Geoderma 315 (2018) 20–26

Contents lists available at ScienceDirect

Geoderma

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

# Differences in soil chemistry remain following wildfires on temperate heath and blanket bog sites of conservation concern

Ruth Kelly[a,b,*], W. Ian Montgomery[a,c], Neil Reid[a,c]

[a] School of Biological Sciences, Queen's University Belfast, MBC, 97 Lisburn, Road, Belfast BT9 7BL, UK
[b] Zoology Building, School of Natural Sciences, Trinity College Dublin, Dublin 2, Ireland
[c] Institute for Global Food Security (IGFS), Queen's University Belfast, 18-30 Malone Road, Belfast BT9 5BN, UK

ARTICLE INFO

Handling Editor: Yvan Capowiez

*Keywords:*
Fire
Peatland
Plant nutrients
Highmoor peat
Soil management
Vegetation

ABSTRACT

Wildfires have the potential to change the physico-chemical characteristics of soils, and further research is required to establish the nature, extent and duration of these impacts. The extent to which the impacts of wildfires differ from the more frequently studied prescribed burns is an active area of investigation with serious implications for landscape managers and conservation biologists. Here, we take advantage of multiple large wildfires which occurred in vulnerable upland habitats of conservation importance, to measure in-situ differences in soil conditions between burnt and unburnt areas ca. 1.5 years and 3.5 years after fires. There were no detectable differences in pH, total nitrogen, total carbon, potassium or magnesium concentrations between burnt and unburnt locations 15–18 months after wildfires, suggesting that these were either unaffected by the fires, or more likely, as suggested by previous research, had exhibited transient differences immediately after the wildfires which had returned to baseline conditions within 1.5 years. By contrast, burnt and unburnt locations differed with respect to phosphorus and calcium concentrations which remained elevated up to 3.5 years post-fire. Calcium concentrations remained greater in burnt plots across all three habitat types, whilst available phosphorus concentrations remained elevated in blanket bog but returned to the same level as unburnt control plots in wet and dry heath. Taken together, our findings suggest that there is the potential for wildfires to have longer-lasting effects on phosphorus and calcium concentrations in some temperate European Annex I habitats of conservation concern, particularly blanket bog, than previously expected based on results of studies of experimental burning or wildfires in other habitat types. The magnitude and duration of fire impacts on soils depends largely on the environmental and meteorological characteristics of the region. Hence, this study highlights the need for more research across a broader range of sites taking advantage of unexpected wildfires, to assess the extent to which their impacts may differ between habitat types and from those of experimental or controlled burning.

## 1. Introduction

Wildfires play a major role in shaping ecosystems globally and changes in fire regimes are increasingly common in many parts of the world as a result of climate change, changes in land management and increasing anthropogenic pressure (FAO, 2007; Krawchuk et al., 2009). In many parts of the world fires are part of the natural cycle and ecosystems are adapted to fire and require fire for their continuation (FAO, 2007). Greater impacts of wildfires on ecosystem processes are generally expected in naïve ecosystems which have little fire history (Chuvieco et al., 2014). Climate change and anthropogenic land-use changes are likely to increase the risk of wildfires in temperate regions and alter the capacity of natural habitats to cope with such events. In the UK and Ireland wildfires are predominantly anthropogenic in origin, with > 95% of wildfires started by people (Birot et al., 2009; Mc Morrow et al., 2009). Peatland fires across the UK frequently overlap with designated sites of conservation importance (Douglas et al., 2015), leading to growing concern about potential negative impacts on soils, biodiversity and ecosystem services (Bain et al., 2011; Lee et al., 2015). In response to observed global changes in the frequency, severity and location of fires, significant attention has been placed on the potential impacts of fires on soil properties, including hydrology, microbiology, organic matter content and soil nutrient availability (Bento-Gonçalves et al., 2012, Brown et al., 2015, Certini, 2005).

The effects of fire on soil chemical properties is highly complex, and depends on a range of factors relating to both the fire (e.g. severity,

* Corresponding author at: School of Biological Sciences, Queen's University Belfast, MBC, 97 Lisburn, Road, Belfast BT9 7BL, UK.
*E-mail addresses:* kellyr44@tcd.ie (R. Kelly), i.montgomery@qub.ac.uk (W.I. Montgomery), neil.reid@qub.ac.uk (N. Reid).

https://doi.org/10.1016/j.geoderma.2017.11.016
Received 21 July 2017; Received in revised form 5 November 2017; Accepted 8 November 2017
0016-7061/ 

intensity and duration) and the location (e.g. soil characteristics, hydrology, topology and climate conditions). Fires influence soil chemical properties via a number of mechanisms, including the deposition of organic materials on the soil surface and direct heating of topsoils which causes changes in molecular structure and solubility of elements, in addition to changes in soil physical structure and water repellence (Certini, 2005; Clay et al., 2009; González-Pérez et al., 2004). Initial increases in plant macronutrients including calcium, phosphorus, potassium and magnesium are frequently documented following fires (Adams and Boyle, 1980; Arocena and Opio, 2003; Certini, 2005; Gómez-Rey et al., 2013; Gómez-Rey and González-Prieto, 2014; Ludwig et al., 1998; Xue et al., 2014), but differences in chemistry may be qualitative as well as quantitative with complex changes reported in carbon and nitrogen structure and composition (Certini, 2005; Certini et al., 2011; González-Pérez et al., 2004. The duration of these changes in soils also varies greatly depending on climate, topography, soil characteristics, hydrology and vegetation recovery. Studies from European dry heath, woodland and shrubland often show a relatively rapid return to baseline conditions of between 3 months to 2 years depending on the nutrient studied (Certini, 2005; Gómez-Rey et al., 2013; Gómez-Rey and González-Prieto, 2014). However, this is not always the case and residual impacts on soil nutrients of much longer durations have been observed following intense fires in other habitat types and regions, for example residual increases in soil calcium, magnesium and phosphorus were still evident after 11 years on following smoldering peatland fires in Poland (Sulwiński et al., 2017). Furthermore, under certain conditions initial increases in nutrient concentrations may be followed by decreases below baseline levels as a consequence of increased leaching and run-off from bare soils (Adams and Boyle, 1980; Fonseca et al., 2017; Gómez-Rey et al., 2013). Thus, it is difficult to predict impacts of fires on soil chemistry across habitats or regions with confidence based on current knowledge, and further research is needed on a broader range of sites.

Upland heather moorland, including heathlands and blanket bog, are of significant international importance encompassing thirteen vegetative communities recognised in the EC Habitats Directive [92/43/EEC], six of which occur in Britain and Ireland (Thompson et al., 1995). These provide an important habitat for flowering plants, bryophytes and lichens (Diaz et al., 2013), and a diverse fauna involving soil microarthropods, nematodes and fungi (Bardgett et al., 1993), epigeal macroinvertebrates (Usher, 1992; Scott et al., 2006) and terrestrial vertebrates (Usher and Thompson, 1993; Smith et al., 2001). Furthermore, peatland habitats such as blanket bog provide important ecosystem services including water retention and carbon storage, which are in turn dependent on the quality of the soil, water and vegetation within these habitats (Rydin and Jeglum, 2006).

Previous studies on the impacts of fire in Northern European upland ecosystems have focused mainly on controlled burning of upland heath vegetation which has a history of human influence, for example through grazing, burning and cutting (e.g. Harris et al., 2011; Davies et al., 2010). In contrast, there is little information on the potential impact of wildfires on less intensively-managed sites, particularly blanket bog and wet heaths. Soils in areas burnt by wildfires may be degraded more than those subject to managed fires due to higher temperatures and longer durations of fire, combustion of surface litter and peat, greater changes in plant communities and eventual increases in soil erosion and/or pollution of upland water courses (Brown et al., 2015; Davies et al., 2016). However, these differences have not been thoroughly investigated, and the extent to which fire impacts of soil differ between prescribed burns and wildfires is a topical issue in current research (Bento-Gonçalves et al., 2012; Davies et al., 2016).

In contrast to controlled burning, it is not possible to use a before-and-after experimental design to study the impact of wildfires due to the inherent unpredictability of their timing and locations. Therefore, here we use space-for-time substitutions to examine differences in soil chemistry between paired burnt and unburnt areas within 6 upland sites where large wildfires occurred in spring 2011. This allowed us to examine differences in soil conditions within sites, in-situ ca. 1.5 and 3.5 years post wildfire. Furthermore, these sites were selected for inclusion in this study due to the presence of relatively high quality heathland and blanket bog habitats prior to the wildfires, indicated by their prior designation as UK Areas of Special Scientific Interest (AsSSI) under the European Habitats Directive [92/43/EEC].

Soil chemical parameters were selected for inclusion in this study based on their importance in determining vegetation composition and recovery on peatland sites, and in biogeochemical cycles. The soil chemical regime in European peatlands and heathlands has been described as comprising of two main axes which influence plant communities; the first is variation in pH, electrical conductivity and base availability (primarily calcium) and the second is a nutrient gradient primarily characterised by availability of nitrogen, phosphorus and potassium. The relative importance of these two axes in terms of their impacts on vegetation composition will also vary between sites and habitats (De Graaf et al., 2009; Rydin and Jeglum, 2006). We selected for inclusion elements relating to both of these axes, namely pH and calcium which relate primarily to the first axis and the major nutrients nitrogen, phosphorus and potassium relating to the second axis. In addition, we included total carbon and magnesium which have shown differences in concentrations following fires in other habitat types.

Due to the close association between these soil chemistry parameters and upland vegetation, differences in these soil chemical parameters following wildfires could therefore have important implications for rare plant communities, secondary succession and related ecosystem functions such as carbon sequestration and water retention provided by these protected habitats. This study aimed to provide information on the potential medium-term impacts of wildfires on less-intensively managed European blanket bog and wet heath sites about which there is currently a lack of information. Furthermore, we aimed to help inform the current debate on the impacts of wildfires relative to those of prescribed/controlled burning in these key habitats of conservation concern. Specifically, we aimed to describe any differences in the following soil chemical parameters; calcium (mg/l), carbon (%), magnesium (mg/l), total nitrogen (%), available phosphorus (mg/l), potassium (mg/l) and pH which are important in vegetation processes over a 3.5 year time period following wildfires. This study was undertaken as part of a wider ranging ecological study examining the recovery of designated habitats following a spate of wildfires which occurred in spring and early summer in 2011 when 3800 ha of land within Areas of Special Scientific Interest (AsSSI) were burnt across Northern Ireland (Kelly et al., 2016a; Kelly et al., 2016b).

## 2. Methods

### 2.1. Site selection

Geographical Information System (GIS) mapping was used to identify Areas of Special Scientific Interest (AsSSI) within which large wildfires had occurred in 2011. The location and size of each fire was derived from maps produced by the European Forest Fire Information System (EU Joint Research Centre, 2012). These fire locations were then overlaid with Northern Ireland Environment Agency (NIEA) designated *Natura 2000* sites, specifically AsSSI. Of the nine AsSSI on which large wildfires had occurred in spring 2011, six were selected for inclusion in this study based on the presence of three EU Annex I upland habitat types 'blanket bog', 'Northern Atlantic wet heaths with *Erica tetralix*' (hereafter, wet heath), and 'European dry heaths' Information on the distribution of these Annex I habitat classes within each ASSI were derived from botanical surveys conducted by the NIEA between 2005 and 2008 based on the Joint Nature Conservation Committee (JNCC) National Vegetation Classification (NVC) system for UK habitats (JNCC, 2006; Averis, 2004).