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Climate benefits of forest-to-bog restoration on deep peat – Policy briefing

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1 Summary

The Scottish Government is committed to expanding the area of healthy peatland , with benefits to climate change and to wider biodiversity. The process of restoration takes time, and it is important to understand what happens over the decades that follow. This briefing draws together the results of several projects that examined how the peatland responds when trees are removed from former conifer plantations on deep peat and the drainage channels are blocked

2 Key points

- We found that undisturbed bogs, and restoration sites older than 15 years do help to combat climate change by storing more greenhouse gases than they emit.
- Despite some uncertainty, our results showed a clear contribution to global climate cooling in the decades following peatland restoration. While disturbance tended to increase greenhouse gas emissions, this is compensated by the amount of net climate cooling after 15-20 years. Continued monitoring will improve our understanding of the likely climate effect of over longer time scales.
- The results confirm the benefits of forest removal on deep peats where conifer yields have been low. In addition to habitat improvements, we found a long-term climate benefit that is unlikely to be matched by forestry. Newer management techniques, such as intensive drain and plough-furrow damming may help faster recovery of carbon sequestration
- Continued monitoring of vegetation response and water table depth across a network of sites is advisable to inform cost-effectiveness of restoration after forest removal.

While the science is complex and there are still things we don't know, we found that restoring peatlands that were planted with conifer forests has clear benefits over the medium term.

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3 Restoring peatland in the Flow Country

Significant amounts of carbon can be stored in the soil, particularly in peatland. As part of its wider strategy to combat climate change, the Climate Change Plan for Scotland[1] sets targets for the restoration and maintenance of peatlands. This is achieved by raising the water table in peatland areas by blocking ditches and drains, and removing trees. While there is confident knowledge about the overall benefits of restoration, we don't fully understand what happens to the exchange of greenhouse gases and release of carbon into water courses during the restoration process, especially on deep peat sites.

Late twentieth century commercial forestry in the Scottish Flow Country caused significant degradation of almost a fifth of the internationally significant blanket peatland resource. The RSPB began restoration work in the 1990s, removing trees and blocking drains to raise water levels supported by UK and EU public funding, using a technique known as 'felled to waste', (trees felled and rolled into furrows, collector drains blocked). Restoration work is on-going, and improved restoration techniques have been developed over time to deal with larger trees, and as we have learned that intensive blocking of plough furrows throughout restoration sites (rather than just main collector drains) works more effectively in terms of recovery of hydrological conditions and reestablishment of *Sphagnum* mosses and other peatland vegetation.

Whilst we know that converting forests back into bogs has clear benefits for biodiversity and broader conservation value, we don't fully understand the impact of tree removal and hydrological restoration (i.e. raising of the water table) on the balance of greenhouse gas emissions. The RSPB co-sponsored a series of PhD studentships hosted by the Universities of Stirling, The Highlands and Islands and St. Andrews, with support from Scottish Government to quantify climate impacts of the restoration process. Similarly, Scottish Governments' Rural Affairs Food and the Environment Strategic Research (RESAS) Strategic Research Programme (2016-2021) funded long-term monitoring of GHG exchange using eddy covariance equipment on peatland restoration sites, and the SNH Peatland Action project funded vital equipment. These projects were based at the long-term restoration experiment at RSPB's reserve near Forsinard, and this report captures the main findings from these studies.

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4 Why does it matter

Reducing emissions of greenhouse gases from disturbed peatlands is a key target, but the disturbance caused by removal of forestry and subsequent blocking of ditches and drains may in itself lead to a short-term net increase in greenhouses gas emissions. The projects examined here were designed to help us understand how these short-term changes are balanced against long-term reductions of greenhouse gas emissions.

Whilst these studies have focused specifically on the removal of trees in plantation forestry of the Flow Country, they support and extend a general body of evidence on the impact of peatland disturbance and its restoration.

5 What we learned

We were able to compare the differences between currently forested areas and those restored to functioning peatland. We found

a) definite long-term climate cooling effects of forest-to-bog restoration:

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[1] https://www.gov.scot/binaries/content/documents/govscot/publications/report/2018/02/scottish-governments-climate-change-plan-third-report-proposals-policies-2018/documents/00532096-pdf/00532096-pdf/govscot%3Adocument

- After felling to waste, it takes more than ten years for vegetation and water levels to recover sufficiently to allow the rewetted peatlands to start accumulating carbon again (Khomik et al., 2016; Hambley et al, 2019). We don't yet know whether the more advanced restoration techniques used today are speeding up this process or not.
- Whilst carbon dioxide fixed from the atmosphere is stored in tree biomass, the deep peat soils on which the plantations grow are a significant source of carbon dioxide (Hermans, 2018; Hambley et al 2019). The rate of CO_2 emissions was partly linked to changes of peat conditions during forestry that persisted throughout restoration period of over 15 years (Hermans et al., 2019). Net ecosystem exchange budgets measured over remaining forestry areas on deep peat will soon become available and provide further context[2]
- We found that methane is emitted from soil on undisturbed and recovered peatland, while forest soils take up more methane than they emit (i.e. they are a methane sink; Hermans, 2018).
- Our data suggest a small soil sink of nitrous oxide (another greenhouse gas) across forested, restored and undisturbed bog sites (Hermans, 2018). As these rates of uptake are negligible, and we found no difference between restoration states, it has no significant role in the net greenhouse gas balance of forest removal on peatlands.
- Taking the differences between the global warming potential of methane and carbon dioxide into account, we found that undisturbed bogs, and felled-to-waste sites older than 15 years do help to combat climate change by storing more greenhouse gases than they emit. On the other hand, we found that younger sites (less than ten years since restoration) continue to emit more greenhouse gases than they store and have a net warming effect, albeit temporarily. Flux values showed large inter-annual variability; longer-term data will enable us to confirm more precisely the time scale of the transition from a net warming to a net cooling balance on these sites. Regular (but less intensive) monitoring of greenhouse gas fluxes will extend the data series for individual plots, adding more certainty to time-since-restoration estimates of when restored peatlands become net sinks. Contrasting restoration techniques that partly confound our current estimates can then be separated from direct time effects.
- Loss of carbon via transport in water is relatively small compared to emissions of gas into and out of either forests and peatlands (restoration areas and near natural) (Gaffney et al., 2018). The solute chemistry of surface water and deep pore water showed good recovery post restoration, whilst shallow pore water retained a small but measurable 'legacy' of forestry more than 15 years post restoration (Gaffney, 2018).

b) that quantifying individual impacts of management at these complex and remote sites proved challenging. We were able to identify general trends, but incomplete time series data following restoration combined with underlying differences between restoration sites of different age mean that we cannot be confident that all impact trends can be expressed with sufficient confidence. Further monitoring of greenhouse gas exchange from restored sites alongside forested and undisturbed bogs will enable greater certainty on the net climate effect of current restoration practices.

- For example, sporadic peaks in methane emissions were observed in the year following tree removal that could not be explained by temperature or water level. We saw no evidence of such "flushes" in older restored peatlands or undisturbed sites; we have no mechanistic explanation for these peaks, and treat them as disturbance-related phenomena. On balance this is not a significant finding, but if the trend is identified

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[2] This dataset will become available during 2019-2020. For further information please contact Dr Mhairi Coyle,

elsewhere, further research will be required to establish the extent of such episodic emissions following restoration.

Taken together, the results of these three studies provide the first overview of restoration impacts on greenhouse gas emissions from formerly afforested blanket peatlands. Despite some uncertainty on individual drivers and spatial variation, we found a clear climate cooling effect over medium timescales (decades) following peatland restoration. Disturbance tended to increase emissions of greenhouse gases, but this is compensated by the overall scale of net climate cooling after 15-20 years. New data from continued monitoring of greenhouse gas exchange is required to obtain projections regarding the likely climate effect of restored sites over longer time scales (>20 years).

The results support a continuation of forest removal on deep peats in the Flow Country and other areas where conifer yields have been low. In addition to habitat improvements, our data show a long-term climate benefit that is unlikely to be matched by forestry after the first rotation, as poor timber growth results in low-grade uses (pulp, fuel) that return C to the atmosphere quickly.

Forest removal in combination with hydrological restoration (ditch blocking) shows largest benefits for vegetation recovery, which in turn improves net carbon sink strength. Felled-to-waste has largely been replaced by newer management approaches (whole tree harvest, re-profiling, furrow blocking), which have the potential to accelerate recovery of water table and vegetation. This could also lead to faster recovery of carbon sequestration. Therefore, continued monitoring of vegetation response and water table depth across a network of sites is advisable to inform cost-effectiveness of restoration after forest removal.

6 What we did

For this research, three interlinked PhD projects were created, and a (still ongoing) Scottish Government (RESAS) project from the current Strategic Research Programme (2016-2021)[3] ran alongside these. All projects used the same sites between 2012 – 2016 to document the effects of forest-to-bog restoration on:

1) We continuously monitored carbon emissions using Eddy Covariance, a micrometeorological technique that integrates net fluxes in and out of an ecosystem. This allowed us to collect continuous greenhouse gas fluxes and micro-meteorological data from 3 restoration areas and one near-natural blanket bog over 3 years (Coyle *et al*., unpublished).
2) Soil greenhouse gas exchange (carbon dioxide, methane and nitrous oxide fluxes measured using chambers from replicated sampling points in time sequence of four sites under restoration (2015, 2012, 2006 and 1998, plus forested and open bog control sites)
3) The impact of forest removal on pore and surface water chemistry and aquatic carbon export from peatland sites following restoration.

Taken together, the three studentships along with the RESAS Strategic Research Programme project enable us to construct the first carbon and greenhouse gas balance following restoration of formerly afforested bog to provide necessary insight to guide further restoration efforts. Several studies carried out by PhD students have been published or accepted for publication in peer-reviewed journals, with a synthesis publication envisaged for later in 2019. Alongside the academic outcomes, the projects enhanced engagement with the local community, such as collaboration with the North Sutherland Community Forest Trust sawmill at Forsinain for the construction of board walks at research sites.

The RSPB was a key partner in this research. A number of individuals within the RSPB were instrumental in setting up replicated plots, co-supervising early career researchers and sharing of data and resources.

[3] Research Deliverable RD1.1.3, led by Dr Jagadeesh Yeluripati, James Hutton Institute.

7 Conclusion

This concerted research effort illustrates the general benefits of habitat restoration on the carbon balance of peatlands. It extends existing knowledge of hydrological drivers of greenhouse gases in these systems to the specific case of forestry on deep peats, and shows that short-term disturbance effects of the restoration management with associated net increases of greenhouse gas fluxes are compensated by long-term carbon sequestration and net climate cooling. Continuing monitoring of greenhouse gas fluxes in both restoration sites, and sites undergoing novel management will reduce uncertainty and improve our understanding of the different drivers of the carbon balance.

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