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UK Peatland Restoration: Some Economic Arithmetic

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ABSTRACT

Over 80% of UK peatlands are degraded to some extent and their widespread restoration could contribute to meeting various climate change, water quality and biodiversity policy targets. Economic analysis of costs and benefits is, however, hampered by scientific uncertainty and a lack of data on biophysical condition, about impacts and restoration costs. This paper presents a simple ‘ready-reckoner’ Table of possible net economic benefits under different combinations of simplifying ‘what if?’ assumptions for key parameters that characterise restoration calculus. The results strongly suggest that even a narrow focus on carbon benefits alone is sufficient to justify restoration in many cases, and including possible additional non-carbon benefits reinforces this. However, results are sensitive to assumptions and better data for, in particular, restoration costs associated with modest emission savings from lightly degraded sites would be helpful. Some other areas for further research are also identified.

KEY WORDS: Peatland restoration; economics, cost-benefit, carbon emissions

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1. Introduction

Over 80% of UK peatlands are degraded to some extent as a result of, for example, atmospheric pollution, burning, cultivation, drainage and grazing. This has reduced the flow of many ecosystem services derived from peatlands, prompting calls for widespread restoration to help meet climate change, water quality and biodiversity targets and political agreement to restore 1m ha of degraded peatlands (Bain et al., 2011; JNCC, 2011; Bonn et al., 2013; Quick et al., 2013).

Restoration involves modifying or ceasing current damaging activities plus, in most cases, remedial actions to stabilise, re-wet and/or re-vegetate damaged sites (Bain et al., 2011; Bonn et al., 2013). The type of restoration required varies with site conditions and objectives, and the effectiveness and time taken are somewhat uncertain (Lindsay, 2010; Bain et al., 2011; Artz et al., 2012; Bonn et al., 2013). The costs are also variable and often poorly reported (Holden et al., 2008; Chapman et al., 2012; Moran et al., 2013).

This scientific uncertainty and lack of data hinder economic analysis of the merits of restoration. Where economic analysis has been attempted, it has typically relied on fixed assumptions (e.g. Natural England, 2010; Moxey, 2011) and/or the use of (biophysical) process models requiring detailed data available only at a local level (e.g. Worral et al., 2009b; Harlow et al., 2012).

This paper presents results from some simple economic arithmetic on the costs and benefits of restoration under different circumstances. Specifically, different values for key variables and parameters are combined to generate a ‘ready-reckoner’ Table of possible net benefits under different sets of ‘what if?’ assumptions.

The approach is not intended as an alternative to more scientific process-based modelling nor as a tool for detailed site-specific assessments. Rather, the aim is explore the general circumstances under which restoration may be merited and to do so in a manner that presents key assumptions.
transparency. It is hoped that this will facilitate debate and research on the likelihood of particular circumstances and outcomes and help to identify areas for further research and policy development.

The paper is structured as follows. The next section outlines assumptions about the key restoration parameters underlying a cost-benefit analysis. Section three presents results, which sections four and five present discussion and conclusions.

2. Restoration parameters

Restoration aims to improve the condition of degraded sites towards that of near-natural peatlands in terms of ecosystem functionality. In particular, whereas near-natural sites typically act as carbon sinks, degraded sites act as carbon sources. For governments seeking low cost mitigation options, restoration thus offers the possibility of not only protecting the accumulated carbon stock embedded in peatlands but also achieving additional sequestration. Restoration also offers potential gains with respect to water quality, flood management, habitats and biodiversity, protection of buried paleo-archaeological features and recreational enjoyment (Haines-Young & Potschin, 2009; Kimmel & Mander, 2010; Bonn et al., 2013). Hence the economic case for restoration may go beyond mitigation to include the value of these co-benefits.

However, as with other land use choices, restoration incurs costs that need to be compared to the value of any benefits if the economic merits of restoration are to be judged (HMT, 2003/11; Hanley & Barbier, 2009). That is, restoration regardless of cost is not economically rational and differences in the costs and benefits for different categories of peatland might mean that not all categories merit restoration (Natural England, 2010; Moran et al., 2013). Such comparisons involve consideration of a number of variables and parameters.

2.1 Carbon benefits
Current estimated Green House Gas (GHG) emission factors for different peatland categories in the UK exhibit some variation, reflecting both sparsity of actual field measurements but also heterogeneity across sites and natural year-on-year variation (Billet et al., 2010; Bussell et al., 2010; Worral et al., 2011; Evans et al., 2011). Calculations are made more complex by losses to water (e.g. Particulate & Dissolved Organic Carbon, POC & DOC) as well as air plus, especially, the increased presence of methane (CH$_4$) under wetter conditions partially offsetting lower carbon dioxide (CO$_2$) emissions for restored and near-natural sites (Baird et al., 2009; Lay, 2009; Holden et al., 2011). In particular, a methane “spike” after initiation of restoration can more than offset carbon savings in the short-term before net emission savings (expressed as carbon dioxide equivalents, CO$_{2e}$) are achieved later (Worral et al., 2011; Couwenberg & Fritz, 2012; Artz et al., 2013).

For the purposes of this paper, precise characterisation of variable emission profiles for non-restored and restored sites was not attempted but instead the potential differential between such profiles was used. Specifically, it is assumed that a differential of between 1t CO$_{2e}$/ha/yr and 20t CO$_{2e}$/ha/yr is achieved ten years after restoration commences and that this differential is maintained thereafter. This is an illustrative range. The lower-bound is unlikely to be less, but the upper-bound could be higher since some estimated emission factors for badly degraded sites are above 20 (especially if emissions to water are included) whilst most estimated emission factors for restored sites are negative (see Natural England, 2010; Artz et al., 2013; Birnie & Smyth, 2013).

The differential could relate to the difference between a damaged site and a near-natural site, but equally could refer to the difference between a damaged site and a restored site where restoration does not fully achieve near-natural conditions; the distinction does not matter in this analysis, nor does the precise balance between separate emissions types.

For the purposes of this paper, it is assumed that there is a methane spike equivalent to 2.5t CO$_{2e}$/ha/yr for each of the first ten years. The duration and magnitude of the methane spike is highly
uncertain and an assumed net differential loss of 25t over ten years is an illustrative figure based on discussions with various peatland researchers (pers. comms. Artz, Evans, Holden, Lindsay and Smyth). A “spikier” non-uniform distribution and/or different duration would alter results slightly whilst a higher (lower) total would reduce (increase) net benefits.

The economic value of estimated net CO$_{2e}$ savings (i.e. CO$_2$ emissions avoided plus any CO$_2$ sequestered, less any CH$_4$ emitted) in a given year is the differential multiplied by the price of carbon in that year. The prices used here are the UK government’s agreed set of carbon values for policy appraisal and evaluation, more specifically the low, central and high non-traded values of carbon as published by DECC (2011).

2.2 Non-carbon benefits

Near-natural peatlands are internationally recognised as important habitats supporting biodiversity and providing significant cultural benefits through, for example, preservation of archaeological features and distinctive landscapes. They may also help to maintain water quality and hydrological functions, thereby avoiding the need for expensive treatment facilities or flood management infrastructure. Such services clearly have a value to society, but multi-dimensional (co-)benefits are hard to quantify and are not yet priced as explicitly or consistently as carbon (Reed et al., 2013). For example, different valuation methodologies can yield different prices (Wichmann et al., 2013) and both habitat connectivity and hydrological benefits appear to be highly dependent on circumstances elsewhere in a catchment (Holden et al., 2011; Bonn et al., 2013).

For the purposes of this paper and following Harlow et al. (2012), selected non-carbon benefits are approximated by using non-market valuation estimates derived from work by Christie et al (2011) in relation to worsening, maintaining or improving peatland condition under Biodiversity Action Plans. Specifically, a value of £94/ha/yr is applied each year. This value excludes carbon sequestration and
hydrological (i.e. water quality and flood control) benefits, and does not distinguish between restoring different degrees of degradation.

2.3 Capital costs

In many cases, restoration incurs upfront expenditure on capital works such as blocking grip drains, erecting fencing, clearing scrub, stabilising surfaces and re-seeding or re-vegetating bare areas. Such costs can vary significantly with the degree of degradation being addressed but also ease of access to sites. For example, simple grip blocking may cost only a few hundred pounds per hectare, but scrub clearance and re-seeding can cost several thousand, even more for remote sites where helicopter deployment may be required. Uncertainty over capital costs also stems from a lack of standardisation in reporting. For the purposes of this paper, capital costs are assumed to fall in the range of £200/ha to £10,000/ha (Holden et al., 2008; Matthews, 2012; Moran et al., 2013).

2.4 Recurrent costs

Restoration is a process rather than a one-off event and capital costs are followed by recurrent costs. These reflect an on-going need for management and monitoring of the process, plus any opportunity cost incurred through the displacement of existing land use activities. For example, monitoring is desirable to confirm that restoration is progressing as intended and to identify any maintenance requirements that require a management response such as repairing dams or combating scrub encroachment through appropriate grazing. Opportunity costs may be incurred if restoration partially or completely displaces an existing profitable activity such as agriculture, forestry, grouse shooting, peat extraction or recreational pursuits (Natural England, 2010).

For the purposes of this paper, separate elements of recurrent costs are not identified individually and no judgement is made on the likelihood of displacement effects for particular activities nor on their profitability. Rather, aggregate average annual recurrent costs are assumed to lie in the range
of £25/ha to £400/ha, with the lower end of this range probably reflecting minimal monitoring costs with no management or opportunity costs and the upper end reflecting high opportunity costs and/or high management and monitoring costs (Moran et al., 2013).

2.5 Time horizons & discounting

The time-period over which costs and benefits are compared matters since costs and benefits do not necessarily occur at the same point in time, nor necessarily have constant values. For example, capital costs are incurred at the start of restoration and DECC carbon prices rise over time. Following published government guidance (HMT, 2003/11), an annual discount rate of 3.5% is used to convert all costs and benefits to a comparable Present Value, with values for each year being summed to give total costs and benefits.

For the purposes of this paper, two example time periods of 20 and 40 years are considered. The first is rather short-term, but still sufficient for any methane spike to have passed; 40 years approximates to target dates for emission reductions but also to periods over which re-establishment of functioning peatlands might be expected (Lindsay, 2010).

2.6 Combining assumed values

Values for most of the parameters described above were expressed as ranges rather than point estimates, to reflect scientific uncertainty and/or data gaps. Sensitivity to variation in parameter values can be explored through calculating the outcomes for different combinations of values within the given individual ranges. For example, low emission differentials with low recurrent costs and a short time horizon vs. high emission differentials with high recurrent costs and a short time horizon.

‘Ready reckoner’ tables with different parameter values across rows and columns offer a convenient means of illustrating how different sets of assumptions affect the merits of restoration. The
approach clearly lacks the realism offered by process-based models\(^3\) or the local detail contained within site-specific cases-studies. However, the intention here is not to provide an alternative to such methods but rather to explore the sensitivity of cost-benefit results to variation in key parameters that are clouded by acknowledged scientific uncertainty and a lack of data, and to do so in a manner that makes the underlying assumptions readily apparent.

If the results suggest that restoration is merited under a range of different circumstances that mostly lie within the bounds suggested by current scientific understanding and available data, then the basis for promoting restoration is relatively robust. That is, whilst the precision of results might be improved by refinement of the underlying assumptions as scientific understanding and data availability improve, the general case for restoration does not rely on such advances. Conversely, if the case for restoration in many or some particular cases appears to be highly sensitive to variation in one or more parameters, this may indicate priority areas for further research.

3. Results

Table 1 presents summary results from a simple spreadsheet model combining different parameter values as described above. Different time periods and emission differentials are represented in each column and pair of columns respectively, with different recurrent costs in each block of three rows and (within each block) different DECC prices in each row. Each cell reports the net present value of benefits less recurrent costs, and can be interpreted as the maximum (or break even) capital cost that can be justified.

For example, the top-right cell of Table 1 suggests that it worth spending up to £20.9k on capital works when recurrent costs are £25/ha/yr, the low DECC carbon price is used with an emission differential of 20.0t/ha/yr and the time-period considered is 40 years. The cell immediately to the

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\(^3\) For example the “Durham Carbon Model” (Worral et al., 2009a) or “GEST” (Couwenberg et al., 2011)
left shows that this falls to £8.6k if the time period is shortened to 20 years. The cells immediately below show that this increases to £17k and £26.5k respectively if central or high DECC prices are used. Columns to the left report lower values as the differential decreases; rows further below report lower values as the recurrent costs increase.

Where reported values are negative, no capital investment is merited and restoration is not worthwhile. Where positive values are reported, some capital investment is merited but whether this is sufficient to undertake restoration activities will depend on the type of capital works required under different assumptions. For lightly degraded and easily accessible sites, low values may be sufficient to cover necessary expenditure. For more degraded and/or inaccessible sites, higher values would probably be needed.

Table 1 excludes non-carbon benefits, but these can be included crudely by adding £1.3k to each cell with a 20 year time horizon or £2.0k for a 40 year time horizon. These are simply the Present Value of £94 per year, calculated by summing the discounted annual value over 20 or 40 years. Since the same value is added to each cell, all values increase but the same relative pattern across rows and columns is retained.
Table 1: Maximum (break-even) capital cost (£k/ha) justified by carbon benefit values alone.

| Differential between restored and unrestored sites (tCO₂e/ha/yr) |
|------------------|------------------|------------------|------------------|------------------|------------------|
|                  | 1.0              | 2.5              | 5.0              | 10.0             | 20.0             |
|                  | NPV Years        | NPV Years        | NPV Years        | NPV Years        | NPV Years        |
| Recurrent Costs  | DECC prices      |                  |                  |                  |                  |
| £25/ha/yr        |                  |                  |                  |                  |                  |
| Low              | -0.5             | -0.1             | 0.2              | 1.6              | 4.3              |
| Central          | -0.7             | 0.4              | 0.8              | 3.7              | 9.2              |
| High             | -0.8             | 0.8              | 1.3              | 5.8              | 14.1             |
| £50/ha/yr        |                  |                  |                  |                  |                  |
| Low              | -0.9             | -0.6             | -0.2             | 1.0              | 3.8              |
| Central          | -1.0             | -0.2             | 0.4              | 2.8              | 8.7              |
| High             | -1.2             | 0.3              | 1.0              | 4.6              | 13.6             |
| £100/ha/yr       |                  |                  |                  |                  |                  |
| Low              | -1.6             | -1.7             | -0.9             | -0.1             | 0.3              |
| Central          | -1.8             | -1.3             | -0.3             | 2.0              | 7.6              |
| High             | -1.9             | -0.8             | 0.2              | 4.2              | 12.5             |
| £150/ha/yr       |                  |                  |                  |                  |                  |
| Low              | -2.3             | -2.8             | -1.6             | -1.2             | -0.4             |
| Central          | -2.5             | -2.4             | -1.0             | 1.0              | 6.5              |
| High             | -2.6             | -1.9             | -0.5             | 3.1              | 11.4             |
| £200/ha/yr       |                  |                  |                  |                  |                  |
| Low              | -3.0             | -3.9             | -2.3             | -2.3             | -1.1             |
| Central          | -3.2             | -3.5             | -1.7             | -0.1             | 0.7              |
| High             | -3.3             | -3.0             | -1.2             | 2.0              | 10.3             |
| £400/ha/yr       |                  |                  |                  |                  |                  |
| Low              | -5.8             | -8.3             | -5.1             | -6.6             | -3.9             |
| Central          | -6.0             | -7.8             | -4.6             | -4.5             | -2.2             |
| High             | -6.2             | -7.4             | -4.0             | -2.4             | -0.4             |

Note: assumes annual methane spike of 2.5t CO₂e/ha for first ten years and no non-carbon benefits. Non-carbon benefits can be approximated by adding £1.3k to each 20 year cell or £2.0k to each 40-year cell.
4. Discussion

The results show that different combinations of parameter values do affect the estimated economic merits of restoration. Casual comparison of the reported values in individual cells with the assumed range (£200/ha to £10000/ha) of capital costs suggests that restoration is merited in many, but not all, cases. Inclusion of non-carbon benefits strengthens each case, although some negative values still remain.

Unsurprisingly, the case for restoration appears strongest where emission differentials are high and recurrent costs are low (top-right of the Table) and weakest where differentials are low and recurrent costs are high (bottom-left). Very low differentials are only sufficient to justify restoration if recurrent and/or capital costs are low, unless non-carbon benefits are also considered. Higher differentials are sufficient to justify restoration without considering non-carbon benefits, even if recurrent and/or capital costs are also high.

Longer time-horizons generally enhance the merits in each case since they allow a longer period for benefits to accrue beyond the methane spike, although rows towards the bottom of the Table reveal that high recurrent costs can exceed annual benefits – meaning that longer time period yield increasingly negative aggregate values. Higher prices yield greater value than lower prices.

The actual joint distribution (spatial co-incidence) of differentials, recurrent (monitoring, management and opportunity) costs and capital costs is unknown. Nevertheless, it is possible to subjectively assign different peatland categories to different sections of the table. For example, more degraded sites are generally associated with higher emissions and it is likely that they will yield higher differentials when restored. However, they may also incur higher opportunity costs if they displace activities such as arable cropping, peat cutting or commercial forestry. Hence they may lie towards
the right and bottom of the Table. Where opportunity costs are likely to be low, such as with badly eroded or bare peat, a position towards the top-right of the Table may be more appropriate.

Conversely, lightly degraded sites are generally associated with lower emissions and hence it is likely that they will yield more modest gains when restored. For associated land uses such as extensive grazing or grouse moors, both the current profitability and degree of displacement by restoration are uncertain – meaning that the opportunity costs of restoration could be very low (implying a top-left position) or moderately high (implying a middle-left position).

Capital costs are also likely to vary spatially, being relatively high for badly degraded sites and low for lightly degraded sites. Hence capital costs are likely to increase from left to right across the Table, implying that the hurdle to clear (i.e. reported cell value) may be closer to the upper-bound (£10000) of the suggested range on the right-hand side and closer to the lower-bound (£200) on the left. However, capital costs may also vary with other factors not necessarily directly linked to degree of degradation - such as ease of access, need for vegetation clearance and need for exclusion of livestock. For example, remoteness greatly increases material delivery costs, timber and scrub clearance requires significant effort and fencing can be expensive.

Notwithstanding uncertainty about capital costs, many of the cells do contain values in excess of the relevant range identified from the literature. As such, the results strongly suggest that – provided a reasonably long time period is considered - restoration is merited in many, but not all, cases. This holds true even for a narrow focus on carbon benefits alone, but is reinforced by inclusion of non-carbon benefits. As such, the results generalise the more specific findings reported by Worral et al. (2009b), Natural England (2010) and Harlow et al. (2012) based on more restrictive assumptions and/or better local data.
Given scientific uncertainty and data gaps, the results are of course open to interpretation. Indeed, the transparent presentation of assumptions deliberately invites debate about the plausibility of particular parameter values and their joint distribution(s). However, the results do suggest a reasonably robust case for restoration under a range of circumstances – lending economic credence to the stated policy aims of increasing restoration efforts towards the target of 1m ha. Yet the results (and the process of deriving them) also reveal the need for further attention to a few issues.

First, although the magnitude of possible emission differentials was derived from published emission factors, the range and assignment to particular peatland categories could be improved. In particular, the assumption of a constant differential could be refined by better information on duration and intensity of methane spikes, the time taken for restoration to reduce emissions on different peatland categories, the extent to which restored sites actually behave as never-degraded sites, and the actual shape of emission profiles with and without restoration. For example, whether pre and/or post-restoration profiles are linear, curved or stepped (i.e. with thresholds).

This may be facilitated by international and domestic research efforts already underway, notably forthcoming guidance from the International Panel on Climate Change (Couwenberg & Fitz, 2012) and research underpinning the Peatland Carbon Code currently being piloted by the UK government (Reed et al., 2013). However, it is not clear whether such research is considering the possible effect of accelerating climate change on emission profiles. For example, if increased climate pressure affects degraded sites more rapidly than near-natural or restored sites, it may be reasonable to expect differentials to widen over time – in which case the benefits of restoration would be enhanced.

Second, the various unit costs (£/ha) associated with restoration are currently highly uncertain. Improved reporting of capital, monitoring and management costs for different peatland categories would be very helpful in refining the analysis. The same applies, perhaps even more so, to
opportunity costs. For these, there is a need for better data on both the degree of (in)compatibility of land use activities with restoration and on the profitability of potentially displaced activities. This may be particularly relevant to lightly degraded sites currently under extensive grazing or grouse management, where emission differentials are probably low and modest opportunity costs may, when combined with monitoring and management costs, be sufficient to render even low capital costs excessive. Improving understanding of this will entail dialogue with land managers as well as further scientific field measurements.

Separately, although assumed constant for this exercise, variation in unit costs over time might be expected and some attempt to forecast changes might be possible. For example, labour costs might be expected to rise. Conversely, it may be possible for management and monitoring costs to reduce over time through, for example, the use of volunteer staff and/or technological advances in remote sensing. Similarly, there is some evidence that capital costs are declining over time as practical experience spreads and/or machinery is adapted (Birnie & Smyth, 2013). Opportunity costs also might increase over time with, for example, rising global food prices - but rising energy and fertiliser prices might counter this and keep net margins constant or even falling.

Third, the choice of time-horizon affects the results. Given that restored, functioning peatlands may be relatively durable even under climate change pressure (Lindsay, 2010) and that methane spikes and high upfront capital costs dominate results in the early years, using more distant time-horizons may be more appropriate. However, policy horizons may be shorter and emphasise quick gains which restoration cannot necessarily deliver. Related to this is the issue of discounting future benefits – the higher the discount rate, the less weight that is placed on more distant years. Again, this emphasises the short-term, down-playing durability and emphasising upfront costs. Hence, notwithstanding that adherence to published government guidance already generates broadly supportive results, further consideration of the treatment of durability of benefits might be prudent.
Finally, different unit prices for carbon and non-carbon benefits could be used. Higher prices would increase the case for restoration, lower prices would reduce it. For example, rather than the DECC prices, observed prices from existing compliance and voluntary carbon markets could be used. These are considerably lower than DECC values and would dramatically reduce the value of benefits, but arguably are inappropriate since they do not capture the full social value of carbon savings and are not available as forecasts.

Alternative non-market valuations for benefits do exist, but are often context specific and somewhat variable (Wichmann et al., 2013). In the absence of a bespoke valuation exercise, the values derived from Christie et al. (2012) are reasonable given their specific attention to peatlands (pers. comm. Christie) and are of a similar order of magnitude to other recent studies such as Eftec (2009) and Bateman et al. (2011). However, they are indicative rather than definitive, not least since they do not differentiate between different degrees of degradation. Moreover, as with unit costs, no account has been taken of possible changes over time. If the value of non-market ecosystem services increases over time with rising income levels and environmental scarcity (after Krutilla-Fisher, 1985), this would further increase the benefits of restoration.

5. Conclusions

Restoration of UK peatlands is being promoted as a means of helping to meet climate change, water quality and biodiversity targets. However, formal analysis of the relative costs and benefits of restoration is hampered by scientific uncertainty and data gaps.

By presenting results of some simple economic arithmetic, this paper has illustrated how the merits of restoration vary with different assumed circumstances. Specifically, generating a ‘ready reckoner’ Table allows exploration of a range of ‘what if?’ combinations of parameter values. These suggest that in many, but not all, cases the circumstances under which restoration appears to be merited lie
within the bounds of plausibility suggested by current scientific understanding and available data. This holds even for a narrow focus on carbon benefits alone, with inclusion of non-carbon benefits reinforcing the case. However, the results are sensitive to assumptions and, in particular, the costs associated with restoring sites likely to yield modest emission savings need to be better understood.

The approach is not intended as an alternative to more scientific process-based modelling nor as a tool for detailed site-specific assessments. Rather, the aim was explore the general circumstances under which restoration may be merited and to do so in a manner that presents key assumptions transparently. It is hoped that this will facilitate debate on the likelihood of particular circumstances and outcomes and help progress areas identified for further research and policy development.

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