Is wetter better? Why grouse moor management needs to consider science and be open to change

Dr Andreas Heinemeyer *is a scientist at the Stockholm Environment Institute (SEI) at the University of York (part of the Environment Department). He routinely measures and models how and how fast carbon cycles through terrestrial plant-soil systems, how much carbon is stored and how carbon and water cycles interact. Currently, he leads a Defra project on assessing upland peatland management impacts on ecosystem services we all rely on, such as carbon storage (mitigating rising atmospheric* CO_2 *levels), water storage (providing drinking water) and biodiversity (plants, invertebrates and birds).*

Blanket bogs cover much of the UK uplands 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 up to 8,000 years old! It is the overall wet and cold conditions slowing down decomposition of organic matter which leads to this build-up of peat, locking away vast amounts of carbon (about 100 kg of carbon under each step you take!). However, climate change poses a real threat to these systems as normal conditions are set to change – and we are increasingly witnessing "odd" warm and dry or very wet seasons. Therefore, decomposition might increase and stored carbon might be released back into the atmosphere. Although these systems store a lot of carbon, they also emit methane, a greenhouse gas – the net warming balance is important. As organic matter decomposes under waterlogged conditions methane is produced and escapes via diffusion, bubbles or plant stems, particularly from sedges. Importantly, management also plays a part in determining the bog condition, particularly issues such as drainage and heather management can affect how wet a peatland is, affecting the bog's ecosystem functions and resilience to climate change. 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 the uplands for various reasons, but they are facing an uncertain future and we need to understand how management can help to sustain the peatlands we all rely on in many ways.

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 provides background and up-to-date project information and I do invite you to look at it. The overarching aim of this study is to compare a 'business as usual' **burn** rotation to alternative **mowing** within paired catchments and additional **uncut** areas 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 final 5th year of the first phase, and although we can report some overall findings most of this is to be seen as a short-term trajectory of a very slow moving system – cold and wet systems tend to be slow! Hopefully we will manage to secure a second phase to gain understanding on how climate and humans affect these systems over a complete management rotation and how best to manage these beautiful areas for future generations; funding is tight these days, but I am still optimistic. Our updated findings so far are summarised below.

<u>Sites</u>: the three sites offer an excellent testbed of representative grousemoors as they differed in plant diversity and moisture, covering a range of near "intact" high water table and *Sphagnum* cover (Mossdale), "intermediate" (Whitendale) to "degraded" low water tables and *Sphagnum* cover (Nidderdale) sites, likely reflecting climatic differences (wet to dry) and management intensity (low to high burn frequency).

<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 compaction impact, not even when measuring the peat bulk density (mass per unit volume) near the surface. However, the micro-topography of the peat was less variable after mowing (i.e. flatter due to cutting off some of the hummocks).

Water budgets: from a few months after mowing replaced burning water loss via streams declined by 10% compared to the burnt catchments in two sites, which also related to overall 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 a brash covered mown area slowing down runoff, absorbing and storing rainfall (and likely preventing flooding downstream).

Stream water quality: water quality indicators like colour and specific UV-spectra revealed no clear overall management effect on water quality, with high variability between sites and seasons. However, any signal will be diluted by as yet unmanaged areas and it might take years for a clear overall signal to emerge in the main streams, clearly more monitoring is needed.

Vegetation impacts: whereas mown areas showed quicker revegetation from both moss and sedges (cotton grass), burnt areas showed initially much larger bare areas and dead moss cover. However, four years after management *Sphagnum* moss (a key peat forming species) and sedge cover were again similar (**Fig. 1**). Moreover, although heather germination and seedling growth was noticeably better on burnt areas over the first two years after management, overall regrowth and heather cover was similar. Notably, we detected similarly increased nutrition levels, specifically nitrogen, magnesium, manganese and potassium, in re-grown heather shoots from both burnt and mown compared to uncut areas.

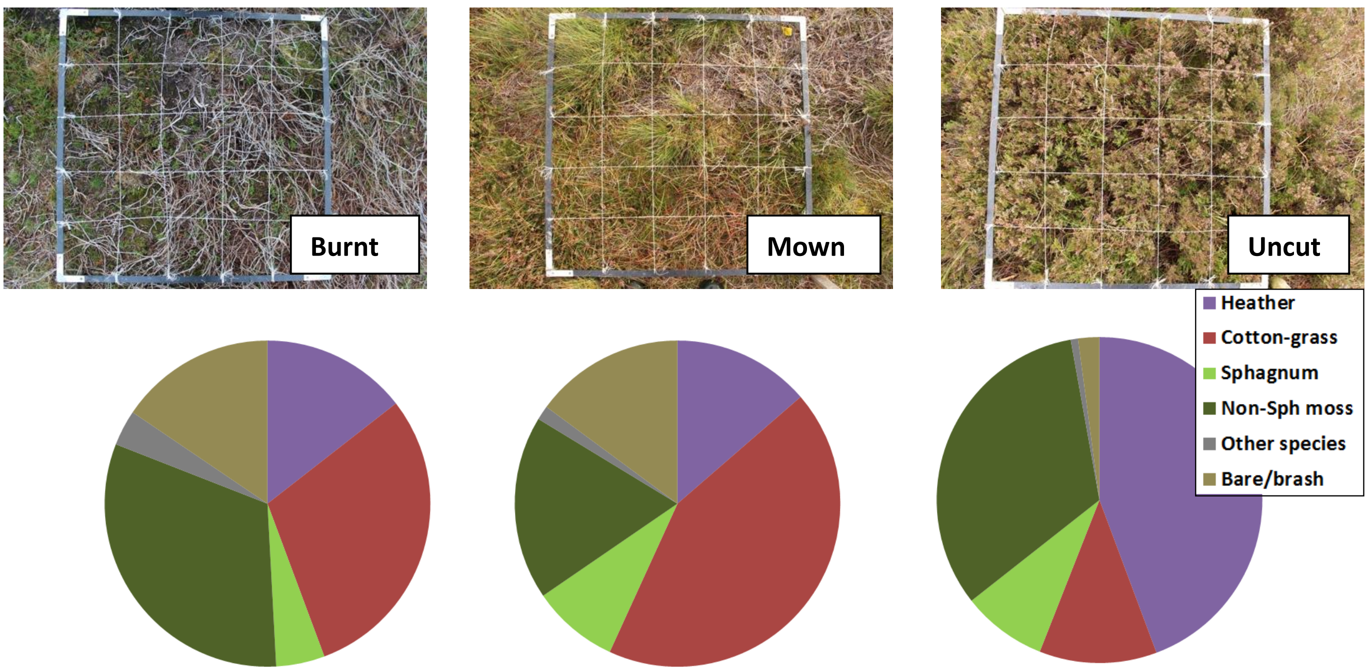

Figure 1: (*top*) Example photos of burnt and mown plots (1x1 m) in 2014, two years after burning, at Nidderdale *versus* the uncut control plot (within the mown catchment but uncut). Note the much more open **bare and brash** areas on the burnt and mown plots, respectively. (*bottom*) Average vegetation composition (100%) across the three sites in 2015, three years after management; note the similar **heather** cover for mown and burnt areas but higher mown **sedge** (cotton grass) cover.

Carbon budgets: over the three years after management, uncut areas stored on average 380 g of carbon [all in per m^2], but burning lost about 350 g of carbon from the burnt areas based on flux chamber measurements (**Fig. 2**), mainly from decomposing peat. Burning the vegetation released an additional 560 g of carbon, together amounting to nearly 1 kg of carbon lost over three years. In contrast, mowing lost only 350 g of carbon as it stored carbon in the brash layer and decomposition losses were reduced by larger carbon uptake due to faster initial regrowth of vegetation. However, whereas emissions from mown areas increased over time, they reduced for burnt areas (see Mossdale example; **Fig. 2**) – so burnt areas might yet catch up; clearly only measuring over a full rotation will reveal the full story!

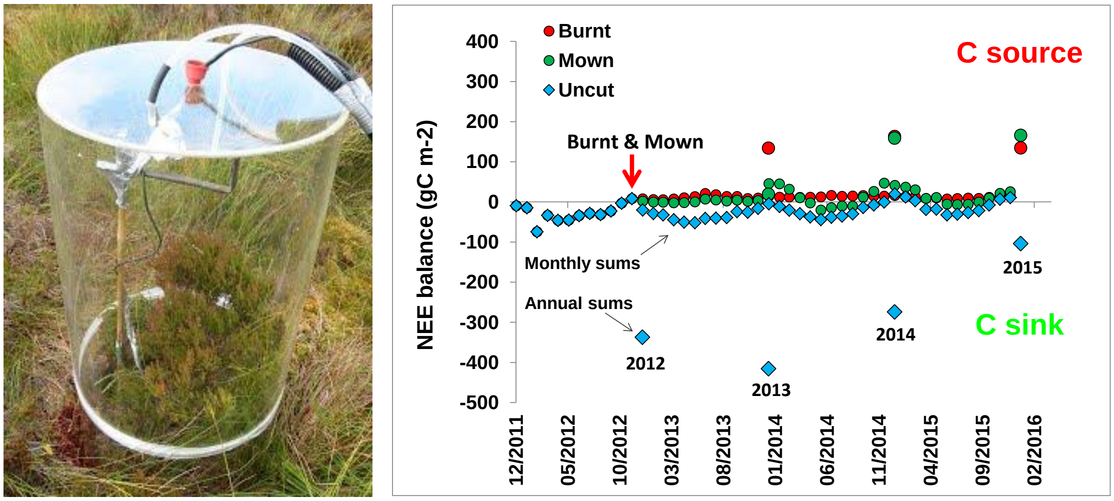

Figure 2: Modelled monthly carbon balance (and annual totals) for burnt, mown and uncut control plots at the Mossdale site (based on chamber measurements, left). Note the initial negative (carbon gain) monthly carbon budgets for mown, but positive (carbon loss) for burnt plots, but the subsequent annual change, particularly on mown plots, becoming positive (carbon loss).

<u>Greenhouse gas emissions</u>: overall soil methane (CH_4) emissions did not differ between management, but between sites (wet Mossdale had highest emissions) and vegetated areas confirmed that sedge cover is linked to increased methane emissions. So, mown areas with larger sedge cover do have a ‘side effect’ to be considered. Importantly, overall the net warming potential of CO_2 and CH_4 was still negative for the two wetter sites (climate cooling), yet Nidderdale had a slight net warming effect.

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

<u>Decomposition impacts</u>: peat incubation studies in the laboratory showed that peat from burnt areas shows higher temperature sensitivity – warmer soil stimulating peat decomposition – than peat from mown areas. However, we did not observe any clear differences in peat decomposition in the field, which agrees with no meaningful differences in soil temperature.

Blanket bogs provide many other **ecosystem services** alongside carbon and water, one of which is biodiversity. This habitat is very rare globally and many **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, the crane fly larval stage (mid-summer) desiccates when too dry with low numbers emerging the following year, thus limiting food for the birds. In fact, carbon, water and biodiversity are equally linked in many other food webs.

<u>Biodiversity impacts</u>: we monitor annual crane fly numbers and emergence during May till July, a crucial time for Red Grouse and other bird chicks. We just published a collaborative study with the RSPB and BTO in the journal *Nature Communications* on predicting climate change scenario impacts on upland birds via this crane fly link (PDF is available on request). Based on increasing summer droughts, we predicted that by 2051-80 the Dunlin could see a 50% decline in numbers, with the Golden Plover down 30% and Red Grouse down 15%. Moreover, higher soil moisture on mown plots increased cranefly abundance and thus predicted bird survival (for Golden Plover up to 100% more fledglings than on burn).

I do hope you agree that blanket bog management aimed at maintaining ecosystem functioning under future climate change should be aimed around “a wetter bog is better”. As the environment is changing, we need to 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 begin of 2017) 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 a real UK treasure but they are under threat. Thankfully, plenty of work is going on trying to restore many severely degraded areas of bog – many of it with EU money. However, large areas looking ‘intact’ are in fact also in need of ‘preventative’ management adjustments in the view of climate change and ensuring resilience of large upland areas. This project gains real scientific insights into how these systems functions and how we depend on this functioning. The issue is, it is not a simple story as many aspects are interconnected, mostly via soil processes – hidden from plain view; I would like to reiterate last year’s final statement: a good GP needs to understand how the entire body works in order to treat the patient most effectively. Our results are a vital start in understanding how this habitat responds to environmental and management change. Notwithstanding current financial constraints, we hope to be able to continue this project together with the Heather Trust, the Moorland Association, the gamekeepers and other stakeholders to ensure its future.