Changes in the Soil Organic O Layer Composition after Surface Fire in the Dry-mesic Pine Forest in Rucava (Latvia)

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Abstract

Forest fires, a common occurrence around the world, are an important and typical disturbance factor in boreal and hemiboreal forests in Europe. The statistics of forest fires in Latvia over the last century shows occasional extreme fire events. The most severe forest fires occurred in 1963, when 12 013 ha of forest area was burned. In the period of 1992 – 2014, the area of burned forest ranged from 90 ha in 2012 to 8 412 ha in 1992. In Latvia, dry coniferous forest stands are subject to the highest risk; 85% of all forest fires occur in dry Scots pine forests. Scots pine (*Pinus sylvestris* L.) is the dominant tree species in 915 000 ha of forest area in Latvia occupying ~ 29% of all forest land. The aim of this study was to assess the instantaneous impact of low severity surface fire occurred in the beginning of August 2014 on the chemical and biological composition of soil organic O layer in a 60-year-old dry-mesic Scots pine (*Pinus sylvestris* L.) forest stand classified as *Vaccinio vitis-idaeo-Pinetum* community in Rucava, Peši site, SW Latvia.

Our results indicate that the composition and decay level of the soil organic O layer in dry-mesic Scots pine forests is mostly dependent on the abundance of herbs and especially grasses in the ground vegetation layer. Analysis of the soil organic O layer showed that the instantaneous impact of low severity surface fire on soil organic O layer has manifested itself not only quantitatively, but also qualitatively. Fire-affected part of the 60-year-old dry-mesic Scots pine forest stand had reduced soil organic O layer thickness by 24%. The mean differences between organic C and total N stored in the soil organic O layer in the burned and unburned part of the forest stand were 16.5 t C ha^{-1} and 0.3 t N ha^{-1} or 26.5% of the organic C pool and 15.7% of the total N pool in the soil organic O layer was lost due to the low severity surface fire. Properties of the mineral topsoil (E horizon) below the soil organic O layer were not affected by surface fire.

Key words: dry-mesic pine (*Pinus sylvestris* L.) forest, surface fire, soil organic O layer properties, carbon and nitrogen pools.

Introduction

Forest fires are not only a major environmental concern around the world (Inbar et al. 2014), but also a typical forest disturbance in the Baltic States. These are occasionally caused by natural factors (during thunderstorms), but mostly occur due to anthropogenic factors. In Latvia, forest fires most often occur in dry coniferous forest stands around large cities and along roads, especially in urban forests. Fires are frequent in dry Scots pine forests (85% of all forest fire occurrences); fires are most dangerous for conifer monocultures (Kronītis 1990, Rozītis 2000).

Since 1922, several hundred forest fire occurrences have been reported regularly every year in Latvia, in some years more than one thousand forest fire occurrences are observed. The largest number of forest fire occurrences has been observed during the last 25 years: in 2006 – 1 929, in 2002 – 1 742, in 1992 – 1 510, in 1999 – 1 196 and in 1996 – 1 095 occurrences. It should be noted that the duration of dry periods during the growing season and the number of days with extremely high air temperatures has increased over this period (Avotniece et al. 2010, 2012), contributing to the risk of forest fires.

The most severe forest fires took place in 1963, when 12 013 ha in total of the forest area burned. The statistics of forest fires in Latvia over last century shows occasional extreme events of fire. In the time period between 1992 and 2014, the most severe fires took place in 1992, when was an exceptionally dry summer. In that year 8 412 ha of forest burned; the area of burned forest in other years of that period ranged from 90 ha in 2012 to 3 790 ha in 2006 (State Forest Service 2015). However, in the 20th and 21st century, both the number of forest fire occurrences and the area of burned forest increased in Latvia. There is a trend for an increase in the number of forest fire occurrences and burned area also in years of social changes (during the 2nd world war in 1941–1944 or during forest management reorganisation in

1991–1995, when a common reason for delayed quenching of forest fire was shortage of fuel).

Forest fires result not only in direct loss of existing plants and alterations in scenery, but also in long-lasting, residual changes to the soil caused by the wide spread distribution of ash over the soil (Escudey et al. 2014). Fire affects nutrient cycling and many physical, chemical, mineralogical and biological properties of soils occupied by forests (Kutiel and Shaviv 1992, Certini 2005, Marozas et al. 2013, DeBano 2015). Combustion of litter and soil organic matter increases the availability of some nutrients, although others are volatilized (for example, N, P and S). Soil organic matter loss also affects cation exchange capacity, organic chelation, aggregate stability, macropore space, infiltration, and soil microorganisms (DeBano 2015). The effects are chiefly a result of burn severity, which consists of peak temperatures and duration of the fire. Climate, vegetation, and topography of the burnt area control the resilience of the soil system; some fire-induced changes can even be permanent. Low to moderate severity fires, such as most of those prescribed in forest management, promote renovation of the dominant vegetation through elimination of undesired species and transient increase of pH and available nutrients (Certini 2005). No irreversible ecosystem change occurs, but the enhancement of hydrophobicity can render the soil less able to soak up water and more prone to erosion (Certini 2005). Kutiela and Inbarb (1993) found that light and moderate forest fires may increase soil fertility without causing a marked difference in soil runoff and erosion. Severe fires generally have several negative effects on soil. They cause significant removal of organic matter, deterioration of both structure and porosity, considerable loss of nutrients through volatilisation, ash entrapment in smoke columns, leaching and erosion, and marked alteration of both quantity and specific composition of microbial and soil-dwelling invertebrate communities (Certini 2005).

The aim of this study was to assess the instantaneous impact of low severity surface fire occurred in the beginning of August 2014 on the chemical and biological composition of the soil organic O layer in a 60-year-old dry-mesic Scots pine (*Pinus sylvestris* L.) forest stand classified as *Vaccinio vitis-idaeo – Pinetum* community in Rucava, Peši site, SW Latvia.

Materials and Methods

Study sites

The dry-mesic Scots pine (*Pinus sylvestris* L.) forest stand on mineral soil was selected to assess the impact of forest fire on soil organic O layer properties in the intensive vegetation monitoring plot of Integral monitoring plot in Rucava, Peši site, SW Latvia (Figure 1). Coordinates of study site: lat. 56.1984, lon. 21.1270, the mean annual air temperature in 2014 was 8.3 °C. The study site is located in a 60-year-old Scots pine stand, classified as *Vaccinio vitis-idaeo – Pinetum* community. *Vaccinium myrtillus*, *V. vitis-idaea*, *Deschampsium flexuosa* and *Melampyrum pratense* dominate in the ground layer and *Hylocomium splendens*, *Pleurozium schreberi* and *Dicranum polysetum* dominante in the moss layer. In a well-lit place, there are *Vicia cassubica*, *Lathyrus sylvestris*, *Pyrola chlorantha*, *Pteridium aquilinum*, *Calamagrostis arundinacea* and other species growing in lighter and warmer sites, but in microhollows in more shaded areas small patches of meso-eutrophic moss species *Sphagnum girgensohnii* are found in the moss layer (Laiviņš and Rūsiņa 2007, Laiviņš et al. 2007). According to the content of wavy hair grass in the field layer, the bilberry, Scots pine community was differentiated into two variants: *Vaccinio vitis-idaea–Pinetum* typicum (subplots A and B) and *Vaccinio vitis-idaea–Pinetum* var. *Deschampsia flexuosa* (subplot C). Within the study area three permanent intensive vegetation monitoring plots (A, B and C, Figure 1) of 30 × 30 meters in size (the total area of each subplot was 900 m^2) were established in 1993. Since 1994 regular mapping of vascular plants, moss and lichen species diversity and frequency was done. The last species mapping carried out in the beginning of July 2014. A low severity surface fire took place in the study area in the beginning of August 2014, the reasons are not clarified. The ground vegetation layer and soil organic O layer was strongly affected by surface fire in the subplot A, but subplots B and C were not affected by surface fire at all. Nomenclature of vascular plants were determined according to Gavrilova and Šulcs (1999); mosses according to Āboliņa (2001).

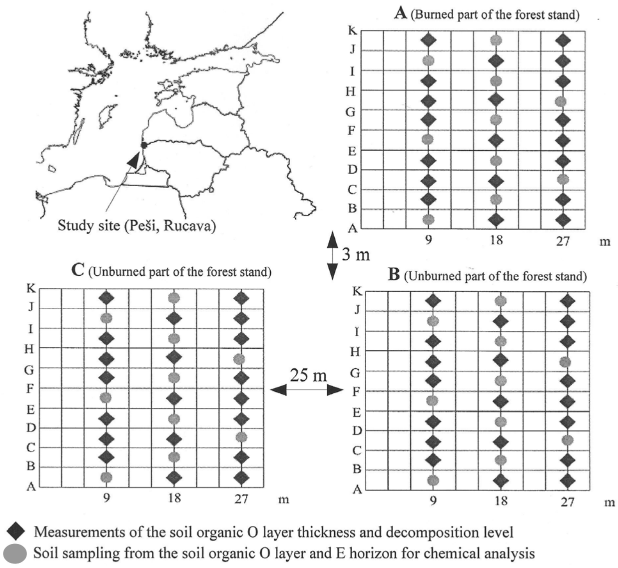

Figure 1. Location of the study site (Rucava, Peši) in Latvia and sampling design

Sampling design and characterization of the soil organic O layer

Subplots A (the burned part of the forest stand) and B (control) were located close together (3 m distance), subplot

C (control) was located at a 25-m distance from subplot B (Figure 1). Each permanent subplot (A, B and C) was divided into 3 × 3 m squares (100 in total in each subplot) for mapping of vegetation diversity and estimate vegetation cover. The cover of vascular plants, moss and lichen species was estimated visually in three-degree scale: 1 – cover of species is less than 1%, 2 – cover of species is 1 – 25%, 3 – cover of species exceeded 25% (Laivins et al. 2007). Vegetation cover of dominant species shortly before fire at the study site is shown in Table 1. Regular and systematic soil organic O layer measuring (thickness and decomposition level) and sampling sites as well as soil sampling from mineral E horizon sites were selected using subplot division into 9 m^2 squares (Figure 1). 30 repetitions of soil organic O layer monolith (10 × 10 cm) were sampled in each subplot using a stainless-steel square soil sampler. The soil organic O layer is usually differentiated into two horizons depending on the decomposition level: a poor decay (OL) and a medium decay (OF) horizon. The total thickness of the soil organic O layer monolith and thickness of each soil organic O layer horizon with marked decomposition level were measured at four points, mean value of soil organic O layer thickness was calculated. The proportion of the four main litter fractions of the OL horizon (mosses, grasses [perennial herbs], dwarf shrub roots, needles and cones) was estimated visually. In addition, soil organic O layer and mineral topsoils (0-5 cm, top layer of E horizon) were sampled in 10 repetitions for chemical and physical (bulk density and mass) analysis in each subplot in October 2014.

Table 1. Vegetation cover of dominant species before fire at the study site; estimated in three degree scale: 1 – cover of species is less than 1%, 2 – cover of species is 1–25%, 3 – cover of species exceeded 25%

Dominant species	Mean vegetation cover, three degree scale		
	Burned site (A)	Control (B)	Control (C)
Deschampsia flexuosa	2.3 ± 0.3	2.1 ± 0.1	3.0 ± 0.0
Dicranum polysetum	0.4 ± 0.2	0.4 ± 0.2	0.8 ± 0.2
Hylocomium splendens	2.7 ± 0.2	2.3 ± 0.3	1.5 ± 0.4
Luzula pilosa	0.2 ± 0.1	0.3 ± 0.3	0.2 ± 0.1
Maianthemum bifolium	1.1 ± 0.3	0.7 ± 0.2	1.4 ± 0.2
Melampyrum pratense	2.5 ± 0.2	1.9 ± 0.3	2.1 ± 0.2
Picea abies	0.4 ± 0.3	0.5 ±0.2	0.3 ± 0.3
Pinus sylvestris	0.9 ± 0.5	2.1 ± 0.5	1.5 ± 0.5
Pleurozium schreberi	2.5 ± 0.2	2.6 ± 0.2	2.5 ± 0.2
Pteridium aquilinum	1.2 ± 0.4	0.7 ±0.3	1.1 ± 0.4
Ptilium crista-castrensis	1.1 ± 0.4	0.5 ± 0.3	0.0 ± 0.0
Quercus robur	0.5 ± 0.2	0.2 ±0.1	0.3 ± 0.2
Scleropodium purum	1.1 ± 0.3	0.7 ±0.3	1.0 ± 0.3
Sphagnum girgensohnii	0.5 ± 0.3	0.0 ±0.0	0.0 ± 0.0
Trientalis europea	1.1 ± 0.2	1.0 ± 0.2	1.7 ± 0.2
Vaccinium myrtillus	2.5 ± 0.2	2.7 ± 0.2	2.4 ± 0.2
Vaccinium vitis-iadaea	0.6 ± 0.2	0.6 ± 0.2	1.5 ± 0.3

Analysis of soil samples

Soil samples were prepared for analyses according to the ISO 11464 (2005) standard, fine earth fraction of soil (D < 2 mm) was used for chemical analysis. The following parameters were determined in the soil samples: soil exchangeable acidity (pH) in potassium chloride (1 M) suspension was measured according to ISO 10390 (2002); total nitrogen (N) content was determined using a modified Kjeldahl method according to ISO 11261 (2002); organic and total carbon (C) content was determined using elementary analysis according to ISO 10694 (2006); phosphorus (P) was extracted with concentrated nitric acid and determined according to LVS 398 (2002); potassium (K), calcium (Ca) and magnesium (Mg) were extracted with concentrated nitric acid and determined by flame atomic emission or absorption spectroscopy; the content of adsorbed bases and base saturation was determined in 0.1 M hydrochloric acid solution using titrimetry, hydrolytic acidity was determined in 1.0 M sodium acetate solution using titrimetry according Kappen and soil bulk density according to ISO 11272:1998. To calculate the chemical element pools in the soil organic O layer in the burned and unburned part of forest stand the mass of absolutely dry (dried at 105 ^{o}C) O layer monoliths (10 × 10 cm) was measured.

Statistical analysis

The experimental data of the soil organic O layer thickness as well as differences in soil organic O layer thickness between study subplots were statistically analysed by applying the *t*-test (Paired two Samples for Means and Two-sample Assuming Equal variance). Normality of variables was checked by the Kolmogorov-Smirnov test. One way ANOVA was applied to analyse the effect of the qualitative factor on the response variables. The LSD test was used for multiple comparisons of the means in case the assumptions were satisfied. When data did not follow a normal distribution, or when group variance was not homogenous, the nonparametric Mann-Whitney Test analysis of variance was used. In all cases the level of significance $\alpha = 0.05$ was accepted. For data analyses the software package SPSS Statistics 17.0 was used. Pearson correlation analysis was used to assess a possible linear association between the soil organic O layer composition and vegetation, but multidimensional analysis of the soil organic O layer composition and composition of above-ground vegetation species was performed by canonical correspondence analysis CCA (Arhipova and Bāliņa 2003, McCune and Grace 2002).

Results

Thickness of the soil organic O layer

Thickness of the soil organic O layer varied significantly both within the *Vaccinio myrtilli-Pinetum Deschampsia flexuosa* community and between study subplots (Table 2). The largest thickness was found in the unburned part of the forest stand (subplots B and C) and there were no statistically significant differences between the mean values of the soil organic O layer thickness in subplots B and C. The mean soil organic O layer thickness in the burned part of the forest stand was thinner by 1.9 cm compared with the mean soil organic O layer thickness in the unburned part of the forest stand, there were statistically significant differences ($p = 0.02$) in the soil organic O layer thickness between burned and unburned parts of the forest stand. Variation of soil organic O layer thickness (coefficient of variation, Table 2) in the burned part of the forest stand (subplot A) was two times higher compared to the unburned part of the forest stand (subplots B and C).

There was spatial variation not only of total thickness of the soil organic O layer overall, but also in the thickness of poor and medium decay O horizon in the Scots pine stand. Thickness of the OF horizon was more constant compared with the thickness of the OL horizon. The mean soil organic O layer decomposition parameters (Table 2) were similar between more closely located subplots (A and B). A higher thickness of OF horizon was found in subplot C, which is located further away from subplots A and B, the difference was statistically significant ($p = 0.02$). The thickness of the OL horizon is thinner and there was a high variation of thickness of the OL horizon in the burned part of forest stand, a statistically significant difference between the burned and unburned part of forest stand ($p = 0.01$) was found.

Table 2. Mean thickness of the soil organic O layer at the study site

Statistical parameter	Total thickness of O layer, cm			Thickness of poor decay O horizon (OL), cm			Thickness of medium decay O horizon (OF), cm		
Study subplot	Burned site (A)	Control (B)	Control (C)	Burned site (A)	Control (B)	Control (C)	Burned site (A)	Control (B)	Control (C)
Mean ± S.E.	6.3 ± 0.6^{b,c}	8.6 ± 0.4^{a}	7.9 ± 0.3^{a}	4.1 ± 0.5^{b}	6.1 ± 0.3^{a,c}	4.6 ± 0.2^{b}	2.2 ± 0.2^{c}	2.5 ± 0.2^{c}	3.3 ± 0.2^{a,b}
Coef. of var., %	52.3	25.0	21.9	66.7	27.7	27.1	40.3	42.4	29.9
Range, min-max	1.0-11.0	3.0-12.0	6.0-12.0	0.0-8.0	1.0-10.0	2.0-7.0	1.0-4.0	1.0-5.0	2.0-5.0

Note: Significant differences ($p < 0.05$) between subplots A, B and C are denoted by ^{a,b} and ^{c}

Chemical properties of the soil organic O layer and mineral topsoil

The characterization of the soil organic O layer chemical composition at the study site is shown in Table 3. There was a reduced content of $C_{org.}$ and N_{total} as well as a lower C/N ratio value in the soil organic O layer in the burned part of the forest stand. The results highlight a statistically significant difference ($p < 0.05$) between organic carbon content in the soil organic O layer in the burned part of the forest stand (mean $C_{org.}$ content is 394.4 ± 73.8 g kg^{-1}) and both subplots located in the unburned part of the forest stand (mean $C_{org.}$ content is 502.2 ± 23.9 g kg^{-1}). Also, lower total nitrogen content in the soil organic O layer was found in the burned part of the forest stand (mean 13.3 ± 1.1 g kg^{-1}), but there was a statistically significant difference only between subplots A and B ($p = 0.01$). Also, a lower C/N ratio value in the soil organic O layer was found in the burned part of the forest stand, but there was a statistically significant difference only between subplots A and C ($p = 0.03$).

There were no statistically significant differences ($p > 0.05$) in nutrient (P, K, Ca and Mg) content as well as the content of adsorbed bases in soil organic O layer in the burned and unburned part of the forest stand (Table 3). Base saturation was relatively higher in the burned soil organic O layer (23.6 ± 14.1%), but a statistically significant difference was found only between subplots A and B ($p = 0.04$).

Organic carbon, total nitrogen and other nutrient pools in the studied subplots are shown in Table 4. There was a statistically significant difference ($p < 0.05$) between $C_{org.}$ and N_{total} pools in the soil organic O layer in the burned and unburned parts of the forest stand. The mean difference between $C_{org.}$ pools in the soil organic O layer in the burned and unburned parts of the forest stand was 16.5 t ha^{-1} (18.3 t ha^{-1} between A and B subplots and 14.8 t ha^{-1} between A and

Table 3. Mean pH and chemical parameters of the soil organic O layer at the study site

Parameter, unit	Mean values ± 95% confidence intervals		
Study subplot	Burned site (A)	Control (B)	Control (C)
pH_{KCl}	2.9 ± 1.0	2.8 ± 1.0	2.9 ± 1.0
$C_{org.}$, g kg^{-1}	394.4 ± 73.8^{b,c}	518.3 ± 22.2^{a}	486.1 ± 45.1^{a}
N_{total}, g kg^{-1}	13.3 ± 1.1^{b}	15.4 ± 0.9^{a}	14.2 ± 1.5
C/N	29.6 ± 5.0^{c}	33.8 ± 2.1	34.6 ± 2.5^{a}
P, mg kg^{-1}	654.7 ± 201.7	644.7 ± 49.2	641.6 ± 79.2
K, mg kg^{-1}	949.9 ± 180.5	880.7 ± 93.4	1028.0 ± 148.8
Ca, mg kg^{-1}	2494 ± 1415	1997 ± 347	2341 ± 630
Mg, mg kg^{-1}	511.0 ± 91.9	496.7 ± 55.8	509.2 ± 69.5
Adsorbed bases, cmol kg^{-1}	17.6 ± 4.9	14.8 ± 2.1	15.9 ± 4.1
Base saturation, %	23.6 ± 14.1^{b}	12.4 ± 2.5^{a}	15.3 ± 3.4
Hydrolytic acidity, mgeq 100 g^{-1}	76.1 ± 24.6^{b}	108.4 ± 14.1^{a,c}	86.3 ± 5.9^{b}

Note: Significant differences ($p < 0.05$) between subplots A, B and C are denoted by ^{a,b} and ^{c}

C sunplots), the mean difference between $N_{org.}$ pools in the soil organic O layer was 0.3 t ha^{-1} (0.4 t ha^{-1} between A and B subplots and 0.2 t ha^{-1} between A and C sunplots). There were no statistically significant differences ($p > 0.05$) in P, K, Ca and Mg pools in the soil organic O layer in the burned and unburned parts of the forest stand.

More basic pH_{KCl} values in the soil organic O layer and also a higher variation of exchangeable acidity were observed in the burned part of the forest stand (pH_{KCl} ranging from 2.7 to 5.9) compared with the unburned part of the forest stand (pH_{KCl} ranging from 2.6 to 3.3). Consequently, there was no statistically significant difference (p > 0.05) between exchangeable acidity in the soil organic O layer in the burned and unburned part of the forest stand.

Table 4. Mean nutrient pools in the soil organic O layer at the study site

Parameter, unit	Mean values ± 95% confidence intervals		
Study subplot	Burned site (A)	Control (B)	Control (C)
$C_{org.}$, kg ha^{-1}	45750 ± 8557^{b,c}	64006 ± 2745^{a}	60523 ± 5621^{a}
N_{total}, kg ha^{-1}	1545.6 ± 122.2^{b,c}	1902.6 ± 106.2^{a}	1763.5 ± 191.0^{a}
P, kg ha^{-1}	75.9 ± 23.4	79.5 ± 6.1	79.9 ± 9.9
K, kg ha^{-1}	110.2 ± 20.9	108.8 ± 11.5	128.0 ± 18.5
Ca, kg ha^{-1}	289.3 ± 164.1	246.6 ± 42.9	291.5 ± 78.5
Mg, kg ha^{-1}	59.3 ± 10.7	61.3 ± 6.9	63.4 ± 8.7

Note: Significant differences ($p < 0.05$) between subplots A, B and C are denoted by ^{a,b} and ^{c}

There were no statistically significant differences ($p > 0.05$) in analysed chemical parameters in the mineral E horizon in the burned and unburned parts of the forest stand (Table 5). Chemical properties of mineral topsoil (E horizon) below the soil organic O layer were not affected by surface fire.

Composition of soil organic O layer

*The composition of s*oil organic OL horizon at the study site is shown in Table 6. The dominant litter fraction in OL horizon was mosses of varying degrees of decay, the mean mosses abundance in the OL horizon was > 90% in the subplots A and B, dwarf shrubs and herb***s*** roots was 4 – 6%, needles, cones and branches was < 3% and dead parts of ***grasses*** comprised < 2%. There was no statistically significant difference ($p > 0.05$) between the composition of litter fractions in subplots A and B. In contrast, in subplot C, the proportion of mosses fraction was > 75% in OL horizon, but a relatively large content of undecomposed grasses, especially tillers of wavy hair grass (*Deschampsia flexuosa*) were found. The proportion of needles, cones and branches in the OL horizon in subplot C was similar to subplots A and B. The proportion of the moss, grass and root fractions in subplot C were statistically significantly different from the proportion of these fractions in subplots A and B ($p = 0.05$).

In dry pine forests, the composition and ***decay*** level of the soil organic O layer is mostly dependent on the content of ***herbs*** and especially grasses in the ground vegetation layer. The proportion of grasses in the OL horizon depends on the total abundance of ***herbs*** in the ground vegetation layer ($r = 0.56, p = 0.01, n = 30$), but especially on the content of wavy hair grass in the ground vegetation layer ($r = 0.54, p = 0.01$). More intensive litter decomposition and a thicker OF horizon were observed due to increased abundance of ***herbs*** in the ground vegetation layer.

The differentiation of the soil organic O layer between subplot C and subplots A and B was also shown by CCA ordination of soil organic O layer decay, litter and dominant plant species composition (Figure 2). The first main axis (eigenvalue 0.084, 64.0%, Monte Carlo test $p = 0.0260$) was related to differences in dominance of grass and moss species in the ground vegetation layer, along the first axis positive values for the most informative indicators are *Deschampsia flexuosa* (0.564) and *Vaccinium vitis-idaea* (0.264), the indicator species of subplot C, while negative values were found for mosses, *Ptilium crista-castrensis* (-0.408) and *Hylocomium splendens* (-0.293), which are characteristic in subplots A and B (Figure 2). Differentiating indicators along the second axis (eigenvalue 0.008, 6.1%) are positive values of *Scleropodium purum* (0.375) and nega-

Table 5. Mean pH and chemical parameters of the soil E horizon at the study site

Parameter, unit	Mean values ± 95% confidence intervals		
Study subplot	Burned site (A)	Control (B)	Control (C)
pH_{KCl}	3.1 ± 1.1	3.1 ± 1.1	3.0 ± 0.9
$C_{org.}$, g kg^{-1}	25.3 ± 7.2	21.3 ± 9.3	36.4 ± 38.8
N_{total}, g kg^{-1}	0.8 ± 0.1	0.7 ± 0.3	1.12 ± 1.0
C/N	33.7 ± 7.4	29.6 ± 5.9	28.8 ± 4.6
P, mg kg^{1}	91.1 ± 29.4	76.2 ± 32.1	98.1 ± 62.4
K, mg kg^{-1}	219.0 ± 59.3	182.0 ± 51.3	230.5 ± 69.9
Ca, mg kg^{-1}	5.7 ± 8.8	1.0 ± 1.7	3.0 ± 2.4
Mg, mg kg^{-1}	68.3 ± 23.2	48.7 ± 19.6	90.0 ± 38.4
Adsorbed bases, cmol kg^{-1}	0.2 ± 0.3	0.1 ± 0.1	0.3 ± 0.6
Base saturation, %	1.4 ± 2.3	0.6 ± 1.1	0.4 ± 1.0
Hydrolytic acidity, mgeq 100 g^{-1}	11.6 ± 2.1	10.7 ± 2.8	14.5 ± 11.4

Table 6. Mean composition of the soil organic OL horizon at the study site

Study subplot	The mean value (range, min – max) of proportion of the litter fraction, %			
	Mosses	Grasses	Roots	Needles, branches, cones
Burned site (A)	90.6 ± 1.7^{c} (79 – 96)	1.9 ± 1.4^{c} (0 – 14)	4.7 ± 1.0^{c} (1 – 10)	2.4 ± 0.5 (1 – 6)
Control (B)	91.2 ± 0.7^{c} (87 – 95)	0.5 ± 0.3^{c} (0 – 2)	5.6 ± 0.6^{c} (3 – 8)	2.7 ± 0.5 (1 – 5)
Control (C)	75.4 ± 2.3^{a,b} (62 – 85)	12.8 ± 2.0^{a,b} (2 – 25)	8.5 ± 0.6^{a,b} (5 – 11)	3.3 ± 0.5 (1 – 6)

Note: Significant differences ($p < 0.05$) between subplots A, B and C are denoted by ^{a,b} and ^{c}

tive values of *Melampyrum pratense* (-0.449), *Vaccinium myrtillus* (-0.336), that separate dry pine forest litter by site trophic level.

Pine stands at the Peši site were clearly differentiated by litter composition and chemical content (Figure 3). Although the differentiation of sampling sites is lower than in the previous CCA ordination, and the relationship between the composition of the litter fraction and chemical properties were not statistically significant (randomization test for the first axis p = 0.1882), the first axis (eigenvalue 0.029, 21.9%), as in the previous CCA ordination, distinguished the grassy OL horizon of subplot C with a more dense OL horizon interwoven with roots of cereals and *Vacciniosa*, and less an intensive humus mineralization process (C/N ratio correlation with the first axis 0.618). The second axis of site trophic level (eigenvalue 0.005, 4.9%) differentiated the OL horizon in subplot A, with a more neutral soil exchange reaction, greater exchange base content and a higher level of saturation (Table 3), correlation between saturation and the first axis is 0.395.

Discussion and Conclusions

In the study site located in the Coastal Lowland, there is a significantly higher proportion of the grass fraction (culms, roots) in the soil organic O layer in the grassy maritime dry-mesic pine forests (*Vaccinio vitis-idaeo-Pinetum* var. *Deschampsia flexuosa*), which affects the physico-chemical properties of soil organic O layer and mineral soils (litter mass, carbon and nitrogen content). It is assumed that the high proportion of the grass fraction in the soil organic O layer increases the productivity of forest stands as was found in the Coastal Lowland Engure ecoregion in Latvia (Laiviņš et al. 2014).

The results of our study highlight that the ratio between thickness of poor and medium decay O horizons is 2:1 (approximately 70% of soil organic O layer is poor decay, but 30% is medium decay). The clearest ratio value 2:1 of these layers was found in the unburned part of the forest stand (subplot B). In the burned part of the forest stand

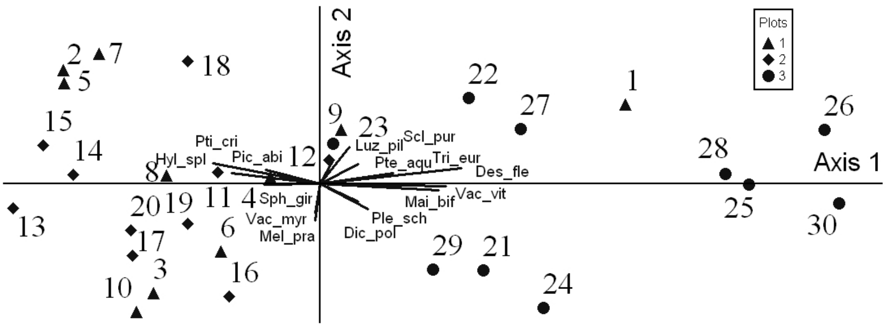

Figure 2. Soil organic O layer ordination (CCA) by decomposition level, litter and dominant plant species composition in the Scots pine forest; plot: 1 – subplot A (burned site, number 1-10), 2 – subplot B (control, number 11-20), 3 – subplot C (control, number 21-30); species: Des_fle – *Deschampsia flexuosa*, Dic_pol – *Dicranum polysetum*, Hyl_spl – *Hylocomium splendens*, Luz_pil – *Luzula pilosa*, Mai_bif – *Maianthemum bifolium*, Mel_pra – *Melampyrum pratense*, Pic_abi – *Picea abies*, Ple_sch – *Pleurozium schreberi*, Pte_aqu – *Pteridium aquilinum*, Pti_cri – *Ptilium crista-castrensis*, Scl_pur – *Scleropodium purum*, Sph_gir – Sphagnum girgensohnii, Tri_eur – *Trientalis europea*, Vac_myr – *Vaccinium myrtillus*, Vac_vit – *Vaccinium vitis-idaea*

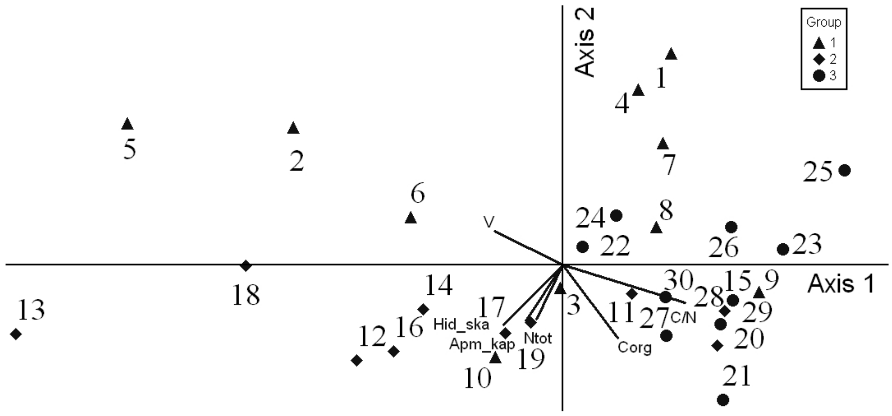

Figure 3. Soil organic O layer ordination (CCA) by decomposition level, composition and chemical condition in the Scots pine forest; group: 1 – subplot A (burned site, number 1-10); 2 – subplot B (control, number 11-20); 3 – subplot C (control, number 21-30); soil chemical parameters: pH – exchangeable acidity, Hid_ska – hydrolytic acidity, V – cation saturation, Corg – organic carbon, Ntot – total nitrogen, C/N – $C_{org.}/N_{total}$

(subplot A), the ratio between thickness of poor and medium decay O horizon was also about 2:1 considering thickness of the medium decay O horizon. Analysis of thickness of the total and poor decay O horizon in subplots A and B indicated that soil organic O layer thickness was reduced by 1.9 cm immediately after surface fire.

Certini (2005) emphasized that the most intuitive change soils experience during burning is the loss of organic matter. The effects of fire on soil organic matter content and properties are highly variable and depend on several factors including fire type (canopy, ground and underground fires), fire intensity, soil type, vegetation, climate, and topography (Cui et al. 2014). Depending on fire severity, the impact on the organic matter consists of slight distillation (volatilisation of minor constituents), charring, or complete oxidation (Certini 2005). According to Giovannini et al. (1988) destruction of organic matter begins at 200–250 °C and becomes complete at 460 °C. In a work by Fernandez et al. (1997) the top 10 cm of a soil under Pinus sylvestris was heated at 220 °C, where 37% of organic matter was lost. In our study the effects of fire on soil organic C were evaluated not only on a quantitative basis but also on a qualitative one. As expected, our results clearly demonstrate that surface fire reduced both organic C and total N content in the soil organic O layer and organic C and total N pools in the soil organic O layer, which is consistent with previously reported results (e.g. Inbar et al. 2014, Poirier et al. 2014). Consequently, a lower C/N ratio value in the soil organic O layer in the burned part of the forest stand was observed, which indirectly indicate that the decline in the organic C content in the soil organic O layer is higher then decline in the total N content in the soil organic O layer during fire. The mean differences between $C_{org.}$ pools in the soil organic O layer in the burned and unburned part of the forest stand was 16.5 t ha^{-1} or 26.5% of $C_{org.}$ pool in the soil organic O layer was lost due to the low severity surface fire. C emissions due to forest surface fire from the study site calculated using Tier 2 methodology of 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) are 25.7 t ha^{-1} that is significantly higher than the measured value obtained in our study. The mean differences between N_{total} pools in the soil organic O layer in the burned and unburned part of the forest stand was 0.3 t ha^{-1} or 15.7% of N_{total} pool in the soil organic O layer was lost due to the low severity surface fire. There were no statistically significant differences between P, K, Ca and Mg pools in the soil organic O layer in the burned and unburned part of the forest stand and the properties of mineral topsoils (E horizon) located below the soil organic O layer were not affected by surface fire. In addition, soil organic O layer as a continuous forest ecosystems floor lose continuity of soil organic O layer thickness after surface fire. After surface fire, especially around large trees, soil physical properties change drastically, also changes of soil moisture regime and enhanced desiccation of soil surface are observed.

Soil pH is inexorably increased by heating of the soil as a result of denaturation of organic acids. However, significant increases occur only at high temperatures (> 450–500 ºC), together with the complete combustion of fuel and the consequent release of bases that also leads to an enhancement of base saturation (Certini 2005, Kutiev and Shaviv 1992). Escudey et al. (2014) found that in general, forest fire ashes on soils caused an increase in the soil pH, primarily within the first 10 cm of soil depth. Marozas et al. (2013) reported that the influence of surface fire on soil chemical properties in 1–4-year-old burned sites in Scots pine mature forests is minor, but slight increases in pH were detected. Also, our results demonstrate that low severity surface fires do not statistically significantly increase soil organic O layer pH, but a clear trend of increasing pH values in the soil organic O layer in the burned part of the forest stand was observed.

Kutiel and Shaviv (1989) found that an increase in the temperature of soil from 250 ţC to 600 ţC was followed by a reduction of most of the available nutrients. Fire-induced changes to cycles of soil nutrients other than N and P generally are slighter and more ephemeral. The availability of these nutrients generally is increased by the combustion of soil organic matter and the increase is strictly dependent upon type of nutrient, fire severity, burnt tree species, soil properties, and pathway of leaching processes (Kutiel and Shaviv 1992, Dzwonko et al. 2015). Our results of soil organic O layer chemical analysis show relatively higher variation of soil organic O layer properties in the burned part of the forest stand. The high variation in chemical properties and thickness of soil organic O layer in the burned part of forest stand is related to severe or even complete combustion of soil organic O layer around the stems of Scots pine and Norway spruce trees. The resinous tree bark and tree roots in topsoils burn slower, promoting stronger heating of organic matter, stable higher temperatures and longer-term smouldering and burning of the soil organic O layer. In the more glade-like parts of the forest stand between trees only the dry top layer of litter burned, combustion temperature was not as high and the deeper horizons of the soil organic O layer were not affected by surface fire.

In general, our results indicate that the composition and decay level of the soil organic O layer in dry-mesic Scots pine forests located in the Coastal Lowland is mostly dependent on the abundance of herbs and especially grasses in the ground vegetation layer. Despite the large variation in chemical properties of soil organic O layer in the burned part of forest stand we found that the instantaneous impact of low severity surface fire on soil organic O layer is not only quantitative, but also qualitative. Fire-affected part of the 60-year-old dry-mesic Scots pine forest stand had reduced organic C and total N pool stored in the soil organic O layer, but properties of the mineral topsoil below the soil organic O layer were not affected by surface fire.

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