Feeling the heat: Defra project on blanket bog management for biodiversity, carbon and water

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To keep with the World Cup theme, we are now well into half time of our Defra-funded project assessing management of heather dominated blanket bog and the impacts on key services that blanket bogs provide to us, namely carbon storage, water provision and biodiversity. The study is unique in so far that it includes plot-level experimental design within an overall catchment-scale research platform replicated across England. Notably, the study included establishing a baseline period (1 year) before changing management. The project now has a re-located website http://peatland-es-uk.york.ac.uk/home providing background and up-to-date information in addition to the update provided here. There are sections on the treatments (management), what we do (methods) and overall findings (results). Notwithstanding the fact that management impacts are certainly complex, recent contrasts of drought like summers followed by near permanent flooding later in 2013 caused impacts via streams and rivers well beyond the uplands, showing the need to better understand these systems, especially in relation to a more extreme climate.

So, how do we assess the potential issues of heather dominance in relation to burning and other management options? And, more importantly, are there ways of managing blanket bogs that might benefit grouse shooting whilst also supporting increased benefits to other ecosystem services provided to us? Basically, are there win-win scenarios and how achievable are they on the ground?

Figure 1 Feeling the heat: burning and alternative large-scale mowing of equal areas in the Dales at the Mossdale site.

The overarching aim of this initially 5-year long study is to assess different management techniques based on field experiments which compare ‘control’ to 'treatment' areas at three sites, two in collaboration with the Yorkshire Peat Partnership, Nidderdale and Mossdale, and another in the Forest of Bowland (United Utilities). At each site, two adjacent sub-catchments (each ~10 ha) have been set up. Within the ‘*treatment*’ sub-catchments, catchment-level mowing and other plot-level alternatives replace the 'business as usual' burning, which is to be continued in the ‘*control*’ sub-catchments on equal areas (**Fig. 1**). A workshop in February 2012 defined five plot-level treatments: **mowing** either with or without **brash removal** and with or without ***Sphagnum*** **addition**, and a “**do nothing**” **comparison** to capture natural climatic and environmental variations (e.g. drought, pests). These plots will be compared to the

burnt controls with or without ***Sphagnum* addition** (as *Sphagnum* moss is key to blanket bog water balance and functioning). The replicated 5 x 5 m monitoring plots ensure a rigorous statistical analysis of management effects on key ecosystem parameters: carbon stocks and fluxes, greenhouse gas emissions, peat pipes, vegetation dynamics, water balance and quality. Modelling will allow up-scaling the findings in space and time and make use of monitoring of carbon export via streams to derive a full carbon budget.

The pre-treatment monitoring for carbon revealed similar peat depths, carbon stocks and peat pipe abundance between sites and catchments. However, plant diversity, peat densities and water tables differed between sites, indicating a gradient from intact to degraded peat habitat. Interestingly, a first simple empirical model based on chamber CO_2 flux measurements (**Fig. 2**) mirrored these site differences, with highest net uptake of carbon at the most plant divers and *Sphagnum* moss rich site (i.e. Mossdale), and also showed considerable interannual variation (i.e. climatic conditions). The bog's carbon balance is partly driven by light enabling photosynthesis, but also by the water table regulating decomposition of organic matter; the warm and dry conditions in 2013 switched the bog's carbon balance from a net sink to a source (**Fig. 2**). Moreover, annual carbon export via streams is in the order of 1 g C m^{-2} Particulate Organic Carbon (POC) and 20 g C m^{-2} Dissolved Organic Carbon (DOC), equal to a loss of 10 and 200 kg C per ha, respectively! This is considerable when on average long-term peat accumulation rates are only around 20 g C m^{-2} (small amounts, but over ~6,000 years resulting in just under 10,000 tonnes of carbon per catchment).

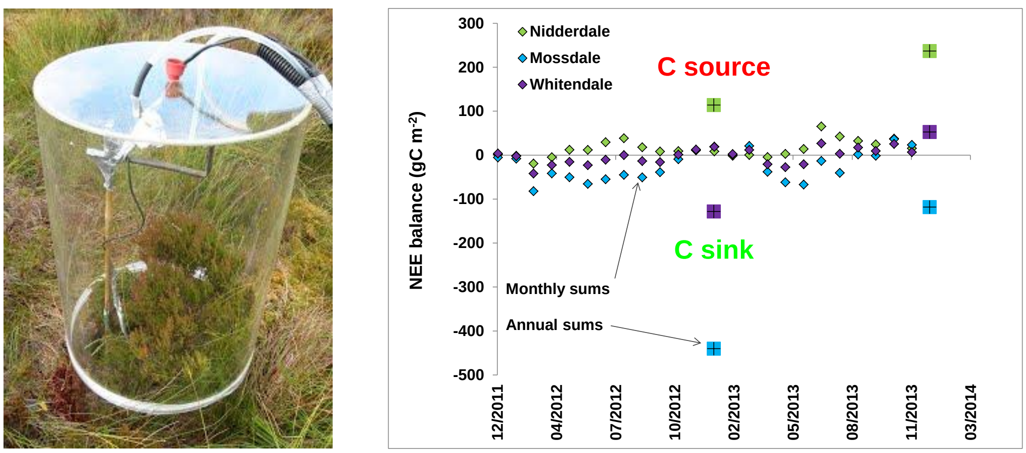

Figure 2 Carbon sink or source? Field deployment of clear Perspex chambers for measuring net ecosystem CO_2 exchange (NEE: sum of C uptake and release) and resulting monthly and annual NEE model predictions; negative values indicate a net C uptake (sink) and note the large differences between sites (Mossdale: large C uptake *versus* Nidderdale: large C losses) and years (2012 wet and cool *versus* 2013 warm and dry summer).

Assessing management impacts on peatland water and carbon budgets therefore requires linking the two processes, carbon and water cycles, as shown for the important role of carbon export via streams. So far we only had time to do this at the catchment scale. It will be interesting to see if there are any changes in response to management change at the plot level. We monitor carbon and greenhouse gas fluxes in relation to vegetation dynamics with chambers (**Figs. 2&3**). It takes a surprisingly large amount of light (about 1/3rd of the average daytime peak) to turn a bog from a net carbon source (net respiration) into a net sink and then there are the other greenhouse gases (GHGs), mainly methane (CH_4) and nitrous oxide (N_2O). Importantly, including both these GHGs turns all three sites into a small but net contributor to global warming. However, bogs are not flat and we need to consider topography of the catchments, which in turn affects drainage lowering the water table, but also surface runoff responsible for eroding peat. Consequently, we are also looking at water tables and carbon export across slopes in relation to management (with much appreciated Heather Trust funding). So far we have seen indications of larger stream flow (and consequently less rainfall held back in the bog) in two of the burnt catchments and only starting after burning and mowing in 2013, likely affecting both flooding and water quality for people downstream of the bog. More on all this next year!

Figure 3 Hands-on measurements: field deployment of gas flux chambers for measuring greenhouse gas emissions (GHGs) using latest analyser technology (Los Gatos) for measuring net methane (CH_4) emissions in the field.

To start with, all sites were characterised by relatively tall and dense heather (**Fig. 4**) with notably low plant diversity (the dense heather cover of about 60% further contained mostly about 10% sedges (*Eriophorum* sp.), *Sphagnum* moss and other moss - only about 8 species per 1 m^2). After mowing and burning it was very interesting to see that, although heather regeneration measured as coverage was higher for mown areas (**Fig. 4a**), heather regeneration from germination was largest on burnt plots (**Fig. 4b**), although this differed per site. Obviously, the difference in regeneration will have implications on food supply for grouse. We shall monitor this further.

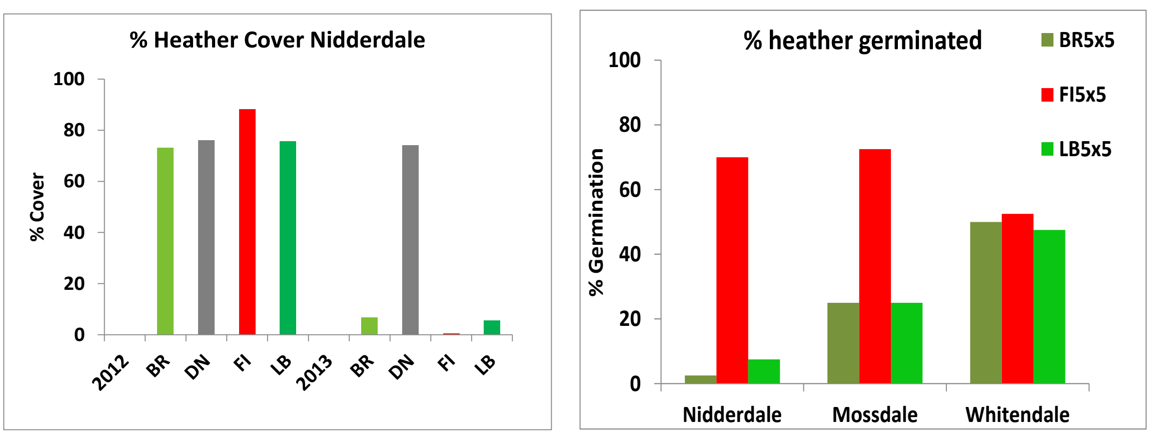

Figure 4 Food for thought: **4a** (*left*) Average heather coverage (~80%) across the Nidderdale site in 2012 (pre treatment) *versus* 2013 (post treatment) per treatment plot (BrashRemoval; Do Nothing; Fire; LeftBrash) showing lowest cover on burnt plots, and **4b** (*right*) average percentage of heather germination (seedlings) per 5 recorded size classes within the 5 x 5 m plots across all sites showing highest germination on burnt (FI) plots (BrashRemoval; LeftBrash).

As to other findings comparing burning and mowing, one big concern was that the heavy mowing machinery (**Fig. 1**) would cause lasting peat compaction, thus increasing runoff and changing the water balance. Indeed, we measured about 20 cm compaction during mowing but the peat just sprung back and no change in peat depth or peat densities was detectable after one year. I take this as good news!

Finally, why does this all matter? Take, for example, red grouse (or many other upland birds). The chicks depend considerably on crane flies (*tipulids*) for their initial growth and survival, which in turn depends on moist peat. Therefore, whereas high water tables benefit crane flies and consequently the birds that eat them, as climate changes, lower summer water tables are predicted, with the potential for large scale negative impacts on these important upland bird species (see **Fig. 5**). Interestingly, so far our 2014 crane fly counts are overall low, possibly reflecting the warm and dry summer 2013, and show highest numbers in the mown catchments, which might have been moister due to less dark surface and a sheltering brash layer. Only time will tell if this is a real trend but for now this is very interesting.

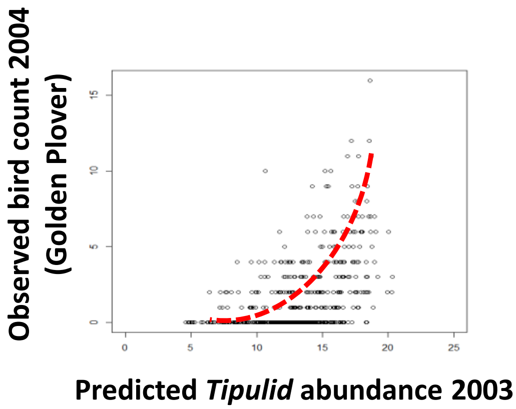

Figure 5 From bug to bird: **5a** (*left*) observed bird numbers per 5 x 5 km grid (Golden Plover) against predicted crane fly (*Tipulid*) abundance per 1 m^2 for 2003 based on MILLENNIA peatland model; data are taken from the PhD thesis by Dr. M. Carroll. **5b** (*right*) Measuring crane fly emergence using sticky traps (the inside of the white basket is covered in sticky tape).

Finding the best way forward for good management practice relies on robust evidence, a shared understanding of the complexities of ecosystem functions and processes, but also on a willingness to engage with other points of view. This project can be seen as a stepping stone towards such engagement, slowly revealing not only the complexities and processes, but also possible impacts on the land user community and people living further downstream. A final word of thanks goes to the Moorland Association and all the landowners, managers and, particularly, the game keepers in supporting our work on the ground in many ways, not least by tolerating our presence and building a certain level of trust without which the legacy of any such work would be meaningless.