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Effect of Forest Fire on Some Physical, Chemical and Biological Properties of Soil in Çanakkale, Turkey

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ABSTRACT

This study was conducted in burned and un-burned forest area in around Lapseki town in Canakkale Province, Turkey in 2002. The objective of this study was to investigate the effect of the forset fire on physical, chemical and biological soil properties two weeks after the fire. According to the results, the mean soil organic carbon value was 7.14% for burned and 7.74% for un-burned soils, total organic nitrogen value was 0.57% and 0.44% ($P < 0.001$), urease activity was 26.95 mg kg^{-1} 2 h^{-1} and 171.97 mg kg^{-1} 2 h^{-1} ($P < 0.05$), electrical conductivity (EC) was 576.67 (μmhos cm^{-1}) and 189.67(μmhos cm^{-1}) ($P < 0.001$), total porosity value was 48.52% and 53.44% ($P < 0.001$), available P (mg kg^{-1}) were 51.74 and 18.52 ($P < 0.01$), available K (mg kg^{-1}) were 194.15 and 167.05 ($P < 0.01$), and hydraulic conductivity (cm h^{-1}) values were 5.47(cm h^{-1}) and 10.50 (cm h^{-1}) for burned and un-burned soil samples, respectively. As a conclusion, the fire after two weeks increased soil pH, EC, available P and K, organic N content; reduced CEC, porosity, Ksat, urease activity, TOC and soil water content.

Key Words: soil; Forest fire; Organic carbon; Total organic nitrogen; Total porosity

INTRODUCTION

Wildfires are one of the most widespread factors responsible for ecosystem degradation around the world, by destroying the vegetation cover and increasing nutrient and soil losses by leaching and erosion (Chandler *et al*., 1983). Especially in the Mediterranean basin fire is considered the main disturbance (Trabaud, 1984; Naveh, 1990; Barbero *et al.*, 1998; Ekinci & Kavdir, 2005) and can change soil quality. Fires greatly alter the physical characteristics of soils. For example, during burning, plant cover and litter layers are consumed, and mineral soil is heated. It is resulted in changes of soil bulk density, porosity, texture, color, moisture content, and permeability (Wells *et al*., 1979). Recovery of soil health is very low after soil fire. Choromanska and DeLuca (2001) reported that C and N mineralization decreased after fire and did not recover after 9 months of study period. The quantity and the composition of soil microbial biomass are particularly sensitive to changes in the soil environment.

Previous studies have demonstrated that soil bio-chemical parameters such as soil enzyme activities are sensitive indicators of stress so it can be used as a measure of the health and sustainability of managed ecosystems (Dick & Tabatabai, 1992; Dick, 1994; Bergstrom *et al*., 1998). Fire may also influence soil aggregate stability due to consumption of SOC and changing soil organic matter constituents (Kavdir *et al*., 2005). Soil aggregate stability is mostly influenced by texture, by the presence of humified organic material and particularly by the most stable carbon fraction (Oades, 1984). In the short term, fire causes reduction in soil microbial bio-mass (Prieto-Fernandez *et al*., 1998). Also after a fire there is an increase of available nutrients in soil, mainly in the form of water-soluble components of ash (Pyne, 2001). Part of this effect derives from an increase in soil pH due to an increase in exchangeable cations in soil (Raison, 1979).

The aim of this study was to investigate the effects of forest low-medium fire that occured two week before soil sampling on some physical, chemical and biological soil quality parameters in Lapseki region of Canakkale Province, Turkey.

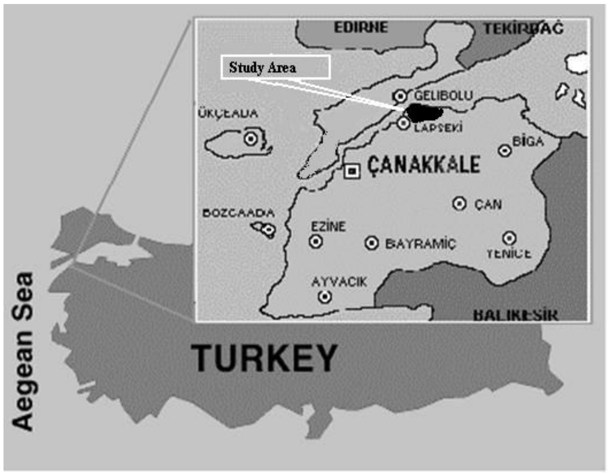
MATERIALS AND METHODS

Site description. The study region was located between Lapseki-Biga in Çanakkale (latitude 40°22'30" N–longtitude 26°52'30" E) in of (Fig. 1). Study site has Mediterranean type climate with an annual average rainfall of 650-700 mm and average temperature of 14.5°C, and climatically, the area has hot dry summers and cool rainy winters.

Mean monthly temperature ranges from 25 to 35°C in summer. Dominant soils are Xerorthents in the study region. Dominant parent materials in the fire area are sand stones and schists. Research site stands were 5–25 years. The some major plant species included *Spartium junceum, Quercus spp., Pistacia spp.* and *Pinus spp***.** Fire type was low-medium intensity (250-450°C) fires occurrence interval is average of 25 fires year^{-1}.

Soil sampling. Soil samples were collected from both burned and un-burned sites. Sampling points were collected from areas where physiographical, topographical properties, parent material and plant cover were similar. From each replication point, three samples were taken. Each of three

Fig. 1. Location of study area



samples in a replication was 1 m apart from each other. Burned and un-burned sites were approximately 20–30 m apart from each other depending on the site. Both un-disturbed core and disturbed samples were collected from 0–5 cm soil depth after removing litter on the soil surface carefully. Some of the samples were kept in a cooler at 4°C for microbial biomass, urease activity and nitrogen analysis. The remaining parts of the samples were air-dried. Comparison was made between burned forest floors and un-burned nearby area.

Laboratory analysis. Soil pH, EC and cation exchange capacity (CEC), using the methods described in Soil Survey Staff (1996). Soil bulk density was determined by the un-disturbed soil core method (Blake & Hartge, 1986). Soil texture was determined in soil after removing the OM and Fe-oxides with 3.3 g H_2O_2 l^{-1} and oxalate solution (0.1 M) at room temperature by hydrometer method (Ge & Bauder, 1986). Porosity was calculated from bulk density assuming a particle density of 2.65 g cm^{-3} (Danielson & Sutherland, 1986). Saturated hydraulic conductivities of soil samples were determined in un-disturbed soil cores under constant level water head as described by Klute and Dirksen (1986). Water content measurements were made gravimetrically on samples taken from the A horizon at the 0–5 cm depth (Gardner, 1986).

Total organic N was determined by steam distillation by Kjeldahl automatic analyzer using the Bremner method (Bremner, 1996). Soil organic C was analyzed using the dichromate oxidation technique (Nelson & Sommers, 1996). Microbial biomass carbon of soil samples was determined by using chloroform fumigation method (Horwath & Paul, 1994). Air-dried soil samples were extracted by using Mechlich I solution. Extractable phosphorus (P) and potassium (K) were determined from this extracts by using ICP-AES. Urease activity was determined according to method described by Tabatabai (1994).

Statistical analysis. Data were analyzed according to Proc-GLM with the Statistical Analysis System (SAS) (SAS Institute, 1997). Mean seperation was carried out using LSD test at 0.05 significance level. Experimental design was complete randomized block. When the data were shown abnormal distrubition the data were transformed to log.

RESULTS AND DISCUSSION

The results of variance analysis for parameters measured in burned and un-burned soils are presented in Table I. Table II shows the means of the selected physical and chemical properties of soils collected from the area.

The results showed that pH, electrical conductivity (EC), organic nitrogen, bulk density, avaible potassium and phosphorus values in soil samples obtained from burned areas were higher than those of un-burned areas. Hydraulic conductivity (Ksat), total porozite, soil water (%), cation exchange capacity (CEC), urease activity and soil organic carbon (SOC) were found to be higher in un-burned areas comparing burned areas. Un-like, soil microbial bio-mass did not change before and after fire.

Total organic carbon (TOC). As it is seen from the Table II, negative effects of forest fire on surface soil carbon contents were observed two weeks after the fire. Differences in the burned and un-burned soils for C content were not significant. Organic C content of burned soil (7.14%) were less than that of un-burned soil (7.74%). The main reason of carbon loss from the burned soil was volatilization of organic carbon and conversion of organic matter to ash (Boerner, 1982; Raison *et al*., 1985).

Organic carbon losses were higher than 50% in the upper 10 cm of a Humic Cambisol under pine forest have been reported after a wildfire (Fernandez *et al*., 1997). Lower C content was found in soils affected by prescribed fire and higher soil C content following wildfire. The latter is attributed to the accumulation of charcoal and recalcitrant hydrophobic OM and to the encroachment of post-fire N-fixing vegetation.

Total organic nitrogen. The effect of forest fires on N availability is important because N availability is one of the most common limiting factors to forest productivity worldwide (Fisher & Binkley, 2000). Organic N contents of both burned and un-burned soils are presented in Table II. Organic N contents of burned soils (0.57%) were found to be higher than un-burned (0.44%) and this difference was significant ($P < 0.001$). The samples taken from Lapseki region two weeks after forest fire had an average of 2500 kg ha^{-1} more N than the samples from un-burned areas. This could be attributed to increases in the bacteria species fixing nitrogen as a result of an increase in mineralization in a short period after forest fire. So this resulted in more nitorgen in the soil. This finding was also confirmed by Rundell (1983) and Kutiel *et al*. (1993). They stated that N losses can occure during fire period via volatilasition and after fire there could be an increase in biological N fixatition as a result of increasing mineralisation rate in the soil. As

Table I. Analysis of variance of different soil properties

Soil parameters	*Mean Squares*		
	Fire (df: 1)	**Replication (df: 2)**	**Error (df: 2)**
EC	224.653.50***	4778.67	152.00
pH	0.32	0.07	0.04
Urease activity[1]	10.88*	0.20	0.58
Organic N	0.03***	0.00	0.00
Microbial biomass carbon	0.00	0.19	0.15
Soil organic carbon	0.53	0.48	0.50
Available P	1655.02**	80.13	14.83
Available K	1103.34*	71.58	414.83
Cation exchange capacity	39.53	6.92	11.08
Total porosity	36.41***	0.26	0.02
Hydraulic conductivity	37.95*	0.48	1.59
Soil bulk density	0.01	0.02	0.00
Soil water content	7.04	1.06	3.68

* and *** : significant at 0.05 and 0.01 and 0.001 respectively.

[1]: The data were transformed to log.

Table II. Mean values of physical, chemical and biological properties of burned and unburned forest soil

Soil parameters	*Burned*	*Unburned*	*$LSD_{0.05}$*
EC (□mhos cm^{-1})	576.67a	189.67b	43.31
PH (1:2.5 water:soil)	5.88	5.41	
Organic nitrogen (%)	0.57a	0.44b	0.02
Microbial biomass carbon (mg C g $soil^{-1}$)	2.00	2.00	2.00
Urease activity (mg $kg^{-1}2h^{-1}$)*	2.28b	4.97a	2.67
Soil organic carbon (%)	7.14	7.74	
Available P(mg kg^{-1})	51.74a	18.52b	13.53
Available K(mg kg^{-1})	194.15a	167.05b	18.37
Cation exchange capacity (cmol kg^{-1})	20.13	25.27	
Total porosity %	48.52b	53.44a	0.51
Bulk density (g cm^{-3})	1.31	1.22	
Hydraulic conductivity (cm h^{-1})	5.47b	10.50a	4.43
Soil water content (%)	1.93	4.10	

* The data were transfored to log.

Lapseki fire was low-medium intensity fire, it led to formation of charcoal and partial burned organic matters, was remained Johnson (1992) also pointed out that increase in N and C concentrations in upper soil was a direct result of forest fire and amount of N fixing bacteria increased after the fire.

In this study ammoniun-N content of the burned soil was 188 mg kg^{-1} and it was 144 mg kg^{-1} in the un-burned soil. Depending on the ecosystem, the frequency and severity of fire, etc. increase, decrease or non-variation in total soil N content have been reported; on the other hand, most authors found an increase in the ammoniacal N content immediately after burning, which is maintained for several months or, in some cases, is followed by an increase in the nitrate content (Raison, 1979; Neary *et al*., 1999; Johnson & Curtis, 2001).

Other alterations like a reduction in the urease and protease activities have also been described (Hernández *et al*., 1997). It has been shown that, after soil burning or heating, the soil NH_4^+-N concentration increased (DeBano *et al*., 1979; Prieto-Fernandez *et al*., 2004). Castro *et al*. (2005) reported that soil burning reduced the soil organic N reserves, through N volatilization and decreased N bio-availability, through an important net transfer of N from the labile to the recalcitrant pool; jointly, both processes will increase the negative effects of wildfires on the N cycle.

Microbial biomass carbon (MBC). Soil microbial diversity and bio-mass are very important properties in terms of soil health. Because, there are close relationships among microbial diversity, soil and plant quality and ecosystem sustainability. In this research MBC values of burned and un-burned soils remained un-changed.

Urease activity. The difference between burned and un-burned soils in terms of urease activity was found to be significant ($P < 0.05$). Urease activitiy of burned soil was lower (26.95 mg $kg^{-1}2h^{-1}$) than un-burned (171.97 mg $kg^{-1}2h^{-1}$) ones (Table I & II).

Soil enzyme activities are positively correlated with nutrient release from organic matter. Enzymes are denatured at temperatures higher than 60ºC and because of the most of the enzymes are lower in burned areas (Blank *et al*., 2003).

Soil biota and soil organic matter content are affected after forest fire (Gonzalez-Perez *et al*., 2004) due to: ash formation, change of soil organic matter composition after fire (Kavdir *et al*., 2005) change of soil characteristics and microflora (vegetation & soil cover change) and sterilization of soil microorganisms. Burning causes a more or less severe heat input into the soil, and this can immediately kill or injure soil microbes (Walstad *et al*., 1990).

PH and electrical conductivity (EC). Soil sampled from burned sites had higher EC and pH values than un-burned control (Table II). Hernández *et al*. (1998) reported that EC values of burnt plots were greater than that of un-burnt plots. Burning of organic matter releases ash and charcoal on the ground. Ash contains the inorganic elements. Base cations such as Ca^{2+}, Mg^{2+} and K^+ in the ash leads to increased pH and EC. A study conducted in Chile showed that fire increased soil pH (Creighton & Santelices, 2003).

Soil pH increases immediately following severe slash or debris burning (Bauhus *et al*., 1993) and its effect typically remains for several years. At Lapseki site soil changes persisted for 2 weeks following fire (Table II). Compared with the un-burnt surface soil (0-5 cm), burned soil had a higher pH value (0.47 units) but it was not significant (Table I).

Available P and K contents. Available soil P values of burned soil were higher than un-burned control after 2 week following fire, and this difference was significant ($P < 0.01$). (Tables I & II).

Especially, amount of organic plant material is higher in the pine forests compared to other forest types (Hernández *et al*., 1997). The change of soil P content generally depends on soil temperature during the fire and tends to increase in burned soils (Marion *et al*., 1991; Kutiel & Shaviv, 1993). DeBano and Conrad (1978) reported that plants and plant residues turn back to the soil as ash following fire. If it is not carried out from soil by wind or run off, it will stand in the soil and increase soil P contents.

In this study, available P concentration was higher in burned soils (51.74 mg kg^{-1}) compared to un-burned control (18.52 mg kg^{-1}) after 2 week following fire.

Available K content of burned plots (194.15 mg kg^{-1}) was higher than that of un-burned soils (167.05 ppm), and it was statistically significant ($P < 0.05$) (Tables I & II). The fire directly affects K and P availability of soil by chemically altering of these elements and indirectly by altering soil temperature, pH, and water flow. De Ronde (1990) reported that K content was significantly higher in burned forests 21 months after fire.

Cation exchange capacity (CEC). In general burning tended to reduce soil CEC values in Lapseki soils but the difference was not significant (Tables I & II). CEC value of burned soil and un-burned soil was 20.13 and 25.27 cmol kg^{-1}, respectively. Fire should not affect the CEC of mineral soils but may change CEC of soils rich with organic carbon, which was also observed in our study area.

Hydraulic conductivity and porosity. Saturated hydraulic conductivity (Ksat) and porosity values of burned soils were highly significantly lower than un-burned control (Tables I & II). The major determining factor of Ksat is the amount of disturbance to the surface material by fire, which is usually organic debris that protects the un-derlying mineral soil Valzano *et al.* (1997) found that Ksat of soils decreased approximately 50% in the burnt plots relative to the adjacent un-burnt plots Dyrness (1963) studied the effects of slash burning, finding that severe burning decreases soil porosity and infiltration capacity thus increasing the potential for soil erosion.

Soil water content. Soil water content of un-burned soil was higher than burned soil but the difference was not significant (Tables I & II). Since vegetations are destroyed by fire, evaporation increases in burned areas during dry and hot season (Creighton & Santelices, 2003). Consequently soil water content decreases. Another reason of lower soil water content in burned soil was low Ksat and infiltration values as it was explained above. In our study un-burned soils had higher water content than burned soils two week after the fire.

CONCLUSION

After forest fire, alterations in the soil take a long period and the forest fire is known having a complex dynamics more than as seen. Prescribed and regular fires can eliminate un-desirable vegetation from the land and reestablished desired vegetation especially in rangelands. However wildfires negatively influence soil biological properties, disturb surface cover, increase surface run-off and erosion and degrade soil ecosystems. In this study, influences of low-medium intensity forest fire occurred in 2002 on some soil characteristics were investigated. As a conclusion, the fire after two weeks increased soil pH, EC, available P and K, organic N content; reduced CEC, porosity, Ksat, urease activity, TOC and soil water content. This study showed that the forest fires do not only cause air pollution but also cause losses in soil properties.

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