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Short-term impact of prescribed fire on soil pH, organic matter and water repellency in a *Calluna vulgaris* heathland located in Lithuania. First results

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Keywords

Landscape management
Prescribed fire
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Abstract

The aim of this work is study the short-term effects of a prescribed fire used for landscape management on soil pH, organic matter (SOM) and soil water repellency in different size fractions (2-1, 1-0.5, 0.5-0.25 and <0.25 mm) in a Calluna vulgaris heathland (After the fire and 4 months after the fire). We selected two different plots affected by different fire severities in order to observe if different prescribed fire severities could have different impacts on the studied soil properties (The severity in plot I was higher than in the plot II). The results showed that independently of the severity, the prescribed fire did not have in the period immediately after the fire did not changed significantly in both plots pH and SOM%. In soil water repellency, no significant differences were observed between control and burned plots. Significant differences were only observed in the burned plot I. Studies are ongoing to identify there will be changes with the time.

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1 Introduction

It is extensively known that fire changes soil properties, depending on fire severity and soil type. Low severity prescribed fires does not change significantly soil properties, contrary to high severity fires that can have negative impacts in soils (Certini, 2005). The vegetation removal and organic matter mineralization increase soil exposition to erosion agents (Cerdà & Doerr, 2005) and ash can change solution chemistry (Pereira et al., 2011; Pereira et al., 2012), modifying temporarily the type and amount of nutrients leached in soil surface. Normally after a fire soil pH can increase (Murphy et al., 2006). This change depends on the degree of organic matter mineralization that increases the amount of soluble cations, mainly sodium and potassium (Raison & McGarity, 1980). Also, fire changes the quantity of Soil organic matter (SOM). Low severity fires can increase SOM due the incorporation of charred material. However, high severity fires reduce the amount of SOM, due the strong combustion that consume all litter and surface SOM (Certini, 2005). Fire has impacts on soil water repellency (WR) with implications on soil erosion, plant growth and surface and subsurface hydrology (Doerr et al., 2009). These changes depends on the temperature and severity reached, type of soil and fuel consumed (DeBano, 2000). The major impacts and changes in soil properties occur in the immediate period after the fire, when ash transport and the erosion are high (Cerdà & Lasanta, 2005; Cerdà & Doerr, 2008; Pereira et al., 2013a). The aim of this work it is study the immediate effects of a prescribed fire in soil pH, SOM and soil WR in the immediate period after the fire.

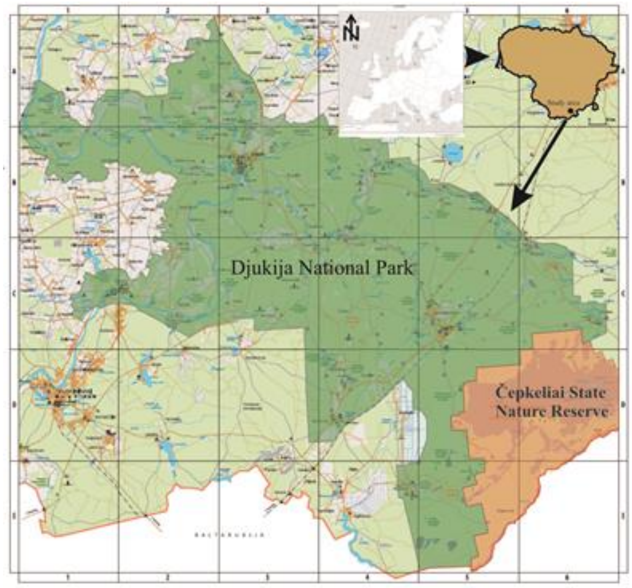

Figure 1. Study area.

2 METHODS

2.1 STUDY SITE

The prescribed fire was carried out in Dzukija National Park, located at 53 54’ N and 24 22’ E (Figure 1) with the aim of improve the habitat of the black grouse (*Lyrurus tetrix*). Since the black grouse mates in spring, the prescribed fire was conducted in autumn in order to not disturb the habitat. After the fire we selected two plots where fire had different severities, evaluated according the ash color (Úbeda et al., 2009). The fire was more severe in the plot I due the major presence of grey and white ash in the burned area. In a contiguous area we designed a control plot in order to evaluate the effects of the prescribed fire. The burned plot I and two had an area of 7500 m^2 and 3000 m^2 respectively. The control plots had both an are of 3000 m^2. In the burned plot I we collected 20 soil samples and in the remained 15. In the studied area the soil classified according to the FAO (2006) as *Cambic arenosols* and the vegetation is composed mainly by *Calluna vulgaris*.

2.2 LABORATORY ANALYSIS

Soils were sampled at 0-5 cm depth, stored in plastic bags and taken to the laboratory. In the laboratory were dried at room temperature during 24 hours. Soils were sieved with the 2mm sieve and pH was determined with 1: 2.5 soil water ratio with distilled water. Soil organic matter was assessed using the Loss of Ignition Method (LOI). Soil WR was assessed in different soil sieve fractions (2-1, 1-0.5, 0.5-0.25 and <0.25 mm) in all soil samples (260), according to Mataix-Solera & Doerr (2004). Sieve fractions were placed separately placed in plastic dishes (50 mm in diameter). Subsequently were exposed to controlled laboratory atmosphere (20 ^{o}C and 50% relative humidity) during one week to reduce the potential impacts of atmosphere humidity on soil WR (Doerr et al., 2002). Soil WR was measured using the water drop penetration time (WDPT). Three drops of distilled water were placed on soil surface and the infiltration times were recorded according Bisdom et al. (1993). Soils were classified as hydrophilic (WDPT ≤5 s), slightly (6-180 s), strongly (181-900 s), severely (901-3600 s) and extremely water repellent (>3600 s).

2.3 STATISTICAL ANALYSIS

Previous to data statistical analysis, we tested data normal distribution with the Shapiro-Wilk test (Shapiro and Wilk 1965). Normal distribution was considered at a p>0.05. In this case, the data did not respect the Gaussian distribution, even after a neperian logarithm, box-cox, and square root transformation. Only the ranked data accomplished the normal distribution requisites. Thus statistical analyses were carried out with ranked data, however the graphics are presented with the original data. The comparison between treatments, fractions and sampling periods were carried out with an ANOVA repeated measures. In the case of significant differences, a post-hoc Tukey HSD test was applied. An ANOVA-one way

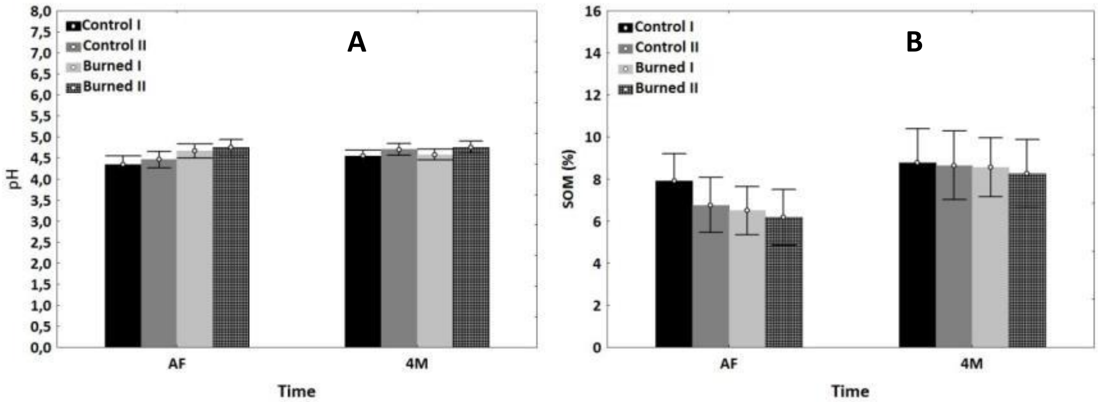

Figure 2. pH and SOM in Plot 1 and Plot 2, After and 4 months after the fire.

test was carried out to identify differences between control and burned plots between the studied periods. Significant differences were considered at a *p*<0.05. A Principal Components Analysis (PCA) based on the correlation matrix was carried out in order to identify relationships between the variables and if the prescribed fire changed importantly the soil proprieties (Pereira et al., 2011).

3 Results

The results showed that no significant differences were observed between treatments and time in pH in the plot I for treatment (F= 2.17, *p*>0.05), time (F= 0.46, *p*>0.05) and for time x treatment (F= 2.48, *p*>0.05). In the plot II no significant differences were also identified for treatment (F= 3.76, *p*>0.05), time (F=1.97, *p*>0.05) and time x treatment (F= 3.22, *p*>0.05) (Figure 2a). The same results were observed in SOM in plot I for treatment (F= 0.60, *p*>0.05), time (0.08, *p*>0.05) and for time x treatment (F=0.05, *p*>0.05). In the plot II no significant differences were also identified for treatment (F= 1.57, *p*>0.05), time (F= 0.16, *p*>0.05) and time x treatment (F= 1.40, *p*>0.05) (Figure 2b).

In the plot I after the fire, in the composite sample of the control plot, we did not identify any hydrophilic sample and the majority showed strong to severe WR. In the burned plot, few samples were hydrophilic and the majority showed strong water repellency. In relation to the different sieved fractions, the soil WR was especially high in the coarse fraction (high frequency of samples with severe and extreme water repellency), than in the finer fractions (Figure 3a and b). In the Plot II the soil composite fraction in the burned plot showed higher WR than the control that was especially water repellent in the coarser fractions, as identified in the Plot I (Figure 3c and d).

Four months after the fire in the control I, the composite soil samples showed strong to severe WR. In relation to the burned plot, this number was low and some samples showed slight WR. The same pattern was observed in sieve fractions after the fire. The coarser fractions showed higher WR than the finer. Comparing the sieved fractions of the burned and unburned plot, the frequency of samples with higher WR was high in the unburned plot (Figure 3e and f). In the plot II, the frequency of composite samples with high strong and severe WR was higher than in the control plot. In relation to the sieved fractions, the frequency of strong and extreme soil WR was observed in the burned plot in the coarser fractions (2-1 and 1-0.5 mm), occurring the contrary in the finer fractions (Figure 2g and h). The results of the ANOVA test for soil WR showed no significant differences between the same fractions collected in unburned and burned areas in plots 1 and 2. In relation to the different sieve fractions, 2-1 and 1-0.5 mm fractions were significantly more water repellent than the finer ones in the burned and unburned plot (Figure 4a and b). The comparison of control and burned plot in the different periods showed that significant differences were only observed in the composite sample 2-1mm and 1-0.5 mm samples collected in the plot 1 (Table 1).

The PCA indentified 3 factors that explain at least 1 variable. The factor 1 explained 35.00% of the variance, the factor 2 22.87% and the factor 3 13.11%. In total, explained 70.98% of the variance. The intersection

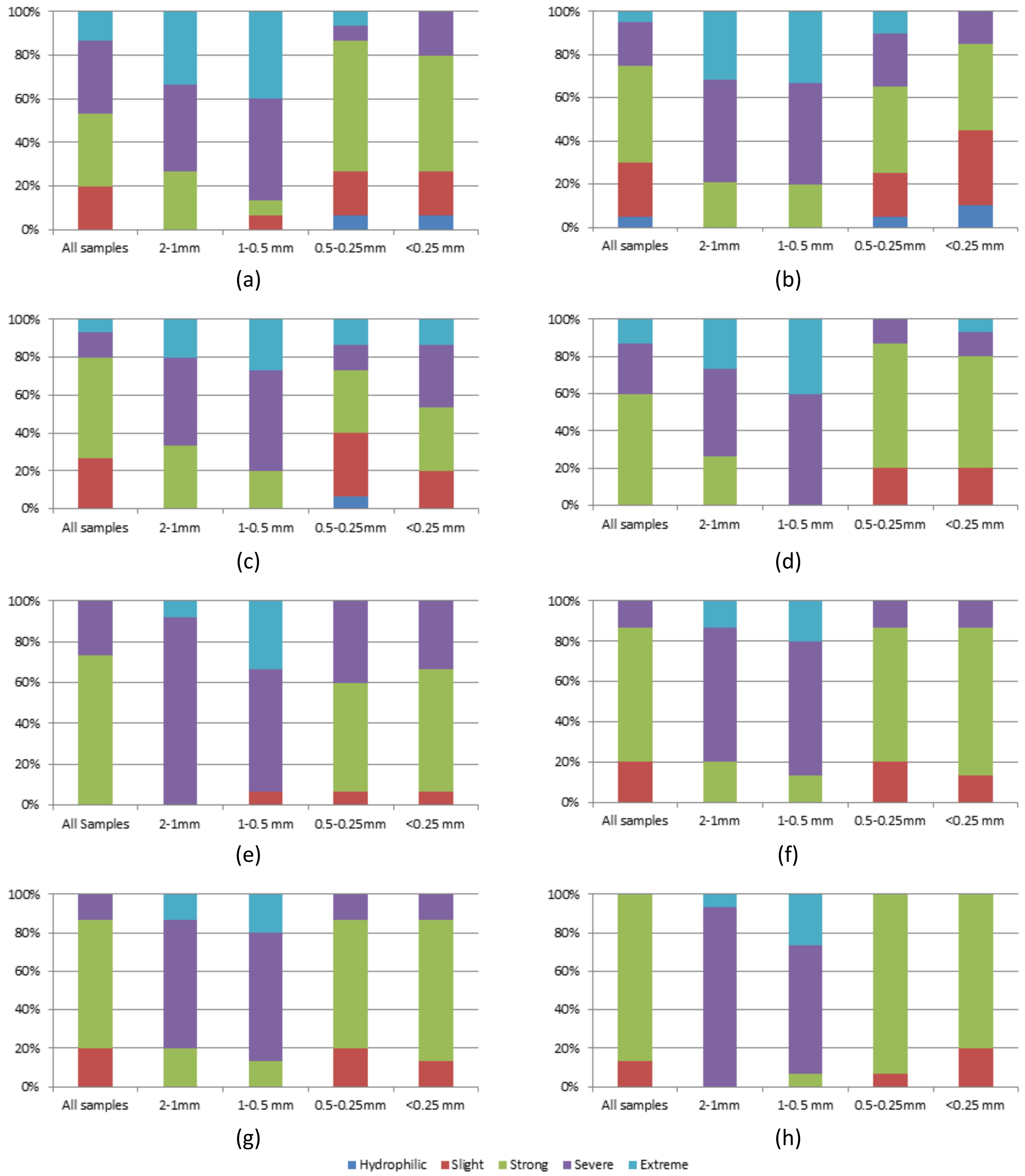

Figure 3. Relative frequency (%) of soil WR for different sieve fractions. a) control 1; b) burned 1, control 2; c) and burned 2; d), immediately after the fire; e) control 1; f) burned 1, control 2; g) and burned; h), four months after the fire.

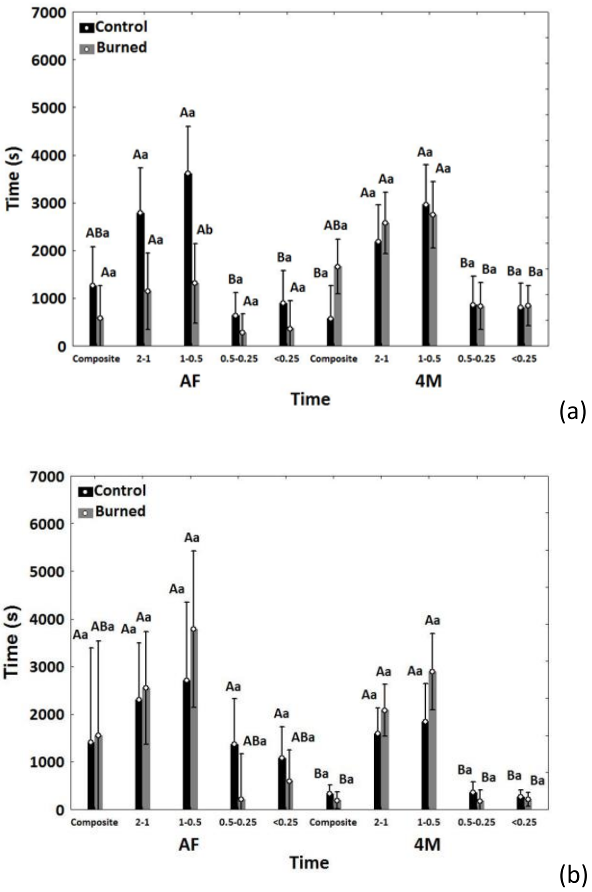

Figure 4. Mean soil WR in plot I and plot II. Error bars represent 95% of confidence. Large caps differences among fractions and small caps between burned and unburned plot in composite and burned plot. Different letters represent significant differences at a p<0.05. Tukey's mean separation: A>B>C.

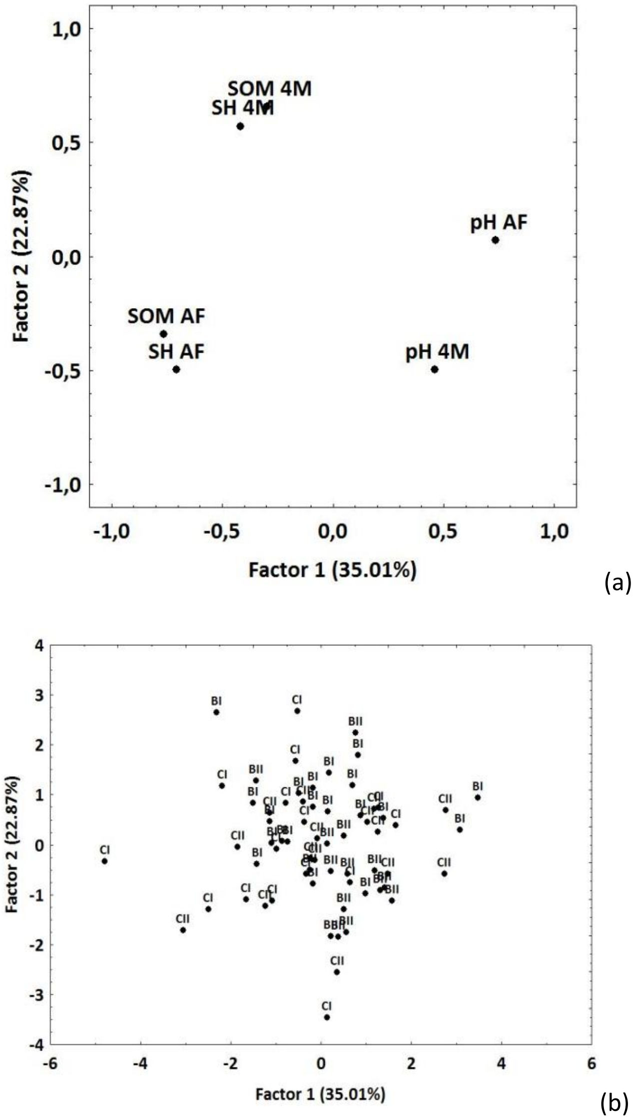

Figure 5. Relation between factor 1 and 2 factor: (a) variables and (b) cases. Control 1 (CI), Burned 1 (BI), Control 2 (CII) and Burned (BII).

between the first and second factors (the ones that explain the better the variance) shown that soil water repellency was strongly connected with the SOM and correlated negatively with soil pH (Figure 5a). The intersection of the cases showed that in the period of study, the fire did not change importantly these soil properties, since no clear pattern between control and burned plots (Figure 4b).

4 DISCUSSIONS AND CONCLUSIONS

The prescribed fire applied did not induced changes in soil pH and SOM in the period immediate after the fire. Despite the fact that the fire severity was higher in the Plot I, no difference was observed in each plot. The fire spread very fast and affected especially the aerial plant biomass. Thus it is very likely that the direct impacts on soil were reduced. It is recognized that ash can be removed by wind after the fire, redistributing or evacuating the nutrients from the burned area, especially in areas without tree cover (Pereira et al., 2013b) and this can be a potential cause for the mineralized organic matter did not remained in the plot and induce and changed soil properties. The reduced time of fire residence and temperatures, decrease the impacts of fire on soil properties (Úbeda & Outeiro, 2009; Jordán et al., 2011). Normally after prescribed fire soil pH increases due the mineralization of the SOM and ash that increase the availability of major elements (Úbeda et al., 2005) including when applied in Boreal environments (Malmstrom et al., 2009). However in *Calluna vulgaris* environments, prescribed fire seems that not have important implications on soil pH. Marcos et al. (2009) observed that after a prescribed fire applied in

Table 1. Mean and Standard Deviation (SD) soil WR in control and burned plots in the composite and in the different size fractions considered Significant differences at p<0.05 (*) and p<0.01 (**). NS: non-significant differences at a p<0.05.

	Treatment	Composite	SD	p	2-1 mm	SD	p	1-0.5 mm	SD	p	0.5-0.25 mm	SD	p	<0.25 mm	SD	p
Plot I	Control (AF)	1347.31	1949.05	NS	2736.4	2549.27	NS	3368.77	2633.45	NS	596.46	1282.22	NS	831.97	1888.79	NS
	Control (4M)	538.24	498.756		2184.16	974.06		2766.26	1420.77		925.17	925.17		756.91	821.22	
	Burned (AF)	547.15	1023.77	*	1139.97	856.81	**	1313.07	1076.21	**	273.23	270.32	NS	362.44	355.62	NS
	Burned (4M)	1662.40	1584.43		2578.95	1643.95		2745.07	1709.45		833.10	1182.10		844.73	844.73	
Plot II	Control (AF)	1401.57	4367.01	NS	2304.02	2500.10	NS	2702.07	2656.00	NS	1370.08	2533.06	NS	1076.71	1351.01	NS
	Control (4M)	335.00	440.16		1590.35	1243.99		1243.99	1556.88		350.73	585.68		259.40	347.31	
	Burned (AF)	1549.84	3042.819	NS	2547.64	1939.24	NS	3786.76	3503.01	NS	215.97	201.37	NS	598.95	1105.94	NS
	Burned (4M)	191.22	133.883		2082.267	737.53		2889.20	1457.87		123.07	123.07		205.97	170.43	

Calluna vulgaris located in north of Spain did not have changed soil pH. The same results were identified in UK by Worrall et al. (2007). Similar to pH, after low severity prescribed fires SOM usually increases after the fire due the ash and charred material incorporation into soil profile (Mataix-Solera & Guerrero, 2007; Knicker, 2007). To our knowledge, no studies were identified on fire effects on SOM in *Calluna vulgaris* heathlands, thus we cannot compare our results with other studies. However, as in the case of pH the SOM was not affected significantly, that is an indication of the little effects of soil properties.

The studied soils were naturally hydrophobic and fire did not change it. Previous studies identified that dry sandy acid soils present a high WR (Jonge et al., 1999; Doerr et al., 2000; Suominen et al., 2003; Rodriguez-Alleres et al., 2007) similar to the observed in the studied area. In soils were WR is natural as in this case, fire is very likely to not have important implications on repellency (Doerr et al., 2000). In low severity fires, fire does not change importantly soil water repellency as observed by Jordán et al. (2011). Since the SOM did not changed with the fire, soil WR may not be affected also. There are several studies that link SOM with soil water repellency (Mataix-Solera & Doerr 2004; Taumer et al., 2005; Rodriguez-Alleres et al., 2007; Martinez-Zavala & Jordán-Lopez, 2009) as we observed in this work. Despite the lack of impact of fire in soil water repellency, significant differences were identified among fractions as in other studies in burned and unburned soils (Mataix-Solera & Doerr 2004; Rodriguez-Alleres et al., 2007). In burned calcareous soils Mataix-Solera & Doerr (2004) observed that the finer fraction was more repellent. Similar results were identified by Jordán et al. (2011) in volcanic soils that observed that the finer fraction of the burned soils were more hydrophobic than the coarser, especially in the affected by a high severity. In the unburned plots the coarser fraction was more hydrophobic as it is observed in this work. This suggests that the fire did not changed soil fractions water repellency, and the effects of this prescribed fire were reduced. Nevertheless, there was significant increase of soil water repellency in the burned plot I 4 months after the fire in the composite sample and in the 2-1 mm and 1-0.5 mm fractions. We observed a non-significant increase of SOM% in the burned plot I that may be sufficient to increase soil WR. This can be linked with the high fire severity, however further studies are needed to accurate this situation.

The prescribed fire did not have important impacts on the studied soil properties. Considering that pH and SOM are soil properties that can be importantly changed, especially in the immediate period after the fire (Certini, 2005), that can change soil hydrological properties as water repplency, it is very likely that this fire did not change greatly soil properties. Thus the application of prescribed fire in Lithuanian *Calluna vulgaris* heathland from the soil point of view may be a good technique for landscape management.

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