A Burning Issue: Investigating the impacts of climate change and management on blanket bog

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Blanket bogs are a common sight in the UK uplands, covering the landscape in vast 'blankets' of peat of up to 2 m or more. The peat is the result of thousands of years of accumulated organic matter; the base of the peat is often 8,000 years old! Dead plants do not decompose fully under wet and cold conditions, thus leading to this enormous build-up of organic matter in the form of deep peat, and with it locking away vast amounts of carbon (about 100 kg of carbon under each step you take!). However, these peatlands are facing an uncertain future as, based on climate change scenarios, the normally cold and wet conditions are set to change – and we are increasingly witnessing warmer, dryer summers yet wetter winters. Although these systems store a lot of carbon, they also emit methane, a potent greenhouse gas. As organic matter decomposes under waterlogged conditions methane is produced and diffuses, escapes via bubbles or via plant stems serving as a 'chimney', particularly in sedges. Management also plays a part in determining the bog conditions, particularly issues such as drainage and heather management can affect how wet a peatland is. Crucially, an intact bog provides several services to our society, not only **carbon** storage, but also **drinking water** and **recreation** linked to **biodiversity** aspects such as scarce and specialised plants and birds. I am sure, we all value these upland peatlands for various reasons, but they are facing an uncertain future.

As part of a Defra-funded project we are assessing climate and management impacts on these bog systems within grouse moors and try to provide better understanding on how these systems work, what the key processes are and how sensitive they are to either climate or management or both. Our project website http://peatland-es-uk.york.ac.uk/home provides background and up-to-date project information and I do invite you to look at it.

The overarching aim of this initially 5 year-long study is to compare a 'business as usual' **burn** rotation to alternative **mowing** within paired catchments across three sites, two in collaboration with the Yorkshire Peat Partnership, Nidderdale and Mossdale, and another in the Forest of Bowland (United Utilities). We are now entering the 4th year and although we can report some initial overall findings most of this is to be seen as a short-term trajectory for a very slow moving system – cold and wet places tend to be slow. Our findings so far are summarised below.

<u>Mowing impacts on peat</u>: although during mowing we observed about 20 cm of peat 'bounce' under the tractor wheels, to our surprise, we did not detect any long-term change in peat depth overall, not even when measuring the bulk density of the peat near the surface (mass per unit volume).

<u>Water budgets</u>: water loss via streams is about 10% greater for the burnt catchments and seems to relate to lower water tables in the burnt compared to the mown catchments. Most likely this reflects quicker runoff from an exposed, burnt peat surface compared to the brash covered mown areas.

<u>Vegetation impacts</u>: whereas mown areas showed quick revegetation from both moss and sedges (cotton grass), burnt areas show much larger bare and dead moss cover; in fact, cover of *Sphagnum* moss (a key peat forming species) was greatest in the uncut control plots and lowest in the burnt plots (**Fig. 1**). However, heather germination and seedling growth was noticeably better on burnt areas over the first two years after management. Currently we are looking at differences in nutrition levels in (re-grown) heather.

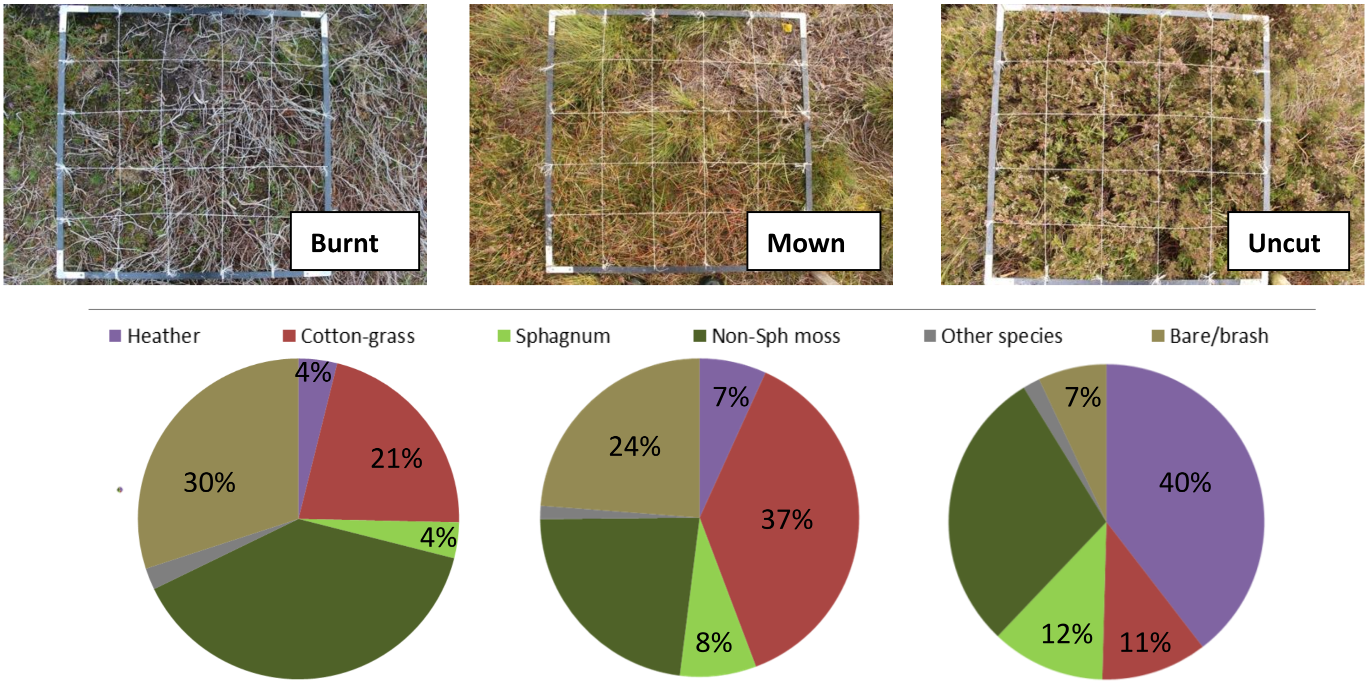

Figure 1: (*top*) Example photos of burnt and mown plots (1x1 m) at Nidderdale two years after burning *versus* the uncut control plot (within the mown catchment but uncut). Note the much more open peat surface on the burnt and the brash layer on mown plot. (*bottom*) Average vegetation composition across the three types of management; note the differences in bare and sedge (cotton grass) cover.

<u>Carbon budgets</u>: over two years after burning, about 300 g of carbon was lost per square metre via burning the vegetation and in addition an equal amount was emitted from the largely non-vegetated burnt areas based on flux chamber measurements (**Fig. 2**), mainly from decomposing peat, together amounting to nearly 1 kg of carbon. In contrast, mowing stored carbon in the brash layer and decomposition losses were reduced by larger carbon uptake due to faster regrowth of vegetation on mown areas. In fact, the Mossdale mown catchment with considerable sedge (cotton grass) growth is a net carbon sink again, and, the uncut control plots acquired about 400 g of carbon during the two years after management (**Fig. 2**)!

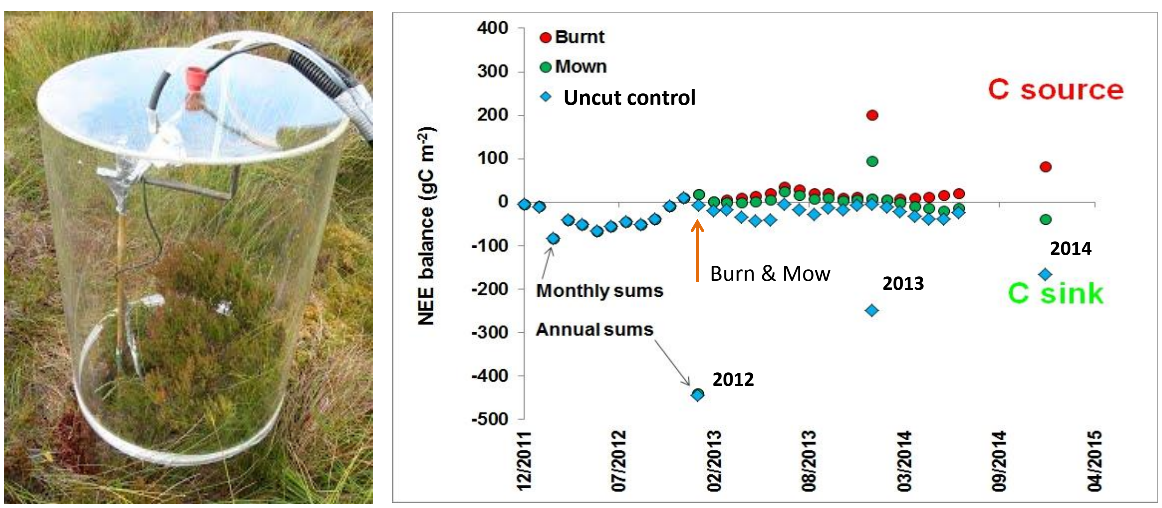

Figure 2: Shown is the modelled monthly carbon balance (and totals per year) for burnt, mown plots and uncut control plots at the Mossdale site. Note the initial positive (carbon loss) annual carbon budgets for both, mown and burnt plots, but the quick recovery, particularly on mown plots, becoming negative (carbon gain) after two years; based on chamber measurements (left).

Greenhouse gas emissions: overall soil methane emissions did not differ between management, but vegetated areas confirm that sedges, particularly present on mown areas, result in increased methane emissions via the 'chimney' stem transfer. So, mown areas do have a side effect to be considered.

Soil environment: we have started to capture this effect in more detail as higher soil temperatures could lead to increased decomposition of peat via stimulating decomposer organisms. However, so far soil surface maximum temperatures increased only slightly on burnt areas, and did not affect deeper layers.

Decomposition impacts: whereas we did not observe any clear differences in peat decomposition in the field, peat incubation studies in the laboratory show that peat from burnt areas shows higher temperature sensitivity – stimulating peat decomposition – than peat from mown areas. However, field data are more complex and need to be analysed for different water table depths, moisture and vegetation effects.

Stream water quality: water quality indicators like colour and specific UV-spectra revealed a clear overall negative effect of management on water quality, but this was similar for burnt and mown catchments. But it takes a long time for some of the water to percolate through the peat into the main streams, clearly a few more years of data are needed.

Blanket bogs provide many other **ecosystem services** alongside carbon and water, one of which is biodiversity. This habitat is very rare globally and certain iconic **bird species** are adapted to blanket bogs, like the Dunlin, Golden Plover and Red Grouse; in their chick phase these birds benefit from a particular food source, crane flies. Crucially, in their larval stages (mid-summer) crane fly numbers depend on peat moisture; dry summers lead to desiccation and low numbers emerging the following year, thus limiting food for the birds.

Biodiversity impacts: we monitor crane fly numbers and emergence during May till July (**Fig. 3**), crucial for Red Grouse and other bird chicks. So far, our findings show a clear link between the peat moisture and crane flies and, based on this relationship, we just published a collaborative study in the journal *Nature Communications* on predicting climate change scenario impacts on upland birds via this crane fly link (PDF is available on request). We used our MILLENNIA peatland model to predict changes in peat water tables and show that by 2051-80 the Dunlin could see a 50% decline in numbers, with the Golden Plover down 30% and Red Grouse down 15%.

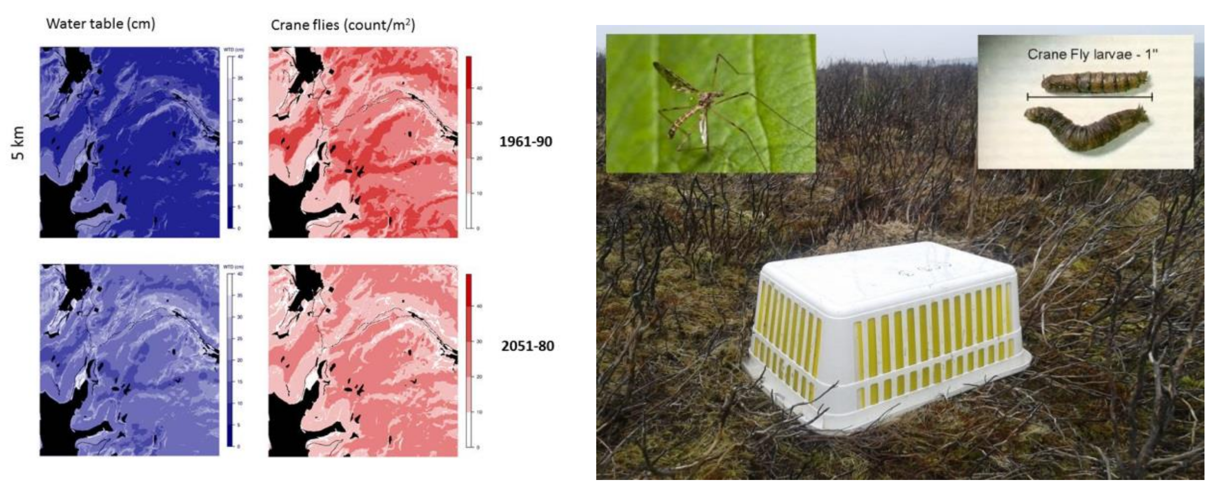

Figure 3: (*left*) MILLENNIA model predictions of water table depth and corresponding crane fly numbers the following year for current [1961-90] *versus* future climate [2051-2080]; shown are results for a site in Wales. (*right*) Measuring crane fly emergence using sticky traps (the inside of the white basket is covered in sticky tape).

These findings certainly highlight the need to consider blanket bog management aimed at maintaining wet conditions under future climate change, particularly considering hotter and dryer summers – reflecting on drainage ditches (grips) and heather management. As the environment is changing, we need to be open to this challenge and adapt management and common perceptions. Adapting to a changing environment requires both open discussion around evidence and local experience. Our project hopes to facilitate this – we shall hold a workshop (likely end of 2016) around blanket bog management and the evidence, including from this project, and would welcome your expression of interest to participate. Please do get in touch.

Blanket bogs are generally inhospitable, cold and wet places, but we depend on this habitat in many ways. Our study is unique in covering several areas and looking at so many aspects which are interconnected; like a good GP we need to understand the entire body first in order to then treat the patient most effectively. The results are only a starting point in understanding how this habitat responds to change and we hope to be able to continue to work on this project together with the Heather Trust, the Moorland Association, the gamekeepers and other stakeholders to determine its long-term trajectory.