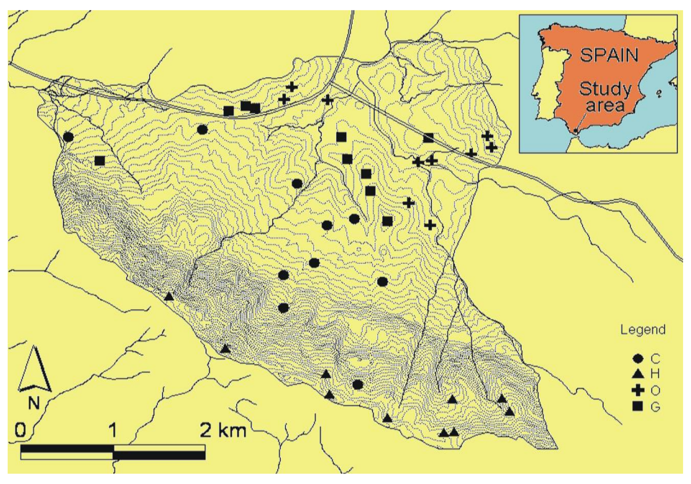
Hydrological effects of fire-induced water repellency in a Mediterranean subhumid area

A. Jordán, L. M. Zavala, N. Bellinfante
Department of Chrystallography, Mineralogy and Agricultural Chemistry, University of Sevilla

MED_Soil
Research Group

INTRODUCTION



Study area

It is established that soil hydrophobicity reduces soil infiltration rates, and enhances runoff flow and soil erosion. Water repellency has been studied with special interest in coniferous and eucalyptus forests, particularly after burning, but the number of studies concerning other Mediterranean land uses is still very low. In this work, we study the effects of fire-induced water repellency in four different soil/vegetation units: cork oak forest, heathland, grassland, and cork oak / olive tree mixed forest. Runoff generation, infiltration rates and soil loss have been studied using simulated rainfall.

Heathland (*Erica australis*, *E. Arborea* and *Calluna vulgaris*).

Cork oak forest (*Quercus suber*).

Olive tree (*Olea europaea*) and grassland.

METHODS

Rainfall simulation

A rainfall simulator similar to that described by Navas et al. (1990 was used). The structure, in the shape of a truncated pyramid, is supported on metal legs. The simulator was covered with a wind protector. The legs are telescopic so that the simulator can be leveled when placed on a sloping surface. At the top of the structure (3.5 m high) there is a single nozzle (Lechler 460.608), which is connected through a rubber pipe to a mobile automatic pump (1.8 kg cm^{-2} pressure). The water from the nozzle falls onto a circular area of 1256.6 cm^2 that is delineated by a steel ring (40 cm in diameter). Rainfall intensity was 56.5 mm h^{-1} and the duration of the simulations was 30 minutes. For each rainfall test, we recorded time-to-ponding (Tp), time-to-runoff (Tr), the amount of precipitation necessary to produce runoff (Pr), and runoff coefficient (Rc).

Soil analysis

Three samples of the top soil (0-10 cm deep) were collected for physical and chemical analysis 0.5 m downslope from the plots, and mean values were taken as representative for each plot. Soil depth was measured from the surface to the consolidated rock, when present. When consolidated rock was not present, soil depth was taken as 120 cm.
Soil texture was determined by the Bouyoucos method (Bouyoucos, 1936). Bulk density was measured by the core method (Blake & Hartge, 1986). Cores used were 3 cm in diameter 8 cm in length and 56.6 cm^3 in volume. Part of the samples was air-dried and sieved (0-2 mm) for soil organic carbon analysis, determined by the Walkley & Black method (MAPA, 1982). Soil moisture was determined by the gravimetric method before and 20 minutes after the rainfall simulation.

Soil water repellency

The water drop penetration time (WDPT) test and the percentage ethanol (MED) test were carried out (Doerr, 1998).

RESULTS

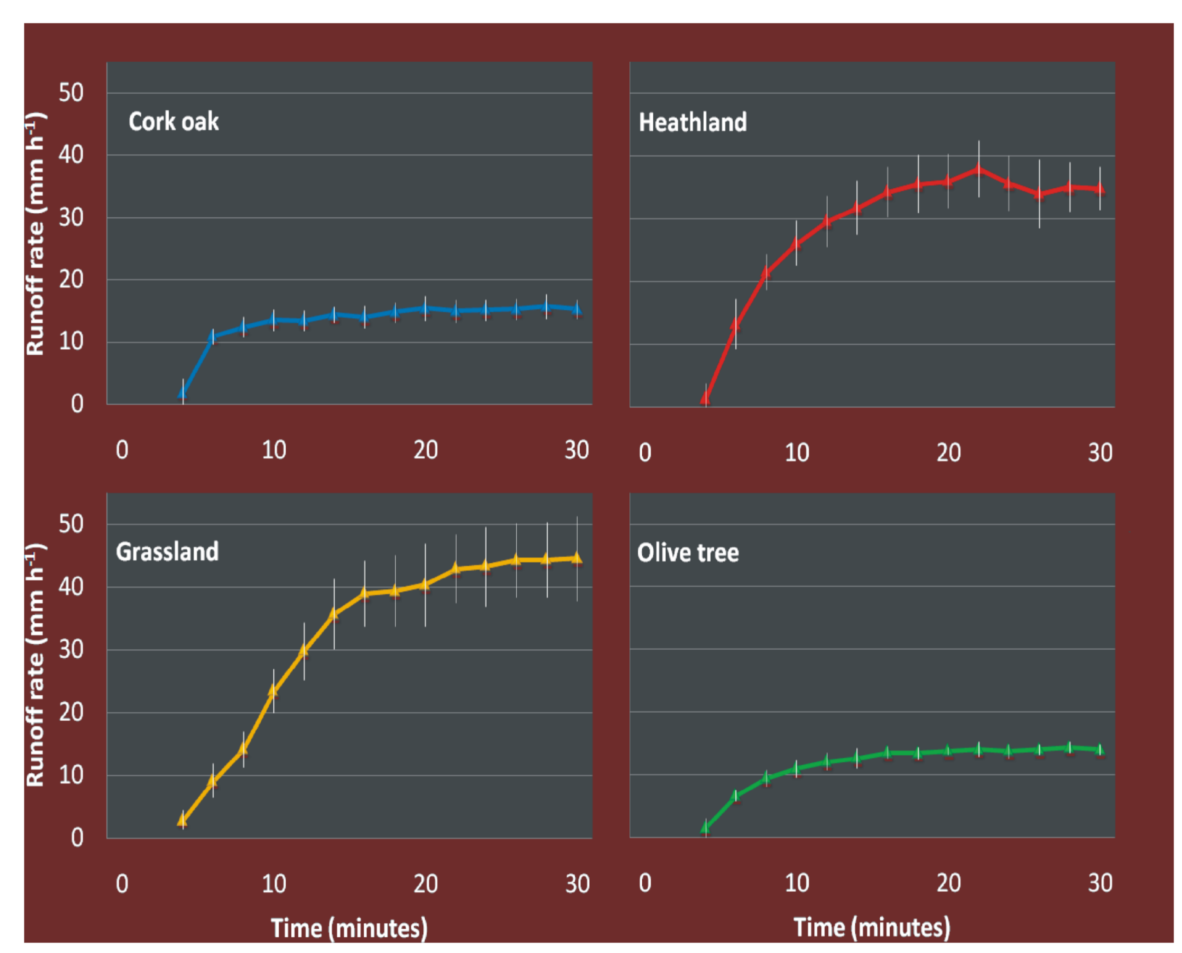
Marked differences in the hydrological behavior of the studied soil/vegetation units were observed after the rainfall simulations. The soils under woodland showed low runoff rates and coefficients. The highest runoff rates were measured on the heath and grass-covered parts of the hillslopes. Soil water repellency, measured from water drop penetration tests, reduced infiltration (especially under the heathland), and seems to be the cause of fast ponding and runoff generation during the first stages of rainstorms, reducing the infiltration rates and limiting the water storage capacity. However, the macropore flow can be enhanced on non-repellent layers, cracks or roots as it is shown by de shape and depth of the wetting fronts. The mosaic of different patterns of hydrological response to rainfall, such as runoff generation or infiltration, is governed by the spatial distribution of vegetation and its influence on the soil surface. The effects of vegetation on soil hydrology should be considered for afforestation works and flooding control.

		Elevation (m)	Slope (%)	Litter cover (%)	Plant cover (%)	Soil depth (cm)	Soil organic C (g kg^{-1})	Gravels (g kg^{-1})	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})	Bulk density (Mg m^{-3})
Cork oak	Mean	325.2 a	8.1 a	57.9 a	42.9 a	80.3 a	28.8 a	55.7 a	654.2 a	140.9	204.9 a	1.4 a
	SD	118.7	3.7	3.4	4.8	4.6	5.9	35.0	58.2	64.0	50.4	0.1
Heathland	Mean	636.3 b	16.8 b	64.4 b	63.0 b	18.6 b	46.4 b	199.4 b	430.9 b	345.3	223.8 a	1.2 b
	SD	28.1	9.3	4.2	12.9	5.1	10.0	36.8	29.6	55.8	38.1	0.1
Grassland	Mean	243.7 c	5.6 a	10.3 c	39.5 a	120.0 c	16.7 c	19.4 c	170.0 c	342.0	488.0 b	1.3 a
	SD	20.0	3.0	1.8	10.4	*	1.3	7.8	23.5	53.5	54.3	0.0
Olive tree	Mean	235.8 c	6.2 a	56.7 a	38.8 a	120.0 c	22.2 ac	18.6 c	580.6 d	195.3	224.1 c	1.4 a
	SD	25.0	4.6	4.9	8.0	*	2.8	3.5	100.0	124.2	47.5	0.1
ANOVA, p		0.0000	0.0018	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	**	0.0000	0.0001

***Soil depth was not determined, and it was considered as 120 cm for the analysis.**
**** Not determined.**

		Time to ponding (s)	Time to runoff (s)	Pr (mm)	Runoff rate (mm h^{-1})	Runoff coefficient (%)
Cork oak	Mean	83^a	257^a	4.0^a	11.6^a	20.6^a
	SD	17.20	20.35	0.32	1.93	3.41
Heathland	Mean	28^b	79^b	1.2^b	25.4^b	45.0^b
	SD	9.06	6.48	0.1	4.56	8.07
Grassland	Mean	75^a	109^b	1.6^b	28.3^b	50.0^b
	SD	22.67	32.69	0.25	5.02	8.88
Olive tree	Mean	77^a	250^a	3.9^a	10.3^a	18.1^a
	SD	16.24	42.44	0.65	1.09	1.93
ANOVA, p		**0.0001**	**0.0000**	**0.0000**	**0.0000**	**0.0000**

	Time to ponding	Time to runoff	Precipitation necessary to produce runoff	Runoff rate	Infiltration rate
Litter	-0.48	-	-	-	-
Plant cover	-0.48	-0.45	-0.47	-	-
Soil depth	0.56	0.35	0.36	-	-
Soil organic C content	-0.44	-	-	-	-
Coarse elements	-0.54	-0.38	-0.39	-	-
Sand content	-	0.73	0.74	-0.77	0.77
Clay content	-	-	-	0.40	-0.40
Bulk density	0.50	0.68	0.68	-0.63	0.63
Soil moisture content	-	-	-	-	-
WDPT	-0.43	-0.79	-0.78	-0.70	-0.70



Relationship between persistence (WDPT class) and intensity (MED class) of soil water repellency under different vegetation types.

Relationship between persistence (WDPT class) of soil water repellency and organic carbon content under different vegetation types.

Relationship between persistence (WDPT class) of soil water repellency and soil acidity (pH) under different vegetation types.

Acknowledgments

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