INFLUENCE OF WILDFIRE AND FIRE SUPPRESSION BY SEAWATER ON SOIL PROPERTIES

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Abstract. During the last decades rapid climate changes have occurred and through frequent fires they have strongly affected the landscape. Wildfires directly influence on soil properties and generally increasing availability of nutrients. Due to the lack of multiple sources of freshwater, most fires in Dalmatia are being extinguished by seawater, which directly affects soil properties. During October 2012 soil samples (0 - 5 cm) were collected at four different locations from a burned and unburned plots in order to observe the impacts of fire on soil properties. Samples were collected 14 and 2 months after the wildfires occurred in 2011 and 2012, depending on the location. This paper analyzes the effects of wildfire and seawater used for fire suppression on soil chemical properties. The results showed significant differences between burned and unburned soil plots for pH, plant available phosphorus (P) and potassium (K), total carbon and total nitrogen. Differences between electrical conductivity (EC), F^-, Cl^-, SO_4^{2-}, Na^+, Mg^{2+} and Ca^{2+} in burned and unburned plots also exist. Burned plots contain higher average values of K, P, EC and all water-extractable elements. Soil pH conditions after wildfire favors the solubility of some elements presented in this paper. These investigated parameters are under the direct influence of fire intensity and seawater on the ground. This study is useful for understanding changes in soil chemistry after fire and seawater application.
Keywords: *Dalmatian region, seawater, soil properties, wildfire*

Introduction

Fire is great disturbances in the ecosystems, but it is also an important ecological element (Pereira et al., 2012), fundamental for the landscape sustainability. In forest system wildfire can alter vegetation composition and even promote tree regeneration (Martínez-Sánchez et al., 1999; Cammeraat and Imeson, 1999). Fire was used in landscape management, and there are ecosystems like Mediterranean whose functions cannot be understood without fire (Pereira et al., 2010a; Mataix-Solera and Cerdà 2009). In the period of 1998–2008, out of all the forest fires in Croatia 31.7% were recorded in Dalmatia region (Croatian Mediterranean area that consists of 4 Croatian counties). In burned forest areas of Croatia, Dalmatia participates with as much as 64.3%, and for the most part (50.2%) these areas are overlain by Coppice Forests, shrubs, garrigues and thickets (Mamut, 2011). Wildfires are natural events, but the increased recurrence of wildfires in recent decades has an obvious anthropogenic component (Rovira et al., 2012).

Following wildfire, ash commonly covers the soil surface for some time until it is removed by wind or water erosion. Fires reduce soil organic matter on the surface and leave the soil unprotected from erosion which leads to very fast loss of ash material from the surface (Cerdà and Doerr, 2008; Pereira et al., 2013), especially if the burned areas are at higher inclinations. The erosion moves ash material which affects chemical

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properties of soil. This layer is a key factor for soil chemistry after the fire and can be many centimeters thick and can affect soil erosion (Cerdà, 1998a) and runoff generation processes and rates (Cerdà, 1998b).

Chemical composition of forest fire ash can be very variable and depends on various factors (Dlapa et al., 2013), like burning temperature, type of plant species, part of plant combusted, time of exposure to heat, fuel density and arrangement, and other factors affecting combustion conditions (Liodakis et al., 2005; Pereira et al., 2011). Dominant elements in wood ash are calcium (Ca), potassium (K), magnesium (Mg), silicon (Si), manganese (Mn), aluminium (Al), phosphorus (P), sulphur (S), iron (Fe), sodium (Na) and zinc (Zn) (Etiegni and Campbell, 1991; Liodakis et al., 2007). Many researchers (Andreu et al., 1996; Monleon et al., 1997; Hatten et al., 2005; Certini et al., 2011; Yinghua et al., 2012; Rovira et al., 2012; Bogunovic et al., 2014) have investigated wildfire and their impact on biological and chemical soil characteristics. Some of them have determined the reduction of total carbon (TC) (Certini et al., 2011) and N in soil (Rovira et al., 2012), low K variations and similar pH and P content one year after the fire (Andreu et al., 1996), while others (Yinghua et al., 2012; Bogunovic et al., 2014) observed higher soil pH and P content in burned soils 15 months post fire. Some studies (Hatten et al., 2005) recorded negligible difference in soil properties between burned and unburned areas, while Monleon et al. (1997) noted that 12 years post fire TC and inorganic N content were returned to unburned levels.

A serious problem of fire suppression in Dalmatia is the access to fresh water. Fire brigades use fresh water in wildfire ground suppression, but in many cases due to the inaccessible terrain air forces use seawater for wildfire suppression. According to chemical composition, the seawater is unsaturated homogeneous solution composed of water as a solvent (96.5%), dissolved salts (3.5%), small amounts of particulate matter, dissolved gases and organic ingredients. More than ninety chemical elements are found in seawater, and six major elements dominate: Na^+, Mg^{2+}, Ca^{2+}, K^+, chlorine (Cl^-) and S, while Na^+ and Cl^- account for more than 85% of the total (Martinac, 2010). These elements from seawater and ash material are leached into run-off and into the soil profile and may have impacts on surface soil chemistry.

There are several types of soil salinity and all refer to areas where soils contain high levels of salts (e.g. Na^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^- and SO_4^{2-}) that can affect plant productivity and soil organisms (Navarro-Pedreño et al., 1997). In this study the saline water application is not a result of arid environment or irrigation, since the source of salts is the seawater used for fire suppression. Seawater affects the natural ecosystem in the form of water and salt stress. Accumulation of dispersive cations, such as Na^+ in soil solution and the exchange phase (K^+, Mg^{2+}, Ca^{2+}) affect the physical properties of soil, such as structural stability, hydraulic conductivity, infiltration rate and erosivity (Juan et al., 2011). A plant in a drying, saline soil is exposed to increased levels of both water stress and osmotic stress, because the matric potential and the osmotic potential decrease simultaneously with decreasing soil moisture (Johnson, 1992). At the same time, the seawater undoubtedly affects burned soil. Researchers have investigated the effects of saline water on crops and soil (Richards, 1992; Sheng et al., 1997; Katerji et al., 2003; Ahmed et al., 2010; Chen et al., 2010; Ben Ahmed et al., 2012) but there is lack of studies of impact of seawater on fire-affected forest soils in the environmental conditions of Dalmatia, a part of Mediterranean.

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The aim of this paper is study the effect of seawater on burned soil properties, TC, total nitrogen (TN), K and P, EC and water extractable ions (F^-, Cl^-, SO_4^{2-}, Na^+, Mg^{2+}, Ca^{2+}) after a wildfire in Dalmatia, Croatia.

Material and Methods

Site Characteristics

The study area is located in island Korcula and Peljesac peninsula in southern Dalmatia: Smokvica (42°55' N, 16°54' E, 97 m.a.s.l.), Blato (42°56' N, 16°50' E, 185 m.a.s.l.), Panjika (42°51' N, 17°30' E, 305 m.a.s.l.), Ponikve (42°50' N, 17°37' E, 240 m.a.s.l.). All four areas are in similar ecosystems with a Mediterranean climate characterized by long, dry and hot summers and mild and humid winters. Air temperatures are relatively high throughout the year (mean annual air temperature is 11.2 °C), and only during January and February temperatures are below 10 °C. Average minimum month temperature is 9.8 °C in January and average maximum month temperature is 26.9 °C in July (Meteorological and hydrological institute of Croatia, period 1961 - 1990). Average annual rainfall is 1300 mm and increases from the coastal area to the interior of the island, and from lower to higher altitudes. Average annual number of sunny hours amounts to over 2500 at some locations. The area is covered with Mediterranean flora and sometimes pine trees. All wildfires on investigated locations were supressed from air with seawater, while *Table 1* shows detailed information on the characteristics of individual sampling locations.

Table 1. *Site characteristics for burned and unburned sampling locations on Chromic cambisols. B-burned; C-unburned*

Sample code	Latitude/ longitude	Altitude (meters)	Year of fire	Slope (°)	Aspect	Dominant species
Smokvica B	42°55'25"N 16°54'19"E	82	2011	32	N	Strawberry tree (*Arbutus unedo* L), Holm oak (*Quercus ilex L.*), Heather (*Calluna vulgaris L.*)
Smokvica C	42°55'20"N 16°54'18"E	68		28	S	Black pine (*Pinus nigra* J.F.Arnold), Phillyrea (*Phillyrea latifolia* L)
Blato B	42°56'51"N 16°50'25"E	163	2012	39	N	Different pines, Phillyrea (*Phillyrea latifolia* L)
Blato C	42°56'50"N 16°50'21"E	155		42	N	Aleppo pine (*Pinus halepensis* Miller)
Panjika B	42°51'19"N 17°30'51"E	310	2012	17	W	Strawberry tree (*Arbutus unedo* L), Holm Oak (*Quercus ilex* L), maquis (macchie), Prickly Juniper (*Juniperus oxycedrus* L.)
Panjika C	42°51'24"N 17°30'25"E	336		25	W	Different pines, Strawberry tree (*Arbutus unedo* L.),

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Ponikve B	42°50'55"S 17°37'21"E	223	2011	18	NI	Holm Oak (*Quercus ilex* L), Black pine (*Pinus nigra* J.F.Arnold), Prickly Juniper (*Juniperus oxycedrus* L.)
Ponikve C	42°50'57"N 17°37'20"E	236		12	N	Different pines, Prickly Juniper (*Juniperus oxycedrus* L..), Holm oak (*Quercus ilex L.*)

Survey areas consisted mainly of carbonate sedimentary rocks, limestones and dolomites. The karst bedrock in southern Dalmatia is dominantly covered by *terra rossa* - chromic cambisols (FAO, 2006), which cover the largest part of the coastal terrain and most of the islands. Most elevated areas in the highest mountain areas of the Peljesac peninsula are overlain by rendzic and mollic leptosols. Smaller patches on the island of Korcula are overlain by aric anthrosols.

Plot Design and Soil Sampling

At each site we collected 3 soil samples (0 - 5 cm) from burned and 3 from unburned plots (each taken sample consists of 10 individual samples homogenized into one) with similar aspect, slope, elevation and vegetation characteristics and those that have been diversely affected by wildfires in 2011 (areas burned 14 months prior to sampling) and 2012 (areas burned 2 months prior to sampling). The total number of collected samples is 24. Near each burned area unburned sample points were chosen according to their similarity to the burned areas in order to determine the differences between samples. Each composite sample was taken 40 m from another sample and represent an area of approximately 1200 m^2. Samples were taken with spade and stored in plastic bags without air and taken to the laboratory for analysis.

Preparation of Samples and Chemical Analysis

In the laboratory prior to chemical analysis, the samples were air dried, milled and passed through a sieve of 2 mm diameter. The following soil properties were monitored in the <2 mm fraction: soil pH, EC, plant available phosphorus (P) and potassium (K), TC, TN, F^-, Cl^-, SO_4^{2-}, Na^+, Mg^{2+} and Ca^{2+}. The soil pH was measured using the electrometric method in 1:2.5 (w/v) ratio with the Beckman pH-meter Φ72, in KCl suspension (according to HRN ISO 11464:2004 norm). TN content was determined by dry combustion method according to HRN ISO 13878:1998. TC content was determined after dry combustion (HRN ISO 10694:1995). Plant available P and K were extracted by ammonium lactate (AL) solution (Egner et al., 1960) and detected by spectrophotometry and flame photometry, respectively. Electrical Conductivity was calculated at 25 ^oC on soil water (1:5) extract according to HRN ISO 11265:2004. Water-extractable anions (F^-, Cl^-, SO_4^{2-}) and cations (Na^+, Ca^{2+}, Mg^{2+}) in soil samples were extracted in ultra-pure water in 1:10 (w/v) ratio according to ÖNORM L 1092 norm. After the extraction, samples were centrifuged, filtrated and contents of anions and cations were detected by suppressed conductivity on Doinex ICS-1000 system with an analytical column: for anions - Ion Pac AS 17 (4x250 mm) and for cations - Ion Pac CS 16 (5x250 mm), all in compliance with HRN EN ISO 14911(2001) and HRN EN ISO 10304-1(1998). One-way ANOVA was carried out to test whether the investigated properties varied significantly amongst burned and unburned plots at each location. In

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case it did, the *post-hoc* Fisher test was applied to separate mean values at $P \leq 0.05$. All statistical analyses were carried out with SAS Institute 9.1.3.

Results

Statistically significant differences were found in all chemical variables measured in soils that have been burned 14 and 2 months prior to sampling in contrast to unburned plots. Detailed results are presented in *Figure 1* and *Table 2*.

TC concentrations were lower in the surface horizon of burned plots on Smokvica and Blato location, while burned plots on Panjika and Ponikve area recorded higher TC results. TC values ranged from 6.04% to 17.10% in burned samples, and from 6.82% to 13.07% in unburned samples. Mean value of TC was 10.19% in burned soils and 9.21% in unburned plots. Burned samples recorded higher value of TN in 3 of the 4 locations. The mean value of TN in burned samples was 0.55% and 0.37% in unburned samples. Burned plots contain higher amounts of TN than unburned and there was no significant difference only at Smokvica location.

The level of plant available P and K was significantly different among all locations. In unburned samples P ranged in very low supply levels (14 to 48 mg kg^{-1} P_2O_5), while the burned samples had moderate to very rich P supply and values from 135 to 424 mg kg^{-1} P_2O_5, except for Blato location where 30 mg kg^{-1} P_2O_5 were found. The average values of soil K supply were 737 mg kg^{-1} K_2O in unburned samples and 425 mg kg^{-1} K_2O in burned samples. These results show that the soil is very well supplied with K, with the exception of unburned samples from Ponikve site.

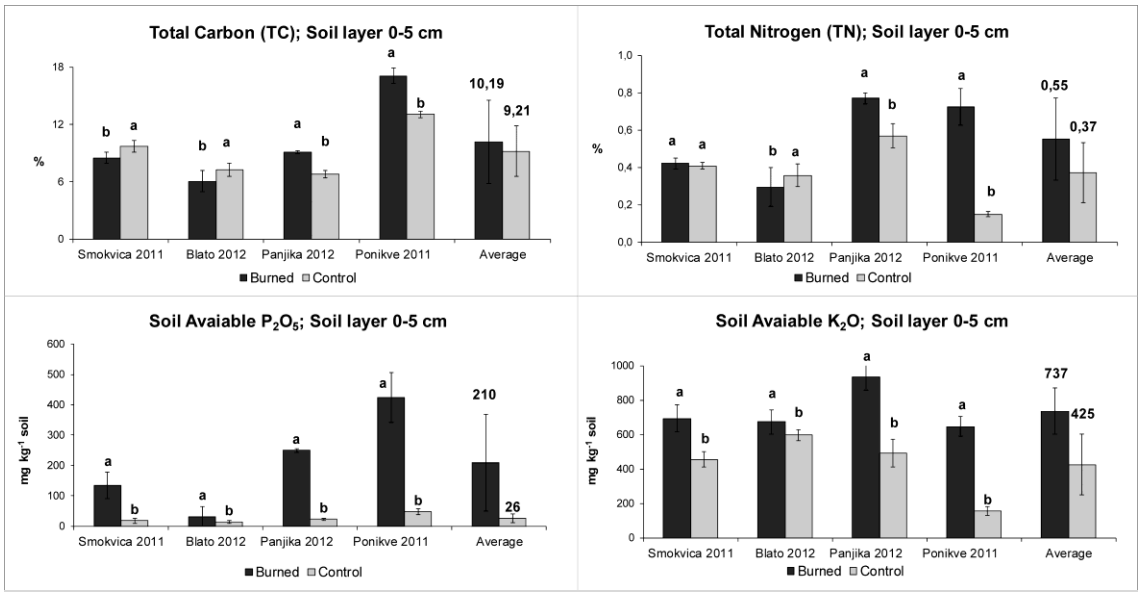

Figure 1. *Mean values of soil chemical properties for burned and control plots. For each chemical property at each location bars with different lowercase letters are statistically different (p<0.05). Hanging bars represent standard deviation.*

Burned plots recorded neutral to alkaline pH which varied from 6.78 to 7.90. The mean soil pH for unburned plots was 6.62, while unburned plots were low acid to neutral and their soil pH varied from 5.97 to 6.67. Statistical differences between unburned and

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burned plots were observed in the pH in each location. In this study significant differences between burned and unburned samples were identified in F^-, SO_4^{2-}, Na^+, Mg^{2+} and Ca^{2+}, in all investigated locations (*Table 2*). The amounts of Ca^{2+}, Mg^{2+}, Na^+ and SO_4^{2-} were significantly higher in burned plots than in unburned. Relatively high concentrations of SO_4^{2-}, Na^+, Mg^{2+}, F^-, Cl^- and Ca^{2+} were recorded in burned samples from all locations (with the exception of Na^+, F^- in Blato location). EC also showed significantly higher values in all four investigated sites, with almost 87% higher average value (295.88 µS cm^{-1}) in burned than in unburned plots (157.83 µS cm^{-1}).

Table 2. *Mean concentration of pH, EC and water-extractable elements in the burned (B) and unburned (C) plots.*

Sample code		pH	EC	F^-	Cl^-	SO_4^{2-}	Na^+	Mg^{2+}	Ca^{2+}
		-log(H+)	µS cm^{-1}	mg kg^{-1}					
Smokvica 2011	B	7.09±0.12a	266.0±9.21a	1.89±0.07a	42.81±1.48a	52.46±1.82a	55.42±1.92a	29.96±1.04a	542.79±18.80a
	C	6.20±0.17b	155.9±5.40b	0.39±0.01b	18.75±0.65b	21.91±0.76b	44.30±1.53b	6.92±0.24b	308.53±10.69b
Blato 2012	B	6.78±0.05a	221.0±7.66a	0.26±0.01b	47.88±1.66a	65.97±2.29a	57.19±1.98b	28.61±0.99a	381.44±13.21a
	C	5.97±0.10b	146.5±5.07b	0.33±0.01a	42.19±1.46a	28.89±1.00b	67.91±2.35a	19.45±0.67b	245.64±8.51b
Panjika 2012	B	7.31±0.03a	335.5±11.26a	4.29±0.05a	104.33±7.41a	327.66±8.21a	57.17±2.51a	27.30±2.17	607.99±12.88a
	C	6.67±0.11b	173.5±8.26b	0.10±0.01b	22.12±1.22b	39.08±2.36b	42.13±1.32b	<0.01	374.96±17.52b
Ponikve 2011	B	7.90±0.04a	361.0±12.51a	5.84±0.20a	43.39±1.50a	219.81±7.61a	23.96±0.83a	175.56±6.08a	447.59±15.51a
	C	6.62±0.02b	155.4±4.16b	0.33±0.08b	31.83±2.66b	34.55±0.66b	12.95±0.91b	46.79±2.55b	215.90±10.85b
Average	B	7.27±0.13	295.91±17.29	3.07±0.65	59.60±7.98	166.48±34.44	48.43±4.34	65.36±19.23	494.95±26.99
	C	6.62±0.20	157.8±3.89	0.29±0.04	28.72±2.85	31.10±2.02	41.82±5.92	18.29±5.42	286.26±19.18

* Values of standard error of mean are given after ±. Different letters within a row for each location indicate significant differences ($p<0.05$).

Discusion

Carbon movement in the soil depends on fire severity (Pereira et al., 2010b), fire intensity, fire type (canopy or aboveground, underground fires), and even slope (González-Pérez et al., 2004). Low-intensity fires have little effect on the soil carbon while wildfires drastically reduce the amount of carbon in the soil (Johnson, 1992). Lower levels of carbon in burned samples one year after the fire in pine forests was recorded (Johnson, 1992), while other research (Binkley et al., 1992) observed lower amount of TC in burned soil than in unburned samples one and three years after the fire. Other studies recorded a nearly 50% increase of soil carbon content in burned area than in unburned area (Rovira et al., 2012 ; Choromanska and DeLuca, 2002). Increases in soil carbon are also reported due to an increased deposition of dry leaves and charred plant materials in fires that affect the tree canopy (González-Pérez et al., 2004). Our findings also show contradictory results of TC on investigated locations.These differences could be explained with differences in vegetation characteristics between locations. Control plots on each location have different dominant species and therefore we can presume that recorded wildifers had an uneven amount of fuel for burning, different combustion process, such as air temperature and humidity, wind speed, and topography of the site. All these factors had an influence on fire severity and therefore

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on TC. Average values (all four locations) of TC between burned and unburned plots were small. These trends may be due to the lower temperatures and incomplete combustion of soil organic matter at Smokvica and Blato location. It is already noted that severity of wildfires strongly influence on soil organic matter. Fire does not necessarily reduce topsoil organic matter content in a significant manner and low intensity fires have even been reported to increase organic matter content (Varela et al., 2010). Furthermore, in time of sampling, 14 and 2 months after fire it is visible generally fast recovery on vegetation (*Figure 2*) in all locations, but especially at Blato and Smokvica location. We can presume that small differences in average values of TC between burned and unburned plots are consequence of fast organic matter recovery in burned plots which affects on C sequestration. It is also noted in others studies (Johnson and Curtis, 2001; Wang et al., 2012) that fire had little effect on soil carbon. Even though it is evident that burned areas record generally fast vegetation recovery, on Blato location burned plot recorded the lowest TC concentration compared to all other locations, likely due to erosion removing material from the soil surface. Furthermore, these different observations between locations may be attributed to differences in sampling time after fire, soil properties, vegetation differences between investigated locations and fire severity.

A) *B)* *C)*

Figure 2. *From left to the right. Vegetation recovery on Blato (A, B), and Smokvica (C) location*

Total nitrogen follow similar pattern on investigated locations like TC. Our results agree with previous studies carried out by Weston and Attiwill (1990), Rovira et al. (2012) and Choromanska and DeLuca (2002) who also observed differences in TN depending on fire severity and the time that has passed since the fire. Permanent study shows that fire can increase and decrease the amount of N in soil. Different study results are also reported in studies of Schoch and Binkley (1986) and Yinghua et al. (2012) who observed minimal N loss from a fire, but decomposition of the forest floor was stimulated by fire, releasing additional N during the following growing season, after the regeneration of vegetation. Results of TN in this study are different because N is soil after fire depends on many factors. Immediate after fire soil organic N is losing through volatilization (Binkley and Fisher, 2012), but some substantial portion of soil organic N can survive low intensity fires. Moderate to high intensity fires convert most soil organic N to inorganic forms. Ammonium is a consequence of the combustion, while nitrate forms are created from ammonium some weeks or months after fire as a result of nitrification (Covington and Sackett, 1992). These N-forms if are not taken by plants

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can leach (nitrate) or held by negatively charged minerals in soil (ammonium), thus affecting the overall result of TN in the soil.

It is generally expected that the pH increases in forests after the fire and decreases over time at the rate which it does so being dependent on precipitation (Woodmansee and Wallach, 1981). During wildfires the combustion of wood causes the mineralization of organic matter which increases the amount of basic elements, carbonates, oxides, hydroxides and base cations compounds that are rich in alkaline metals (Etiegni and Campbell, 1991; Ulery et al., 1993) that raise and explains the increase of soil pH and EC in our study. Furthermore, pH values increase as a result of oxidation of soil organic matter by combustion of some organic acids (Certini, 2005), and EC increase as result of release of inorganic ions from combusted organic matter (Hernandez et al., 1997). Also, topsoil pH could increase as much as three units immediately after burning (Ulery et al., 1993). This rise was essentially due to the production of K and Na oxides, hydroxides, and carbonates, which did not persist through the rainy season in contrast to neo-formed calcite that was still present 3 years after burning, and maintained moderately alkaline soil pH. It is estimated that capacity of ash to neutralize soil acidity is well correlated with the sum of the concentrations of K^+, Ca^{2+}, and Mg^{2+} in the ash itself (Khanna et al., 1994). Except ash extracts that are rich in K (Badía and Martí, 2003; Ùbeda et al., 2009) higher noted levels of soil K supply were also result of natural content for *terra rosa*. Ca^{2+} also comes from limestone which is parent material on investigated areas. After fire, precipitation trough leaching and erosion move nutrient rich materials, washes away basics elements which finally leads to a decrease in pH during time. Even though the research areas were in the zones of mixed vegetation, forests, and low vegetation, the obtained results confirmed the above assertion. Investigated areas have an uneven precipitation distribution which is reflected in the long spring-summer dry season and rainy winters, and further research should provide insight into the time needed for the soil pH decreasing to pre-fire levels.

Average P supply value was eight times higher in burned samples than in unburned samples, as shown in other study (Yinghua et al., 2012). Some studies found no differences between burned and unburned samples (Binkley et al., 1992) and others (McKee, 1982) recorded significantly higher amounts of P in burned soil. These differences in burned and unburned soil are result of soil pH and fire. After fire, P in ash can leach into run-off and into the soil profile and may have impacts on surface chemistry. Burning converts the organic pool of soil phosphorus to orthophosphate (Cade-Menun et al., 2000), the sole form of P available to biota. The maximum P bioavailability values were recorded at pH of about 6.5 (Sharpely, 2000). But generally, fire-induced change in soil pH toward neutrality has a positive effect on P bioavailability, as shown in this study. Our results recorded higher pH values in burned plot than in unburned which directly affects on correlation with measured higher P values in burned plots in contrast to the unburned.In our work, we observed that all water-extractable base cations were significantly higher in burned soil compared with unburned soil solutions. Water extractable elements concentrations in burned plots are result of higher soil EC as a consequence of nutrient rich ash material on surface. Furtermore, fire suppression by seawater are reason for aditional source of Na^+, Mg^{2+}, Ca^{2+}, K^+, Cl^- which explains the higher values of these ions in burned soil compared to unburned soil solution. Increased concentrations of soluble elements helps increased alkalinity of burned soils. There are a number of factors that influence the vulnerability of sites to total salt accumulation (Oster et al., 1996). These factors include the position

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of a site within a landscape (Manning et al., 2001), soil type and rainfall. Soil type was the same - *terra rossa*, in all four investigated locations. Average annual precipitation rate was relatively high with 1300 mm (Meteorological and hydrological institute of Croatia), but with extremes in distribution, because almost 80% of rain falls in a period from September through May. The rain did not reduce the amount of salt in the soil, not even in locations that burned two years ago. Although, this depends of several factors as rainfall intensity, topography, vegetation cover etc. Our results show that time that has passed after the fire didn't have effects on salt accumulation in investigated locations. At all sites burned plots recorded higher total salts (EC) values compared to control although the sites burned in 2011 had one more rainy season. Also, the magnitude of salt accumulation in a single growth season is often small and may not be readily detectable by the routine soil sampling in the field (Chen et al., 2010). However, it should be noted that data of the size and intensity of rainfall at each investigated location were not available, so it is based on assumption. Thus, further research should clarify this situation. It remains to been seen how many years it will take for the soil that was treated with seawater to return to pre-burned conditions. In future research will be interesting to observe separated influence of seawater on burned soil properties compared to burn soil suppressed by freshwater on soil.

Conclusions

This study was conducted in southern Dalmatia fire-sensitive coniferous forests of pine trees with maquis and it shows that there is a difference in terms of soil properties between areas burned by wildfires suppressed by seawater and similar areas that remained unburned. The results show a difference in almost all investigated soil properties. Higher values of P, K, TN and TC have been recorded in burned plots. After the fire soil pH, EC and extractable cations and anions increase and this is attributed to the effect of ash and salt water used for suppression. Soil pH conditions after wildfire favors the solubility of some elements presented in this paper. This study cannot separate effect of seawater and fire influence on soil chemistry. The fact that the fire is extinguished with seawater may have implications on soil chemistry in the post fire period, but this can be clearer in a long-term study that compares burned soils extinguished with seawater and fresh water. This study is useful for understanding changes in soil chemistry after fire and seawater application. However, further studies with better establish experiment that includes divided causes on soil, fire and salt water, and continuous monitoring of soil changes is needed.

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