# Changes in soil water repellency increased preferential flow and soil erosion risk after intense wildfire (Huelva, 2004)

A.J.P. Granged[a, b], L.M. Zavala[a, c]*, A. Jordán[a, c], G. Bárcenas[a, c], J. Gil[a, d], N. Bellinfante[a, c], E. Escalante[a, c], B. Segovia[a, c], R.M. Sánchez[a, c]

[a] MED_Soil Research Group, Universidad de Sevilla, Sevilla (Spain); [b] Departamento de Física Aplicada, Universidad de Sevilla; [c] Departamento de Cristalografía, Mineralogía y Química Agrícola, Universidad de Sevilla; [d] Departamento de Química Agrícola y Edafología, Universidad de Córdoba, Córdoba (Spain)
*lorena@us.es

## Introduction

Many authors have reported increased water repellency in fire-affected areas [1, 2]. Research on post-fire soil erosion shows a range of results. Many authors have found increased soil erosion and runoff rates after fire, due to factors as loss of vegetation canopy, low structural stability of soils and enhanced runoff flow on soil surfaces affected by fire-induced hydrophobicity. Fingered wetting fronts in water repellent soils have been reported by different authors [3, 4, 5] while a uniform and broadly horizontal wetting front developed in wettable soils. However, the heterogeneity of results, the influence of vegetation, and the diversity of responses after burning makes necessary the study and characterization of these processes with special interest in recurrently burned Mediterranean areas.

## Objectives

The objectives of this research are to study the effect of burning in water repellency (WR) in Mediterranean soils under oaks and pines, to study the relationship of fire-induced WR and other soil parameters, and to study the effect of fire-induced WR in hydrological and erosional responses of soils under oaks and pines in the study area.

## Methodology

Four arson fires were confirmed on 27 July 2004 in different points of the Río Tinto mining area (Huelva, SW Spain) after abnormally high temperatures and a very dry period. Twenty four plots were selected in burned areas under oaks (OB, 6 plots) and pines (PB, 6) and unburned areas under oaks (OC, 6) and pines (PC, 6) for rainfall simulations, wetting front determinations and the study of WR in the soil profile. A portable rainfall simulator was used [6] at an intensity of 85 mm $h^{-1}$ during 60 minutes. Runoff samples were collected every 5 minutes in order to determine runoff rates and sediment concentration in runoff. Fifteen minutes after simulations, a hole (40 cm wide, 20 cm deep) was excavated at each plot and soil moisture was determined at a grid of points separated horizontally every 5 cm and vertically every 2 cm by TDR. Soil samples from each point were collected for WR determinations. Soil WR was determined by the water drop penetration time (WDPT) test [7] and WDPTs were classified [8].

## Results and conclusions

Different hydrological responses were observed at burned and unburned soils under oak and pine forest after rainfall simulations. Figure 1 shows the behavior of runoff and sediment concentration in runoff as a function of time. The maximum runoff rate was reached in the first 35-60 minutes of simulation in most of the plots. PC plots showed the lowest runoff rate. Runoff rate increased at PB plots, where the runoff rate increased rapidly and linearly in the first 5-25 minutes after rainfall started, approaching a limit value. Observed runoff flow at $^{o}$C plots increased slightly during the first 15 minutes, grew linearly between 15 and 30 minutes and stabilized at 12-21 mm $h^{-1}$. In the case of OB plots, mean runoff grew rapidly between 0 and 45 mm $h^{-1}$ during the first 15 minutes, and reached 74 mm $h^{-1}$ at the end of the experiments. Average runoff rate from burned plots under oaks was 50 mm $h^{-1}$.

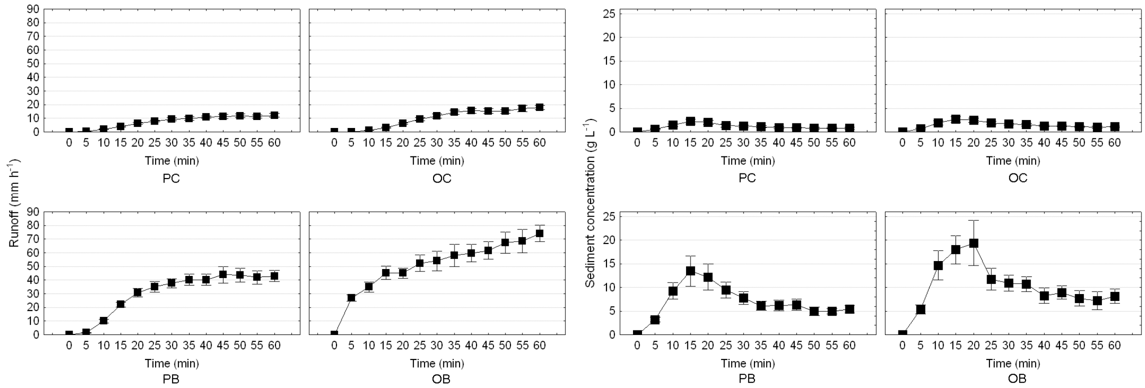


**Figure 1.** Runoff rate and sediment concentration in runoff for control unburned and burned plots under pine and oak forest. OB: burned soil under oak forest; OC: control soil under oak forest; PB: burned soil under pine forest; PC: control soil under pine forest. Some standard deviation bars are hidden by plots.

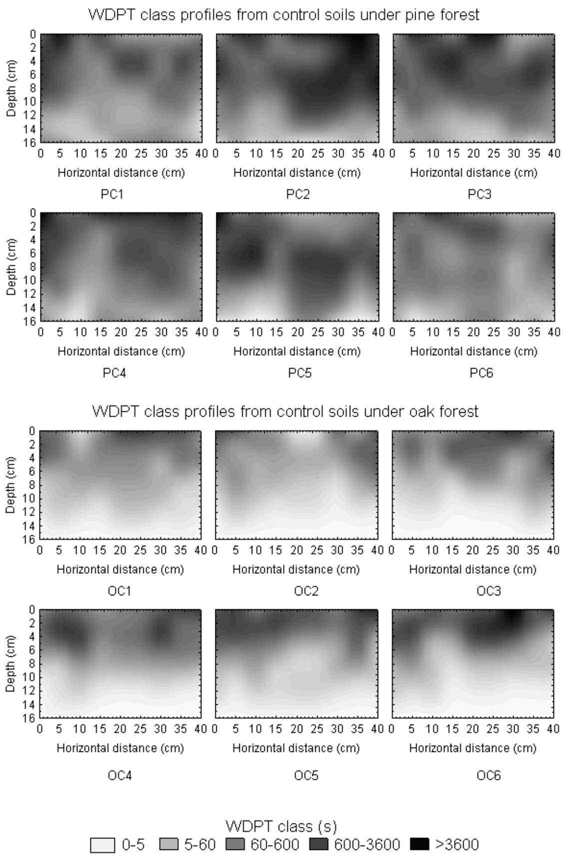


**Figure 2.** Soil water repellency profiles from unburned control plots under pine forest (PC1-PC6) and oak forest (OC1-OC6).

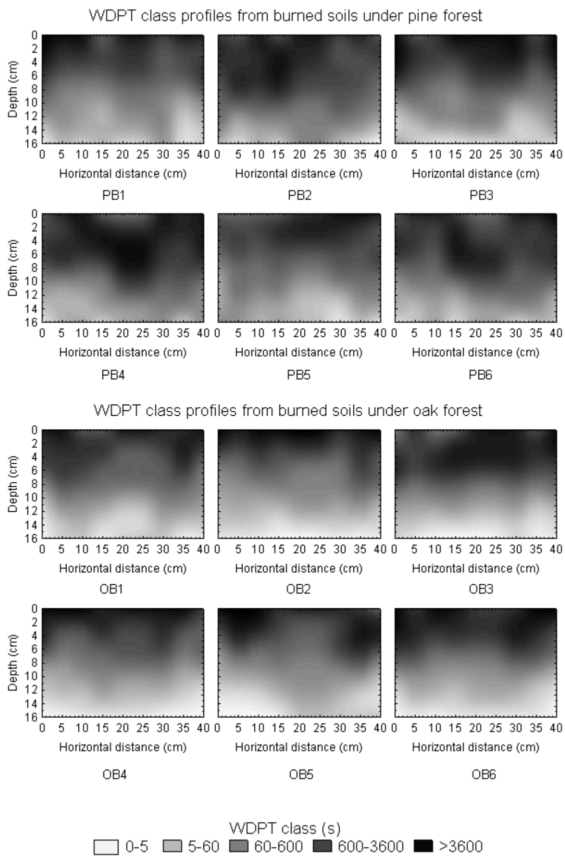


**Figure 3.** Soil water repellency profiles from burned plots under pine forest (PC1-PC6) and oak forest (OC1-OC6).

Sediment concentration in runoff also showed great differences among plots (Figure 1). Generally, sediment yield increased linearly during the first 15-20 minutes of rainfall because it takes time for the soil to get wet, as well as for the soil particles to become detached from the surface. After that, a peak of sediment yield was reached for all plots, relatively low at PC and OC plots, and higher in the case of burned soils. After these peaks of sediment concentration in runoff, a steady decrease of sediment concentration was observed.

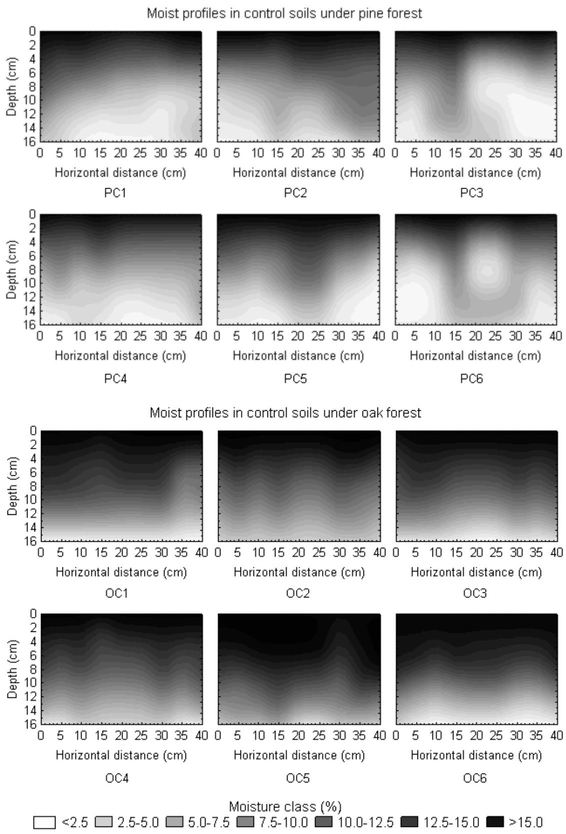


**Figure 4.** Moist profiles in unburned control plots under pine forest (PC1-PC6) and oak forest (OC1-OC6).

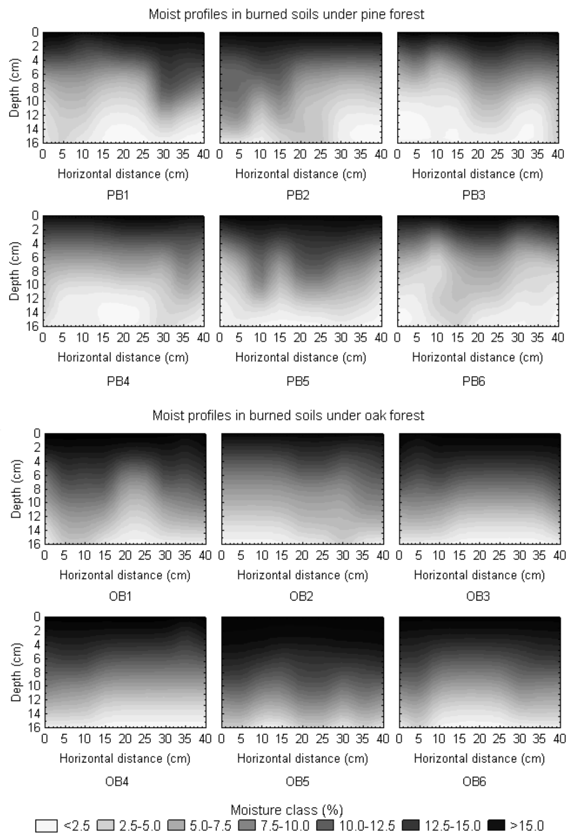


**Figure 5.** Moist profiles in burned plots under pine forest (PB1-PB6) and oak forest (OB1-OB6).

WDPT profiles from OC and PC plots are shown in Figure 2, and from OB and PB in Figure 3. The proportion of wettable samples in PB plots was < 1 % at 0-10 cm, and 12-18 % between 12 and 16 cm. Although WR decreases with depth, an irregular pattern was found, with severe to extremely water repellent soil bodies near the surface. The proportion of wettable samples from PC plots ranged between 4 % (0 cm) and 54 % (14 and 16 cm). WDPT class profiles from PB and OB plots show a higher degree of repellency. The proportion of wettable soil samples from PB plots did not differ from PC plots. WDPT class profiles from OB plots show stronger WR and more thickness of the hydrophobic layer respect to unburned plots.

A quite irregular moisture pattern was observed at PC plots (Figure 4). No dry soil (moisture content < 2.5 %) was observed at any case between 0 and 4 cm, but the proportion of dry soil samples increased progressively between 6 cm (11 %) and 16 cm (70 %). Moisture profiles from OC plots showed a deeper and more homogeneous infiltration. No dry soil samples were observed between 0 and 12 cm, although the proportion of dry soil samples increased rapidly below this depth (13 % at 14 cm and 59 % at 16 cm). Under burned pine forest (Figure 5), the proportion of dry soil samples was 0 % between 0 and 4 cm, and 6 % between 6 and 8 cm, but it ranged between 20 and 87 % in the 10-16 cm layer. In burned soils under oaks, the proportion of dry soil samples was 100 % between 0 and 12 cm, and it increased up to 83 % at 16 cm.

**Conclusions**

The spatial pattern of soil WR is associated to vegetation types. Soils under pines and oaks in the study area show a high degree of WR under immediate pre-fire conditions, although wildfires are associated to Mediterranean forests, but a precise relationship between wettability/WR and land-use has not been established. After burning, runoff rates and sediment yields were enhanced in soils under both studied species, but the increase was much larger under oaks. A hydrophilic layer was not observed at the soil surface, but the thickness of the water repellent layer was considerably enlarged after fire. In unburned/burned soils under oaks and pines, the severity of WR was commonly higher at the soil surface, where the presence of hydrophobic substances is normal after burning, and it decreased with depth in the first 16 cm. In burned soils under oaks, the water repellent layer retarded or inhibited infiltration during rainfall simulations. The topsoil was soon saturated with water above the wettable layer and this led to a continuous increase in runoff rate and higher peaks of sediment concentrations in runoff.

Preferential flow paths were observed in unburned and burned soils under pines. After rainfall simulations, runoff rates and sediment concentration in runoff were increased in comparison with pre-burn conditions. In addition, runoff rate from burned soils under pines increased asymptotically and became stable after 30 minutes of simulated rainfall at 85 mm $h^{-1}$.

**References**

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