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Data from the Peatland Action Programme and their use for evaluations of ecosystem benefits

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Summary

Between 2012 and 2017 the Scottish Government supported restoration of peatlands through the Peatland Action Programme. The Programme was administered through Scottish Natural Heritage (SNH) and in just over four years funded restoration of over 10,000 ha of peatland. A small proportion of the budget supported surveying and monitoring work. This project examined the information and data collected under the programme and their wider potential to support delivery of ecosystem benefits.

Key findings

- Based on a purely qualitative assessment, the Peatland Action project as a whole has produced an impressive number of direct and co-benefits to ecosystem service delivery on the restored areas. It was, however, not possible to calculate the areas for each individual type of restoration activity with the data provided to date, or, alternatively, to partition the total 10,315 ha of restored land into categories of site condition 'before' and 'after' restoration. This means an assessment of the total carbon benefits in terms of avoided emissions, and an economic evaluation of carbon benefits for the programme as a whole, cannot yet be undertaken.
- Digitisation and collation of a number of the datasets collected in the project to date should be prioritized in order to support policy needs, particularly for reporting on greenhouse gas emissions abatement and habitat condition targets. Firstly, high resolution peat depth information has been collected at 110 of the restored sites, which could be used to improve national soil maps and estimates of the carbon stocks safeguarded by restoration efforts. On-going research to refine peat soil maps using digital soil modelling approaches would benefit enormously from access to the Peatland Action peat depth data resource and every effort should be made to make this dataset available in full for scientific purposes.
- Secondly, restoration cost information from the programme should be collated and made available. The average cost of restoration was £815 per ha, which included most of the project administration costs. Costs for individual restoration activities have also been calculated and these have potential to inform economic cost-benefit calculations in any future project.
- Thirdly, economic or carbon emissions evaluations require data on the extent of the interventions and the starting condition. We were unable to calculate the areas for each individual type of restoration activity (e.g.

drain blocking, tree felling) with the available data because many sites had experienced several different types of damage. Where possible, any digitized data on locations of the interventions as well as the overall site boundaries should be collated. As a minimum, expert opinion should be used to classify the existing PA sites into starting condition categories that are compatible with the UK Greenhouse Gas Inventory approach.

- The baseline surveys (including the aerial photography data) form an invaluable dataset of the site condition for the relevant sites. Considerable benefit would be gained if these data could be made available in future for use by researchers wishing to calculate future carbon benefits of restoration, or those involved in modeling of peatland vegetation or condition through the use of remotely sensed data.
- Future restoration programmes should, as a minimum, collate data on site boundaries, starting condition category, peat depths and digitized locations of (blocked) drains, scrub and erosion control measures, to enable future emissions abatement calculations and quantification of the type and extent of habitat restoration.
- The potential for further evaluation of other ecosystem service benefits besides greenhouse gas mitigation was also assessed, however the current programme did not capture sufficient data for these to be assessed using any monetary or non-monetary evaluations. With relatively little additional effort, benefits to downstream water quality, on-site hydrological water balances and skills development could potentially be captured.

Conclusions and Recommendations

We can conclude that the data collected under the Programme are extremely valuable for potential assessments of the contribution of the programme to emissions abatement and habitat restoration policy targets, although there are significant limitations in terms of access and completeness of these data at the present time. It is yet unclear whether an estimate of net emissions prior to, and after, restoration efforts could be captured, particularly where there are several sources of damage. This is crucial, especially given that the UK GHG Inventory compilations rely on national scale land cover surveys, which do not spatially specify some of the damage types (e.g. erosion, drainage) in peatlands, which are important to identify and quantify in order to correctly calculate emissions under the current UNFCCC and KP guidance.

We recommend that

1. Existing non-sensitive data from the Peatland ACTON project, highlighted in yellow In Table 1, be compiled to an agreed standard and be made publicly available. This will require additional resources, however, it is clear at the present point that neither a full carbon cost: benefit analysis for the Peatland ACTION project as a whole, or indeed a representative set of sites, can be conducted. Any data collected on the extent of drainage and erosion features before and after restoration activities should be made publicly available. Further evaluations of ecosystem service benefits may be feasible using the framework presented in Table 4, however data supporting such analyses have not been collected in a standardised manner and such assessments could carry a significant staff cost. Discussions on whether such evaluations would be beneficial should be conducted as soon as possible, as such surveys would be hard to conduct at a later date when people may have moved.
2. Further assessment is carried out on the 17 sites for which baseline condition survey data are available to gauge how representative they in terms of numbers of sites, area, or indeed restoration category. This should be assessed as a minimum, before further recommendations could be made on resurveying needs.
3. Future restoration programmes should, as a minimum, collate data on site boundaries, starting condition category, peat depths and digitized locations of (blocked) drains, scrub and erosion control measures, to enable future emissions abatement calculations and quantification of the type and extent of habitat restoration.

Additional assessment of benefits for cultural services could include an assessment of the skills development via targeted interviews of people involved in the process. Similarly, a direct assessment of the benefits to downstream water quality could be made by implementing before-and-after assessments in streams leaving the relevant catchments.

Introduction

The Peatland ACTION project (previously known as the Green Stimulus Peatland Restoration Project) was funded to carry out active peatland restoration across Scotland between 2012 and 2017. The project started in December 2012 with initial funding of £200,000 for 3 months. The second tranche of funding in 2013 also carried with it a change of name to Peatland ACTION. The overall project objectives were to manage the land to protect and enhance existing carbon stocks, and, specifically, to maintain the extent of existing peat deposits and the extent and health of existing peat-forming habitats. A further aim was to ensure land use change and land management practices enhance the sequestration of new terrestrial carbon, to enhance ecosystem resilience to climate change, and specifically, to restore 6500 ha of damaged peat-forming habitats to create fully functional peatland ecosystems. By 2016 the project objectives had broadened to include the full range of ecosystem and socio-economic benefits peatland restoration can enhance. For example, the project by then included funding of a small number of projects that didn't directly deliver on-the-ground restoration, but would increase people's enjoyment and knowledge of peatlands, benefit peatland biodiversity and build peatland restoration capacity and understanding amongst land managers, contractors, advisors and the public. After completion, ClimateXChange commissioned two short external reports on the project, with the view that these would compile and assess the information that was gathered during the Peatland ACTION project in terms of their future use for evaluations of the delivery of ecosystem benefits (this report) and lesson learnt during the project delivery (Byg and Novo, 2016).

Methods

The James Hutton Institute and Scottish Natural Heritage staff had a number of telephone-based meetings to discuss what data had been gathered during the Peatland ACTION project between July and September 2016. Data protection regulations have restricted the data that was available for analysis which limited somewhat the data available for evaluation. However, we were able to compile a sufficiently large sample to ascertain future uses for a number of the data that have been acquired.

SNH were able to share a redacted version of the master spreadsheet containing the information on applications to the project, whether these were successful or not in being funded, and what type of restoration work had been performed. Costs for defined categories of restoration work were obtained separately. From these data, summary statistics were calculated to show the percentage of successful applications and the average cost for different restoration treatments.

A limited number of the site-specific data were also shared, where the permissions to do so had been obtained. Amongst these, we assessed the availability and usefulness of site boundary data, peat depth measurements, site aerial photography surveys using unmanned aerial vehicles (UAV) and site baseline condition surveys.

A redacted internal SNH document (Peatland ACTION Programme 2012/16 - Project Review, Lessons and Proposals, Andrew McBride, First final version August 2016) and some of the individual project completion reports (where permissions were in place) were also shared.

The information received by the 13th of September 2016 was assessed against a framework of ecosystem services based on the UK National Ecosystem Services classification, and examples of perceived or observed benefits in the assembled data summarised. Finally, a short review of how these perceived or observed benefits could be assessed in monetary or non-monetary terms was conducted.

Results

The discussion during the telephone-based meetings resulted in a list of data types that were gathered during the Peatland ACTION project (Table 1). Email-based follow-ups and one face-to-face meeting with SNH staff ascertained the number of sites for which each of the datasets had been collected, as well as the exact nature of the data (Table 1.)

The redacted SNH master spreadsheet contained information on 189 applications, of which 142 are shown as accepted status (2 not paid via grant), 1 as halted due to doubt over land ownership, 1 not accepted, 10 refused, 8 withdrawn and the rest of unknown status (1 in discussion, 9 N/A, 16 deferred or no information presented or possibly redacted). Spend information was generally redacted from the master spreadsheet, so further information on restoration costs was obtained in an additional spreadsheet via email (Andrew McBride) to calculate average spend by restoration activity. Hence, information on the actual spend in the programme had to be assumed to be complete due to the restrictions on sharing the full dataset with the primary author of this report (Table 1).

Restoration costs

Peatland restoration generally requires site-specific approaches, as former uses can be as broad as to include plantation forestry, drainage for peat cutting or to stimulate vegetation growth, or indeed extraction of peat or use as agricultural land. In addition, these uses often occur side by side on sites earmarked for restoration. Furthermore, drainage density is often variable and upland sites in particular can show significant levels of peat erosion. Hence estimating the potential cost of restoration projects, on an individual or national basis, can be extremely challenging. The overall spend within the Peatland ACTION project was £8.44 million, and a total of 10,315 ha (150% of the target) was restored or improved in condition. The average cost of restoration was £815 per ha, which included most of the project administration costs.

Table 1. Data gathered during the Peatland ACTION project, content of the individual datasets and completeness. Datasets that are highly recommended to be centrally compiled and made available in order to support policy are indicated in yellow, with data in orange viewed as highly useful for future research needs.

Dataset	Number of sites included	Content	Completeness/Accessibility
Actual spend (=restoration cost	All	Aggregate spend on restoration activities, split by type of restoration practice (e.g. felling/mulching, grip blocking), expressed as £ ha^{-1}.	Assumed complete, but subject to access limitations. The assessed spreadsheet had site identifier information and some complete entries redacted.
Final project reports	All	Site photographs before, during and after the completion of works, some observations on the work carried out.	Assumed complete, but subject to access limitations. The assessed examples were seen in full, but varied in quality, so a full assessment of content and usability was not feasible.
Peat depths	110 sites	High resolution data of the full depth of the peat column across multiple locations on each site.	Assumed complete, but access limitations restricted availability to this report to 67 sites. Data are of varying quality and require some further processing.
Baseline condition surveys	17 sites	Mapped areas of management interventions, drainage channels/networks and other features. Multiple quadrats to assess cover of all plant species, cover of bare peat/open water, grazing animal dung, damage to the bryophyte layer, or peat compaction. Fixed point and illustrative photographs.	Complete, but only the final report from the contractors was made available for this report. It is unclear if all of the primary data would be freely accessible.
Aerial photography data (UAV)	17 sites	Visual and near infra-red range aerial photography of the entire site at high resolution.	Data are held within SNH and are available through an Open Government licence in raw image format. Some very limited image processing for one site has taken place to date, but these data are not in an accessible format.
Hydrological monitoring	Uncertain (possibly >14 sites)	No data were directly made available. Sites with dipwell locations for manual water table measurements, and a smaller number of sites with automated water level loggers, are documented by application case number, and sometimes site name.	The existence of these data was only indirectly confirmed within this report. It is unclear exactly how many sites have manual or automatic measurements, the replication across the sites, whether historic water table data are held centrally within SNH, or in how many sites monitoring is still ongoing.
Site boundaries, digitised drainage and erosion features	Uncertain (>2 sites)	No data were directly made available.	These data appear to be held by the contractors, and in some cases, by the Peatland ACTION officers. Only paper copies of maps showing these data for two sites was available at the time of writing.

A breakdown of the restoration cost by activity is presented in Table 2, which shows that restoration costs can not only vary considerably between different activities, but also between sites (as evidenced by the high standard deviation). These data are of very high value for future economic cost: benefit calculations. While the majority of applications were for practical restoration, the types of applications in the redacted master spreadsheet also included 47 projects where the outputs were for site surveys, feasibility studies, monitoring equipment, knowledge exchange activities or strategic planning. Costs for these could not be assessed in this report, as the information was not available.

Table 2. Restoration cost summary. Costs reported per hectare (ha), metre (m), or kilometre (km).

Type of restoration activity	Average (£)	Median (£)	Standard deviation (£)	Number of observations
Drain blocking (ha)	879	517	906	14
Hag Reprofiling (ha)	704	688	155	10
Living mulch on bare peat (ha)	2976	1487	3642	4
Forestry removal (ha)	2996	1480	3720	7
Forestry mulching (ha)	2425	2425		1
Peat dams and reprofiling (m)	1	1		1
Hag Reprofiling (km)	99.3	66.6	149	11

The areas that were restored using the each of the activities in Table 2 cannot be assessed with the data provided to date, partially due to the redaction of the master spreadsheet. However, such data should be relatively easy to obtain, either from the full master spreadsheet or indeed from maps that individual Peatland ACTION officers have been provided with by contractors. It has been assumed that active restoration activities not explicitly mentioned in the costings, but present in the master spreadsheet as separate headers, e.g. bunding, surface smoothing/reprofiling, have been bundled. However, the master spreadsheet also details other activities such as timber or sediment traps and fence installation, where it is unknown whether these were viewed as distinct restoration activities or as part of (presumably) bundles of activities. Further information on this should be obtained in any future scheme, or as part of future assessments of Peatland ACTION, so that accurate figures of restoration costs can be calculated for economic evaluations.

Final site reports

The individual site reports that were released are of very varying quality in terms of the information that can be gleaned from them. In many cases, exact figures on areas restored or indeed the restoration techniques were not presented in the reports seen by the primary author of this report. In all cases, however, site photographs before, during and after the completion of works are presented. These could be of value for the estimation of site condition class for assessments of the avoided emissions due to the restoration activities. It is not possible to state whether the site reports would likely contain further information of value for other evaluations of the success of the project, due to the limited number of reports obtained.

An estimate of the carbon cost:benefits of the Peatland ACTION project could be relatively easily calculated once all data sources have been compiled. This would require information on the extent of the area that benefited from each

individual restoration activity and the baseline site condition. The emissions calculator for peatland restoration developed by the James Hutton Institute could be used for these calculations. It was not possible to calculate the areas for each individual type of restoration activity with the data provided to date, or, alternatively, to partition the total 10,315 ha of restored land into categories of site condition 'before' and 'after' restoration. This means an assessment of the total carbon benefits in terms of avoided emissions, and an economic evaluation of carbon benefits for the programme as a whole cannot yet be undertaken.

This could be partially possible on individual Peatland ACTION examples for which most of the data are available to date, however even in these cases the information on total spend per project is missing. For example, the Peatland ACTION project at Black Hill (Balmoral Estate) restored 116 hectares of eroded peatland. Using the most up to date peatland emission factors[2] to give an estimate of net avoided emissions due to restoration suggests these to be around 835 t CO_2e per year, once the site has returned to a near-natural state. The project at the Oa, in comparison, restored 8 hectares by ditch blocking on a site that had been drained but still contained peatland-type vegetation. An assessment of the carbon benefits would presume this site to move from the modified to the near-natural state and carry a relatively modest 31.2 t CO_2e in carbon benefits on transition to the restored state. The National Trust for Scotland (NTS) already produced a leaflet showcasing the carbon benefits of restoration on NTS sites carried out under PA (available at http://www.nts.org.uk/carbon/), however they also stopped short of presenting per hectare cost figures of restoring relative to the avoided emissions.

Peat depth surveys

A number of additional benefits were noted of the large data sources that have been obtained during the Peatland ACTION project. Of particular note is the extremely valuable peat depth survey database, which would be highly beneficial to modellers to improve digital models of peat location, depth and stock. During the Peatland ACTION project, 110 sites covering 20,122 ha were surveyed for peat depths. Peat depth data was available for 67 of these sites, which contained just under 10,500 individual peat depth readings. Figure 1 shows the geographical spread of the locations of these released data. There were a small number of data quality issues concerning incorrect locations, and a few sites only reported site centroids rather than individual locations for each of the peat depth measurements, which limits the use of such individual datasets severely. In its totality, however, this dataset must be the largest peat depth data at this level of resolution in existence. In comparison, the James Hutton Institute peat depth data consist the averages of the 1960s Peat Surveys, which informed the 1:250,000 Soils of Scotland mapping for peat depths and some additional point data from the National Soils Archives (NSIS Phase 1 and 2) which specified sample locations as peat or other soil types but did not categorically measure peat depth. The British Geological Survey has compiled its information on peatland location in the 1:50,000 maps. In the vast majority of the Peatland ACTION sites, the peat depth surveys undertaken as part of the project improves the estimate of the carbon stock considerably (Table 3).

In some cases, especially on small sites, the resolution of the currently available national scale maps is insufficient to show the peat at such sites at all (Table 3, Figure 2). On-going research to refine peat soil maps using digital soil modelling approaches would benefit enormously from access to the Peatland ACTION peat depth data resource and every effort should be made to make this dataset available in full for scientific purposes.

[2] DBEIS report (in press), 2016

Table 3. Examples of comparisons of peat depth estimates at restoration sites using the existing national scale datasets with the new Peatland ACTION data sources.

Site	Hutton 1:250,000 map average depth (m)	Presence in Hutton 1:25,000 map (partial national coverage)?	Presence in BGS 1:50,000 map?	Peatland ACTION average (m)
Upper Glen Ey	1.05	No	Mostly	0.80
Inshriach	No data	No	Yes	1.83
Portlethen Moss	No data	Yes	Yes	1.55
Glenshee	Composite of 2 polygons, weighted average of 0.85	No	Yes	0.59
Castle Fraser	No data	Yes	Southern part of site only	0.95
Dundreggan Phase 1	0.525 (partial coverage)	No	No	1.41
Dundreggan Phase 2	0.75	No	Partial	1.11
Nairnside Trust	Approximate weighted average of 1.75	Yes	Mostly	2.24
Glenmullie	1.5 m (incomplete coverage)	Mostly	Mostly	0.97
Corrour	0.525	No	Partial	0.91
Greenhead Moss	No data	Yes	Yes	3.38
Talla and Gameshope	0.75	No	Partial	0.92

Baseline condition survey and aerial photography data

Data that could be used to assess the success of the Peatland ACTION project in terms of restoring peatland hydrology, surface topography and vegetation complement include baseline condition surveys, aerial photography and assessment of the terrain, and any hydrological monitoring. Due to the nature of the funding, only a small proportion of the total Peatland ACTION sites had monitoring in place that would allow a rigorous assessment of restoration success if a re-survey was conducted.

Penny Anderson Associates Ltd (PAA) was commissioned by SNH in 2014 to monitor the performance of Peatland ACTION during 2014 and 2015. The surveys included 17 PA sites (10 blanket bog and 7 raised bog sites). The areas where different management interventions were applied were mapped, along with any drainage channels/networks and other features of interest. These maps were used to identify suitable plot locations for baseline monitoring prior to the field visits. The monitoring approach used randomly placed 2m x 2m quadrats within each sample plot to assess the main bog vegetation. Within each quadrat the cover of all plant species was recorded, along with a number of environmental

factors, including cover of bare peat and open water, presence/absence of grazing animal dung, any damage to the bryophyte layer or peat compaction. A site walkover, to describe the general character of each sample plot and to take fixed point and illustrative photographs, was also conducted. It was unclear during the writing of this report whether the original data gathered by PAA had been passed to SNH, as only the final project report was made available to the primary author of this report.

All of these sites were surveyed by unmanned aerial vehicles (UAV) to take high resolution aerial photographic records shortly after the restoration activities had been completed. At the point of reporting, it has not yet been feasible to ascertain the resolution of these survey data, although it is believed to be in the region of 5-10 cm. Only at one of these sites has some limited image processing been performed, and only a limited assessment of the area covered by easily identifiable 'objects' (e.g. bare peat or open water bodies) has been concluded at the present time (Duncan Blake, SNH, pers. Comm.). These data are accessible under Open Government licence.

The baseline surveys (including the aerial photography data) form an invaluable dataset of the site condition for the relevant sites. Considerable benefit would be gained if these data could be made available in future for use by researchers wishing to calculate future carbon benefits of restoration, or those involved in modeling of peatland vegetation or condition through the use of remotely sensed data.

Hydrological monitoring

Hydrological monitoring of peatlands after restoration efforts, in other words, testing whether restoration results in a less variable water table closer to the surface, is one of the crucial evaluations of success. Due to the cost of such monitoring, however, only a small number of the Peatland ACTION sites appear to have been instrumented. The master spreadsheet contains at least 14 sites where monitoring is mentioned but it is unclear whether this always includes hydrological monitoring. In one of these, there may be multiple sites that have not been individually included, so the total monitoring effort is not clear at this point.

It is also unclear how the hydrological monitoring of the sites where equipment has been installed is still being conducted at present, or indeed how the continuing monitoring and evaluation of such data will be funded. It is important that a representative sample of the project overall is evaluated on the success of creating rewetting of the restoration sites, and for this evaluation such data are critical. It should be ascertained whether a sufficiently large number of sites, within each restoration category, and across the geographical area of the overall project, are being monitored to enable evaluations of success rates.

Digitised drainage and erosion features

In addition, it became clear that there are further data sources that are not currently held centrally, but which were collected by individual Project Officers and are held locally. These include digital maps of drains or eroded areas as mapped by the contractors before, during or after the restoration at each site. Such data were also collected for some of the feasibility studies, where restoration activities have not been carried out to date. It would be of very high value to make these data publicly available. For example, there is currently no estimate of the national area of drained peatland due to a lack of information on drainage extent. This is information required to correctly calculate the greenhouse gas emissions from peatlands in the UK National Inventory, under UNFCCC and Kyoto Protocol requirements. We

understand that outstanding data protection issues and staff time constraints limit further distribution at present. However, any further funding for peatland restoration efforts should aim to compile these, and any new, baseline data on drainage and erosion features, and make these available to the UK National Inventory compilation team.

In addition, there are various research projects that aim to quantify drainage and erosion in peatlands using modeling approaches and the Peatland ACTION datasets would be invaluable as training and validation data.

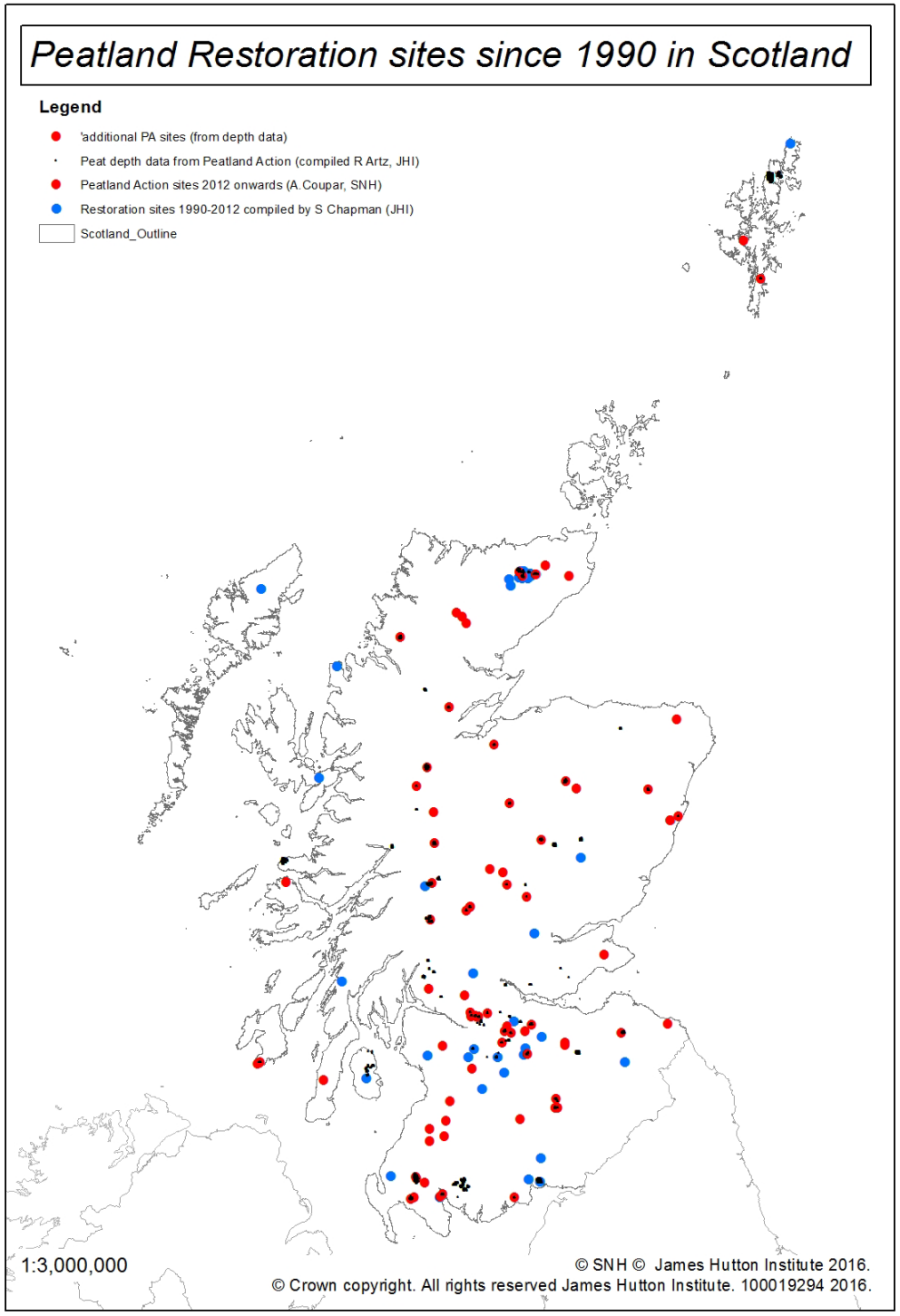

Figure 1. Locations of the 67 Peatland ACTION sites where permission to share peat depth data is in place (out of 110 sites).The figure shows previously known restoration sites (Chapman et al, 2012[3]) in blue, Peatland ACTION sites where data clearance has been given in red, and sites with peat depth data in black (some of which may not yet have been restored).

[3] Chapman, S., Artz, R., and D. Donnelly (2012) Carbon Savings from Peat Restoration. Report to the Centre for Expertise on Climate Change.

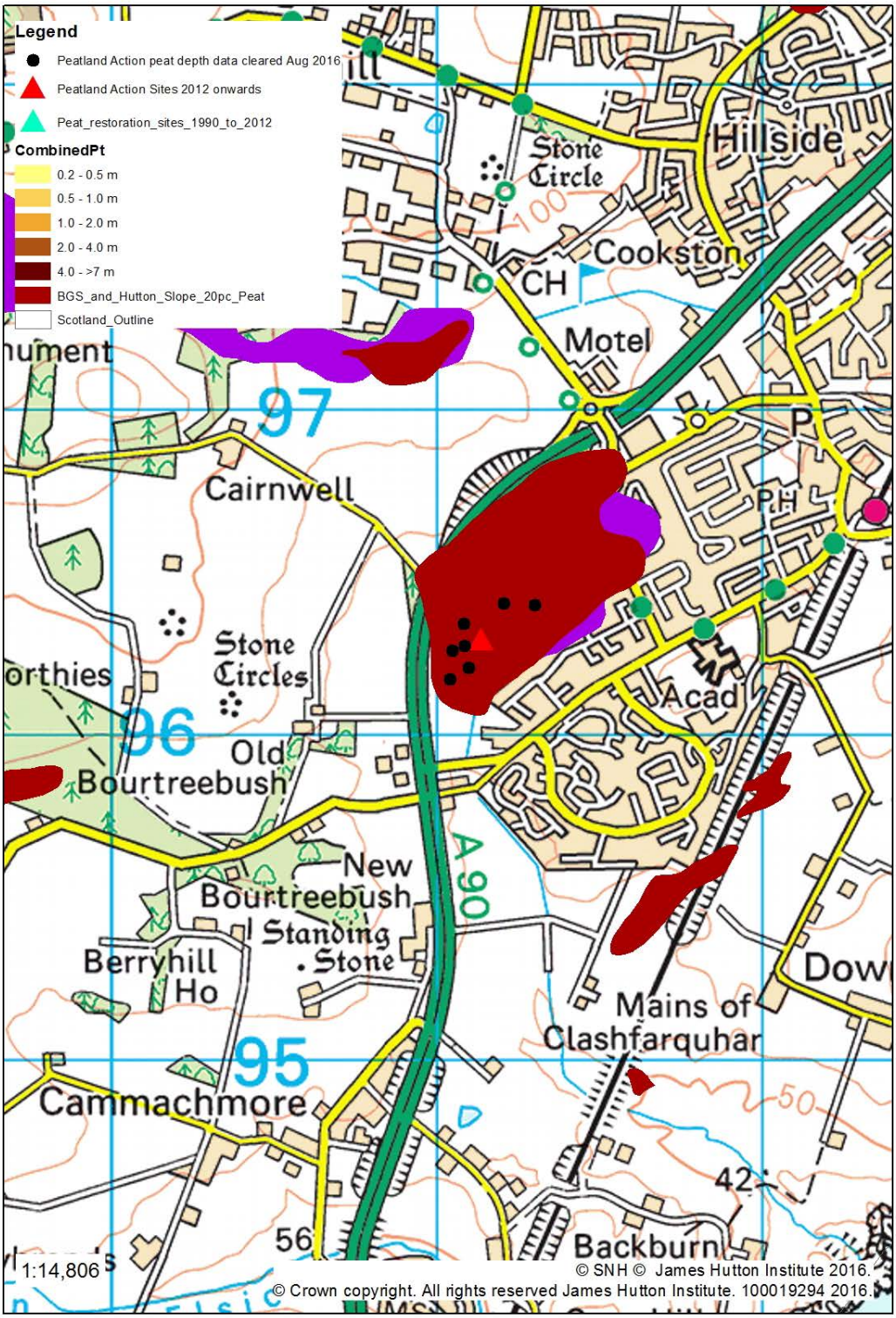

Figure 2. An example from the Portlethen Moss restoration site location (triangle) showing the superiority of the peat depth data sites collected during the Peatland ACTION project (black). There is no coverage of peat depth in any of the existing national peat depth data sources, although the location of the peat partially concurs with the most recent modelling attempts using Hutton 1:250,000 and BGS 1:50,000 mapping combined with a 20% slope cutoff (red), and the Hutton 1:25,000 data (purple).

Potential for evaluations of ecosystem service benefits from the Peatland ACTION data

Further ways to evaluate the success of the Peatland ACTION project to produce ecosystem service benefits in monetary and non-monetary terms have been summarised in Table 4. Data sources that could be used to obtain information on potential ecosystem service benefits or disbenefits due to the Peatland ACTION project outcomes were the internal SNH 'Lessons Learned' document and some of the shared individual project reports. The report by Byg and Novo (2016) produced further evidence through interviews with a large proportion of the former Peatland ACTION project officers, who were also able to summarise information they had been given by individual land owners, contractors, and other users of the restored peatlands.

The summary assessment of the effects of the Peatland ACTION project on delivering ecosystem service benefits can be found in Table 4. There is currently no evidence that the data required for such evaluations are readily available. In a purely qualitative assessment, however, the Peatland Action project as a whole has produced an impressive number of direct and co-benefits to ecosystem service delivery on the restored areas.

Table 4. Assessment of the data gathered within the Peatland ACTION programme and potential uses to evaluate ecosystem service benefits

Functional group	Ecosystem services	Reported peatland-specific benefits or disadvantages of the Peatland ACTION programme	Direct aim of PA?	Source of the data	Possible cost: benefit evaluation method (*)	Likely data coverage
Provisioning Services	Food	Potential lower income from livestock/shooting, however also positive benefits noted e.g. higher grouse chick survival affecting shooting income, future apiarists use, being able to focus limited farming/keepering resource on those areas which are most productive or need of additional management rather than low productivity areas, lower erosion benefits salmonids including egg survival rates, increased range (further tributaries).	(x)	Interview based qualitative evidence from PA officers (Byg and Novo, 2016); SNH internal 'Lessons learnt' document (2016)	Opportunity cost, avoided cost, non-monetary methods	Uncertain whether any quantitative data have been obtained. Some qualitative data, not assessed whether they are of sufficient quality for non-monetary evaluations.
Provisioning Services	Fresh Water	Lower water purification costs, lower cost to land owners to control fires.	x	Scottish Water case study mentioned by A McBride; Byg and Novo,	Avoided cost, non-monetary methods	Uncertain whether any quantitative data have been obtained. Some qualitative

				2016; some qualitative data in individual site reports		data, not assessed whether they are of sufficient quality for non-monetary evaluations.
Provisioning Services	Fuel	Perceived negative effect on income generation (capital land values decrease in formerly afforested areas not replanted after felling, or peat harvesting sites), however removal generally involves unproductive and uneconomic crops.	(x)	No qualitative or quantitative information obtained	Opportunity cost	None
Functional group	Ecosystem services	Reported peatland-specific benefits or disadvantages of the Peatland ACTION programme	Direct aim of PA?	Source of the data	Possible cost: benefit evaluation method (*)	Likely data coverage
Provisioning Services	Fibre	Negative effect on income generation, though this is probably negligible due to fleece values. Taking sheep off sites probably only has the effect of loss of subsidy. Increased forage area. Reduction in lamb losses in blocked ditches.	(x)	Byg and Novo, 2016); SNH internal 'Lessons learnt' document (2016)	Opportunity cost	Uncertain whether any quantitative data have been obtained.

Provisioning Services	Biochemicals	No direct examples provided, although one consultation response talked of the health giving benefits of balneotherapy.	(x)	No evidence	Factor income	None
Provisioning Services	Ornamental resources	No examples provided	(x)	Not applicable	Factor income	None
Provisioning Services	Genetic resources	The project used the genetic resource of donor areas to re-seed bare peat areas, thus creating larger areas of genetic resource in the future	(x)	Pers. Comm. A. McBride.	Non-monetary evaluations	Anecdotal evidence only
Regulating Services	Climate	GHG emissions based on assumption (supported by current scientific consensus) that change in land cover equals change in net emissions. Perceived reduction in wildfire risk due to surface rewetting	x	SNH internal 'Lessons learnt' document (2016)	Avoided cost, replacement cost	Anecdotal evidence only
Regulating Services	Human or animal disease	Perceived lower disease risk to humans/animals (reduced ticks numbers reduced following restoration, although potential problem with *Narthecium* in recovering sites).	(x)	SNH internal 'Lessons learnt' document (2016)	Avoided cost	Anecdotal evidence only
Regulating Services	Bioregulation	Perceived higher resilience to plant pests, although anecdotal evidence that heather beetle has preference for stressed heather created by	(x)	Pers. Comm. A. McBride.	Avoided cost	Anecdotal evidence only

		rewetting				
Functional group	Ecosystem services	Reported peatland-specific benefits or disadvantages of the PA programme	Direct aim of PA?	Source of the data	Possible cost: benefit evaluation method (*)	Likely data coverage
Regulating Services	Water regulation (flood risks)	Perceived decreased downstream flood risk (particularly in ex-forestry sites where track damage was reported pre restoration), data in existence to evaluate whether better hydrological on-site conditions are created following rewetting (e.g. Blawhorn Moss, individual final report survey data on drain flow rates), potentially lowering wild fire risk.	(x)	SNH internal 'Lessons learnt' document (2016). Dipwell monitoring data from selected sites. Galloway Fisheries Trust experiences. Final project reports. Byg and Novo, 2016);	Avoided cost	Partial estimates may be possible, however data quality and fitness for purpose could not be assessed.

Regulating Services	Erosion control	Perceived decreased gully erosion and windborne erosion	x	Individual project officers. SNH internal 'Lessons learnt' document (2016)	Avoided cost, factor income	No quantitative data available
Regulating Services	Water purification	No additional examples to those already given e.g. DOC/POC reduction	(x)	Not applicable	Not applicable	Not applicable
Regulating Services	Pollination	Perceived increased success in species reliant on pollinators, potential yield of high quality wild honey	(x)	Pers. Comm. A. McBride.	Factor income	No direct evidence available
Cultural Services	Spiritual and religious	No examples given	(x)	Not applicable	Not applicable	Not applicable
Cultural Services	Recreation and tourism	Increased use of sites (Lenzie Moss); doctors prescribing bog walks (where there are boardwalks) and bogs used widely by dog walkers and runners as circuits; Improved access for clients and estate staff on sporting estates.	(x)	SNH internal 'Lessons learnt' document (2016) Byg and Novo, 2016	Factor income, travel cost	Uncertain whether any quantitative data have been obtained. Some qualitative data, not assessed whether they are of sufficient quality for non-monetary

						evaluations.
Cultural Services	Aesthetic	Increased use of sites, noted health benefits, use for photography or other creative arts	(x)	No direct evidence	Avoided costs, factor income, non-monetary evaluations	No direct evidence available
Functional group	Ecosystem services	Reported peatland-specific benefits or disadvantages of the PA programme	Direct aim of PA?	Source of the data	Possible cost: benefit evaluation method (*)	Likely data coverage
Cultural Services	Inspirational	Increased use for photography or other creative arts	(x)	No direct evidence available	Contingent valuation, factor income, non-monetary evaluations	No direct evidence available
Cultural Services	Educational	Skills development e.g. contractors, children, local residents. Higher value of sites for scientific interest	x	Individual project officers. SNH internal 'Lessons learnt' document (2016)	Cost savings (increased efficiency), factor income, non-monetary evaluations	Uncertain whether any quantitative data have been obtained. Some qualitative data, not assessed whether they are of sufficient quality for non-monetary

						evaluations.
Cultural Services	Sense of place	Increased personal sense of responsibility with restored sites or peatlands per se. Bog restoration is being seen by government as a cultural response to stewardship of the land scape but a wider responsibility to the world climate. Individuals and communities are also beginning to take some of the responsibility.	(x)	Individual project officers. SNH internal 'Lessons learnt' document (2016) Byg and Novo, 2016	Non-monetary methods	Uncertain whether any quantitative data have been obtained. Some qualitative data, not assessed whether they are of sufficient quality for non-monetary evaluations.
Cultural Services	Cultural heritage	Increased perception of connection with intergenerational use of peatlands (e.g. Project Officer involvement in Shetland-based projects)	(x)	Pers. Comm. A. McBride.	Non-monetary methods	Anecdotal evidence only
Supporting Services	Soil formation	Not likely applicable due to short timescale since restoration practice, baseline information available for future surveys in e.g. individual project reports on drain height and width.	(x)	Data in final project reports and baseline surveys could/should form part of any long-term monitoring	Replacement cost?	Not applicable

Functional group	Ecosystem services	Reported peatland-specific benefits or disadvantages of the PA programme	Direct aim of PA?	Source of the data	Possible cost: benefit evaluation method (*)	Likely data coverage
Supporting Services	Primary production	Possibly modest changes observable in primary production due to short time elapsed since restoration	(x)	Vegetation and UAV based monitoring data available as baseline for long-term monitoring	Replacement cost?	Not applicable
Supporting Services	Nutrient cycling	Not likely applicable due to short timescale since restoration practice	(x)	No direct evidence of any data having been collected? (Scottish Water in runoff?)	Replacement cost?	Not applicable

* *Avoided cost:* Services allow society to avoid costs that would have been incurred in the absence of those services (e.g. waste water treatment in the absence of peatland restoration). *Replacement cost:* Services could be replaced with man-made systems (e.g. replacement cost of the sequestering function of intact peatlands by use of carbon capture methodologies). *Factor income:* Services provide for the enhancement of incomes (e.g. improved water quality and shooting access increases the commercial income of estates). *Travel cost:* Service demand may require travel, whose costs can reflect the implied value of the service (e.g. value of ecotourism experience is at least what a visitor is willing to pay to get there). *Hedonic pricing:* Service demand may be reflected in the prices people will pay for associated goods (e.g. house prices increases due to better aesthetic quality). *Contingent valuation:* e.g. Willingness to pay etc. Service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives (e.g. visitors willing to pay for increased access to national parks).