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Short-term low-severity spring grassland fire impacts on soil extractable elements and soil ratios in Lithuania

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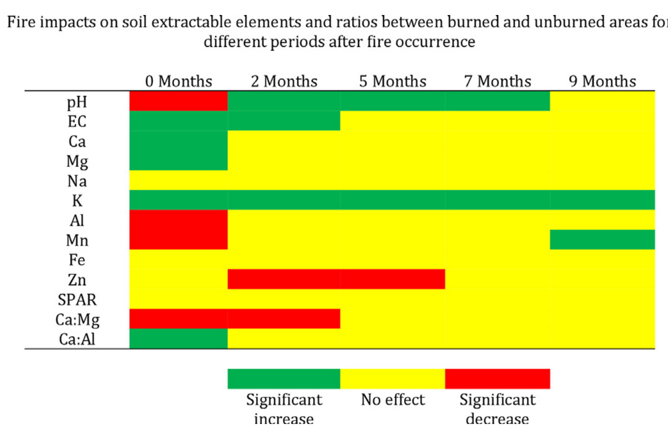
HIGHLIGHTS

- Short-term spring low severity grassland fire impacts on soil properties were analysed.
- Fire impacts were mainly observed in the first two months.
- Fire increased soil EC of Ca, Mg and K, did not change Na, Fe and Zn and reduced Al and Mn.
- Fire did not affect SPAR, decreased Ca:Mg ratio, and increased Ca:Al ratio immediately after the fire.
- This grassland ecosystem is resilient to low severity spring fires.

GRAPHICAL ABSTRACT



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ABSTRACT

Spring grassland fires are common in boreal areas as a consequence of slash and burn agriculture used to remove dry grass to increase soil nutrient properties and crop production. However, few works have investigated fire impacts on these grassland ecosystems, especially in the immediate period after the fire. The objective of this work was to study the short-term impacts of a spring grassland fire in Lithuania. Four days after the fire we established a 400 m^2 sampling grid within the burned area and in an adjacent unburned area with the same topographical, hydrological and pedological characteristics. We collected topsoil samples immediately after the fire (0 months), 2, 5, 7 and 9 months after the fire. We analysed soil pH, electrical conductivity (EC), major nutrients including

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calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K), and the minor elements aluminium (Al), manganese (Mn), iron (Fe) and zinc (Zn). We also calculated the soil Na and K adsorption ratio (SPAR), Ca:Mg and Ca:Al. The results showed that this low-severity grassland fire significantly decreased soil pH, Al, and Mn but increased EC, Ca, Mg, and K,. There was no effect on Na, Fe, and Zn. There was a decrease of EC, Ca, Mg, and Na from 0 months after the fire until 7 months after the fire, with an increase during the last sampling period. Fire did not significantly affect SPAR. Ca:Mg decreased significantly immediately after the fire, but not to critical levels. Ca:Al increased after the fire, reducing the potential effects of Al on plants. Overall, fire impacts were mainly limited to the immediate period after the fire.

1. Introduction

Spring grassland fires are common in boreal ecosystems after winter to remove dead grasses as a result of slash and burn agricultural practices. This activity is carried out on an annual basis. In the early spring, grassland areas are covered by highly flammable dry grass that burns easily. The fires that occur during this period have insignificant effects on soil organic matter concentration, and can be positive for wildlife habitat and human activities such as the creation of pastures for grazing and open areas for cattle (Granstrom, 2001; Granstrom and Niklasson, 2008; Pereira et al., 2013b, 2013c). The vegetation normally recuperates rapidly after grassland fires (Pereira et al., 2013a, 2013b; Valko et al., 2016). Despite the frequency of grassland fires in European boreal grasslands, few studies about the impact of these fires on soil properties have been carried out (Pereira et al., 2014a; Végvári et al., 2016).

Fire is considered a soil forming factor (Certini, 2014) and its impacts on soil properties depend on the type of soil and vegetation affected, fire severity, type of ash produced, topography, aspect, and meteorological characteristics during and after the fire (Bodí et al., 2014; Brook and Wittenberg, 2016; Campos et al., 2016; Mataix-Solera et al., 2009; Unzue-Belmonte et al., 2016). One of the most widely reported impacts of heating and fire on soils is pH change (Blank et al., 2003; Marcos et al., 2007), which it is attributed to the denaturation of soil organic acids (Certini, 2005), the formation of oxides (Giovannini et al., 1988), and incorporation of ash into the soil profile (Pereira et al., 2014b; Raison and McGarity, 1980). Low-severity fires or prescribed fires do not have any impact (Marcos et al., 2009) or increase soil pH (Úbeda et al., 2005) in the period immediately after a fire. Moderate or severe wildfires typically increase soil pH for a short to medium time after a fire (Murphy et al., 2006; Martínez-Murillo et al., 2016); however, this effect depends on the type of soil affected. For example, Badia et al. (2014) observed no difference in soil pH between burned and unburned areas after a moderate to high severity wildfire in calcareous soils. The increase in soil pH after a fire can change soil nutrient availability (Certini, 2005; Wang et al., 2016), with implications for plant recuperation after the fire. Similarly, organic matter mineralization and ash incorporation into burned soils can increase electrical conductivity (EC) due to the greater solubility of major cations such as calcium (Ca), magnesium (Mg), sodium (Na) or potassium (K) caused by increased pH. In contrast, the solubility of minor elements such as aluminium (Al), manganese (Mn), iron (Fe) or zinc (Zn) may be decreased (Badia et al., 2014; Inbar et al., 2014; Ponder et al., 2009).

Despite abundant research about fire impacts on soil chemistry (Gomez-Rey et al., 2013; Shakesby et al., 2015; Tomaz et al., 2014; among others), few publications have included analyses of the ratios between soil chemical elements (Blank et al., 2003; Inbar et al., 2014) beyond the frequently reported carbon to nitrogen ratio. Soil ratios can give us information about changes in soil properties (e.g., sealing of soil pores, water infiltration, erosion potential, acidity) or risk to plant nutrition and growth (Cronan and Grigal, 1995; Narhi et al., 2013), which are important to assess in burned areas. For example, sodium adsorption ratio (SAR) is used to identify the impact of salts on clay dispersion. However, previous reports showed that ash and soil solutions can be rich in K after fire (Gimeno-Garcia et al., 2000; Pereira et al., 2012, 2014b), which can also have important influences on clay dispersion and soil structure. Sodium (Na) and K are recognized as nutrients with a high capacity to disperse soil clays (Levy and Torrento, 1995; Pils et al., 2007). Thus, a new cation ratio was proposed by Sarah (2004) called sodium and potassium adsorption ratio (SPAR), which calculates the ratio between monovalent (Na and K) and bivalent (Ca and Mg) cations. The soil Ca:Mg ratio is an indirect indicator of soil structure. Calcium ions have a higher flocculation capacity than Mg ions. This is attributed to the larger Mg ion hydrated radius. Solutions with higher Mg than Ca can have negative implications on soil structure, infiltration, and hydraulic conductivity (Bame et al., 2013; Yilmaz et al., 2005). The ratio between soil Ca and Mg also affects the behaviour of other nutrients such as phosphorous (Manimel Wadu et al., 2013), nitrogen (Favaretto et al., 2012), and copper (Lombini et al., 2003), as well as plant biomass and nutrient accumulation in tissues (Kopsell et al., 2013; Drzewiecka et al., 2014). The soil Ca:Al ratio is an indicator of ecosystem stress as a result of acid deposition and soil infertility. For example, Al toxicity may inhibit plant nutrient uptake (Cronan and Grigal, 1995). Previous research has shown that in low-severity fires, extractable Al can increase in ash slurries relative to the unburned sample (Pereira et al., 2011a) with potential impacts on soil acidity. Despite the importance of the analysis of these ratios for understanding fire effects on soil status and the capacity of vegetation to recover after fire, few publications to our knowledge have investigated their temporal evolution in fire-affected areas. A recent work carried out by Francos et al. (2016) studied the impacts of an extreme rainfall period on SPAR, but did not compare it with an unburned area. The goal of this work was to study the impacts of a low severity grassland fire on soil extractable elements and ratios in the first 9 months after the fire.

2. Materials and methods

2.1. Study area, sample design and laboratory analysis

The fire occurred on 15 April 2011 and affected an area of approximately 22.5 ha. The burned area was located near Vilnius, Lithuania at 54° 42′ N, 25° 08′ E with an elevation of 158 m a.s.l. (above sea level). The fire was anthropogenic, as a consequence of burning wood residues and grass. The soil is classified as an Albeluvisol (WRB, 2014) with a silt loam texture. The vegetation was mainly composed of fall dandelion (*Leontodon autumnalis* L.) and sweet vernal grass (*Anthoxanthum odoratum* L.). Mean annual temperature is 8.8 °C and total annual rainfall is 735 mm (Pereira et al., 2014a). Four days after the fire we selected flat burned and unburned areas with the same topographical characteristics and established a plot of 400 m^2 (20 × 20 m, with a grid with 5 m spacing between sampling points) in each of the two areas. We collected 25 individual samples of mineral soil (0–5 cm depth, single sample) on each of five different sampling dates at the same gridpoints 0, 2, 5, 7 and 9 months after the fire. We sampled at 5 cm depth in order to identify the direct and indirect impacts of fire on the first 5 cm of the soil, as used in previous works (Francos et al., 2016). The ash layer was removed prior to sampling. Two months after the fire the ash layer was