. In addition, cost information also includes details on own and in-kind contributions. The following section includes the applicant declaration and the last section of the application form focuses on the applicant's level of knowledge about peatland restoration, size of the land holding and main motivations to apply for a peatland restoration grant.

[4] Peatland Action application form and final reporting form available at: https://www.nature.scot/climate-change/taking-action/carbon-management/restoring-scotlands-peatlands/peatland-action-2018-2019

Each project funded by Peatland Action must produce a final report by the end of the financial year. The final report builds on the application form and it’s also structured into five different sections. The first section covers personal details and the second section focuses on project details, including open sections where applicants can provide short narratives about different aspects of the restoration project (e.g. mission of the project, site basics description, history and challenges overcome, etc.). This second section also includes information on the peatland area restored by site, the visible changes that can be noticed after restoration, such as changes to water colour, vegetation and fauna, engagement activities conducted and actual restoration activities implemented per site. Information on changes to planned activities and reasons for changes are also recorded as that might understand variations in costs. The third section records information on actual cash costs per site and changes compared to planned restoration costs. Cash costs for non-site specific activities, actual in-kind contributions and comparison to expected in-kind contributions are also recorded here. Applicants are also requested to report the share of the total time (%) spent on each phase of the restoration project as that can provide a good overview of effort and opportunity costs. The next section elicits information on the applicant’s experience with restoration, the positive and negative effects of restoration on the business/organisation and what features of the Peatland Action grant process should be retained in the future. The final section records detailed information on the actual restoration techniques.

In sum, both the application and final reporting forms use the same framework for cost recording, with the application form serving as the baseline against which actual implementation costs are compared. Data analysis will allow us to explore cost variation based on the type of restoration technique, site-specific characteristics and location.

Specifically, a statistical model will be developed to explain the cost per hectare (dependent variable) in terms of the measures being used (independent variables). Cost would be the total cost across the different financial years, as the breakdown into financial years would depend on the starting month for the project. Mixed models will be used in place of ordinary regression models to allow the inclusion of random as well as fixed effects. The random effects would include the effect of owner/land manager, to allow for the fact that more than one restoration site may have the same owner/land manager. The year in which the grant was awarded could also be included as a random effect. Fixed effects would include explanatory variables giving information about the measures applied and possibly also the initial condition of the site.

An appropriate method for modelling spatial effects would need to be chosen based on the sample size and the geographical distribution of the restoration sites. If sites are clustered in a small number of regions, then it may be most appropriate to simply include a random effect for region. Alternatively, if sites are more widely scattered then a spatial autoregressive or geostatistical model may be more appropriate. These can be fitted using classical or Bayesian methods. For a spatial autoregressive model a spatial weights matrix needs to be defined based, for example, on nearest neighbours, all units within a certain distance, or inverse distance. Alternatively, geostatistical models which account for spatial autocorrelation of the residuals as a function of distance can be used. However, these are based on point rather than areal data, so it is necessary to define a central point to represent each site.

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7. Appendix

Appendix 1 – Variable list generated Peatland Action Application Form 2017- 2018

Variable	***Description***
Section 1 – Project details	
Project title	(open)
Project start date	(open)
Estimated completion date	(open)
Site based restoration activities	
Site ID	1, 2, 3, etc.
Site name	Name or A,B,C, etc.
Central Grid Reference	Reference per site
Site designation	1=SSSI; 2=SAC; 3=SPA; 4=NSA; 5=NNR; 6=Other (specify)
Current site use	1=Rough grazing (sheep); 2=Forestry; 3=Field sports (specific: grouse or rough shooting); 4=Deer management; 5=Biodiversity conservation; 6=Other (specify)
Restoration area (per site)	Area of each peatland site (ha) to be restored under Peatland Action
Peatland condition (per site)	1=Near natural; 2=Modified; 3=Drained; 4=Actively eroding; 5=Currently under forestry; 6=Currently under scrub
Bordering other peatland sites	Yes; No
Site maps attached	Marked=1?; Blank?
Site photos attached	Marked=1?; Blank?
Site restoration activities start	Start date
Site restoration activities end	End date
Ditch blocking	Planned meters (m) per site
Peat dams	Planned hectares (ha) per site
Rock/timber dams (m)	Planned meters (m) per site
Rock/timber dams (ha)	Planned hectares (ha) per site
Ditch re-profile	Planned meters (m) per site
Hag re-profile (m)	Planned meters (m) per site
Hag re-profile (ha)	Planned hectares (ha) per site
Bunding (m)	Planned meters (m) per site
Bunding (ha)	Planned hectares (ha) per site
Forestry-tree removal	Planned hectares (ha) per site
Scrub removal/mgt	Planned hectares (ha) per site
Mulch	Planned hectares (ha) per site
Living mulch	Planned hectares (ha) per site
Peat pan stabilisation	Planned hectares (ha) per site
Other activities (m)	Planned hectares (m) per site
Other activities (ha)	Planned hectares (ha) per site
Plastic piles use	Yes; No
NOT site based restoration activities	
Project activity	(open)
Outputs	(open)
Expected timescale	(open)
Other information about sites/restoration project	
Other relevant information	(open)
Engagement local communities	(open)

Measure engagement success	(open)
Section 2 – Restoration costs	
Total proposal cost 2017/18	Total £
In-kind contributions 2017/18	Total £
Costs – site based restoration activity	
Project Cost Description	Type of cash cost per site id
Cash Cost 2017/2018	Cash cost per site id/project cost description (£)
SNH Grant Requested 2017/2018	Grant requested per site id/project cost description (£)
Estimated Cash Cost 2018/2019	Estimated cash cost per site id/project cost description (£)
Estimated SNH Grant Requested 2018/2019	Estimated grant requested per site id/project cost description (£)
Estimated Cash Cost 2019/2020	Estimated cash cost per site id/project cost description (£)
Estimated SNH Grant Requested 2019/2010	Estimated grant requested per site id/project cost description (£)
Total cash Cost 2017/2018	Total cash cost (£)
Total SNH Grant Requested 2017/2018	Total grant requested (£)
Total estimated Cash Cost 2018/2019	Total estimated cash cost (£)
Total estimated SNH Grant Requested 2018/2019	Total estimated grant requested (£)
Total estimated Cash Cost 2019/2020	Total estimated cash cost (£)
Total estimated SNH Grant Requested 2019/2010	Total estimated grant requested (£)
Costs – NOT site based restoration activity	
Not site Cash Cost 2017/2018	Not site cash cost per project cost description (£)
Not site SNH Grant Requested 2017/2018	Not site grant requested per project cost description (£)
Not site estimated Cash Cost 2018/2019	Not site estimated cash cost per project cost description (£)
Not site estimated Cash Cost 2019/2020	Not site estimated cash cost per project cost description (£)
Not site total cash Cost 2017/2018	Not site total cash cost (£)
Not site total SNH Grant Requested 2017/2018	Not site total grant requested (£)
Not site total estimated Cash Cost 2018/2019	Not site total estimated cash cost (£)
Not site total estimated Cash Cost 2019/2020	Not site total estimated cash cost (£)
Summary of cash costs	
Total site cash costs	Total site cash costs 2017/18 (£)
Total site grant requested	Total site SNH Grant requested 2017/18 (£)
Total site estimated cash costs Yr2	Estimated site cash costs Year 2 (£)
Total site estimated cash costs Yr3	Estimated site cash costs Year 3 (£)
Total non-site cash costs	Total non-site cash costs 2017/18 (£)

Total non-site grant requested	Total non-site SNH Grant requested 2017/18 (£)
Total non-site estimated cash costs Yr2	Estimated non-site cash costs Year 2 (£)
Total non-site estimated cash costs Yr3	Estimated non-site cash costs Year 3 (£)
Total cash costs	Total cash costs 2017/18 (£)
Total grant requested	Total SNH Grant requested 2017/18 (£)
Total estimated cash costs Yr2	Estimated cash costs Year 2 (£)
Total estimated cash costs Yr3	Estimated cash costs Year 3 (£)
Cash funding from own/other sources	
Own cash funds Yr1	Cash contribution Year 1 (£)
Estimated own cash funds Yr2	Estimated cash contribution Year 2 (£)
Estimated own cash funds Yr3	Estimated cash contribution Year 3 (£)
Other cash funds Yr1	Cash contribution Year 1 (£)
Estimated other cash funds Yr2	Estimated cash contribution Year 2 (£)
Estimated other cash funds Yr3	Estimated cash contribution Year 3 (£)
Total cash funds Yr1	Cash contribution Year 1 (£)
Total estimated cash funds Yr2	Estimated cash contribution Year 2 (£)
Total estimated cash funds Yr3	Estimated cash contribution Year 3 (£)
In-kind contributions	
In-kind contributor	(open)
Description in-kind contributor	(open)
In-kind Yr1	In-kind contribution Yr1 per contributor/description (£)
Estimated in-kind Yr2	Estimated in-kind contribution Yr2per contributor/description (£)
Estimated in-kind Yr3	Estimated in-kind contribution Yr3per contributor/description (£)
Total in-kind Yr1	Total in-kind Yr1 (£)
Total estimated in-kind Yr2	Total estimated in-kind Yr2 (£)
Total estimated in-kind Yr3	Total estimated in-kind Yr3 (£)
Peatland Action – Monitoring information	
Information source	Peatland Officer; Consultant; Neighbour; Other (specify)
Knowledge: Ecology and hydrology of peatlands and restoration	Low; Medium; High
Knowledge: Peatland restoration practices and techniques	Low; Medium; High
Knowledge: Managing projects and specialised contractors in a peatland setting	Low; Medium; High
Knowledge: Understanding the carbon benefits of peatland restoration and relevance to the proposed project	Low; Medium; High
Land holding size	A: <= 10 ha; B: 11-50 ha; C:51-200 ha; D: 201-500 ha; E: 501 – 1,000 ha; F > 1,000 ha
Motivation1: Improved access to the land	Not important; Somewhat important; Very important
Motivation 2: Reduced	Not important; Somewhat important; Very important

mortality of livestock & grouse chicks	
Motivation 3: Improved conditions for biodiversity	Not important; Somewhat important; Very important
Motivation 4: Improved water quality	Not important; Somewhat important; Very important
Motivation 5: Improved fisheries	Not important; Somewhat important; Very important
Motivation 6: Reduced need for controlled burning	Not important; Somewhat important; Very important
Motivation 7: Reduced carbon footprint of land holding/own business	Not important; Somewhat important; Very important
Motivation 8: Water catchment management	Not important; Somewhat important; Very important
Motivation 9: Flood risk reduction	Not important; Somewhat important; Very important
Motivation 10: Maintain a good public image	Not important; Somewhat important; Very important
Motivation 11: Potential for access to carbon or off-set markets	Not important; Somewhat important; Very important
Motivation 12: Be prepared for future regulation on peatlands	Not important; Somewhat important; Very important
Motivation 13: Promote other business activities (specify)	Not important; Somewhat important; Very important
Motivation 14: Others (specify)	Not important; Somewhat important; Very important
Most important motivation/reason	Select motivation 1 - 14
Second most important motivation/reason	Select motivation 1 - 14
Third most important motivation/reason	Select motivation 1 - 14

Appendix 2 – Variable list: Peatland Action Final Report 2017- 2018

Variable	***Description***
Section 1 – Project details (also includes mini-sections on different aspects of the project, qualitative data)	
Project title	(open)
Site name	Name or A,B,C, etc.
Central Grid Reference	Reference per site
Restoration area (per site)	Area of each peatland site (ha) to be restored under Peatland Action
Visible changes per site (multiple answers)	Standing water; Water colour; Vegetation: bare peat covered; Vegetation: Sphagnum; Fauna: birds; Fauna: insects; Better sheep/livestock health; Improved grouse rate; Other (specify)
Other changes	(open)
Partnerships involved	(description)
Social media promotion (multiple answers)	Facebook; Twitter; Instagram; Website; Blog; Newspaper reports; TV; Radio; Other
Social media details	Brief details
Engagement level	(depends on social media type)
Demonstration events	Yes / No
Event participants	Number of people
Event description	(open)
Volunteers	Number volunteers involved with the project
Students	Number school students engaged with the project
Site based restoration activities	
Ditch/gully blocking	Length per site (m)
Dams installed (N)	Number installed per site
Dams installed (ha)	Estimate of area affected per site (ha)
Ditch/gully re-profile (m)	Length per site (m)
Ditch/gully re-profile (ha)	Estimate of area affected per site (ha)
Hag re-profile (m)	Length per site (m)
Hag re-profile (ha)	Estimate of area affected per site (ha)
Bunding (m)	Length per site (m)
Bunding (ha)	Estimate of area affected per site (ha)
Forestry-tree removal	Hectares per site (ha)
Scrub removal/mgt	Hectares per site (ha)
'Forestry' mulch	Hectares per site (ha)
Living mulch	Hectares per site (ha)
Peat pan stabilisation	Hectares per site (ha)
Other activities (type)	Other type of restoration technique per site
Other activities (m)	Hectares per site (ha)
Other activities (ha)	Hectares per site (ha)
Activity changes to AF	Changes compared to Application Form / Reasons (per site)
Section 2 – Restoration costs	
Costs – site based restoration activity	
Actual Cash Cost 2017/2018	Actual cash cost per site id (£)
Subcontractors	Total amount spent on sub-contractors (£)
Cost changes to AF	Reasons for change to Application Form (per site)
Costs – NOT site based restoration activity	
Not site Cash Cost 2017/2018	Not site cash cost per activity description (£)

Other cash costs	(Open)
In-kind contributions	
Actual total in-kind Yr1	Actual total in-kind contribution Yr1 (£)
In-kind contribution level	More than expected; Less than expected; No change
Differences in in-kind	(Explanation if more/less)
Total time contributed	Number of working days of all people contributing labour time
% Salaried workers	Share of total time (%) spent by salaried workers
Value time contribution	Estimate of time contribution in monetary terms (£)
% time in planning	Share of total time (%) spent in planning activities
% time in site implementation	Share of total time (%) spent in site specific activities
% time in non-site implementation	Share of total time (%) spent in non-site specific activities
% time in post-implementation	Share of total time (%) spent in post-implementation activities
Total time	% spent on the restoration project (in principle, should be 100)
Section 3 – Experience with restoration	
Overall experience	1: very bad; 5: very good
Grant application process	1: very bad; 5: very good
Support available	1: very bad; 5: very good
Dealing with suppliers	1: very bad; 5: very good
Project outcomes	1: very bad; 5: very good
Restoration fit	1: very bad; 5: very good
Positive effect on business	Yes/No
Positive effect=yes	(description)
Negative effect on business	Yes/No
Negative effect=yes	(description)
Restoring other sites	Yes, if funded; Yes, in any case; No; I don't have any other sites
Restoring others=yes/no	(description of why)
Knows other potential applicants	Yes; No; Don't know; I haven't discussed about this with any other land managers
Land manager applied	Yes; No; Don't know
Most important to engage land managers	Provide better/more information on the impacts of restoration; More awareness raising / training events; Facilitate application process; Guarantee of not losing single farm payment (or post-Brexit equivalent); Provide means of funding up-front costs; Use SRDP for peatland maintenance
Second important to engage land managers	Provide better/more information on the impacts of restoration; More awareness raising / training events; Facilitate application process; Guarantee of not losing single farm payment (or post-Brexit equivalent); Provide means of funding up-front costs; Use SRDP for peatland maintenance
Third important to engage land managers	Provide better/more information on the impacts of restoration; More awareness raising / training events; Facilitate application process; Guarantee of not losing single farm payment (or post-Brexit equivalent); Provide means of funding up-front costs; Use SRDP for peatland maintenance

Important features PA: Low cost	1: not important; 5: very important
Important features PA: Low hassle to land managers	1: not important; 5: very important
Important features PA: Ease of application procedure	1: not important; 5: very important
Important features PA: Quick reimbursement	1: not important; 5: very important
Important features PA: Flexibility in implementation	1: not important; 5: very important
Important features PA: Learning and experimenting opportunities	1: not important; 5: very important
Important features PA: (semi)-independent advice	1: not important; 5: very important
Important features PA: Quickly visible results	1: not important; 5: very important
Improve PA	(open suggestions)
Heard Peatland Carbon Code	Yes; No
Knowledge: Ecology and hydrology of peatlands and restoration	Low; Medium; High
Knowledge: Peatland restoration practices and techniques	Low; Medium; High
Knowledge: Managing projects and specialised contractors in a peatland setting	Low; Medium; High
Knowledge: Understanding the carbon benefits of peatland restoration and relevance to the proposed project	Low; Medium; High
Details of Restoration Techniques	
Restoration start date	YYYY-MM-DD
Restoration finish date	YYYY-MM-DD
Machinery- detail list for the project	
Undercarriage width	(m)
Undercarriage length	(m)
Machine weight	(kg)
Track width	(m)
Bucket width	(m)
Bucket depth	(m)
Toothed bucket	Yes; No
Ditch – blocking – details of the types of dam used in the project	
Standard Peat Dam	Yes; No
Wave peat dam	Yes; No
Plastic dam	Yes; No
Wood dam	Yes; No
Size-average span	Material size (m)

Size-average thickness	(m)
Size-average height	(m)
Material details	(text)
Stone dam details	
Rock type	(text)
Aggregate size	(cm)
Average dam weight	(kg)
Average span of dam	(m)
Bare peat mulch	
Mulch/mix id	Name/number for each type of mulch used
Mulch composition	(text for each mulch id)
% mulch/mix	% each component
Average size mulch pieces	(cm)
Total average depth	(m)
Bare peat – seed/plug/sphagnum used	
Treatment id	Name/number for each type of treatment
Seed composition	(text)
% seed composition	% each treatment
Plug plant	Yes; No
Plug plant	(text, species of plug plant)
Sphagnum	(text: beads / plugs/ translocation)
Sphagnum source	(text: grid reference of site or supplier)
Fertiliser	Yes; No
Ratio N:P:K	Ratio
Fertiliser application rate	Kg/m^2
Lime	Yes; No
Lime application rate	Kg/m^2
Bare peat – stabilisation	
Stabilisation material	(text: description)
Mesh size	(cm)
Total length roll	(m)
Peg type	(text: e.g. wood / plastic / metal)
Bunding	
Bund distance	Distance between bunds (m)
Material	(text: material type)
Average span bund	(m)
Average bund height	(m)
Bund shape	(text: e.g. fish scale/square)