The costs of peatland restoration

Analysis of an evolving database based on the Peatland Action Programme in Scotland

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Summary and key findings

1. Peatland restoration is increasingly perceived as an inexpensive and effective way to mitigate greenhouse gas emissions. However, there is currently limited information available on both costs and benefits of restoration in monetary terms.
2. The main aim of this report is to provide a characterisation and analysis of a database of peatland restoration activities and their costs, using data collected as part of the grant application and reporting process for the Peatland Action Programme (PAP) in Scotland.
3. The database includes information from 90 unique projects covering 194 restoration sites in Scotland, of which data from 166 sites was suitable for the analysis. We separately consider information from two types of forms completed by applicants and grantees: application forms (AF) and final reporting forms (FF).
4. Restoration activities were broadly categorised into five main categories: A) Ditch (grip) blocking; B) Hag, gully and bare peat restoration; C) Bunding; D) Forest to bog restoration; and E) Scrub removal.
5. More than half of the restoration sites in the database have a site designation, such as SSSI or NNR.
6. In terms of current use, deer management (40%) and rough grazing (37%) rare most frequently mentioned as productive uses, followed by field sports and forestry. Biodiversity conservation was reported as the current use of the sites in 34% of cases.
7. Across all AF, the mean estimate of restoration cost per hectare is £1976 (median: £1157). The corresponding estimate across all FF is considerably lower at £1227 (median: £955).
8. Project Management costs have a median value of between 5% and 6% of the total cost depending on whether predicted (application form) or actual (final reporting form) costs are used. However, project management costs do not typically consider support offered via the Peatland Action officers. Mean values for in-kind costs range between 6.4% and 12.2%, with median values between 2.5% and 9.2%.
9. Restoration cost per hectare is approximately twice as high in the presence of forest-to-bog restoration relative to the absence of such activities.
10. Restoration cost per hectare on sites that are actively eroding and involve removal of scrub and forestry appear to be higher than for sites without these characteristics. However, more information especially from final reporting forms is needed to confirm this trend, and to allow a more reliable appraisal of how restoration costs vary across *ex-ante* site conditions.

Background

1. Peatland restoration is increasingly perceived by policy and decision makers in the UK, across Europe and the world as an inexpensive and effective way to mitigate greenhouse gas emissions (GHG) to the atmosphere (Badiou et al. 2011; Bain et al. 2011; Hansson and Dagusch 2017; Leifeld et al. 2018). Peatland restoration is therefore expected to make a considerable contribution to achieving national emission targets and may in some countries be an indispensable strategy to move towards net zero emissions (Leifeld et al. 2019).
2. Knowledge on costs and benefits is crucial to inform 'value for money' decisions regarding climate change mitigation. This can relate to the relative net benefits of peatland restoration compared to alternative (land-based and other) means of GHG reduction, or to understanding what drives variation in cost-effectiveness and cost-benefits of peatland restoration within an area or country in order to assist with spatial targeting to enhance overall efficiency (Glenk et al. 2014).
3. There is currently limited information available on both costs and benefits of restoration in monetary terms. For the UK, previous assessments of benefits include Moxey and Moran (2014), who focus on GHG mitigation using estimates of carbon prices, and Glenk and Martin-Ortega (2018), who provide estimates of benefits associated with GHG emission reductions, changes in water quality and biodiversity, and restoration-induced changes in land use.
4. In terms of restoration costs, several recent reports and papers are of relevance to the UK. Moxey (2016) discusses challenges to understand opportunity costs of peatland restoration. Artz and McBride (2017) provide an overview of restoration costs by activity based on data collected as part of the Peatland Action Programme (PAP). Artz and McBride (2017) refer to an average restoration cost of £815/ha, including most of project administration costs. They also demonstrate a wide variation in costs by restoration activity, and report considerably higher values of cost/ha for forest-to-bog restoration activities.
5. A similar observation regarding costs related to forestry removal is made by Artz et al. (2018), who used surveys of landholders who had previously undertaken restoration to inquire in detail about costs and merits of peatland restoration. This report provides a great degree of detail on types of restoration measures, evidence on their effectiveness with respect to provision of different ecosystem services, cost information and perceptions of land managers, based on a limited dataset of 19 survey returns (i.e., 19 projects).
6. Okumah et al. (2019) report cost data from restoration sites in England and Scotland. The report also discusses potential factors explaining variation in restoration costs, and outlines a range of information that could contribute towards an improved cost appraisal for peatland restoration in the UK.
7. Similar to previous efforts, the main aim of this report is to provide a characterisation and analysis of a database of peatland restoration activities and their costs.
8. A main difference compared to previous reports (Artz and McBride 2017; Artz et al. 2018; Okumah et al. 2019) is the significantly greater scale of the database that underpins estimation of restoration values. To the best of our knowledge, there is currently no database of comparable dimensions available for the UK, and for peatlands at least across regions with temperate climates.
9. The database was collated by researchers of SRUC, the James Hutton Institute and the University of Leeds using data collected as part of the grant application and reporting process for the PAP, funded by Scottish Government and administered by Scottish Natural Heritage (SNH), between 2016 and 2019 (https://www.nature.scot/climate-change/taking-action/peatland-action).
10. Data collection was greatly facilitated through collaboration between SRUC, James Hutton Institute, the University of Leeds and the SNH Peatland Action coordination and data management team. Through this collaboration, forms to be filled by applicants and grantees were adjusted to

allow meaningful data collection on restoration costs. As discussed further below, however, several challenges regarding collation of data into a database remained.

11. The process of data collection on restoration costs based on PAP and the potential use of the data is outlined in greater detail in Glenk et al. (2019). Here, we focus on a summary and initial analysis of the database. As the database will grow over time, both reliability of estimates and possibilities for analysis will improve.

Overview of information in database and important caveats

This Section summarises the information in the database, as well as key assumptions applied when building the database, and resulting caveats for analysis and interpretation.

1. In this report, we consider information from two types of forms completed by applicants and grantees of the PAP: application forms, prior to any restoration, and final reporting forms, to be completed after completion of restoration works (typically at the end of the financial year). The application form includes a description the planned restoration activities and estimation of all restoration costs (including cash and in-kind costs) for the project. The final reporting forms include details about the actual restoration activities and all costs actually incurred as part of the restoration project, in case they differ from activities or costs included in the application form.
2. The application form includes an amendment that provides 'monitoring information', which includes some basic information on applicants and their main views and motivations for undertaking peatland restoration. Data of these forms was entered (N=73), but will not be analysed here. We will also not consider similar information on grantees' experience that was collected as part of the final reporting.
3. In total, information from 90 unique applications was processed. An application is considered unique if it is submitted in a separate form (typically relating to projects in different locations), or if it is submitted in a different funding year for the same general location.
4. Of these 90 unique applications, 47 provided information from the application form only, 41 provided information from both application and final reporting forms, and 2 provided information only from the final reporting form.
5. We will henceforth refer to application forms as AF, and final reporting forms as FF.
6. One form may refer to one or several specific project sites for activities, which may be restoration or non-restoration (e.g. public engagement) activities. In total, there are 281 records entered into the database; 184 stemming from application forms, and 97 from final reporting forms.
7. The 281 records relate to 194 unique restoration sites; in 87 cases, records refer to the same restoration site in both application and final reporting forms. Final form information is available for half of the 194 unique sites (i.e., for 97 sites).
8. We will henceforth refer to restoration sites entered based on application forms as AFS, and restoration sites entered based on final reporting forms as FFS. AFS and FFS will be analysed separately.
9. For a restoration site based on AF or FF to be included in the subsequent analysis, the minimum information requirement was area restored and total restoration costs. Of the 281 records which were entered, 30 records from 28 restoration sites were dropped for analysis either because i) they do not relate to restoration activities, or because ii) information on costs or area was missing (i.e., minimum requirements are not met). This results in 251 records from 166 unique sites for analysis.
10. Records were entered into the database covering programme years 2016/17 (AFS: N=4; FFS: N=1), 2017/18 (AFS: N=105; FFS: N=34) and 2018/19 (AFS: N=68; FFS: N=39).

11. The following list summarises some of the main assumptions and limitations associated with the preparation of the database:
    a. The application and reporting forms changed between, and sometimes during, funding years, to account for changes in restoration practice and to gather additional information which will assist future monitoring. This represents a challenge for aligning information across years and across AF and FF for the same applicants.
    b. There is a wide range of approaches that applicants and grantees have taken to complete the forms. This leads to missing information, and often a need to infer activities reported and associated costs. We kept a log of all issues emerging during data entry (a 50-page plus word document). In many cases, we used our own judgement to, for example, allocate stated activities to pre-defined restoration techniques, or to allocate cost to activities. It was important for us to be consistent in our approach to allocating and interpreting information from AF and FF, but we cannot rule out the possibility that an external person may have a different interpretation, resulting in different allocations.
    c. Some forms list costs that refer to multiple restoration sites. These often but not exclusively refer to project management costs (including e.g. peat depth surveys and monitoring) and mobilisation costs. These multi-site costs were allocated based on the reported size of the restoration sites. Actual allocations may have differed; for example, a smaller site may actually have drawn more attention/a larger share of multi-site costs than a larger site.
    d. Some forms list in-kind (IK) contributions and their value. In many cases, in-kind costs were not allocated to specific sites. We used the same approach as for multi-site costs (allocation by area).
    e. Costs assigned to non-site activities, such as engagement activities, were not included unless they were (erroneously) referring to actual restoration activities.
    f. Several of the application forms list estimated costs for year 2 and 3, while funding in PAP was only granted on an annual basis. Since we are interested in analysing variation in costs, we merged such costs (and associated activities) with activities taking place in year 1 (if any). Costs for years 2 and 3 are often proxy estimates and not based on quotes.
    g. In a few occasions information on cost or area was missing in the FF and was therefore taken from the AF if present. Care was taken that this was only applied when the FF makes explicit mention of no change against the AF.
    h. Project management (PM) costs were summarised in a single category. This lumps together a wide variety of items or activities, ranging from travel and subsistence to peat depth surveys and monitoring information. In a few cases, PM costs are listed in the forms to include mobilisation costs or costs of equipment. We retained some of these as PM costs, where they could not be otherwise assigned. Reported values of PM costs thus rather represent an upper bound of PM costs that overall includes a broad array of restoration-related items.
    i. Related to point h. above, several forms do not provide a cost breakdown by activity, and/or by site. Thus, we cannot isolate PM costs for all applications and sites. If there is no breakdown of costs by site, costs were allocated by site area. This, of course, can only serve as a crude approximation of actual site PM costs.

Restoration activities

This Section concerns how restoration activities were categorised in the database, and what this means for estimation of restoration costs.

1. Under restoration activities we summarise all on-site restoration actions, i.e., changes made on a site with the aim of restoring peatlands. For a summary of techniques and associated effects on ecosystem services see Artz et al. (2018).
2. The restoration activities listed as default options for applicants and grantees on AFs and FFs differ over the years 16/17; 17/18; 18/19) due to changes that have been made to the forms.
3. In addition, the same type of restoration activities have not always been reported on consistently between AF and FF for a single project. This includes how applicants and grantees refer to certain restoration actions in the AF and FF for a single site, and the units that describe the extent of each activity (i.e., number of items vs. length/width vs. area covered by activities such as dams or ditches blocked).
4. Points 2 and 3 do not refer to differences between AF and FF resulting from changes in activity between application and carrying out the work.
5. In some AF and FF, a cost breakdown by activity is not provided, or does not refer to the types of activities listed, or lumps several activities together, for example for sites but not differentiated by activity.
6. Given the above, detailed questioning of the database to infer costs/unit of specific restoration activities is possible, but not without carefully assessing each considered AF/FF for consistency and reliability with respect to allocation of costs to (extent of) activities. We will therefore <u>not</u> provide information on (costs of) specific restoration activities in the report, but could provide such data and commentary if required.

Table 1. Categorisation of restoration activities.

	A **Ditch (grip) blocking**	**B** **Hag, gully & bare peat restoration**	**C** **Bunding**	**D** **Forest to bog restoration**	**E** **Scrub removal**
1	Ditch blocking	Hag/peat bank reprofiling	Bunding	Forestry - tree removal	Scrub removal or management
2	Peat dams	Hag & gully reprofiling	Surface bund	Ditch and furrow blocking (forestry)	Mulch (scrub removal)
3	Wave dams	Gully reprofiling	Trench bund	Forest mulching	
4	Plastic piling dams	Ditch reprofiling	Cell bund	Ground smoothing	
5	Wooden/composite dams	Hag & gully blocking - peat dams/bunds		Stump flipping	
6	Stone/Rock dams (ditch blocking)	Hag & gully blocking - wooden dams		Ground smoothing, stump flipping	
7	Miscellaneous dams	Hag & gully blocking - geotextile logs or rolls		Ground compaction	
8	Ditch reprofiling	Hag & gully blocking - stone dams		Scrub removal (forestry)	
9	Grip blocking	Bare peat restoration		Mulch (forestry)	
10	Drain blocking	Eroded peat restoration		Brash removing/crushing	
11		Peat pan stabilisation			
12		Living mulch			
13		Seeding			
14		Fertiliser			
15		Sphagnum transplantation			

Note: Columns: broad categories A-E. Rows: Specific restoration activities (1-15).

7. Instead, we broadly categorise restoration activities and can use this information to assess variation in overall costs/ha depending on whether types of activities are present or absent. Note

that this approach does therefore not distinguish costs/ha depending on extent of activities. It rather provides an idea of the types of activities and their distribution across applications in the PAP, and allows for a crude first approximation of how restoration costs/ha vary depending on activity.

8. Restoration activities were broadly categorised into five main categories, following Table 1. This categorisation approximately follows the latest revision of AF and FF forms. All activities not matching with the activities in Table 1 were summarised as "other" but are not analysed (18 AF and 5 FF refer to "other" activities) .
9. Categories D (Forest to bog) and E (scrub removal) were aggregated for the analysis in this report.

Site designation and current use

Table 2 presents a brief overview of site designations and current uses reported for the 166 restoration sites.

11. More than half of the sites have a site designation, with specific designations as shown in Table 2.
12. In terms of current use of restoration sites, biodiversity conservation was reported by applicants and grantees in 34% of sites. In terms of productive use, rough grazing and deer management have considerable shares, followed by field sports and forestry (Table 2).

Table 2. Overview of site designations and current use of sites

	Frequency	Percentage[a]
Designation		
No Designation	78	46.99
SSSI	27	16.27
SAC	9	5.42
SPA	20	12.05
NSA	21	12.65
NNR	15	9.04
Other (incl. National Park, Biosphere Reserve, LNR, Geopark)	45	27.11
Current Use		
Missing information	30	18.07
Rough grazing (sheep)	61	36.75
Forestry	21	12.65
Field Sports (grouse or rough shooting)	36	21.69
Deer management	68	40.96
Biodiversity conservation	57	34.34
Other	15	9.04

Note: [a] Percentage is relative to total number of 166 unique restoration sites, and more than one designation or use is possible on one site (i.e., percentages will not sum to 100 for Designation and Current Use).

Descriptive analysis

This Section provides a descriptive overview of main features of the database, including an overview of costs/ha by application type, funding year, activity and site condition.

1. Table 3 reports area restored, associated costs and costs/ha by application year and whether data from AF or FF are considered. Figure 1 shows a histogram of Costs/ha for AF and FF data.
2. Results from Table 3, also discernible in Figure 1, show that there is a clear difference in cost per hectare between AF (estimated costs) and FF (realised costs): values for cost per hectare are

considerably lower when based on FFS compared to AFS. Across all AF, mean cost per hectare is £1976 (median: £1157). The estimate across all FF is £1227 (median: £955).

3. It is apparent that there is significant variation in cost per hectare estimates for AF and FF: standard deviations are large and remain large even if particularly low or high values are excluded (truncated).

Table 3. Summary statistics (mean, median and standard deviation) of area restored (ha), overall costs (£) and costs/ha (£) by application year (16/17; 17/18; 18/19) and type of form (application form sites: AFS; final reporting form sites: FFS)

	Area (ha)			**Costs** (1k £)			**Costs/ ha** (£)			**N**
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	#
AFS 16/17	134.4	64.7	183.58	61.18	55.98	39.32	1796.76	1629.9	1589.76	4
FFS 16/17	88.9	–	–	80	–	–	899.89	–	–	1
AFS 17/18	64.56	33	124.96	60.01	39.04	67.35	1908.74	1161.72	2059.92	105
FFS 17/18	36.45	22.63	39.04	36.46	21.57	36.98	1435.55	984.77	1470.25	34
AFS 18/19	52.74	25	82.84	59.44	29.56	78.07	2089.93	1064.04	2332.44	68
FFS 18/19	45.20	18.5	72.80	30.89	10.98	55.95	1054.94	760.5	884.21	39
AFS Total	61.59	30	112.12	59.82	37.50	70.9	1975.82	1157.02	2151.73	177
FFS Total	41.77	21.39	59.14	34.11	17.38	47.8	1227.72	955.32	1192.35	74
AFS Truncated[a]	56.73	30	92.68	62.59	40	72.60	1669.31	1157.02	1382.92	157
FFS Truncated[a]	40.98	20.65	60.13	32.33	15.57	48	1061.45	955.32	724.03	66
FFS Trunc no IK	40.98	20.65	60.13	32.33	15.57	48	1034.71	823.07	729.28	66

Note: [a] Truncated: indicates values were included if <= 5th percentile or >= 95th percentile

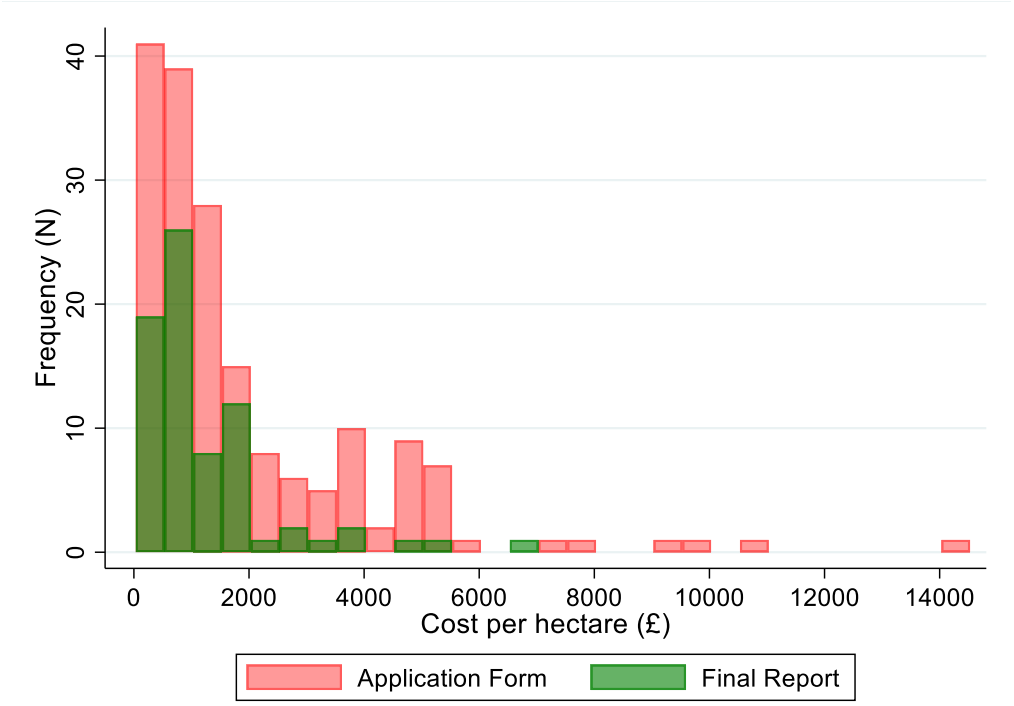

Figure 1. Histogram of costs/ha for records by type of form (Application form and Final reporting form)

4. Calculated values from AFS and FFS data cannot be compared directly because there is only partial overlap of sites. If cost/ha estimates are compared between AFS and FFS for the same restoration sites, the same pattern is observed: cost/ha is considerably larger for AFS. This can be due to several reasons, including i) overestimation of measures needed for restoration; ii) overestimation of restoration costs for specific measures; iii) changes in the area under restoration. Applicants

received guidance on restoration from Peatland Action officers – this likely contributed to adjustments between initial proposals and actual implementation. Differences may also be due to challenges in implementation within a funding and reporting year, or with timely access to contractors or materials for restoration. It would thus be preferred to rely on data from FFS for policy guidance and cost-benefit analysis; nevertheless, data on AFS may still be used to investigate systematic variation in costs.

5. Mean values for truncated estimates are reasonably close to median values. Excluding very small and very large values, the mean for FFS is £1061 per hectare (median: £955).
6. It is too early to make statements about a time trend in restoration costs, especially because only a limited set of FFS has been analysed. However, such trends may be monitored in the future as further information on especially FF is entered into the database.
7. Table 4 summarizes the percentage of overall costs that are incurred as project management (PM) costs and in kind (IK) costs in cases where PM costs or IK costs are reported, or are greater than zero.

Table 4. Summary statistics of share of overall restoration costs related to PM and IK costs for sites (N) where PM or IK costs are reported in either application forms of sites (AFS) or final reporting forms of sites (FFS)

	Mean	Median	Standard deviation	Min	Max	N
PM (%) – AFS	7.95	6.00	7.23	0.37	35.48	116
PM (%) – FFS	7.49	5.28	8.04	0.81	33.47	24
IK (%) – AFS	6.38	2.53	9.95	0.07	55.36	81
PM (%) – FFS	12.21	9.16	7.41	1.83	31.50	20

Note: Total AFS: N=177; total FFS: N=74; AFS and FFS are not directly comparable since they relate to different applications.

8. Because we are not always able to always clearly distinguish PM costs from restoration costs in cases where there was lumping in the forms, these statistics represent rather an upper bound. Given this, it may be preferred to use the median rather than the mean as an indicator. For PM costs, the median value is between 5% and 6% depending on the type of form (AF or FF). For IK costs, mean values for IK costs range between 6.4% and 12.2%, with median values between 2.5% and 9.2%.
9. It is worth noting that PM costs do not typically consider support offered via the Peatland Action officers, and may only sometimes cover, partially, aspects that may be subsumed under transaction costs for the PAP. At the same time, it may be questioned if some expenses, for example for mapping and peat depth surveys, should be counted as PM costs.
10. Table 5 provides a summary of (combinations of) restoration activities proposed or reported as undertaken in AF and FF, respectively, for all those AFS and FFS for which information on activities was available. The Table also lists summary statistics of costs/ha for the combinations of activities. Categorisation of activities follows Table 1.
11. The use of dams was allocated to category A: ditch (grip) blocking, even if dams are also often used in combination with B: Hag, gully and bare peat restoration. This may contribute to explaining the raised value for ditch blocking (A) in final forms relative to hag reprofiling and bare peat restoration (B). Cost/ha for the combination of both (A-B) are in between the values of A and B alone.
12. There is a clear difference between sites which involved forest-to-bog restoration and/or scrub removal (DE present) and those which did not (DE absent). Restoration cost/ha is approximately twice as high in the presence of forest-to-bog restoration relative to the absence of such activities.

This confirms similar findings by Artz and McBride (2017), Artz et al. (2018) and Okumah et al. (2019).

Table 5. Summary of restoration costs/ha by type of restoration activities and type of form

Activities[a]	Application Forms				Final Reporting Forms			
	Cost/ha (£)			N	Cost/ha (£)			N
	Mean	Median	Std. Dev.	#	Mean	Median	Std. Dev.	#
A	577.46	525.86	299.47	14	1104.99	999.68	423.68	6
B	616.62	535.47	450.12	23	562.47	438.84	369.95	4
C	2136.04	–	467.09	2	–	–	–	–
DE	5231.04	4606.98	2743.89	10	1853.08	1603.11	1241.39	16
A-B	1753.83	1171.44	2084.69	82	822.62	575.65	1152.78	31
A-C	4794.67	–	4177.25	2	–	–	–	–
A-DE	2826.09	2831.82	2237.36	22	1135.83	1068.21	465.25	10
B-C	3043.3	2973.46	1995.27	6	1407.88	753.94	1529.92	3
B-DE	3866.77	–	78.91	2	–	–	–	–
C-DE	2669.32	–	274.81	2	–	–	–	–
DE absent	1536.45	984.32	1910.09	129	877.38	630.89	1051.04	44
DE present	3543.24	3806.04	2475.61	36	1577.21	1406.23	1062.63	26

Note: [a] A: Ditch (grip) blocking; B: Hag, gully & bare peat restoration; C: Bunding; DE: Forest to bog restoration & Scrub removal; AFS Total: N= 165; FFS Total: N= 70; Categorisation of activities as per Table 1.

13. Table 6 shows restoration costs/ha by site condition before restoration (as identified by applicants and grantees). Numbers of observations are low for many cells, especially in cases where several conditions have been selected by applicants/grantees. Restoration costs/ha on sites that are actively eroding and involve removal of scrub and forestry appear to be higher, although more information especially from final reporting forms are needed to be more confident about this trend and to allow a more reliable appraisal of how restoration costs vary across *ex-ante* site conditions.

Table 6. Summary of restoration costs/ha by site condition and type of form

Condition[a]	Application Forms				Final Reporting Forms			
	Cost/ha (£)			N[a]	Cost/ha (£)			N[a]
	Mean	Median	Std. Dev.	#	Mean	Median	Std. Dev.	#
Near natural (NN)	–	–	–	–	–	–	–	–
Modified (MOD)	1001.53	727.78	1034.75	9	378.29	327.08	128.45	3
Drained (DR)	1613.99	964.25	1775.89	55	898.62	795.39	890.09	16
Forestry (FOR)	2708.97	2619.23	1348.25	21	335.05	–	240.72	2
Scrub (SC)	2192.83	1991.79	1038.88	6	1667.93	1481.17	1284.19	4
Actively eroding (AE)	2107.52	1414.81	2406.97	48	1462.62	685.83	1779.10	13
NN-MOD	77.03	–	–	1	143.70	143.70	–	1
NN-DR-SC	1251.37	–	–	1	461.43	–	–	1
NN-DR-AE	581.25	–	67.66	2	547.01	–	–	1
MOD-AE	591.59	541.55	356.69	4	392.18	–	–	1
MOD-DR-SC	988.81	844.64	443.95	4	736.26	–	34.29	2
MOD-DR-FOR	682.23	512.86	540.67	9	–	–	–	–
DR-FOR	968.03	–	–	1	1100.84	–	–	11
DR-SC	7783.31	9434.33	3809.63	5	691.41	–	–	1
DR-AE	2021.83	1565.94	1562.34	6	1054.20	1161.45	185.76	3

Note: [a] AFS Total: N= 172; FFS Total: N= 59

Illustrative statistical analysis of systematic variation in restoration costs

In this Section we will illustrate how the data may be used for an analysis of systematic variation in restoration costs. There may be alternatives to the (linear regression) approach used here, for example mixed models.

1. Here, we only use data from FFs, and focus on variation in restoration costs (dependent variable) resulting from different restoration activities implemented (independent or explanatory variables), as shown in Table 5.
2. If the database increases through the entry of additional forms, a more refined analysis may add further useful insights. This includes, for example, including time trends and spatial/geographical factors, or an analysis of variation in costs depending on (initial) peatland condition and use.
3. Given the skewed distribution of restoration costs/ha (see Figure 1), we take the natural logarithm of cost/ha, which then enters the regression. The natural log of Cost/ha is approximately normally distributed. This is therefore a log-linear or semi-log model.
4. All independent variables take the value of one if a restoration activity or combination thereof has been reported for a particular site, else zero (i.e., all independent variables are dummy variables). In semi-log expressions, the coefficients of dummy variables can be interpreted as follows. The coefficient indicates, in percent terms (%), how much lower or higher restoration costs/ha are on average as a result of an activity (or a combination of activities) being present. The % value for a shift from not having a restoration action present (dummy variable =0) to having it present (dummy variable =1) at a particular site is the exponential of the coefficient for the dummy variable minus one (multiplied with 100 to arrive at a percentage).
5. Table 7 shows the results of the regression. Five observations (sites) were omitted from analysis following an outlier analysis using Cook's distance and a rule of thumb of an observation being likely an outlier if Cook's distance is greater than 4/N, where N is the number of observations in the full sample. Variance was estimated using the Huber-White robust alternate estimate of variance.
6. The value of R-squared is decent, suggesting that approximately 47% of variance is explained by indicators of (combinations of) restoration activities alone.
7. Four of the coefficients are significantly different from zero at the 5% level. The value of the intercept (if all explanatory variables are zero) is £708. Effects of activities being present (dummy variable =1) are relative to this value, i.e., a negative coefficient for explanatory variables indicates that a (combination of) activities is on average associated with a decrease in restoration costs; *vice versa* for positive coefficients.
8. Having forest to bog/scrub removal as the dominant activities (*FORSCRUB*) has a positive association with restoration costs. This is the case for *FORSCRUB* alone, or in combination with ditch (grip) blocking (*DITCHBLOCK*). All else equal, the estimated proportional change in restoration costs/ha relative to £708 as a result of FORSCRUB is 117.13% [95% confidence interval: 28.93%; 265.66%]. In other words, the presence of forestry and/or scrub removal activities are associated with more than a doubling of restoration costs estimated at the intercept. With a proportional change in costs/ha of 65.14% [95% confidence interval: 9.83%; 148.31%], the respective estimate for the combination *FORSCRUB-DITCHBLOCK* is lower but still considerable.
9. In contrast to forest to bog restoration and scrub removal, the presence hag, gully & bare peat restoration (*HAGBARE*) is associated with a negative change in restoration costs/ha relative to the intercept value of £708, on its own or in combination with ditch blocking (*DITCHBLOCK*). Proportional shifts in cost/ha resulting from *HAGBARE* and *HAGBARE-DITCHBLOCK* are -47.64% [95% confidence interval: -69.47%; -10.18%] and -46.17% [95% confidence interval: -64.18; -19.1], respectively.

10. The coefficients of Ditch (grip) blocking (*DITCHBLOCK*), alone and in combination with bunding (*DITCHBLOCK-BUND*) are positive but not significantly different from zero. The number of observations for bunding (on its own or in combinations) is very low, thus preventing the conclusion that the presence of bunding if applied in combination with bare peat restoration increases restoration costs. More data is needed to confirm this.
11. Indeed, across all activity categories, sample size (number of records/sites or FFS) is still relatively low. This also contributes to relatively large variance of estimates.

Table 7. Regression of the natural logarithm of restoration costs/ha for sites in final application forms on restoration activities present in sites

Variable	Coefficient	Standard error	p-value
DITCHBLOCK	0.3769	0.2631	0.157
HAGBARE	**-0.647**	0.2696	0.020
FORSCRUB	**0.7753**	0.2604	0.004
DITCHBLOCK-HAGBARE	**-0.6193**	0.2035	0.004
DITCHBLOCK-FORSCRUB	**0.5016**	0.2038	0.017
HAGBARE-BUNDING	0.3374	0.2383	0.162
Intercept	**6.5629**	0.2055	0.000

Note: Number of observations (FFS): 65; R-squared value: 0.4758; significant coefficients (at 5% level) in bold; Abbreviations are as follows: DITCHBLOCK: Ditch (grip) blocking; HAGBARE: Hag, gully & bare peat restoration; BUNDING: Bunding; FORSCRUB: Forest to bog restoration & Scrub removal.

Conclusion

Understanding costs of peatland restoration is very important to inform economic analysis to inform decisions on allocation of (public) budgets to restoration. Information on costs of peatland restoration is currently patchy and fragmented, and often based on small sample size. This report presents a first analysis of what represents, to the best of our knowledge, the largest existing database on peatland restoration costs in the UK (and possibly internationally). This unique database was built on data collected during the grant application and reporting process of the Peatland Action Programme in Scotland.

We find a mean estimate of restoration cost per hectare using data from reports of actually incurred costs of £1227 (median: £955). Excluding very small and very large values, median costs per hectare remain the same at £955, while the mean estimate decreases to £1061 per hectare. On average, project management costs, excluding support offered through Peatland Action and its officers, are estimated to account for 6% of total restoration costs, and in-kind contributions are valued at approximately 10% of total restoration costs.

Differentiating by type of restoration activity and initial peatland condition, there is considerable variance in restoration costs per hectare within each activity and condition. Nevertheless, some systematic variation can be glanced from results. Descriptive statistics and a first regression model suggest that cost per hectare on sites that are actively eroding and involve removal of scrub and forestry appear to be higher, and that costs per hectare are approximately twice as high for forest-to-bog restoration relative to such activities being absent.

Next steps

Here we summarise further steps that can be taken to add value to the existing database, in the order of priority.

1. ***Expand the database by adding further sites, and actually incurred costs in cases where only cost predictions are available at present***. This will improve reliability of estimates and capacity to analyse time trends and variation in costs quantitatively.
2. ***Improve quantitative modelling of variation in restoration costs***. This can be achieved through the use of bespoke statistical modelling techniques and the generation of additional explanatory factors; for example, where available, spatial variables such as distance to roads/markets or a relative remoteness index may be added, in addition to exploring spatial econometric methods that account for spatial associations of restoration costs.
3. ***Analysis of additional information included in AFs and FFs***. Both types of forms entail additional information on, for example, motivations for restoration, the presence of visual impacts of restoration and grantees' experience with the restoration process. Some of this information is available quantitatively, for example via 'monitoring information' in AF and a special section on experience with restoration in FF, but applicants also provide useful textual statements on background, motivation and restoration experience that can provide further perspectives.

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