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Effects of surface fire on soil properties in a mixed chestnut-beech-pine forest in Turkey

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Abstract

Soil properties after low-intensity surface fires have relatively less studied in comparison to moderate to high-intensity crown fires. A mixed forest stand dominated by Castanea sativa (sweet chestnut), Fagus orientalis (oriental beech) and Pinus nigra ssp. pallasiana (Anatolian black pine), which had been burnt by a surface fire in December 2011 near Bursa, Turkey was studied. Soil samples were taken from two depths as 0-15 and 15-30 cm respectively, from burned and unburned (control) sites after a week after fire and seven months later in July 2012. The samples were analysed to determine a series of soil chemical (electrical conductivity, pH, total nitrogen, available phosphorus and organic matter content) physical (soil texture) and biochemical characteristics (β-Glycosidase and phosphatase enzyme activities). We tested the effect of fire, soil depth and season on each variable by three-way ANOVA analysis. The results indicated that soil nitrogen and organic matter were not affected by fire, while soil depth and sampling season had significant effects on these variables. Electrical conductivity was higher in the soil surface than in deeper layers, but not affected by fire. Fire resulted in a significant increase in soil pH and decrease in phosphorus, and those variables have not recovered by seven months after fire. Soil biological properties did not significantly change after fire, but season was significant effect on the enzyme activities. Soil physical components were slightly changed after fire, by which resulted in higher sand (%), lower silt (%) and lower clay (%) in the burned sites. However, these changes were not affected the coarse-textured structure of the soil (sandy loam). Overall, present results pointed out that soil chemical, physical and biological properties do not considerably change after surface fires in the studied mixed forest, except a few variables. In conclusion, we found that surface fires have limited effect on soil properties. This study contributes to our insights on the fire effects on soil properties in surface-fire ecosystems.

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1 INTRODUCTION

Understanding the effect of fire on soil properties is an important issue for a better soil management through the recovery dynamics under burnt forests ecosystems. Surface fires are expected to cause fewer changes in soil properties since the highest temperature reached in the soil is lower than in a crown fire which high amount of heat released during the burning of the vegetation (Campbell et al., 1995). However, the status of soil properties after low-intensity surface fires has relatively less studied in comparison to moderate to high-intensity crown fires (Certini, 2005).

The aim of the present study was to evaluate the effect of a surface fire on a mixed forest ecosystem in Bursa, western Anatolia, Turkey. We hypothesised that surface fire should affect soil chemical and biological properties, but the changes in those parameters might be recovered in a short time after fire.

2 METHODS

A low severity surface fire burned the mixed forest stand dominated by *Castanea sativa* Miller (sweet chestnut), *Fagus orientalis* Lipsky (oriental beech) and *Pinus nigra* Arnold ssp. *pallasiana* (Lamb.) Holmboe. (Anatolian black

Table 1. The summary of three-way ANOVAs on the effect of fire, season and soil depth on soil physical, chemical and biological properties. F values are shown for each factor for each analysis, and statistical significance of each factor in the model is given (ns, not significant; * P < 0.05; ** P < 0.01; *** P < 0.001, **** P < 0.0001, and † <0.1)

	Factor			
Variable	**Fire**	**Season**	**Soil depth**	**Fire*Season**
Soil chemical properties				
pH	11.0 **	1.0	1.3	1.0
EC	2.6	2.8	15.2 ***	4.5 *
Organic matter	2.4	27.5 ****	23.2 ****	0.5
N	0.1	8.2 **	15.2 ***	0.2
P	5.6 *	5.0*	3.2 †	0.0
Soil biological properties				
β-Glycosidase	0.8	2.5	15.6 ***	0.4
Phosphatase	0.0	19.4 ***	0.9	0.6
Soil physical properties				
Sand (%)	16.6 ***	0.4	5.9 *	5.2 *
Silt (%)	7.2 *	0.2	0.1	3.4 †
Clay (%)	14.9 ***	14.3 ***	21.1 ***	2.0

pine) in December 2011 near Uludağ, Bursa, Turkey (40°09’27’’ N, 29°10’01’’ E, 630-870 m). According to the data from Turkish State Meteorological Service (1970-2011), the area has a sub-Mediterranean climate with a dry period lasts for three months. Annual total precipitation is 696 mm and annual mean temperature is 14.6 °C. The study area was located on non-calcareous volcanic substrates.

A total of 32 soil samples were taken from two depths as 0-15 and 15-30 cm respectively from burned and unburned (control) sites after a week after fire and seven months later in July 2012. The samples were analysed to determine a series of soil chemical (electrical conductivity, pH, total nitrogen, available phosphorus and organic matter content) physical (soil texture) and biochemical characteristics (β-Glycosidase and phosphatase enzyme activities). Soil pH was determined in a 1:2.5 soil/water (v/v) ratio (Jackson, 1969). Coarse, fine, and total sand, silt, and clay contents were determined by the Bouyoucos hydrometer method (Bouyoucos, 1962). Organic material was measured by Walkley-Black (Jackson, 1969), available phosphorus was determined according to the method of Bray-Kurtz (Ülgen & Ateşalp, 1972), total N content was determined by Kjeldahl digestion by the Kjeltec (Tecator) Auto 1030 Analyzer (Jackson, 1969), and water content was determined gravimetrically after the soil was oven-dried for 24 h at 105°C. Acid phosphatase and β-glycosidase activities were determined using 1.5 g of soil on a field-moist basis according to Dick & Tabatabai (1992).

Although the main question of the study was related to the fire effects, we included three factors to our study to see the effects of soil depth and season on the variables besides fire. Therefore, we tested the effect of fire, soil depth and season on each variable by three-way ANOVA analysis. All analyses were conducted on log-transformed data and normality and homoscedasticity were checked prior to each analysis.

3 RESULTS AND DISCUSSION

The results indicated that soil nitrogen and organic matter content were not significantly affected by fire, while soil depth and sampling season had significant effects on these variables (Table 1). Electrical conductivity was higher in the soil surface than in deeper layers, but seemed not affected by fire. Fire resulted in a significant increase in soil pH and decrease in phosphorus, and those variables have not recovered by seven months after fire. Soil biological properties did not significantly change after fire, but season was significant effect on Phosphatase enzyme activity, and soil depth on β-Glycosidase. Soil physical components were slightly changed after fire, by which resulted in higher sand (%), lower silt (%) and lower clay (%) in the burned sites. Although these changes were

statistically significant, the coarse-textured structure of the soil (sandy loam) was not affected from the slight changes in sand, slit and clay proportions.

Overall, present results pointed out that chemical, physical, and biological properties of the soil do not considerably change after surface fires in the studied mixed forest. The changes in our observations were most probably due to the effect of the season. Moreover, soil depth was also an effect in most of the variables. However, we found a significant increase in soil pH as result of fire. Soil reaction was reported to shift back to its actual level within few years after fire (Trabaud, 1983; Durán et al., 2008), but it was not the case in this study. It seems that even in the case of low intensity surface fire, more than seven months is needed to observe such a return in soil pH level. Soil phosphorus level was also affected by fire, in which resulted in decrease after fire. Phosphorus in organic matter may have been lost in gas form or released as barely soluble phosphate salts during fire (Fisher & Binkley, 2000).

It should be noted that the insignificant results in soil properties those we expected changes in the soil surface after fire might appeared due to the sampling design of our study that consider the first 0-15 cm of the soil as "surface". A further separation of the surface soils to increase the resolution of data, as e.g. 0-5 and 5-10 cm, might have showed a significant change in soil properties in the most surface layers of the soil (Prieto-Fernandez et al., 1993). The slight, but significant post-fire changes in soil physical components are hard to explain since soil physical properties do not change after fire unless a high-severity fire occurs (Terefe et al., 2008). However, the texture of the soil was the same in both burned and control sites, therefore we conclude that soil physical properties did not considerably change after fire.

4 Conclusions

In conclusion, we found that surface fires have limited effect on soil properties. This study emphasizes the importance of fire severity on forest soils, and contributes to our insights on the fire effects on soil properties in surface-fire ecosystems. The study has a few implications to management in surface-fire ecosystems such as mixed forests in our study area. First, since soil properties do not considerably change after fire in these ecosystems, the management decisions should not include any human intervention to the burned forest floor. Second, prescribed fires can be effectively used without any damage to soil in these ecosystems to allow natural regeneration of dominated tree species or to reduce fire risk by limiting fuel accumulation.

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