Do stones modify the spatial distribution of fire-induced soil water repellency? Preliminary data

J. García-Moreno[a], Á.J. Gordillo-Rivero[a], J. Gil[b], N.T. Jiménez-Morillo[a], J. Mataix-Solera[c], F.A., González-Peñaloza[a, d], A.J.P. Granged[e], G. Bárcenas-Moreno[a], P. Jiménez-Pinilla[c], E. Lozano[c], A. Jordán[a], L.M. Zavala[a]

[a] Dpto. de Cristalografía, Mineralogía y Química Agrícola, Univ. de Sevilla; [b] Dpto. de Química Agrícola y Edafología, Univ. de Córdoba; [c] Dpto. de Agroquímica y Medio Ambiente, Univ. Miguel Hernández; [d] Dpto. de Geografía, Univ. de València; [e] Dpto. de Física Aplicada I, Univ. de Sevilla.

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Introduction and objectives

Increased or induced soil water repellency (SWR) has been reported in many fire-affected soils. Wildfires may be considered as a SWR-triggering factor. Water repellency is a property of many soils that is getting more and more interesting for the scientific community, because of its consequences on soil erosion risk, runoff or infiltration rates and even plant ecology. Although the occurrence and consequences of fire-induced SWR have been deeply studied, some gaps still exist, as the influence of stone cover. Stones on the soil surface may affect the distribution of heat during burning, and, consequently, may change the expected spatial distribution of SWR. In this research, we study the effect of stone cover on the occurrence of fire-induced SWR in a previously hydrophilic soil after experimental burning.

The objective of this research is to study occurrence and spatial distribution of SWR after experimental burning in a previously hydrophilic soil under different stone cover density (0, 15, 30, 45 and 60%).

Methods

Experiments were carried out in the Blanco White experimental area (Sevilla). Soil at the experimental area has a clay-sandy loam texture (sand 64.1%, silt 15.3% and clay 19.6%), a pH of 7.5 and 18.3% of $CaCO_3$ content . Soil plots (1.0×1.5 m^2) were marked with vertical metal bars and stones (8-10 cm in diameter) were regularly arranged at each plot in order to get 0, 15, 30, 45 and 60% stone cover, as shown in Figure 1-a. Stones were kept on the soil surface during three months before experimental burning. A series of thermocouples were inserted 1 cm below the soil surface and soil temperature was recorded every 60 seconds under stones and under no stones. Fuel was added to soil plots in order to simulate natural shrubs (Figure 1-b). Fuel density was 6.5-7.5 kg m^{-2}. Fuel structure was 50% fine branches (<5 mm) and 50% thick branches (15-30 mm). Experimental burning was carried out on February 14th 2012 until fire extinguished spontaneously (Figure 1-c), after full consumption of fuel (15 minutes).

Soil samples (0-10, 10-20 and 20-30 mm) were collected 2 days after burning and monthly during a 4-month period using cylindrical cores (4.8 cm in diameter) inserted 10 cm in soil, Samples were air-dried and homogenized. Part of the soil samples was sieved (<2 mm) for pH (1:5) and soil organic C content determinations (oxidation with $Cr_2O_7K_2$ and quantification by UV-Vis spectrophotometry). Aggregate stability was assessed using the counting the number of water drop impacts method (CND). SWR was assessed under field conditions using the water drop penetration time method, WDTP at the soil surface and at 0-10, 10-20 and 20-30 mm depth soil samples.

Figure 1. Details of experimental design. (a) soil plots with 0, 15, 30, 45 and 60 % stone cover; (b) soil plot after addition of fuel; (c) soil plot during burning; (d) detail of the ash layer, burnt residues and stones after burning; (e) detail of one of the termocouple probes inserted in soil.

Figure 2. Work team.

Results and discussion

Temperature recorded at 1 cm under the soil surface is shown in Figure 3. Temperature in uncovered soil areas reached 300-350 ºC, with short-time peaks. In contrast, temperature at stone-covered soil areas reached 350-400 ºC peaks. In addition, peaks were delayed approximately 5 minutes and were longer in time, with temperatures above 300 ºC over 14 minutes.

Immediately before burning, soil was completely wettable at 0-10, 10-20 and 20-30 mm depth (WDPT 0 s). Figure 4 shows the evolution of SWR (WDPT) with time for different stone cover classes and soil depths. Wettable character was stable below 10 mm, with SWR remaining unaffected by burning. In contrast, soil areas under stones and no stones showed different behaviours. SWR was triggered at 0-10 mm depth in plots under 0% stone cover immediately after burning, and decreased progressively until soil material became wettable two months after burning. Slight SWR (average WDTP between 5 and 10 s) was observed by sampling dates 1 and 3 at exposed inter-stone areas from soil plots under 15, 30 and 45% stone cover. Stone-covered areas remained wettable or slightly water repellent (average WDPT ranging between 1 and 6 s) character. SWR was not observed at 60% stone cover soil plots.

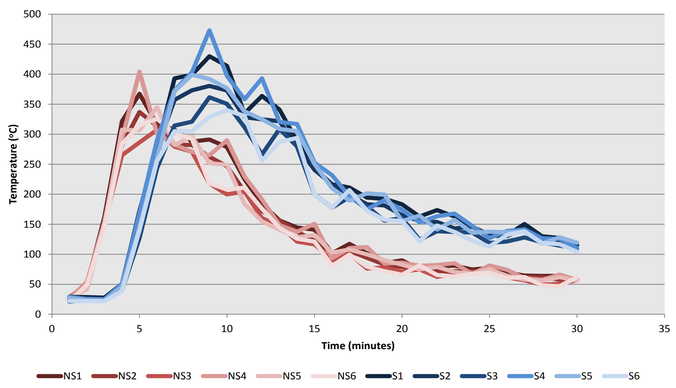

Figure 3. Temperatures recorded 1 cm under the soil surface in areas between stones (NS) and under stones (S).

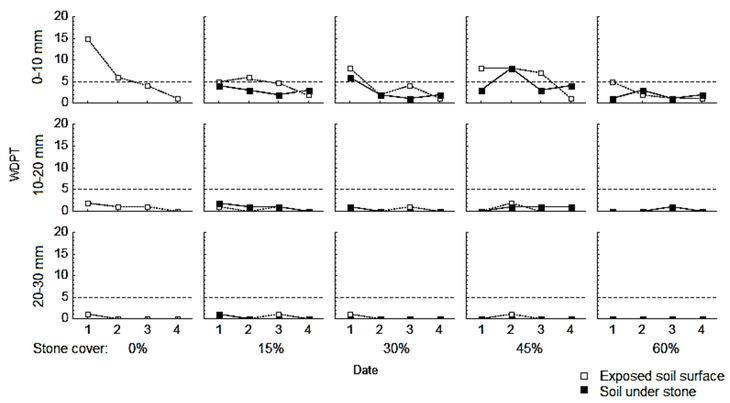

Figure 4. Soil water repellency (WDPT) for different stone cover classes, soil depth and date (months after burning). Dotted line marks WDPT 5 s threshold

At the topsoil surface (Table 1), the ash layer remained wettable through the first 3 months after burning. SWR at the stone-covered soil surface was triggered after burning, and values were considerably higher than in 0-10 mm soil samples. In month 3, mean WDPT decreased from 52 to 18 (slight water repellency). In contrast to 0-10 mm soil samples, the effect of fire at the surface seems to be more intense and conditioned by the presence/absence of stones.

The fine soil layer in contact with stones was exposed to higher temperatures during longer periods of time than inter-stone areas. As a consequence, SWR was triggered at the surface, although this effect was not appreciable in mixed 0-10 mm soil samples. On average, inter-stone areas remained wettable, showing no significant differences with unburnt soil.

Soil pH and AS at all depths did not show significant differences between soil plots under different stone covers. Soil pH (Figure 5) decreased progressively until initial values were recovered after 4 months.

AS (Figure 6) did not show significant differences between stone-covered and between-stone areas, although a slight increase was observed in the latter after 4 months.

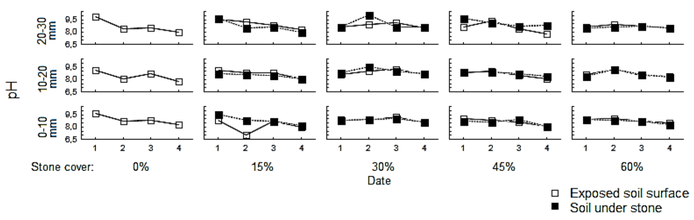

Figure 5. Soil acidity (pH) for different stone cover classes, soil depth and date (months after burning)

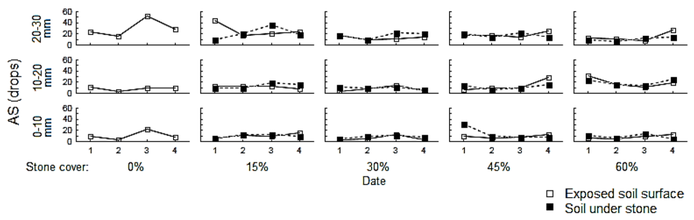

Figure 6. Aggregate stability (AS) for different stone cover classes, soil depth and date (months after burning).

Table 1. Soil water repellency (mean WDPT ± standard deviation) at the topsoil surface (0 cm) measured at the field. Some outliers were removed from the data series: (*) N =24; (**) N = 22. (***). The number of samples from the ash layer was reduced due to remotion of ashes by natural agents, N=19.

Date	N	Ash layer	Stone-covered soil	Inter-stone soil	Unburnt
1	25	3±13*	48±23	3±4**	2±0
2	25	0±0	52±99	3±3	2±2
3	25	1±1***	18±2	2±3	2±1

Conclussions

Both pH and AS at different depths did not show significant differences between soil plots with different stone density cover. Burning temperature induced critical or subcritical SWR in the upper layer (0-10 mm) of previously wettable soil. Fire-induced SWR did not vary with stone cover density, but critical SWR was reached in inter-stone soil areas. At stone-covered soil areas, SWR was increased in 0-10 mm soil samples, but WDPTs remained mostly below the 5 s threshold. In contrast, stones triggered SWR in the topsoil surface.

Research is being carried out in order to study further evolution of properties, wettability at the surface and the dynamics and effect of ash.

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