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In this issue

Conserving carbon in peat in the face of climate change

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Anyone concerned about climate change will be interested in the importance of the historic carbon store and the potential for new sequestered carbon in peat. In upland Great Britain, the implications for nature conservation as well as climate change are given for this in terms of the hydrological and ecological condition of peat. Some of the methods and results of the many GB projects to restore blanket peat are presented.

Figure 1. Gullying and bare peat in blanket bog

Carbon in peat

Soil organic carbon holds some six times more carbon than all the forests of the world and 30% of this is in approximately 3% of the land area holding peat. Drained and degraded peats occur on 0.3% of the land but are emitting 6% of greenhouse gases (Joosten 2010). There is more peat in the tropics - Asia is the world's top peat carbon emitter; Europe is second (Joosten 2012 pers. comm.). Indeed, the main cause of peat loss and degeneration on a worldwide scale is drainage and clearance for agriculture (Joosten 2010).

In the UK, 40-50% of soil carbon is stored in only 8% of the land area, which is equivalent to about 20 years of UK CO_2 output (Moors for the Future 2007). Most of this carbon store is in peat, but around 80% of our peatlands are losing carbon due to various forms of damage. This contributes to the alarming figure of 80% of all carbon losses from UK soils being derived from upland peat soils (Bellamy *et al*. 2005).

So what does this all mean and what are the consequences, at least in Britain? If, like me, you accept that climate change is **the** biggest threat for mankind and the environment, then peatland restoration is critically and urgently required. The importance of peat both as an historic carbon store and in capturing carbon in new peat (Lindsay 2010) shows that effective restoration could change the carbon equation significantly if part of a low carbon economy. The essential requirements are a wet environment with a stable water table just below the surface most of the year and a well-vegetated surface with plenty of peat forming *Sphagnum* species.

Reasons for poor peat condition in upland Britain

There are a multitude of reasons, often interacting, for poor peat condition in upland Britain, the consequent release of stored carbon and lack of active peat formation (Lindsay 2010):

- Miles of densely packed drains (grips, mostly dug with grant aid in the 1960s and 1970s);
- Extensive bared peat and gully systems mostly probably initiated from wildfires, especially in the South Pennines and Peak District (Figure 1);
- Centuries of burning and overgrazing;
- 200 years of air pollution, particularly sulphur dioxide from industrial centres close to moors, which increased peat acidity beyond that tolerated by *Sphagnum* species;
- Conifer planting, often including drainage;
- Peat extraction, from blanket bogs as well as lowland raised mires;
- Drainage and 'improvement' for agriculture, although currently less widespread than in the past;
- Localised damage from recreational access and illegal 4x4 vehicles and motorbikes.

The carbon is being lost through decay and shrinkage of the peat as it dries; much is discharged into the air; some enters streams leading to discoloration which has to be removed by water companies in a process that is environmentally damaging in itself; more ends up as peat sediment. Some peat blows away in drought conditions. The famous post in Holme Fen NNR (Cambridgeshire) now stands 4 m above ground level – the amount of shrinkage since 1850 owing to surrounding drainage operations.

New carbon is not being sequestrated fully, if at all, where the peatlands are too dry as a result of drainage or gullying (Figure 1), and no longer support the peat-forming *Sphagnum* species in sufficient quantity.

Initiatives to restore peat in the UK

Attempts to revegetate bare peat started after widespread and often severe wildfires during the extreme drought in 1975-6. Much experience was gained in the Peak District and North York Moors in the following years (North York Moors National Park 1986, Anderson *et al*. 1997), but efforts focused on repairing bare peat surfaces rather than in making them wetter. Rewetting was started on lowland raised bogs and fens (Rowell 1988, Stoneham and Brooks 1997). Extensive grip blocking in the uplands began around 2000 (e.g. Wallage *et al*. 2006, Armstrong *et al*. 2010) and has since expanded, including a wide variety of projects throughout GB and Ireland.

The key players are nature conservation bodies (statutory and NGOs), Forestry Agencies and landowners plus the water companies. The latter are significant – United Utilities' SCaMP[1] was the first project where the regulator, OFWAT, permitted money to be spent on catchment management both to restore SSSI condition and to reduce colour issues (dissolved organic carbon) in drinking water rather than end-of-pipe engineered solutions. This approach has now been extended to other water companies. Many projects have focussed on nature conservation objectives, but carbon is at the centre of all – keeping it in the peat and providing the conditions for sequestration of more.

Figure 2. Bare peat revegetation under SCaMP, heather visible after 6 years (Photo by Andy Kean)

Figure 3. Plastic dams in a gully, raising water tables in the peat

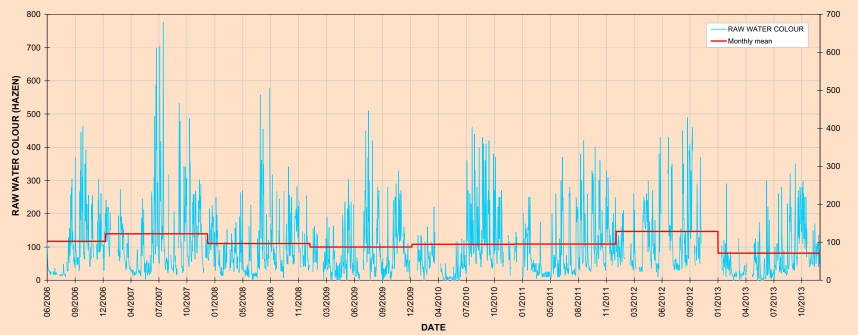

Figure 4. Slight but statistically significant reduction in colour after grip blocking (2007) in a SCaMP catchment

What are the techniques and results?

Peat restoration projects involve one or more of the following: revegetating bare peat; blocking grips, drains and gullies; removing conifers; and establishing sustainable long-term land management practices. The results are encouraging, but we are still a long way from restoring active peat in the most degraded locations.

Revegetation

Much expertise was gained through the Peak District's Moorland Management Project (Anderson *et al*. 1997). Here, not only was there more bare, eroding peat than anywhere else, but the peat had been acutely acidified (pH < 3) by air pollution. This prevented nutrient uptake and plant growth. The addition of lime and fertiliser to raise pH and nutrient levels enough to support blanket bog vegetation, the use of geojute (a jute mesh), a nurse grass seed mix and heather brash (cut material holding ripe seeds) were found by trial and error to be the most effective way of establishing blanket bog vegetation (Anderson *et al*. 1997). This general specification is now used widely; with new logistics for aerial and large scale treatments developed by Moors for the Future and other restoration projects (Anderson *et al*. 2009).

Early monitoring showed that bare ground reduced quickly and blanket bog species colonised the nurse grasses and establishing heather (Figure 2, Anderson *et al*. 1997). Such revegetation also reduces significantly the amount of particulate organic carbon reaching watercourses (J. Price, pers. comm.). Three years after revegetation, the SCaMP project also detected signs of reduced dissolved organic carbon (Penny Anderson Associates 2012). Furthermore, SCaMP, Allott *et al*. (2009) and Price (J. Price, pers. comm.) found that revegetating bare peat raises the water table and with reduced perturbation, possibly related to changes in surface reflectivity and evapo-transpiration rates and retention of moisture in the vegetation. Although active blanket bog needs a water table within 10-15 cm of the surface, this partial rewetting increases resilience to wildfire and drying out. Holden *et al*. (2008) has shown experimentally that cottongrass-dominated blanket peat has half the runoff velocity compared with bare peat and that runoff is even lower from a *Sphagnum*-dominated surface. Revegetating bare peat is therefore important but would be better with a good *Sphagnum* cover.

Grip and gully blocking

The effectiveness of grip blocking is well demonstrated. Dams are made of peat, plastic piling, heather bales or wood depending on local circumstances. A sequence of dams, with each pool passing back to the next dam, is usually needed to avoid failures and reduce erosion (Figure 3).

Monitoring at a catchment scale shows that dams can reduce sediment loss (Armstrong *et al*. 2010) and dissolved organic carbon (DOC), often within two years (Figure 4), although it can sometimes take longer (Wallage *et al*. 2006, Armstrong *et al*. 2010, Wilson *et al*. 2010; Penny Anderson Associates, unpublished data). Water tables are elevated quite quickly and perturbations are reduced after comprehensive dam blocking leading to *Sphagnum* increases (Figure 5) in dam pools and adjacent blanket bog (Figure 6).

Most areas of extensive bare peat are also gullied, often severely. Gully blocking is a fairly recent technique that attempts to reduce the dry nature of damaged peat. The gullies are part of the dendritic drainage pattern so water has to be accommodated within them, making damming more complicated than for grips. Dams use the

Figure 5. Bowland (SCaMP) before grip blocking in 2007 (left) and after blocking (2013) Abundant *Sphagnum* in pools plus raised water table in peat. (Photo by Andy Kean)

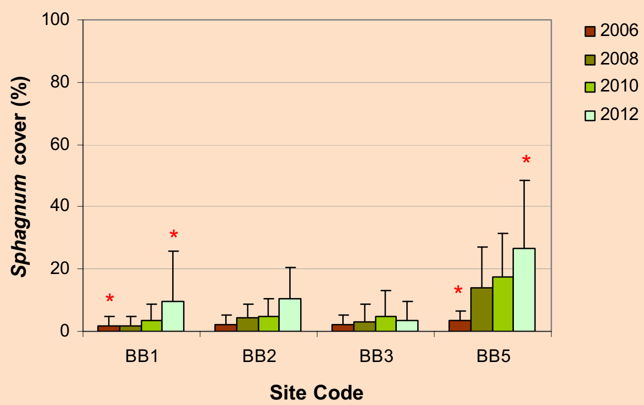

Figure 6. *Sphagnum* cover (mean and standard deviation) Bowland, (SCaMP) before (2007) and after (2009–2012) restoration measures

Key
BB1 – reference site no grips,
BB2 and BB3 - grips blocked on an eroded catchment,
BB4 and BB5 - grips blocked on an intact catchment;
* indicates significant difference at p>0.05

Figure 7. Low dams of stones holding water in deep gullies.

same materials as for grips, plus stone, which can blind with sediment over time (Figure 7). Most dams tend to be positioned to part fill the deeper gullies. It is too soon to judge the effectiveness of gully blocking but water tables should be raised and wetter blanket bog should result, compared with undammed gullied peatland.

Holding water in blocked grips and gullies as well as in the peat could influence the hydrological runoff characteristics. Downstream flooding depends on the peak of discharge as well as the total volume of water moving down the streams/rivers. Peat in good condition has a limited capacity to absorb more rainfall, thus reducing the degree to which it can buffer flooding. Rain-fed peatland catchments tend to have a very flashy hydrological regime (Holden 2009) with a rapid response to rainfall and low baseflows. Contrary to popular view, therefore, peat is not a sponge that can trap rainfall releasing it slowly, thus reducing downstream flooding potential. Only by blocking all the grips and drains in a catchment, is the downstream flooding curve peak likely to be reduced and extended, as found by Wilson *et al*. (2010) after extensive grip blocking in the Lake Vyrnwy RSPB Project.

Conifer removal

Conifers remove water from peat through evapo-transpiration as well as through their weight. Thus, the peat shrinks and may dry out (Lindsay 2010). Cracks can develop in peat under a long-term conifer crop, making the hydrological integrity of the peat difficult or impossible to restore (Anderson 2010). Where conifers are removed and drainage blocked, it may take time to achieve the wetland conditions needed for active blanket bog growth (Anderson 2010). Although some projects have reported successful restoration of water table levels to within 10-15 cm of the surface, in others, despite many dams, water tables have not altered (Anderson 2001).

Management outcomes

The rewetting of peatlands has positive effects on wildlife. Not only does *Sphagnum* cover increase but there are indications of increases in other typical blanket bog species like cranberry *Vaccinium oxycoccos* and bog asphodel *Narthecium ossifragum*. Carroll *et al*. (2011) has shown significantly increased cranefly populations after grip blocking – a critical source of food for many birds. Some species could be lost in the Peak District moors owing to climate change resulting in reduced food availability and higher temperatures (Pearce-Higgins 2010); hopefully, rewetted blanket peat will delay this.

Where revegetation has taken place without full rewetting, dry blanket bog vegetation develops and persists (Penny Anderson Associates 2012). Heather in the revegetation mix can become dominant, excluding some of the earlier-colonising blanket bog species, so more cottongrasses (*Eriophorum* spp.) and crowberry *Empetrum nigrum* are being added now, using micro-propagated plants, rather than heather.

Micro-propagation of *Sphagnum* is also being developed (see http://www.beadamoss.co.uk) that can be spread onto the early stages of re-vegetation where there is adequate moisture (Hinde *et al.* 2010). Now that sulphur dioxide pollution has reduced, *Sphagnum* species are reappearing unaided in the South Pennines - an encouraging sign. Having a significant cover of peat-forming *Sphagnum* is critical as they affect the overall hydrology through their water-holding capacity.

Final Thoughts

This paper focuses on blanket bog restoration in England, set within the wider peatland and carbon context. There are a wide variety of peatland restoration projects from Devon to Scotland, and Wales to Ireland. Many have multiple objectives, but nature conservation is benefiting from them all. Greater plant diversity and increased *Sphagnum* cover will help to move these priority habitats towards more favourable condition - important since many are SSSIs, SACs or SPAs[2]. Supporting the upland farming community and contributing to the rural economy is central to SCaMP and other projects. This shows how peatland restoration projects can contribute to wider ecosystem services, and some have featured in recent appraisals (Waters *et al*. 2012). The development of the Peatland Carbon Code as part of the Payment for Ecosystem Services research initiated by Defra (http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=18642) would provide new funds and has the potential to increase peatland restoration projects as part of Corporate Social Responsibility sponsorship and carbon offsetting. Even more important, if the carbon lost from peat were included in the IPCC calculations related to climate change, it would stimulate greater interest in restoring peat and could provide a real incentive to finance much more restoration work.

Check the web if you are interested in appreciating the scale of the work being undertaken; take the time to visit; be inspired by the huge effort; applaud the success; spread the word and help to secure the future of peatlands in the UK.

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Notes

1 SCaMP – Sustainable Catchment Management Programme

2 SAC – Special Areas of Conservation, SPA – Special Protection Areas for birds

About the Author

Penny Anderson is sort of retired from the long established ecological consultancy, Penny Anderson Associates, of which she is still a Director. She has specialised over the last 35 years in peatland restoration amongst other things.

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