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Changes in peat chemical properties during post-fire succession on blanket bog moorland

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ABSTRACT

This study assessed the impact of prescribed burning on the peat properties of moorlands during the post-fire succession in a multi-site study within a major moorland region of Great Britain. Three replicate moorland sites were sampled; all were ombrotrophic bogs and had peat soils overlying similar geology and similar vegetation. A chronosequence approach was used to sample soils from a post-fire succession (3–52 years since burning) on each site and a number of chemical properties measured. The data on soil chemical properties were analysed using both linear-mixed-effects modelling and multivariate analysis. There were clear differences in some soil properties between moorland sites, but for most soil variables measured there was no change through the post-fire succession. Four variables (available P and Ca; total P and K) showed a significant interaction, i.e. different responses on each moorland site through time. These results suggest that there are complex interactions between nutrient inputs (rainfall and dry deposition which is affected by elevation), storage and cycling within the soil-peat system and losses that differ on the three moorland sites. The most interesting result was the additive response of the C:N ratio which differed between moorland sites; all sites showed the same negative slope with respect to elapsed time since burning, indicating an increased N saturation. This result suggests that the oldest stands sampled here may have either (i) responded to the large N inputs added from the atmosphere in the latter part of the twentieth century, or (ii) the younger ones have had some of this N removed during prescribed burning. This suggestion needs further investigation. Nevertheless, the impacts of prescribed burning on the peat properties during the post-fire succession were relatively small.

1. Introduction

The upland moors of Great Britain (Fig. 1), many of them growing on blanket bog (ombrotrophic mire) have a very high conservation value of international significance (Bain et al., 2011; Littlewood et al., 2010). They are increasingly recognised as making a major contribution to ecosystem services, primarily as a carbon store in peat (Worrall et al., 2010), but also because uplands catchments are used to provide clean drinking water for human use (Labadz et al., 2010). These moors are currently cultural landscapes that have been created and maintained by anthropogenic activity, mainly sheep grazing and prescribed burning. The resultant vegetation is dominated by *Calluna vulgaris* intermixed with other dwarf-shrubs and patches dominated by *Eriophorum* spp., and a large bryophyte component. Whilst fire has been used for hundreds, perhaps thousands of years (Simmons, 2003), it has increased in frequency over the last 150 years as a result of its use in grouse management (Bonn et al., 2009). Currently, approximately, 65% of British upland moors are managed using prescribed burning for the benefit of red grouse (Sotherton et al., 2009).

Usually, prescribed burning is applied to small moorland patches, frequently with a high *C. vulgaris* cover, in a rotation to produce a mosaic of stands in different stages of the burn-recovery cycle (Gimingham, 1972). The aim of prescribed burning is to remove the above-ground, woody plant growth and any old degenerate plants, leaving charred stems and some bryophyte cover (Harris et al., 2011). Prescribed burning for moorland management in England is nowadays usually carried out using the pressurized-fuel-assisted or “cool–burn” approach (Harris et al., 2011) where the aim is to produce a fire of low intensity and severity (sensu Keeley, 2009; Bento-Gonçalves et al., 2012). If this is carried out properly there is rapid regeneration of both seed and resprouting stems (Miller and Miles, 1970). Burning will clearly affect the immediate nutrient content of the vegetation and the burn-recovery cycle will probably impinge on soil chemical properties. At the same time, burning will produce changes in the chemical characteristics of the first centimetres of soil profile (Granged et al., 2011a); through time these changes produced complex biochemical interactions between soil components and released nutrients by fire

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Fig. 1. Upland areas of the British Isles indicating the position of the moorland study areas in the Pennines in England.

(Granged et al., 2011b). However, as moorland communities only exist on very infertile soils (Edmondson et al., 2010; Gimingham, 1972; Marrs, 1993), any management that affects the distribution of nutrients within the ecosystem or their supply from soil processes must be considered important. Clearly, prescribed burning, which transfers nutrients from the stored pool in the vegetation either to the atmosphere or soil could impinge on long-term ecosystem persistence (Marrs, 1993).

During burning, a large proportion of the nutrients within the standing vegetation may be released in more mobile forms, and may either be lost from the system in smoke, or deposited on the site as ash or char (Allen, 1964; Clay, 2009; Evans and Allen, 1971). Ash chemical composition and its water-extractable elements have been shown to change as fire severity increases in wildfires (greater total sulphur and reduced total C, N, C:N and water-extractable P; Pereira et al., 2012). Laboratory assessments of nutrient loss at different burning temperatures indicate that larger quantities of N are lost relative to other elements, although estimates are highly variable, ranging from 57% to almost a complete loss of N at temperatures above 500 °C (Allen, 1964; Evans and Allen, 1971). Lower amounts of P and cations are volatilised with a fraction of these elements being retained in ash (White et al., 1973). Deposition as ash provides a pulse of readily-available quantities of these nutrients which may either be taken up by the vegetation, or lost through leaching or run-off (Clay et al., 2009a,b). The amount taken up by the vegetation will to some extent depend on the balance between rainfall patterns and the time taken for the vegetation to regenerate. As the vegetation recovers, there is an accumulation of biomass and litter (Chapman, 1967), and this will impact on soil chemistry through uptake and cycling of nutrients. Given the importance of prescribed burning and its potential impacts on nutrient release into waterways, it is surprising that almost nothing is known about any change in peat chemical status during the burn-recovery process.

This paper, therefore, assesses the changes in peat chemical properties during the post-fire succession after prescribed burning in a multi-site study within the North Peak Environmentally Sensitive Area (North Peak ESA) in Central England (MAFF, 1993). This area has suffered severe impacts from past industrial pollution, particularly from SO_2, and this has been suggested as the cause of a reduction in plant species diversity, especially bryophytes, from this area (Tallis, 1998). It is likely that these pollutant impacts will impinge on soil chemistry also; but McGovern et al. (2011) have shown soil recovery from acidification in another area of upland Britain. In order to assess soil properties through the post-fire succession a chronosequence approach (sensu Jenny, 1980) was used at three different moorlands to answer three questions: