JOURNAL OF ENVIRONMENTAL ENGINEERING AND LANDSCAPE MANAGEMENT
ISSN 1648–6897 print/ISSN 1822-4199 online
2013 Volume 21(1): 67–75
doi:10.3846/16486897.2012.663087

CHANGES OF GROUND VEGETATION, SOIL CHEMICAL PROPERTIES AND MICROBIOTA FOLLOWING THE SURFACE FIRES IN SCOTS PINE FORESTS

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Submitted 14 Mar. 2011; accepted 09 Nov. 2011

Abstract. The aim of the study was to investigate the influence of low severity surface fires on the ground vegetation, soil chemical changes and soil microbiota in Scots pine stands on sandy soils (*Arenosols*). The study was conducted in the eastern part of Lithuania (55° 35'N, 26° 07'E). The annual investigations in 1–4-year-old burned sites showed that low severity surface fires mostly affected the above-ground part of the ground vegetation. The influence of surface fire on soil chemical properties and soil microbiota was minor. Only slight increases in pH and in the content of total N in soil organic layer were detected. Concentrations of mobile K_2O and heavy metals (Cd, Cr, Cu, Mn, Zn and Fe) slightly increased in the mineral topsoil. The actinobacteria abundance increased in the soil organic layer and the mineral topsoil of the burned sites. The abundance of micromycetes decreased in the mineral topsoil after the surface fires.

Keywords: surface forest fire, *Pinus sylvestris*, ground vegetation, soil, heavy metals, soil microbiota.

Introduction

Nowadays, forest fires are recognized as an important ecological factor affecting vegetation structure and composition, energy fluxes and biogeochemical processes in boreal and hemiboreal forest landscapes (Shugart *et al*. 1992; Parviainen 1996; Angelstam 1998; Bergeron *et al*. 2002; Kuuluvainen 2002; Ryan 2002; Wallenius *et al*. 2007). Modern forest management should consider the impact of fire as the increases in the frequency and intensity of natural and anthropogenic forest fires are expected to occur in the coming decades as a consequence of global climate changes (Päätalo 1998; IPCC 2007; Flannigan *et al*. 2009).

The effect of fires on forest ecosystems depends on intensity and duration of the fire (Ice *et al*. 2004; Certini 2005). Severe crown fires can eliminate above-ground biomass, change successional rates and alter vegetation species composition, belowground physical, chemical and microbial processes. Fire changes forest soils properties including increased bulk density and altered physical structure (Boyer, Miller 1994; Arocena, Opio 2003), increased soil cation stocks (Liechty *et al*. 2005; Neff *et al.* 2005), and decreased carbon (C) and nitrogen (N) stocks in soils (Choromanska, DeLuca 2001; Carter, Foster 2004; MacKenzie *et al.* 2004; Certini 2005). In addition, during severe crown fires some heavy metals could release from the ash to the soil (Breulmanna *et al.* 2002; Pereira, Úbeda 2010). In excessive amounts they could have negative effects on forest ecosystem processes (Alloway 1995; Vasarevičius, Greičiūtė 2004; Ignatavičius *et al.* 2006; Baltrėnaitė, Butkus 2007; Pundytė *et al*. 2011).

Surface forest fires mainly affect the species composition of the ground vegetation; can promote an herbaceous flora, tree regeneration conditions and short-time increase of plant available nutrients in the soil (Parviainen 1996; Granström 2001; Gromtsev 2002; Ryoma, Laaka-Lindberg 2005; Jayen *et al.* 2006; Marozas *et al.* 2007; Parro *et al.* 2009). The effects of surface fires on soil chemical properties are generally relatively minor. In fact, the mineral soils appear to be unchanged in the face of low-intensity surface forest fires (Richter *et al.* 1982; Ferran *et al.* 2005; DeLuca, Sala 2006; Neill *et al.* 2007).

Fires have effect on soil microbial abundance and composition (Tateishi, Horikoshi 1995; Mabuhay *et al.* 2006). It is focused that forest fires induce the changes in microbial populations mainly through the shift of soil moisture content (Hanson *et al.* 2000; Pietikainen *et al.* 2000) and through the increased supply of organic C and N from the burned soil organic layer to the mineral topsoil (Klopatek *et al.* 1988; Ojima *et al.* 1994; Neary *et al.* 1999; Simard *et al.* 2001; Neff *et al.* 2005). Mineral topsoil drying followed by soil moisture retention and capacity reduction on behalf of the burned vegetation and underlying soil organic layer decreases the abundance of microbial communities (Bååth *et al.* 1995; Pietikainen *et al.* 2000). Thus, proceeding into the stationary phase, the ability of recovering and recolonizing of microbial com-

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munities is declined (Prieto-Fernandez *et al.* 1998; Wutrich *et al.* 2002).

Forest fires induce the loss of organic matter along the burning of the ground vegetation and soil organic layer. As the potential organic matter input to soil is decreased, the decrease in the abundance of microbial communities could be also estimated (Almendros *et al.* 1990). Thus, in mineral soil due to the increase of belowground root mass the microbial abundance could increase in burned stands (Ojima *et al.* 1994). Regarding the changes in soil moisture as well as soil C and N content, the mostly reduced microbial population in the burned stands could be soil micromycetes, thus soil bacteria and actinobacteria, in contrast, could be the most abundant in the burned stands (Klopatek *et al.* 1988; Prieto-Fernandez *et al.* 1998; Joos *et al.* 2001).

Mainly the observations on surface fire impact to vegetation of pine forest ecosystems were presented in European hemiboreal forest zone (Zackrisson 1977; Marozas *et al.* 2007; Parro *et al.* 2009). Moreover, there is a lack of more complex investigations on the vegetation reestablishment, the changes in soil chemical properties and microbial population that occur after surface fires.

In Lithuania the annual number of forest fires is about 700 (from 200 to 1600 per year) (LME/SFS 2010). The total burned forest area ranges from 100 to 700 ha annually with an average burned area per one fire of 0.45 ha. Even 84% of fires emerge in Scots pine forests. The most common are surface fires (97.3%), while crown fires and underground fires amount only to 1% and 1.7%, respectively.

The aim of the study was to investigate the influence of low severity surface fires on the development of ground vegetation, soil chemical changes and soil microbiota in Scots pine (*Pinus sylvestris*) stands on sandy soils (*Arenosols*).

1. Materials and Methods

1.1. Study site

The study area was located in the eastern part of Lithuania (Zarasai district) (55° 35'N, 26° 07'E) and it falls in the transitional deciduous coniferous mixed forest hemiboreal zone of Europe (Ahti *et al.* 1968) (Fig. 1).

Fig. 1. Map of study area

The altitude above sea level is about 150–180 meters. The mean annual temperature ranges from +5.4 to +5.8 °C, with a mean January (coldest month) temperature of –6.4 °C and a mean July (warmest month) temperature of 16.9 °C. Annual mean precipitation is between 600 and 700 mm. Period with permanent snow cover continues from 100 to 110 days (Bukantis 1994). Hilly landscape, sandy soils and pure Scots pine (*Pinus sylvestris*) stands prevail in the forests of the study area.

The study was carried out in 60-year-old pure Scots pine stands with the undergrowth of Norway spruce (*Picea abies*). All studied stands were growing on nutrient-poor sandy *Arenosols* (forest type - *Vaccinio - myrtillo Pinetum*). In the ground vegetation cover prevail: *Vaccinium myrtillus*, *V. vitis-idaea*, *Calluna vulgaris*, *Festuca ovina*, *Linaria vulgaris*, *Luzula pilosa* and *Melampyrum pratense* in the dwarf shrub and herb layer, and *Dicranum polysetum*, *D. scoparium*, *Hylocomium splendens* and *Pleurozium schreberi* in the moss layer. In these stands surface fires occurred in the end of April of 2006 and 2009. Since the fires were of low severity, Scots pine trees were not damaged, while Norway spruce undergrowth and shrubs were totally killed and the ground vegetation cover was burned. The area of fires was about 60 ha in 2006 and about five ha in 2009.

1.2. Ground vegetation study and soil sampling

In total 4 permanent transects (20×1 m) with 20 sampling plots (1×1 m) were established for the ground vegetation study in the burned site (the surface fire occurred in April of 2006) and in the untouched nearby not-burned site (control) of Scots pine stand. Vegetation studies were conducted annually in June-July of 2006–2009. Each year species composition (species names according to Jankevičiene 1998) and projection cover (in per cent) of shrubs, saplings, dwarf shrubs, herbs and mosses were recorded in transects.

The soil sampling for the estimation of soil chemical properties and evaluation of the abundance of soil microbiota was carried out in July, 2009 in two burned sites in which surface fires occurred one and four years ago (in April of 2006 and 2009, respectively) and in untouched control sites. In each site, three composite samples of the organic layer (forest litter) and three samples from 0–5 cm mineral topsoil were collected at nine systematically distributed points along 16 meters transects. The organic layer was sampled using a 1000 cm^2 metallic circular frame. Then samples were dried at 105 °C and oven-dry weight (kg m^{-2}) was determined. Mineral soil was sampled with metallic auger of 2.5 cm diameter.

1.3. Analyses of soil chemical properties and soil microbiota

For chemical analyses, the organic and mineral soil samples were dried at 40 °C. Mineral soil samples were sieved through a 2×2 mm sieve. The mobile potassium (K_2O) and mobile phosphorus (P_2O_5) were determined in soil samples using the Egner-Riehm-Domingo (A-L) method (Egner *et al.* 1960); and pH was potentiometrically measured in a 1 M KCl suspension (ISO 10390). Cadmium was determined by flame and electrothermal atomic absorption spectrometric method (ISO I1047-9), whereas Cr, Pb, Ni, Cu, Mn, Zn and Fe were determined by inductively coupled plasma - atomic emission spectrometry (ICP-AES) (ISO 22036:2008). These analyses were conducted in the Agrochemical Research Laboratory of LRCAF. The total nitrogen (N) (ISO 11261) and organic carbon (org. C) (ISO 10694) concentrations were determined using the ECS 4010 analyser (COSTECH) in the Ecology Department of Institute of Forestry of LRCAF. Results were calculated on the mass of dry soil.

Soil microbiota was determined by the standard method of the sowing of organic or mineral soil suspension on the agarised nutrient medium (Thompson, Vincent 1967). Well homogenized 5 g of natural moist soil was suspended for one hour in the 50 ml of sterile water. Soil solutions for the sowing were gradually diluted by 10, 100 and 1000 times. The sowing was performed in three replicates using standard media agar (Plate-Count-Agar/standard methods) for the estimation of total soil microbiota abundance (Annand *et al.* 2003). Microbiota plates were incubated at 27 °C. After 5–7 days the morphology of the bacteria, actinobacteria and micromycetes colonies on plates was assessed by the needle strike and the optical microscopy. The count of colony forming units (CFU) of the microbiota was performed and the abundance of microbiota was counted per 1 g of the constant dry (in 90 °C) weight of the soil (according to Bradshaw 1992; Hassen *et al.* 2001).

1.4. Data statistical analysis

Vegetation data generally do not follow normal distribution (Greig-Smith 1983; Jongman *et al.* 1995). Chi-square test confirmed not normality of vegetation data; therefore we used nonparametric Wilcoxon test to test differences between pairs of data set in different years. Wilcoxon test was used, because we compared the depended data (time series) (Čekanavičius, Murauskas 2002). Soil chemical and microbiota parameters followed normal distribution (checked by chi-square test), therefore we used Student t-test. Statistical analyses were conducted using the STATISTICA 8.0.

2. Results and discussions

2.1. Changes in ground vegetation

In total 28 different species were found during four years period in the ground vegetation cover of burned and control sites of Scots pine stands. Average species number per 1 m^2 significantly ($p < 0.05$) decreased within first year after the low severity surface fire (Fig. 2).

In the subsequent years post-fire the average species number slightly increased, and in the fourth year after the surface fire it was even higher than that in the non-burned control site of pine stand. This increase in species number was mainly determined by spread out of pioneer early succesional herb species (*Calamagrostis epigejos, Equisetum hyemale, Pteridium aquilinum, Rubus idaeus, R. saxatilis, Scorzonera humilis, Solidago virgaurea, Ceratodon purpureus, Polytrichum juniperinum*).

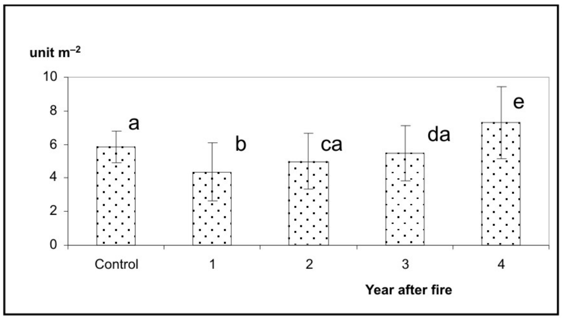

Fig. 2. Changes of average species number in the ground vegetation cover of burned and control sites in Scots pine stands. Values are given as mean ± SD. Significant differences ($p < 0.05$) are indicated by different superscript letters

The similar decline in the number of species immediately after the fire and the subsequent increase within a few further years was reported by Nuzzo (1996) and Parro *et al.* (2009).

In the cover of ground vegetation of Scots pine stand prevailed herbaceous, moss and dwarf species (Table 1).

Table 1. Changes of the average projection cover (%) of shrubs, herbaceous, dwarf shrub, herbaceous and moss species in the burned and control areas

Name of species	Control	Year after fire			
		1	2	3	4
Shrubs					
Frangula alnus	+	+	+	–	+
Sorbus aucuparia	+	–	–	–	–
Saplings					
Quercus robur	+	–	–	–	–
Picea abies	+	–	–	–	–
Herbs and dwarf shrubs					
Calamagrostis arundinacea	0.1	0.1	0.2	0.3	0.2
Calamagrostis epigejos	–	+	0.1	0.1	+
Calluna vulgaris	0.3	–	–	–	–
Convallaria majalis	0.6	+	2.6	1.9	1.8
Equisetum hyemale	–	+	+	+	+
Festuca ovina	+	+	+	0.3	0.5
Luzula pilosa	0.2	–	–	–	–
Melampyrum pratense	0.2	–	+	0.9	1.0
Peucedanum oreoselinum	–	+	0.1	+	–
Polygonatum odoratum	+	–	–	–	–
Pteridium aquilinum	–	0.9	1.5	4.2	4.5
Rubus idaeus	–	–	–	–	0.1
Rubus saxatilis	–	0.8	2.8	2.8	2.6
Scorzonera humilis	–	+	0.2	0.3	0.2
Solidago virgaurea	–	+	+	–	–
Trientalis europaea	–	0.1	1.2	+	+
Vaccinium myrtillus	17.5	2.7	23.2	50.4	47.6
Vaccinium vitis-idaea	13.4	0.4	2.0	3.9	4.4
Mosses					
Dicranum polysetum	–	–	–	–	+
Dicranum scoparium	–	–	–	–	+
Hylocomium splendens	35.7	–	–	–	–
Pleurozium schreberi	60.5	–	–	–	+
Ceratodon purpureus	–	–	–	–	0.8
Polytrichum juniperinum	–	–	–		+

+ – projection cover < 0.1%

Only two species of shrubs (*Frangula alnus* and *Sorbus aucuparia*) and two species of saplings (*Quercus robur* and *Picea abies*) occurred rarely before the fire. Besides, only *F. alnus* was found in the burned site.

In total nine herbaceous and dwarf shrub species occurred in the ground vegetation cover before the fire (Table 1). While, there were 15 species in the burned site. Dwarf shrub Vaccinium *myrtillus* and *V. vitis-idaea* were the most abundant in the control site. These dwarf shrubs were declined by surface fire, however, there were recovered, especially *V. myrtillus*, within 3–4 years.

Herbaceous species of *Calluna vulgaris, Luzula pilosa* and *Polygonatum odoratum* were found only in the control site and still did not occur in the 4-year-old fire site (Table 1). Meanwhile *Rubus saxatilis, Scorzonera humilis, Calamagrostis epigejos, Pteridium aquilinum, Trientalis europaea, Peucedanum oreoselinum, Solidago virgaurea, Equisetum hyemale, Rubus idaeus* occurred only in the burned site.

The reduction of the average projection cover of herbaceous and dwarf shrub species due to the surface fire was observed only during the first year. Projection cover recovered in the second year after the surface fire. Moreover, in the third year the projection cover of herbaceous and dwarf shrub species was even higher than that in the control site (Fig. 3). This increase was mainly because in the burned sites the coverage of *V. myrtillus* (near 50%) was almost 3-folds higher than its coverage in Scots pine stand before the fire.

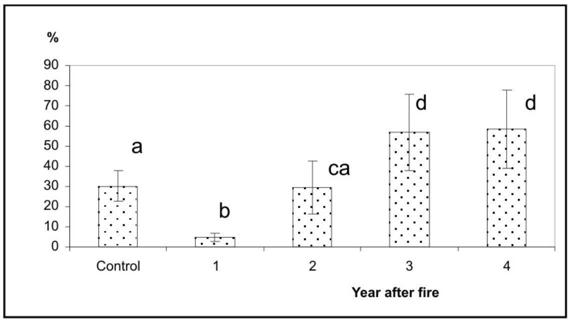

Fig. 3. Changes of average projection cover (%) of herb and dwarf shrub layer in burned and control areas. Values are given as mean ± SD. Significant differences ($p < 0.05$) are indicated by different superscript letters

Only two moss species, *Pleurozium schereberi* and *Hylocomium splendens*, occurred before the fire in observed Scots pine stand but it comprised almost 90% of ground vegetation cover (Table 1). The decline of these mosses was still in fact total in the four year after the fire. Instead of mentioned mosses, four new moss species (*Dicranum polysetum, D. scoparium, Ceratodon purpureus, Polytrichum juniperinum*) occurred in the burned sites. However, the average projection cover of the mosses was still very low (comprised only 1–2%) in 4-year-old fire sites.

Surface forest fires had considerable effect on the ground vegetation coverage. Fire destroyed above-ground part of vegetation, but the herbs and, especially, dwarf shrubs recovered quite rapidly within 3–4 years. It has been reported that the recovery of moss layer is much slower and it takes more than 10 years (Marozas *et al.* 2007; Parro *et al.* 2009). Skre (Skre *et al.* 1998) found that the biomass of *Calluna vulgaris*, *Polytrichum*. *Deschampsia flexuosa* and *Pteridium aquilinum* increased after the fire in pine forests of western Norway while regrowth of *Vaccinium myrtillus* and *V. vitis-idaea* was slower. Other investigations also suggested (Ryoma, Laaka-Lindberg 2005) that *Ceratodon*, *Funaria*, *Pohlia nutans*, *Polytricum* spp. appears quickly after the fire in boreal forests. Investigation of the post-fire recovery of species in Scots pine forest in the central part of the Kola Peninsula (Gorshkov, Bakkal 1996) showed that the herb and dwarf shrub layers recovered within 5–15 years after the fire while the mosses recovered within 90–140 years after the fire.

2.2. Soil chemical properties

There were no differences in the organic layer mass of *Arenosols* between the burned and control sites with average values of approximately 6.5 kgDM m^{-2} at each site (data not shown). The fact that no influence on the mass was detected in the 4-year-old burned site shows that the mineralization of organic layers was not intensified after the fire. However, fire-caused changes in chemical properties were mostly pronounced in the organic layer. Integrated parameter pH_{KCl} of organic layer was significantly higher ($p < 0.05$) in both burned sites to compare to control sites, indicating the alkaline effect of fires (Table 2).

Table 2. The chemical parameters (mean ± SD) of organic and mineral topsoil layers of *Arenosols* in control and burned sites of Scots pine stands

Soil sampling		pH_{KCl}	N, g kg^{-1}	Org. C, g kg^{-1}	C/N	P_2O_5, mg kg^{-1}	K_2O, mg kg^{-1}
Organic layer							
1-year-old burned site	control	2.8 ± 0.2	15.3 ± 0.3	431.9 ± 18.1	28.2 ± 1.2	195 ± 27	421 ± 15
	burned site	3.2 ± 0.1*	13.4 ± 0.7*	432.0 ± 23.5	32.5 ± 1.2*	283 ± 49	390 ± 36
4-year-old burned site	control	2.8 ± 0.2	12.9 ± 0.5	441.4 ± 26.8	34.3 ± 2.1	244 ± 39	434 ± 32
	burned site	3.2 ± 0.1*	14.3 ± 0.8*	438.9 ± 28.6	30.6 ± 0.9*	245 ± 13	415 ± 14
Mineral topsoil (0–5 cm in depth)							
1-year-old burned site	control	3.4 ± 0.2	2.4 ± 0.1	25.3 ± 2.7	10.6 ± 0.7	77 ± 12	48 ± 4
	burned site	3.4 ± 0.1	2.4 ± 0.1	23.2 ± 0.7	9.8 ± 0.6	88 ± 21	61 ± 5*
4-year-old burned site	control	3.7 ± 0.1	2.4 ± 0.1	25.2 ± 1.3	10.5 ± 0.7	117 ± 8	48 ± 3
	burned area	3.4 ± 0.2	2.4 ± 0.1	28.3 ± 0.7	11.9 ± 0.1	115 ± 18	64 ± 7*

* – indicates the significant ($p < 0.05$) changes in burned sites.

In the first year after surface fire total N concentrations in the soil organic layer were lower in the burned site than that in the control (Table 2). Four years after fire, total N concentrations were higher in the burned site and exceeded the pre-fire level. Since there were no significant differences in org. C concentrations in the soil organic layer, the observed changes (increase in 1-year and decrease in 4-year-old burned sites) in the C/N ratio were obviously determined by the changes in total N concentrations. We have not found significant differences in concentrations of mobile K_2O and P_2O_5 between the burned and the control sites.

Only the concentrations of mobile K_2O was slightly higher in the upper 0–5 cm mineral topsoil in both 1 and 4-year-old burned sites to compare to control sites (Table 2). Other chemical soil parameters (pH, total N, org. C, mobile P_2O_5) did not differ significantly in the mineral topsoil. The observed saturation of mineral topsoil with K_2O could be related to the distribution of the ash after surface fire. Unchanged concentrations of mobile K_2O in soil organic layers of burned sites indicated intensive leaching of K_2O from organic layers to the mineral topsoil.

Data on heavy metals show that the concentrations of Cd, Cr, Cu Mn, Zn and Fe significantly ($p < 0.05$) increased in 0–5 cm mineral topsoil after surface fire, while the concentrations of Pb and Ni did not differ between burned and control sites (Table 3). However, the increased concentrations were considerably lower to compare to critical or, even, background levels (HN 60:2004).

The effects of forest above-ground (surface and crown) fires on soil chemical properties strongly depend on fire severity. Crown fires that are severe could lead to significant chemical changes in the mineral soils (Smithwick *et al.* 2005; Hammana *et al.* 2007). The study of a short time change (one week after fire) in soil properties due to the fire was conducted in *Pinus densiflora* stands in Korea (Choonsig *et al.* 1999). It was found that high intensity forest fire increased soil pH, total N, available P, K, Ca, and Mg in the mineral topsoil (0–5 cm). However, no marked changes were observed in the deeper mineral soil layer (5–25 cm). Other studies confirmed that forest crown fires increase soil cation stocks (Liechty *et al.* 2005; Neff *et al.* 2005), but decrease carbon and nitrogen stocks in the surface layer of mineral soils (Choromanska, DeLuca 2001; Carter, Foster 2004; MacKenzie *et al.* 2004; Certini 2005).

Our study showed that the effects of surface forest fires of low severity on soil chemical properties were not significant. Surface fires did not affect the mass of organic layer, the contents of org. C and mobile P_2O_5. Only slight increase of pH and the short-term decrease of total N in the soil organic layer, as well as the increased concentrations of mobile K_2O and some heavy metals were detected in mineral topsoil. Previous studies have reported similar results. Wagle and Kitchen (1972) found no difference in extractable P among 3 years and 14 years old burned and control sites in ponderosa pine forest in the northern Arizona. Very little differences in soil properties, mainly total N decrease within first year after the fire, were found in soils within the low severity burn sites in the coniferous stands of the central and eastern Cascade Mountains of Washington State (Baird 1998; Hatten *et al.* 2005).

2.3. Soil microbiota

The surface fires mainly affect the changes of soil microbial populations in the soil organic layer and in the mineral topsoil (Klopatek *et al.* 1988). Concerning that, the abundance of soil microbiota in the organic layer and in the mineral topsoil layer (0–5 cm in depth) in Scots pine stands was determined.

In our study the mean total abundance of soil microbiota in the organic layer was 5.01 mln. and 5.91 mln. of colony forming units (CFU) per g^{-1}, respectively, in one year and 4-year-old burned sites (Table 4).

Table 3. Concentrations (mg kg^{-1}, mean ± SD) in the mineral topsoil (0–5 cm) in 4-year-old burned sites and controls

Soil sampling	Cd	Cr	Pb	Ni	Cu	Mn	Zn	Fe
Burned site	0.036 ± 0.008*	2.78 ± 0.56*	7.5 ± 0.6	1.1 ± 0.4	1.1 ± 0.1*	96.4 ± 7.1*	6.86 ± 1.25*	3488 ± 1387*
Control	0.017 ± 0.004	1.48 ± 0.38	5.5 ± 1.2	0.5 ± 0.1	0.5 ± 0.1	26.4 ± 10.1	3.94 ± 1.23	1449 ± 417

*– indicates the significant ($p < 0.05$) increase in burned sites.

Table 4. The abundance of soil microbiota in the organic layer and the mineral topsoil in Scots pine stands in control and burned sites (mean ± SD)

Soil sampling		Abundance of total microbiota, mln. CFU g^{-1}	Abundance of bacteria, mln. CFU g^{-1}	Abundance of actinobacteria, mln. CFU g^{-1}	Abundance of micromycetes, mln. CFU g^{-1}
Organic layer					
1-year-old burned site	control	4.62 ± 0.51	3.81 ± 0.32	0.28 ± 0.01	0.53 ± 0.18
	burned site	5.01 ± 0.78	4.03 ± 0.57	0.61 ± 0.18*	0.37 ± 0.03
4-year-old burned site	control	5.36 ± 0.55	4.33 ± 0.40	0.32 ± 0.03	0.71 ± 0.12
	burned site	5.91 ± 0.64	4.86 ± 0.32	0.42 ± 0.19	0.63 ± 0.13
Mineral topsoil (0–5 cm in depth)					
1-year-old burned site	control	0.71 ± 0.16	0.52 ± 0.15	0.12 ± 0.00	0.07 ± 0.00
	burned site	0.82 ± 0.15	0.60 ± 0.13	0.17 ± 0.00*	0.05 ± 0.01*
4-year-old burned site	control	0.93 ± 0.21	0.62 ± 0.18	0.20 ± 0.00	0.11 ± 0.02
	burned site	0.95 ± 0.29	0.70 ± 0.28	0.21 ± 0.00	0.04 ± 0.01*

* – indicates the significant differences ($p < 0.05$) between the control and burned sites.

In the mineral topsoil, the mean microbial counts ranged from 0.82 mln. CFU g^{-1} (1-year-old burned site) to 0.94 mln. CFU g^{-1} (4-year-old burned site). In control sites soil microbiota counts were lower than in the burned sites. Since the estimated differences were not significant ($p > 0.05$), the obtained results are indicating only the tendencies that the increase in soil microbiota counts could be fire-induced.

Crown fires, which burn the organic layers totally, decline microbial communities (Prieto-Fernandez *et al.* 1998; Wutrich *et al.* 2002). In our study low severity surface fires might have been not essentially destructive for soil microbiota since soil organic layer was not burned. On the other hand, the surface fires in studied sites seemed to produce the substances as growth promoting substrates for soil microbiota as reported by Neary *et al.* (1999). Thus, the increase of soil microbiota in burned sites might be caused by the decreased acidity of organic layers and the slight saturation of mineral topsoil mobile K_2O (see Table 2).

The distribution of soil microbiota communities is presented in Table 4 as well. Soil bacterium was dominant in the organic layer as well as in the mineral topsoil. However, mean counts of soil bacteria were not significantly ($p > 0.05$) higher in the burned sites than in the control sites. Though it was expected, no increase in soil bacteria populations was not found even in the 4-year-old burned site, where the saturation with N was increased, especially in the organic layer. Mroz *et al.* (1980) and Klopatek *et al.* (1988) reported that an increase in soil nitrogen ratios after the burning should promote an increase in total bacteria populations. It shows, as Astaraei (2008) assumed, that soil bacteria populations were not sufficiently provided with excess of the nitrogen.

Actinobacteria abundance was found to be increasing in the burned sites (Table 4). Only in 1-year-old burned site the significant 1.5- and 2.2- fold increase in actinobacteria abundance was found in the organic layer and in the mineral topsoil, respectively. Actinobacteria in the soil is sensitive to acidity and tolerate the soils with alkaline or neutral pH values (Klopatek *et al.* 1988; Joos *et al.* 2001). Since in burned sites of our study soil acidity had decreased, that likely influenced the growth of soil actinobacteria populations.

The abundance of micromycetes decreased in average by 1.4 and 2.8 times in the mineral topsoil in 1-year and 4-year-old burned sites, respectively (Table 4). It has been reported that the most of soil micromycetes are sensitive to decreased of moisture retention (Bååth *et al.* 1995; Pietikainen *et al.* 2000). In our study, mineral topsoil layers in the burned sites might have been drying and causing decreases in the soil micromycetes populations. The decrease in soil acidity also could cause the decline in micromycete abundance.

Conclusions

1. Surface fires have destroyed the above-ground part of ground vegetation in V*accinio-myrtillo Pinetum* forests. Nevertheless, ground vegetation began to recover in the subsequent years. Within 3–4 years after the fires the burned sites have had even higher number of species and ground vegetation coverage than in the unburned sites. The pioneer herb species and dwarf shrubs, mainly *Vaccinium myrtillus,* were spread out. However, the recovery of moss cover was still non-significant.

2. Surface fires did not affect the mass of soil organic layer, and the effect on soil chemical properties was minor. Only slight increases of pH and of the content of total N were detected in soil organic layer. Also, slightly increased concentrations of mobile K_2O and some heavy metals (Cd, Cr, Cu Mn, Zn and Fe) were found in the mineral topsoil.

3. Surface fires have caused slight changes of microbiota abundance in the soil organic layer and the mineral topsoil (0–5 cm in depth). Although mean abundance of soil bacteria in the burned sites were not significantly higher than in the control sites, actinobacteria abundance tended to increase in the soil organic layer and the mineral topsoil of burned sites. In opposite, the abundance of micromycetes decreased in the mineral topsoil after the surface fires.

4. Our study showed that low severity surface fires mostly affected above-ground part of ground vegetation in Scots pine stands on *Arenosols* that prevail in Lithuanian forests. The influence of surface fire on soil chemical properties and soil microbiota was minor.

Acknowledgements

The research was supported by Lithuanian Agency for Science Innovation and Technology (Award Numbers 2009 No. 31V-52; 2008 No. 31V-104) and Research Council of Lithuania (No. COST-50/2010). The research was conducted in the frame of COST action FP0701 Post-Fire Forest Management in Southern Europe and COST action ES0805 The Terrestrial Biosphere in the Earth System (TERRABITES).

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