Geoderma 213 (2014) 95–102

Contents lists available at ScienceDirect

Geoderma

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

Soil microbial activity in response to fire severity in Zagros oak (*Quercus brantii* Lindl.) forests, Iran, after one year

Morteza Pourreza [a], Seyed Mohsen Hosseini [a,*], Ali Akbar Safari Sinegani [b], Mohammad Matinizadeh [c], Warren A. Dick [d]

[a] Faculty of Natural resources and Marine Sciences, Tarbiat Modares University, Iran
[b] Soil Science Department, Bu-Ali Sina University, Iran
[c] Research Institute of Forest and Rangelands, Iran
[d] School of Environment and Natural Resources, The Ohio State University, USA

ARTICLE INFO

Article history:
Received 10 December 2012
Received in revised form 13 July 2013
Accepted 18 July 2013
Available online 7 September 2013

Keywords:
Fire severity
Zagros forests
Soil enzyme
Soil respiration
Oak sprout clumps

ABSTRACT

The Zagros forest ecosystem is being threatened by increasing number of forest fires. These forests are generally in coppice form and oak sprout clumps occupy forest area like patches. We examined some microbial and physical–chemical properties of burned soil to understand the response of soil microbial activity to different fire severities one year after burning. Soil collected from areas subjected to different fire severities was visually classified as: unburned-inside of sprout clumps (UI), unburned-outside of sprout clumps (UO), burned with low severity-outside of sprout clumps (BLO), burned with moderate severity-inside of sprout clumps (BMI), and burned with high severity-inside of sprout clumps (BHI). Increases in soil pH and available P and decreases in soil N and C/N ratio occurred only at BHI. SOC decreased in BHI and BMI compared to UI but no change was observed in BLO compared to UO. The areas subjected to high severity burn contained the most bacterial and the least fungal colony forming units (CFUs). Basal respiration decreased in BMI and BHI while substrate-induced respiration (SIR), and alkaline and acid phosphatase activities were only decreased in BHI compared UI. Discriminate analysis showed that the linear combination of acid and alkaline phosphatase activity, fungal CFUs, and SIR were respectively the most effective variables to differentiate the treatments. We concluded that acid and alkaline phosphatase activities can efficiently represent the degree of fire impact on soil even one year after fire.

1. Introduction

Wildfires are one of the key factors that affect forest ecosystem functions (Barreiro et al., 2010; Hebel et al., 2009). Fire can alter a wide range of physical, chemical, mineralogical and biological soil properties depending on their severity (Certini, 2005). Fire severity is highly dependent upon the interaction of fire intensity and duration, heterogeneity of fuel load and its combustibility, combustion type, vegetation type, climate, topography and soil characteristic (Neary et al., 1999). Fire severity is generally classified as low, moderate and high severity (Bento-Gonçalves et al., 2012; Neary et al., 1999).

Fire severity is an accepted term for describing the ecological effects of a specific fire that describes the degree of change in ecosystem components (DeBano et al., 1998; Keeley, 2009; Neary et al., 2005). These changes are generally measured by visual indicators corresponding both soil and vegetation characteristics immediately after fire (Ryan, 2002; Ryan and Noste, 1985). Many indicators have been used in different ecosystems such as forests, shrublands, and grasslands (Parsons et al., 2010; Ryan, 2002; Ryan and Noste, 1985) indicating that measuring fire severity is highly dependent upon the type of ecosystem.

Soil biological and biochemical characteristics are important indicators that have been widely used to determine soil quality and ecological disturbance (Li and Chen, 2004; Martinez-Salgado et al., 2010). For example, microorganisms are involved in the long-term sustainability of soil ecosystems and plant growth by controlling the cycling of nutrients via decomposition, mineralization, and immobilization processes (Fontúrbel et al., 2012; Liu et al., 2010; Ovreas, 2000; van Elsas and Trevors, 1997).

Fire can have short-term and long-term effects on soil microbial activity in forest ecosystems by either directly affecting the mortality of microorganisms or indirectly by altering soil environmental conditions and nutrient availability (Giovannini and Lucchesi, 1997; Granged et al., 2011; Hart et al., 2005; Johnson et al., 2004; Sun et al., 2011). The surface soil can be sterilized directly by fire and some groups of microorganisms are more sensitive to fire than others. Bacteria that are below the soil surface are potentially more protected from fire, and they will often recover more rapidly after fire than fungi (Bárcenas-

* Corresponding author at: Department of Forestry, Faculty of Natural Resources and Marine Sciences, Tarbiat Modares University, Emam Reza Ave., Noor, Mazandaran, Iran, P.O. Box: 14115-335. Tel.: +98 9111213898; fax: +98 91226253499.
E-mail address: Hosseini@modares.ac.ir (S.M. Hosseini).

0016-7061/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.geoderma.2013.07.024

Moreno and Bååth, 2009; Pendy et al., 2011). Bacteria, compared to fungi, also favour higher pH induced by fire (Rousk et al., 2010).

Soil microbial activity is usually estimated via measuring soil respiration rate and enzymatic activity. How microorganisms are involved in stabilizing of soil structure, decomposition of organic matter, and nutrient cycling is related to the activity of soil enzymes (Ebersberger et al., 2003; Kandeler et al., 2006; Martinez-Salgado et al., 2010). Soil enzymes also have close relationships with soil physical–chemical conditions, thus making them good indicators of soil quality and functions (Baum et al., 2003; Chen et al., 2003; Dick et al., 2000; Finkenbein et al., 2013; Sardans et al., 2006).

Phosphatases are a group of enzymes that are involved in catalyzing and hydrolyzing esters and anhydrides of phosphoric acid (Dick and Tabatabai, 1992), and play key roles in sustaining the soil system after disturbances (Dick et al., 2000; Nannipieri et al., 1983). Many phosphatase enzymes are extracellular and the acid phosphatases are produced, and then secreted, into the soil by both microorganisms and plants (Dick and Tabatabai, 1992). Hence acid phosphatase activity is often used as an indicator of overall microbial activity and closely correlated with microbial biomass (Boerner and Brinkman, 2003; Dick and Tabatabai, 1983; Lagerström et al., 2009).

The activity of phosphatase enzymes is also closely correlated with available P (Eivazi and Tabatabai, 1977; Safari Sinegani and Sharifi, 2007; Tadano et al., 2007). Phosphorous is generally considered non-combustible and fire can liberate available P from soil organic matter so that it can accumulate in surface soils (Bárcenas-Moreno et al., 2011; Prokushkin and Tokareva, 2007; Shukla and Varma, 2010) although P volatilization can occur in temperature more than 700 °C (Neary et al., 2005; Raison et al., 1985). There are various studies concerning the fire effect on soil enzymes (Boerner et al., 2000; Eivazi and Bayan, 1996; Fontúrbel et al., 2012; Giai and Boerner, 2007; Hamman et al., 2008; Saa et al., 1993), but little is known about the response of phosphatases to different fire severities although, Vega et al. (2012) tested the ability of visual indicators of soil burn severity by some chemical and microbial properties in pine forests and shrubland. Their results showed that acid phosphatase activity is one of the most effective variables to discriminate the level of soil burn severity.

This present study investigated the response of microbial activity to fire severity in Zagros forests. However, fire is a worldwide issue and knowledge about fire effects in this forest has application to other ecosystems (Bento-Gonçalves et al., 2012). The ecosystem of Zagros forests ranges from the northwest to the southeast of Iran and is classified as a semi-arid forest (Sagheb-Talebi et al., 2004). Oak (*Quercus brantii*) is the main tree species in Zagros forest and is also a widely distributed oak species in other Middle East countries (Iran, Turkey, Iraq, Syria and Lebonan). The Zagros forest has been subjected to drastic disturbances, such as fire, leading to a significant decrease in cover. During the recent decade, increasing reports of fire in Zagros region (Mohammadi et al., 2011; Pourreza et al., 2009) has been attributed to ongoing global climate changes (Bento-Gonçalves et al., 2012; Tavsanoglu and Úbeda, 2011).

Although there are numerous reports about the effect of fire on soil microbial activity in various ecosystems, several gaps in our knowledge remain. There is little information about (1) the effect of fire severity on soil biochemical and biological properties in oak forests and, (2) the assessment of the forest ecosystem response to fire severity is often not possible to extrapolate from one region of the world to another (Bárcenas-Moreno and Bååth, 2009). We therefore studied microbial activities in soil after different burning severities occurred in a *Quercus brantii* stand located in the Zagros Forest (Iran) to determine how soil microbial and biochemical properties respond to fire severity one year after burning. Since microbial activity can represent the interaction among soil physical–chemical, microbial and vegetation properties (Rodríguez-Loinaz et al., 2008), we hypothesized that microbial activity can properly differentiate soils that have experienced different burning severities one year after fire.

2. Materials and methods

2.1. Study area and site selection

The study area is located in Ravansar, Kermanshah Province, Iran with latitude 34° 51′ 50″ and longitude 46° 31′ 02″ (Fig. 1). The climate of the study site is Mediterranean according to Demarton's classification with average annual precipitation about 600 mm. The mean annual temperature is 14.9 °C (August: 29.3 °C and January: 1.8 °C). The soil texture is generally sandy clay loam. The soil of the Zagros Mountains in this region is also generally calcareous (Jazirehi and Ebrahimi, 2003). The area is covered mainly by *Q. brantii* Lindl. with coppice form of oak sprout clumps occupying patches over the forest surface. More than 100 ha of this forest was burned in early September 2010. The forest surface was completely burned but fire severity was different as a result of the heterogeneity and spatial pattern of fuel inside and outside of sprout clumps. Taking advantages of an unburned area adjacent to the burned area helped to compare soil characteristics in burned and unburned areas. The unburned area (25 ha) was adjacent to the burned area and separated by a valley. Both sites are located along a hillside with north-west geographical aspect, with the same slope (45%), elevation (1700–1820 m above sea level), soil properties and vegetation covers. In our study area fire was not reported for at least 1 decade but the oak trees had been frequently cut by the local people, resulting in a coppice form of oak trees.

2.2. Experimental design and choosing treatments

In both burned and unburned area three parallel transects were established along the hillside slope with 100 m distance from each other (Fig. 2). We considered five treatments namely: (1) unburned-

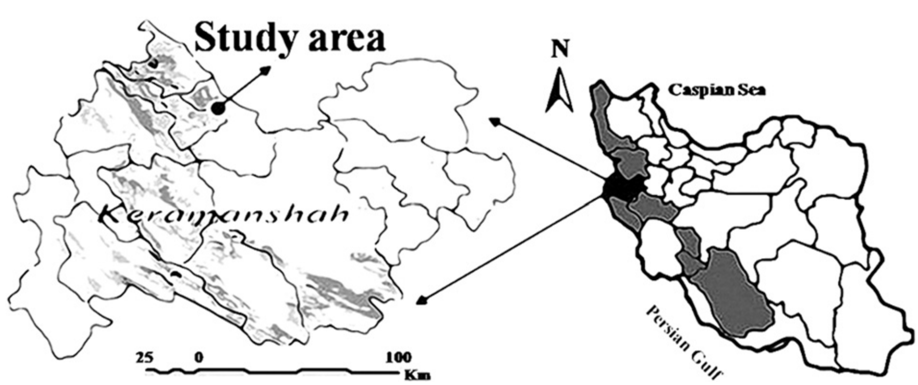

Fig. 1. The location of study area (●) in Zagros region (■) in the western Iran.