Journal of Environmental Management 188 (2017) 278–286

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Historical peat loss explains limited short-term response of drained blanket bogs to rewetting

Jennifer Williamson [a,*], Edwin Rowe [a], David Reed [b], Lucia Ruffino [b], Peter Jones [b], Rachel Dolan [c], Helen Buckingham [c], David Norris [a], Shaun Astbury [a], Chris D. Evans [a]

[a] Centre for Ecology & Hydrology, Environment Centre Wales, Deiniol Road, Bangor LL57 2UW, UK
[b] Natural Resources Wales, Maes y Ffynnon, Penrhosgarnedd, Bangor LL57 2DW, UK
[c] National Trust, Dinas, Betws-y-Coed LL24 0HF, UK

ARTICLE INFO

Article history:
Received 12 September 2016
Received in revised form
5 December 2016
Accepted 8 December 2016
Available online 16 December 2016

Keywords:
Drainage
Ditch blocking
Peatland vegetation
Restoration
Peat subsidence
Water table

ABSTRACT

This study assessed the short-term impacts of ditch blocking on water table depth and vegetation community structure in a historically drained blanket bog. A chronosequence approach was used to compare vegetation near ditches blocked 5 years, 4 years and 1 year prior to the study with vegetation near unblocked ditches. Plots adjacent to and 3 m away from 70 ditches within an area of blanket bog were assessed for floristic composition, aeration depth using steel bars, and topography using LiDAR data. No changes in aeration depth or vegetation parameters were detected as a function of ditch-blocking, time since blocking, or distance from the ditch, with the exception of non-*Sphagnum* bryophytes which had lower cover in quadrats adjacent to ditches that had been blocked for 5 years. Analysis of LiDAR data and the observed proximity of the water table to the peat surface led us to conclude that the subdued ecosystem responses to ditch-blocking were the result of historical peat subsidence within a 4–5 m zone either side of each ditch, which had effectively lowered the peat surface to the new, ditch-influenced water table. We estimate that this process led to the loss of around 500,000 m^3 peat within the 38 km^2 study area following drainage, due to a combination of oxidation and compaction. Assuming that 50% of the volume loss was due to oxidation, this amounts to a carbon loss of 11,000 Mg C over this area, i.e. 3 Mg C ha^{-1}. The apparent 'self-rewetting' of blanket bogs in the decades following drainage has implications for their restoration as it suggests that there may not be large quantities of dry peat left to rewet, and that there is a risk of inundation (potentially leading to high methane emissions) along subsided ditch lines. Many peatland processes are likely to be maintained in drained blanket bog, including support of typical peatland vegetation, but infilling of lost peat and recovery of original C stocks are likely to take longer than is generally anticipated.

1. Introduction

Blanket bogs are a distinctive peatland type characterised by landscape coverage of peat soil that is anoxic, acidic, low in nutrients and dominated by peat-forming species of *Sphagnum* mosses and a limited range of ericoids and graminoids. They are found in high-latitude, oceanic climates with high levels of rainfall, including the British Isles, coastal Canada, Chile and Tasmania (Gallego-Sala and Prentice, 2013). During the 20th century, many UK blanket bogs were subjected to drainage with the aim of increasing their productivity for livestock grazing or plantation forestry. Deep drainage ditches were dug across large areas of the UK uplands (i.e. higher-elevation areas). However, improvements in productivity often proved to be marginal or non-existent (Stewart and Lance, 1983) and the ditches were hazardous for stock (Wilson et al., 2011). Peatland ditches are thought to have increased peak flow streamflow rates, with potential detrimental consequences for flood generation, but made little difference to total runoff volumes (Robinson, 1985) and in blanket peat may only have reduced water table height in sites at the lower limit of their rainfall range (Coulson et al., 1990). More recently, there has been an increase in appreciation of the wider benefits provided by peatlands, including protection of distinctive biodiversity, regulation of water flows, and regulating the exchange of greenhouse gases such as

* Corresponding author.
E-mail address: jwl@ceh.ac.uk (J. Williamson).

http://dx.doi.org/10.1016/j.jenvman.2016.12.018

carbon dioxide (CO_2) and methane (CH_4). There has therefore been considerable interest in restoring the peatlands by appropriate management interventions, most notably ditch blocking.

Studies of the impacts of ditch blocking on blanket peat in the UK uplands have tended to focus on the effects on water table depth and on carbon efflux. Several studies demonstrated that blocking ditches increased the water table in the vicinity (e.g. Armstrong et al., 2010; Cooper et al., 2014; Peacock et al., 2015), although a comparison with an intact peatland in Northern England showed that water tables had not recovered to background levels even six years after blocking ditches (Holden et al., 2011). Water table recovery in blanket bogs is, however, usually small in magnitude, for example 2 cm (Wilson et al., 2010) or 9 cm (Worrall et al., 2007), whereas studies on boreal mires drained for forestry have found that blocking drainage ditches increased the water table in the vicinity by approximately 80 cm (Haapalehto et al., 2014). There are a number of potential reasons for this difference including topography, higher hydraulic conductivity in boreal mires and the presence of trees causing increased evapotranspiration on land drained for forestry.

Despite the importance of peatlands for biodiversity and the specialist plants and lichens they support, the impact of ditch blocking on the floristic diversity of blanket bogs has been less well studied. This is likely to be at least partially because changes in floristic composition may not be evident for a number of years following the initial ditch blocking activity. A study in northern Scotland showed that cover of species indicative of bog recovery increased where ditches had been blocked and was highest when the ditches had been blocked for the longest time, i.e. 11 years (Bellamy et al., 2012). However, a study in Exmoor found that the presence of drainage ditches had no effect on vegetation structure, as measured in transects away from the ditch (Gatis et al., 2016). A recent study in north Wales also showed that blocking drainage ditches had no consistent impact on vegetation in the 3 years following blocking (Green et al., 2015). The majority of work published on the effects of ditch blocking on peatland vegetation has been carried out in Scandinavia, where it has been found that ditch blocking increased the cover of specialist bog plants such as *Eriophorum vaginatum* and *E. angustifolium* (Komulainen et al., 1999) and rich-fen species including *Sphagnum* and wetland bryophytes (Hedberg et al., 2012). A study of rewetted forest swamp in Finland found that the water table recovered to the level seen in an intact site within four years of ditch blocking, but plant communities did not recover to the same extent, with vegetation composition being half way between sites with open ditches and intact sites (Maanavilja et al., 2014).

In summary, blanket bogs appear to be less responsive to drainage or re-wetting than other peatland types. Previously, this observation has been linked to the extremely low hydraulic conductivity of blanket peat, which severely restricts subsurface flow and thus the extent to which ditching is effective in lowering water tables (e.g. Hoag and Price, 1995; Holden and Burt, 2003), particularly in comparison to other peat types (Evans et al., 2014). In this study, however, we investigate another possible contributory factor for the apparent lack of impact of ditch blocking on peatland function not previously measured on blanket peat, namely subsidence, a process first noted by Holden et al. (2016) as being a potential reason for small changes in water table following ditch blocking on sloping blanket peatlands. One of the most consistent effects of peat drainage is accelerated decomposition of peat on exposure to oxygen, which leads to a loss of organic matter within the aerobic zone. Together with compaction of the peat, as the peat matrix is no longer supported by water within pores, this can lead to significant lowering of the peat surface over extended periods (Lindsay, 2010). The role of subsidence is well established in lowland settings, where historical drainage of raised bogs and fens for agriculture have led to subsidence rates in the region of 1–2 cm yr^{-1}, resulting in a cumulative elevation changes of several metres (e.g. Hutchinson, 1980). Subsidence has also been established in the Florida peat swamps following drainage, although at a slightly lower rate of 0.4–1.5 cm yr^{-1} (Aich et al., 2014; Hohner and Dreschel, 2015). In lowland raised bogs, the effects of ditching can extend over large areas, with lowering of the peat surface detected up to 100 m either side the ditch in some cases (Lindsay, 2010). On blanket bog, the undulating topography makes subsidence effects harder to detect, and higher bulk density and resistance to drainage may be expected to limit its extent (Lindsay, 2010). Some of the clearest evidence for subsidence on blanket bogs derives from a site in Scotland, where rates of around 1–2 cm yr^{-1} were recorded during the first 30 years following drainage for plantation forestry (Shotbolt et al., 1998). In the absence of the drying and compression effects of trees, subsidence of blanket bogs drained to increase grazing quality are likely to be smaller, but may (over an extended period) nevertheless be sufficient to influence surface topography in the vicinity of ditches, and could be sufficient to lower the peat surface to the new (post-drainage) level of the water table.

To assess the effects of ditch blocking on blanket bog hydrology and vegetation, a structured survey of a peatland area in Wales was carried out in the late summer of 2015. A chronosequence (i.e. space-for-time) approach was used to assess vegetation near ditches blocked at different times, at two distances from the line of the ditch. Steel bars were installed and later retrieved to assess aeration depth (cf. Bridgham et al., 1991; Carnell and Anderson, 1986; Owens et al., 2008). We tested the following hypotheses: (H1) blocking drainage ditches increases the height of the water table; (H2) blocking drainage ditches results in increases in cover and prevalence of specialist bog species; and (H3) these increases are greater close to the ditches. LiDAR surveying of the site was used to map the extent of the morphological changes seen in the landscape following ditching and to put the results in context of the wider area.

2. Methods

2.1. Ditch survey

The survey was located on the Migneint plateau in North Wales (52° 58′ N 3° 48′ W), an extensive area of peatland at 350–500 m altitude over impermeable silicic siltstones and mudstones (Lynas, 1973) receiving *ca.* 2300 mm precipitation yr^{-1}. Areas of relatively intact peat have blanket bog vegetation (*cf.* M19 *Calluna vulgaris* – *Eriophorum vaginatum* blanket mire) (nomenclature follows Rodwell, 1991), with gradations to wet heath assemblages (*cf.* M16 *Erica tetralix* – *Sphagnum compactum* wet heath) where organic horizons are shallower, and to flush assemblages (*cf.* M6 *Carex echinata* – *Sphagnum auriculatum/recurvum* mire) where there are minerotrophic influences. The plateau was extensively drained during the 1930s and again in the 1970s, resulting in the installation of ditches across nearly all peatland areas. Early ditches were mainly installed perpendicular to the contours of the hillslope by hand. Later ditches were installed mechanically, and predominately diagonally across the hillslope. Based on a recently produced map of Welsh peat extent (Evans et al., 2015), a total area of 3842 ha of peat falls within the Ysbyty Ifan estate, owned by the National Trust, which has undertaken a programme of blocking drainage ditches between 2011 and 2015. Ditches in some areas have not been blocked. The dates of ditch blocking were not random across the site (Fig. 1), but as they were largely selected on the basis of land tenancy rather than physical site characteristics, blocking dates were not strongly associated with other potential sources of variation.