Midterm results of different intensity prescribed fires on soil microbial biomass in black pine stands

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Abstract: Soil microbial biomass (SMB) is a sensitive indicator of soil quality and has a fundamental key role in biochemical soil processes. This study was done in areas applied high and moderate intensity ground fires and adjacent control areas in old Black Pine forest stands at Kunduz series in Osmancık Forest Sub-District Directorate (Vezirköprü/SAMSUN). Soil samples were taken from 0-10 cm layers of soil, in December'13 (one month after burning), in April'15 and in July'15. Chloroform-fumigation-extraction method was used to determine the microbial biomass C and microbial biomass N (MBC and MBN). MBC and MBN values were changed between 50,69 µg g-1 – 69,91 µg g-1 and 15,70 µg g-1 – 154,79 µg g-1, respectively. SMB values were significantly lower in burned plots especially in low intensity fire plots than in control plots one month after fire and after a year approximated to control values. But again, SMB values were significantly lower in burned plots in summer period of that year. Within midterm, low intensity fire had more significant negative effect on SMB. When increase of availability of substrate considered, recovery of SMB is expected within long-term.
Keywords: Soil microbial biomass, Prescribed fire, Fire intensity, Black pine

1. Introduction

Fire has a critical role in ecosystem as devastating or beneficially. Fire in forest ecosystem, via destroying the vegetation leads to erosion and nutrient losses is unwanted (Fernandez et al., 2007). On the other hand, related to change in soil organic matter and pH after fire, amount and activity of soil microorganisms are effected directly or indirectly. Substantially nutrient is released with combustion of organic material and source for plant and microorganisms comes out. Mineral ash residue effects soil pH and so related to decomposition and nutrient turnover microbial activity is affected (Kauffman et al., 1992). Therefore, fire is an event has both positive or negative and neutral influence on forest soil and especially on soil microbiota.

Soil productivity and nutrient cycle are effected by number an activity of microorganisms which have key role in sustaining the fertility of soil. (Jenkinson and Ladd, 1981). Also soil microbial biomass acts as an important ecological indicator and responsible from decomposition and mineralization of plant and animal residues (Marinari et al., 2006). Above mentioned effect of fire is fundamentally related to fire intensity and process after fire or postfire conditions. Depending on fire intensity some nutrients are lost as gas form (Menaut et al., 1993) or depending on post-fire weather released nutrients lost in surface flow (Cerda, 1998; Meyer and Wells, 1997; Marxer, 1997) and by leaching (Korsman and Segerstrom, 1998). But an increase of microbial biomass could diminish the nutrient loses (Wüthrich et al. 2002). Also effect of fire on each fungi and bacteria groups which takes a short time or many years is related to fire intensity too (Mataix-Solera, 2009). Such an increase of soil pH and availability of nutrients which stimulates plant growth and microbial activity (Bara and Vega 1993; Korsman and Segerstrom, 1998) are positive conditions. Although fire may kill soil microbial biomass, it is considered as a restoration treatment and is a part of abiotic factors. So, as well as fire intensity, recolonization of microbial biomass occurs depending on change in soil, recovery of vegetation and postfire weather conditions (Mataix-Solera, 2009).

In this study, we investigated the effect of different intensity fire on soil microbial biomass (SMB) and correlation of SMB with other soil properties and soil respiration in black pine forests. For this purpose, at different intensity prescribed burning treatments were applied at Black pine stands in central Black sea region, Turkey.

2. Material and methods

2.1. Study area

The study area is located at county of Vezirköprü in city of Samsun in Turkey. Test sites were chosen from Kunduz serials with in boundaries of Osmancık forest sub-district directorate connected to forestry operation directorate of Corum and were determined from some black pine stands. Black pine stands in study sites are two over-storied (5-15 and 80 aged). The sites are North-west aspected, and at 1250 m elevation. Slope degree of areas was 5-10%.

Study area remains at Black sea transition zone (Between continental and temperate). Yearly mean precipitation is 527mm and yearly mean temperature is 11.4°C and relative humidity is 68% in study area.

2.2. Field studies

At test sites prescribed burning was applied as ground fire. Burning treatment was done at two different fire intensity; one is low fire intensity (LIF) plot and the other one is medium intensity fire (MIF) plot. Control plots were chosen adjacent to burned plots. Soil samples were taken from 0-10 cm soil layer in December'13 (one month after fire), April'15 and July'15.

2.3. Laboratory studies

Soil samples were air-dried for chemical and physical soil analyses and passed through a 2 mm mesh-sized sieve. Organic matter contents of the soils were determined according to the wet digestion method described by Kalra and Maynard (1991) (modified Walkley-Black method). Soil texture was determined by Bouyoucos` Hydrometer Method described by Gülçur (1974). Soil pH was determined by a combination glass-electrode in H_2O (soil-solution ratio 1: 2.5) (Kalra and Maynard, 1991).

Soil microbial biomass Carbon (MBC) was estimated by extracting 30g oven-dry equivalents of field-moist mineral soil samples in 0.5 M K_2SO_4 (1:4 w/v) by the chloroform-fumigation-extraction method described by Brookes et al. (1985) and Vance et al. (1987). MBC was calculated from the difference in extractable organic C between fumigated and unfumigated soil samples as follows: biomass C = 2.64 EC, where EC refers to the difference in extractable organic C between the fumigated and unfumigated treatments; 2.64 is the proportionality factor for biomass C released by fumigation extraction (Vance et al., 1987).

The Kjeldahl digestion–distillation–titration method was used to determine the total N in K_2SO_4 (Anderson and Ingram, 1993). Microbial N (MBN) was calculated (Brookes et al., 1985) using the equation:

biomass N = $F_N/0.54$,

where F_N = (total N from fumigated soil) - (total N from unfumigated soil).

Soil respiration was determined with the soda-lime method (Edwards, 1982).

2.4. Statistical analyses

Obtained values were analyzed statically by using SPSS™ 15 packet program. For variation and differences of fire effects and for interrelation of soil characteristics, one-way Anova and Pearson correlation analyses were applied, respectively.

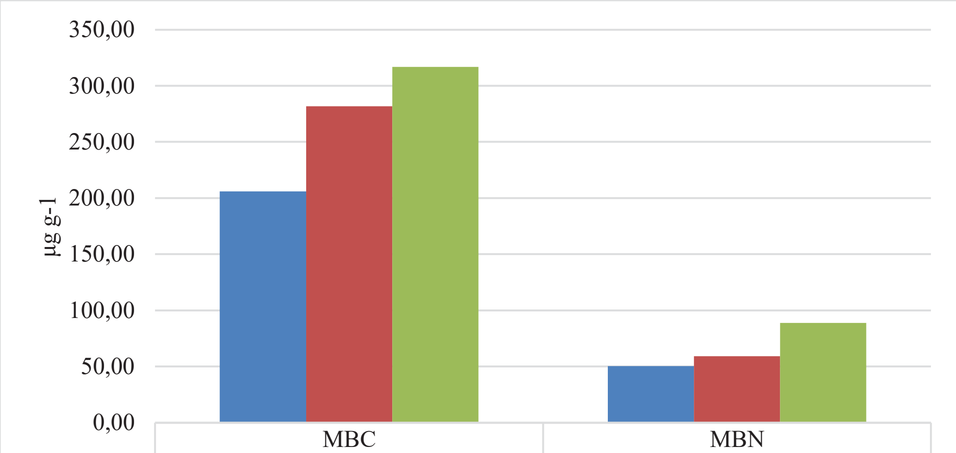
3. Results and discussion

Sand and silt contents values were not significantly different between plots, but only there was a significant difference between clay content values of plots. pH values of plots were not significantly different between plots either in December'13 or in the other terms. Analogous situation was found for soil organic matter (SOM) (Table 1). This situation is unexpected after fire but similarly some studies found fire didn't have significant effect on SOC (Johnson and Curtis, 2001; Wilson et al., 2002; Knoepp et al., 2004; Tüfekçioğlu et al., 2010) and soil pH (Dumontet et al., 1996). Clay contents of burned plots were lower than control values. If the decrease in clay content leaching oriented, pH situation of burned plots may be from same reason. Because burning treatment was done in rainy season and so released ions might be leached or carried by run off from surface soil. Likewise, litter covering of soil was destroyed by fire.

Table 1. Mean values of sand, clay and silt contents, pH and soil organic matter (SOM) rate

Plot	Sand (%)	Clay (%)	Silt (%)	pH	SOM (%)
LIF	69,46	12,99	17,55	5,75	6,90
MIF	65,01	14,91	20,08	5,87	5,48
Control	65,95	16,21	17,85	5,81	6,73

In soils of study area; highest mean value of MBC and MBN content were found in control plots. LIF plot had lowest MBC and MBN values (Figure 1). Results of one-way anova test showed a significant difference between MIF, LIF and control plots by both MBC and MBN values. Also, homogeneity test showed control values were in highest group, LIF values were in lowest group.



	MBC	MBN
LFI	205,92	50,34
MFI	281,92	59,16
Control	316,80	88,92

Figure 1. Microbial carbon and nitrogen (MBC and MBN) contents of plots

One month after the fire in December'13 and in July'15 which was the last measurement term and one more year after fire, MBC mean values were lowest in LIF plot too. But in April'15 MBC values were the highest in LIF plot (Figure 2). Also, these differences between plots were significant.

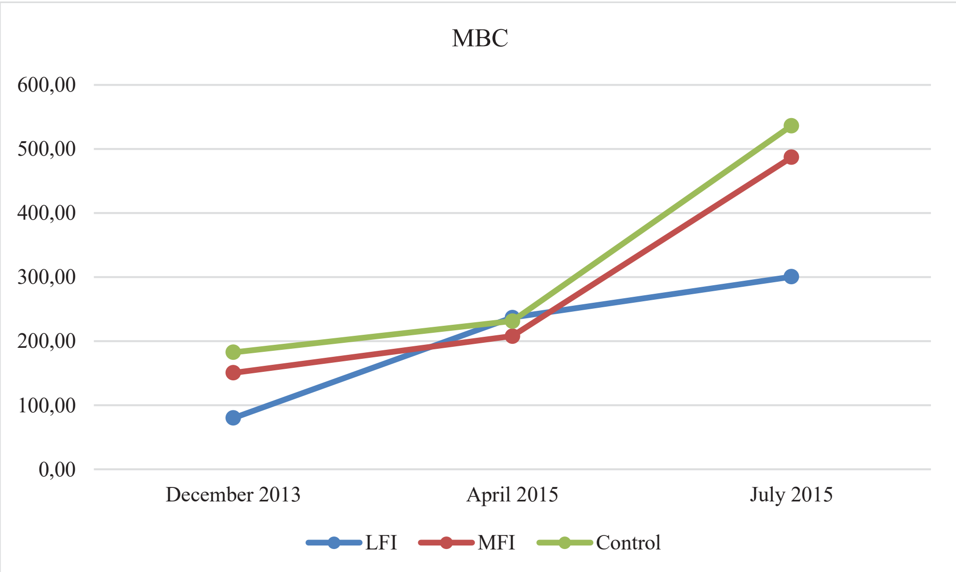


Figure 2. Change of microbial carbon (MBC) during seasons at plots

In all tree term control values of MBN were highest and LIF values were lowest except July'15 (Figure 3). These differences between plots were significant too.

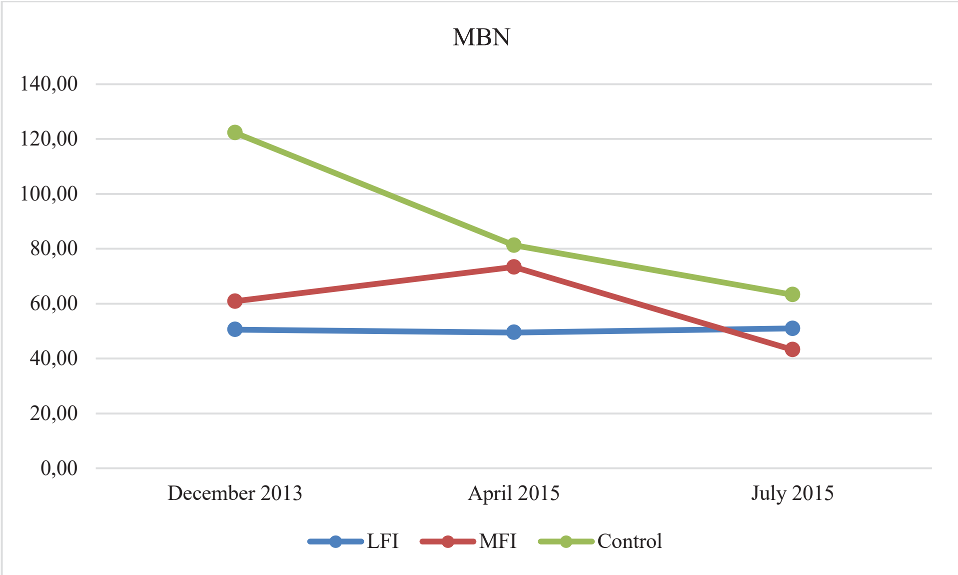


Figure 3. Change of microbial nitrogen (MBN) during seasons at plots

MBC/SOC (microbial carbon/soil organic carbon) rate was the highest in MIF plot and the lowest in LIF. Seasonally comparable results were found except first term December'13; in this term control values were higher than MIF values but mean values were almost the same (Table 2). Difference of values of MBC/SOC rates between plots were significant.

Table 2. Rate of microbial biomass to soil organic carbon during seasons and men values

Plots	December 2013	April 2015	July 2015	MEAN
LFI	0,23	0,49	0,82	0,51
MFI	0,60	0,53	1,79	0,97
Control	0,67	0,47	1,40	0,85

Like our results, in many studies, it was found that MBC (Grady and Hart, 2006; Waldrop and Harden, 2006; Rodríguez et al., 2009; Choromonska and DeLuca, 2001) and MBN (Bauhus et al., 1993; Dumontet et al., 1996) decreased with the effect of fire. High temperatures with fire kill the microorganisms in soil and recovery of microbial biomass is depended on post-fire conditions of soil exposed to fire (Díaz-Raviña, 1992; Acea and Carballas, 1996; Pietikäinen et al., 2000; Badía and Martí, 2003; Guerrero et al., 2005). Solvable carbon compounds which may be metabolize play key role at recolonization of SMB or to reach burned plots values to control values (Mataix-Solera et al., 2009). So, MBC/SOC rate which shows availability of organic substrates may indicate microbial growth or recolonization process. High rates of MBC/SOC shows that usability of organic substrate by microorganisms is well (Kara and Bolat, 2009). Above mentioned carbon compounds provide rather increase of microbiota especially bacteria (Grasso, 1996; Badía and Martí, 2003; Guerrero et al., 2005). In this study because of highest rates of MBC/SOC in MIF plots, higher intensity fire may accelerate dissolving of organic material.

Change of mean soil respiration rates of plots were like SMB, that is highest in control and lowest in LFI (Table 3). But differences between values of plots were not significant. Mean values of soil humidity and soil temperature of plots were not significant.

Table 3. Mean soil respiration, soil moisture and soil temperature values of plots

Plots	S. Respiration (g C d^{-1})	S. Moisture (%)	S. Temperature (°C)
LFI	1,47	33,58	10,33
MFI	1,58	33,08	11,26
Control	1,62	42,13	10,71

4. Conclusions

Fire experiment decreased soil microbial biomass significantly in black pine stands soils of our study. But there was no significant change at soil pH, organic matter and respiration rate even desired a change after fire. It was regarded as loss of available nutrients in ash by leaching or run off water, prevented the pH rise and microbial absorption. Although fire decreased microbial biomass, middle intensity fire increased availability of organic substrate and organic matter did not change significantly. Even if SMB decreased for once in April SMB values reached to control values. So, it was assumed that recovery of microbial biomass was related to fire intensity and other conditions such as season.

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