Key soil properties controlling occurrence and persistence of water repellency after burning

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Introduction

Fire induced soil water repellency (WR) is controlled by many different factors (temperatures reached; DeBano (1991), amount and type of fuel, etc., Arcenegui et al. 2007). Some soil properties may determine the occurrence and intensity of this property in burned soils (Mataix-Solera et al., 2008, 2012). In this research, experimental laboratory burnings have been carried out using soil samples from different sites and collected from under different plant species. Samples collected at different sites differ in some soil properties, while soil samples taken from the same site vary only in quantity and quality of soil organic matter (SOM), as they were collected under different plant species. The hypothesis is that the same heating treatment will produce a very different response of WR. The objectives are to advance in the study of soil properties as key factors controlling WR behaviour by heating as to date some questions remain.

Soil samples, experimental design and methods

Three sites were selected for this study (1 in Cadiz S Spain and 2 in Alicante Province SE Spain) comprising 4 different lithologies (Table 1). Soil samples under different plant species were collected in every site, including: *Pinus halepensis, P. pinaster, Quercus coccifera, Q. suber, Rosmarinus officinalis, Juniperus oxycedrus, Erica australis, Pistacia lentiscus* and *Olea europaea* (Table 1). A total of 12 different soil samples from the combination of factors present were collected for laboratory heating experiments, and called HF1 to HF12 (Tables 1, 2).






Table 1. Main characteristics of the study sites

Location	Coordinates	Altitude (m.a.s.l.)	Slope (%)	Pm (mm)	Lithology	Soil type	Soil sample	Vegetation
"Los Alcornocales Natural Park", Cádiz	36º29'44''N; 5º38'53''W	483	6.5	1440	Miocene sandstone	Lithic Xerorthent	HF1	*Erica australis*
	36º27'27''N; 5º37'49''W	294	13.7	1440			HF4	*Pinus pinaster*
	36º30'53''N; 5º38'29''W	538	14.4	1440		Typic Haploxeroll	HF5	*Quercus suber*
	36º28'23''N; 5º37'13''W	397	5.6	1440	Miocene clay and sandstone	Typic Haploxeralf	HF2	*Pistacia lentiscus*
	36º28'23''N; 5º37'13''W	398	8.5	1440			HF3	*Olea europaea*
"Sierra de la Taja", Pinoso, Alicante	38º22'59''N; 0º58'52''W	803	3.5	260	Jurassic limestone	Lithic Xerorthent	HF6	*Pinus halepensis*
							HF7	*Quercus coccifera*
							HF8	*Juniperus oxycedrus*
							HF9	*Rosmarinus officinalis*
"Sierra de la Grana", La Torre de les Maçanes, Alicante	38º35'54''N; 0º23'33''W	951	2.2	405	Tertiary limestone	Typic Xerorthent	HF10	*Quercus coccifera*
							HF11	*Juniperus oxycedrus*
							HF12	*Pinus halepensis*

Table 2. Main characteristics of soil samples

Soil sample	Sand (%)	Silt (%)	Clay (%)	CO_3^{2-} (%)	SOM (%)	pH	EC (µS cm^{-1})
HF1	80	14	6	2.8	9.5	6.8	127
HF4	62	18	20	3.2	10.4	6.3	54
HF5	72	18	10	0.4	11.1	6.2	76
HF2	32	22	46	0.2	15.5	7.2	267
HF3	34	22	44	0.4	14.5	7.0	268
HF6	22	70	8	21.9	13.0	7.8	394
HF7	42	44	14	33.8	12.8	8.0	323
HF8	36	56	8	21.3	13.7	8.0	306
HF9	36	46	18	31.0	10.9	8.1	274
HF10	54	32	14	60.8	11.8	8.2	380
HF11	46	40	14	69.5	10.4	8.1	357
HF12	58	34	8	68.1	10.0	8.1	402

For example, samples HF1 and HF4 come from the same place, with the same lithology and soil type but were taken from under different plant species (Table 1). The same situation applies to samples HF6, 7, 8 and 9. Differences in some soil properties can be observed between them (Table2). In other cases some soil samples come from the same place but are different in lithology and therefore in soil type, soil properties and plant specie, e.g: HF1 and HF2.

Heating experiments: all soil samples were heated during 20 min in a pre-heated muffle furnace at 200, 250, 300 and 350ºC. After cooling, soil samples were kept during a week in an atmosphere chamber where air moisture and temperature are controlled: 20ºC and 50% air humidity. WR was measured in all soil samples using the WDPT (Water Drop Penetration Time) test.

Results and discussion

Results of WR after the heating treatments are shown in Table 3. Before heating most samples are wettable and only HF4 and HF5 were slightly water repellent (8 and 15 s respectively). The response to the heating treatments was different depending on the soil sample, with some of them reaching extremely severe WR at 200-300ºC (HF1, HF4, HF5 and HF12), and to the contrary some of them had no WR development at any of the temperatures heated (HF7, HF8 and HF9).

Table 3. Soil water repellency (WDPT s) in the control and heated samples at different temperatures

Soil sample	WDPT (s)				
	Control	200ºC	250ºC	300ºC	350ºC
HF1	2	10383	6120	4	2
HF4	8	7443	1	1	1
HF5	15	9532	972	1	1
HF2	1	7	248	1	1
HF3	3	12	3	1	1
HF6	5	7	1	2	1
HF7	2	3	1	1	1
HF8	2	3	2	1	1
HF9	1	1	1	1	1
HF10	2	2	1822	1	1
HF11	2	3	9	1	1
HF12	2	8	5777	2321	1

WDPT Classes

< 5	10	30	60	180	300	600	900	3600	> 3600

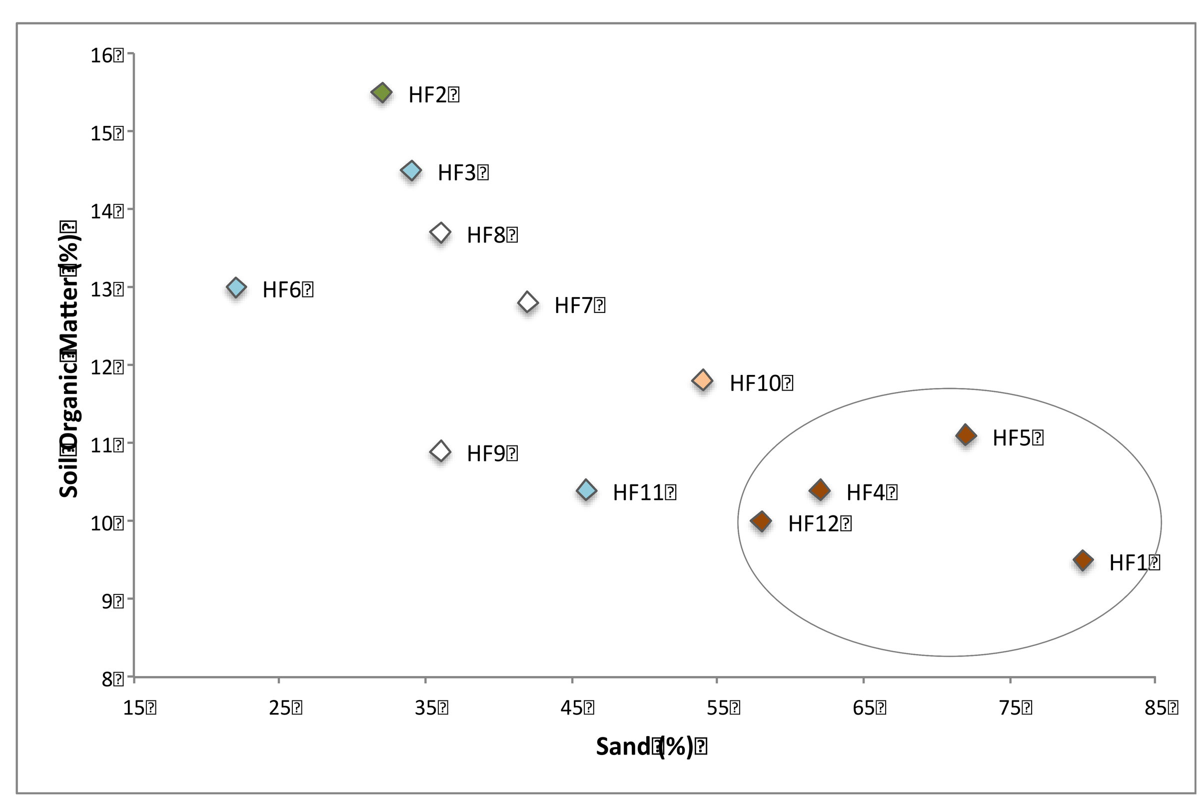

Figure 1. Sand (%) *vs* Soil organic matter content (%) of the different samples. Different colours indicate different maximum persistence classes of WDPT reached after heating. See legend of table 3

The contrast in behaviour of WR can be explained with the analysis of soil properties of the samples used in this study (Table 2). Results showed that both high and slightly calcareous soils can develop extreme WR. The main soil property that affects to the WR response to heating is the texture (Doerr et al., 2000) and especially the sand content, as can be observed in the figure 1. Samples with highest sand content were the ones that developed extreme values of WR. It is not the soil organic matter (SOM) content -as we could initially expect- that is the main factor, although between samples with a similar texture it does seem also to have an effect. But we can also observe that samples from the same place, and therefore with similar soil properties can respond in a different way due to the plant species factor, thus the quality of their SOM. Is important for example in the case of HF2 and HF3 where the only difference between them is that HF2 was taken beneath *Pistacia lentiscus* and HF3 beneath *Olea europaea*. In a similar way, comparing the results of samples HF10, HF11 and HF12 that were taken from same place, we can see a different response of WR to heating and it is suspected this is due not only to the slight differences in texture, but also because the quality of SOM, being the formed beneath *P. halepensis* is more prone to be transformed tohydrophobic when heated at 250-300ºC than SOM from other species.

Conclusions

Little differences in some soil properties can control the occurrence and persistence of soil WR developed by burning. Previous studies pointed out that texture is one of the main factors, sandy soils being more prone due to the lower specific surface area (Doerr et al., 2000). Recent investigations also showed that the mineralogy of clay fraction can greatly control the WR in burned soils (Mataix-Solera et al., 2008, 2012). The results of this study confirm previous research but also include the quality of the initial soil organic matter (depending on the plant specie) as a key factor affecting this property when soil is affected by burning.

The high spatial variability of soil WR in burned areas has been mainly attributed to the expected differences in temperature reached in burned soils as a consequence of the fuel distribution and fire behaviour. But, how little differences in some soil properties affects to the changes in WR when it is affected by a fire can also help to explain the high spatial variability found under field conditions in burned areas.

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