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

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## Introduction

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 while a uniform and broadly horizontal wetting front developed in wettable soils. Preferential flow paths lead to significant variations in water content in the soil profile, and cause uneven distribution of water in the root zone resulting in poor seed germination and plant growth, and accelerated leaching of nutrients and other soluble substances. Other authors have found that stable flow may appear if the depth to the water-repellent layer is sufficiently deep. 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.
The objectives of this research are to study the effect of burning in 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 erosion responses of soils under oaks and pines in the study area.

## Methodology

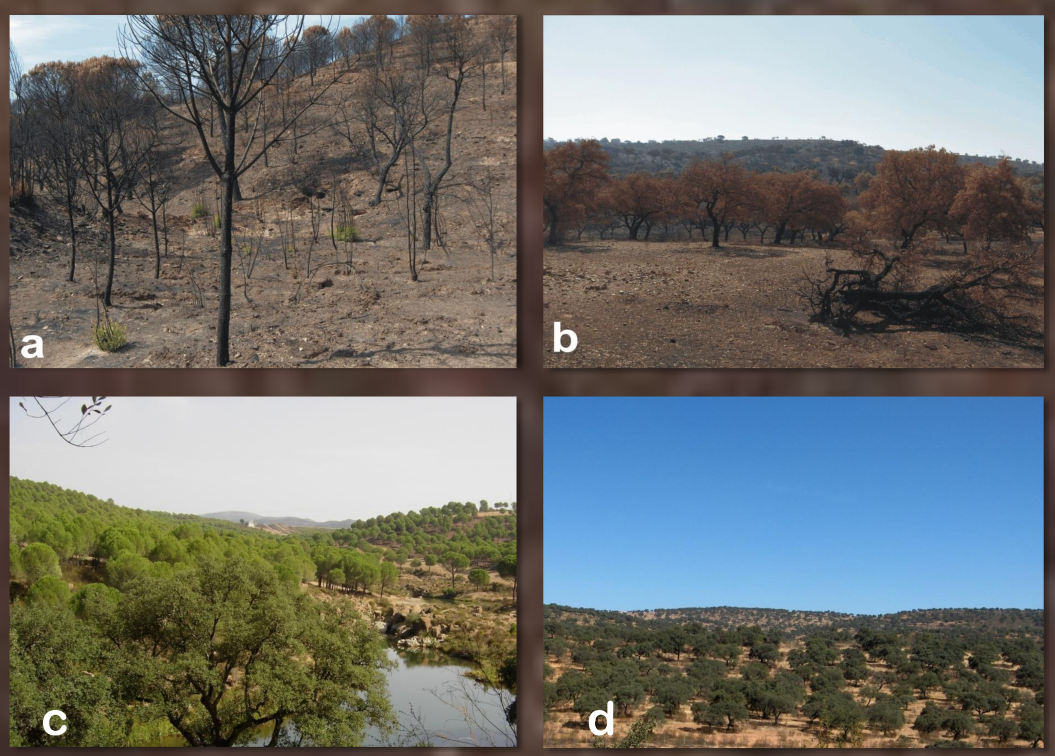



Figure 1. Study area located in fires ocurred on 27 July 2004 in different points of the Río Tinto mining area. a) Pines burned areas;b) oaks burned area; c) pines unburned areas; d) oaks unburned areas.

**Experimental design**
Several plots were selected in burned areas from different points of the Río Tinto mining area (Huelva, SW Spain) under oaks (6 plots) and pines (6) and unburned areas under oaks (6) and pines (6). Rainfall simulation experiments wetting front determinations and the study of WR in the soil profile were performed . The experiments have been carried out using a portable rainfall simulator at an intensity of 85 mm $h^{-1}$ during 60 minutes. All tests were carried out in interrill areas and unburned litter and/or charred litter were carefully brushed away to expose the mineral soil surface. Runoff samples were collected every 5 minutes in order to determine runoff volume and sediment concentration in runoff by desiccation and to calculate the soil loss rates for each plot.
Fifteen minutes after the end of each rainfall simulation, 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. After moisture determinations, soil samples from each point were collected using metal cylinders (81 soil samples at each soil profile). The cylinders were tapped 8 cm deep into the soil layer and samples were transported to laboratory for WR determinations. Soil WR was determined by the water drop penetration time (WDPT) test [9] and WDPTs were classified [10].

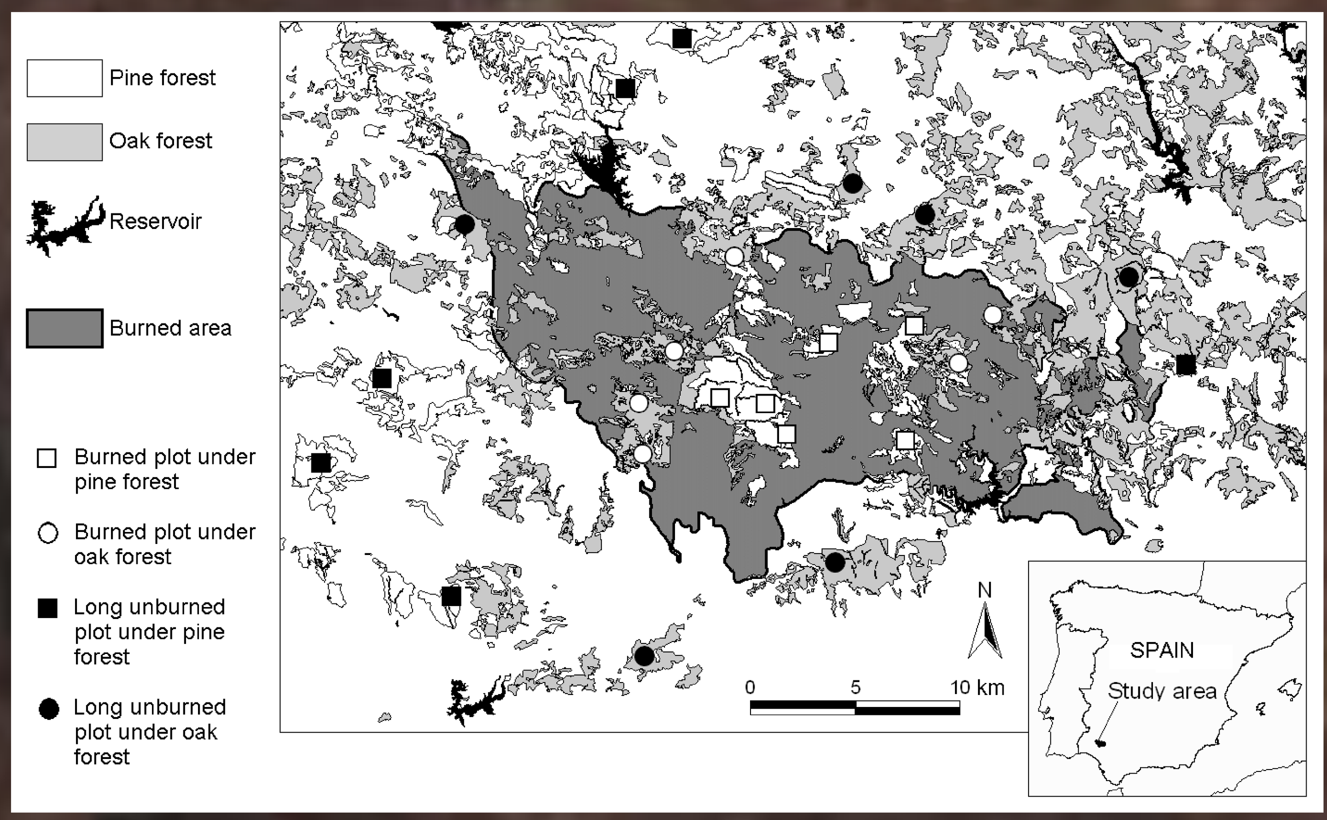
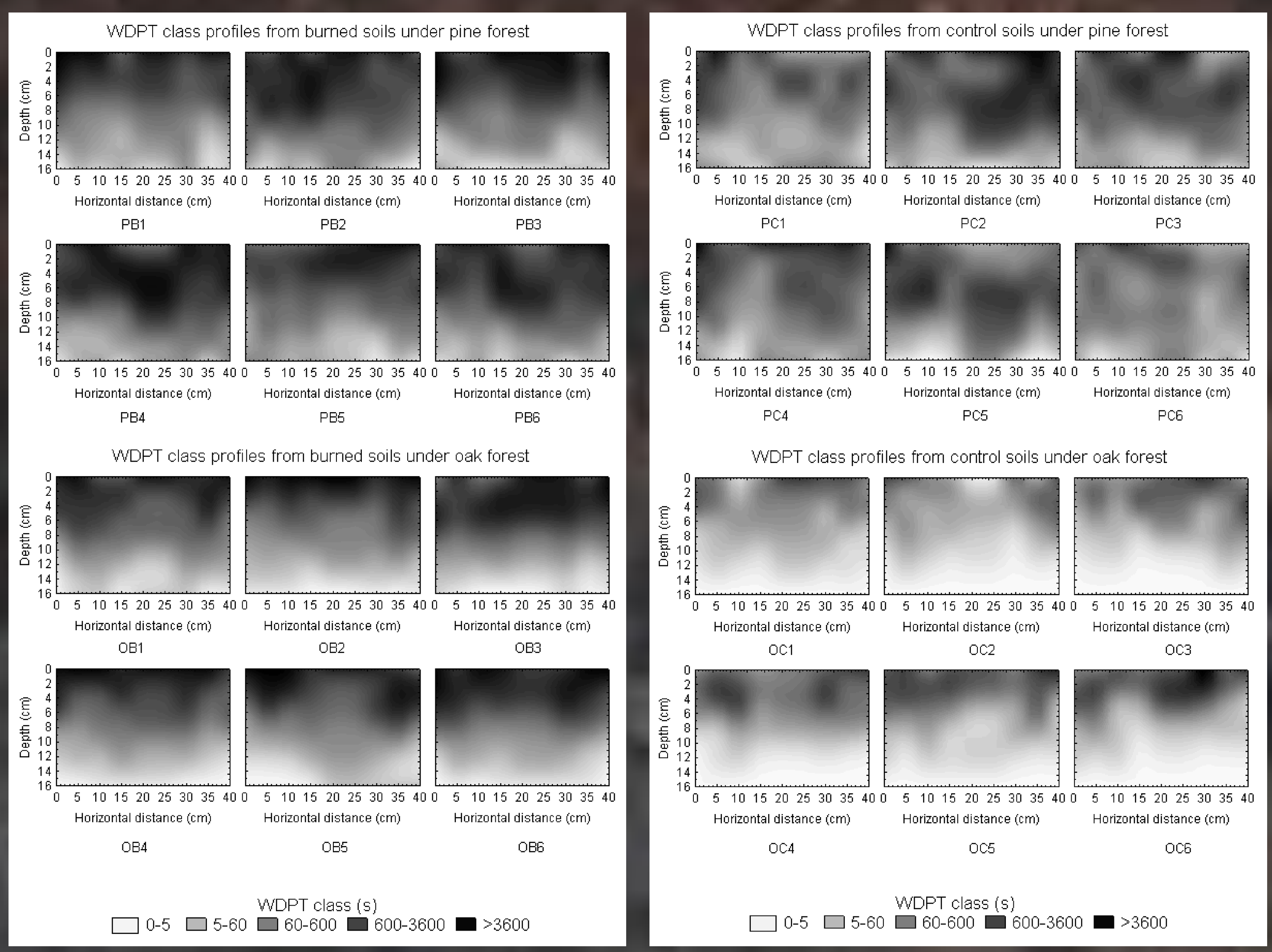
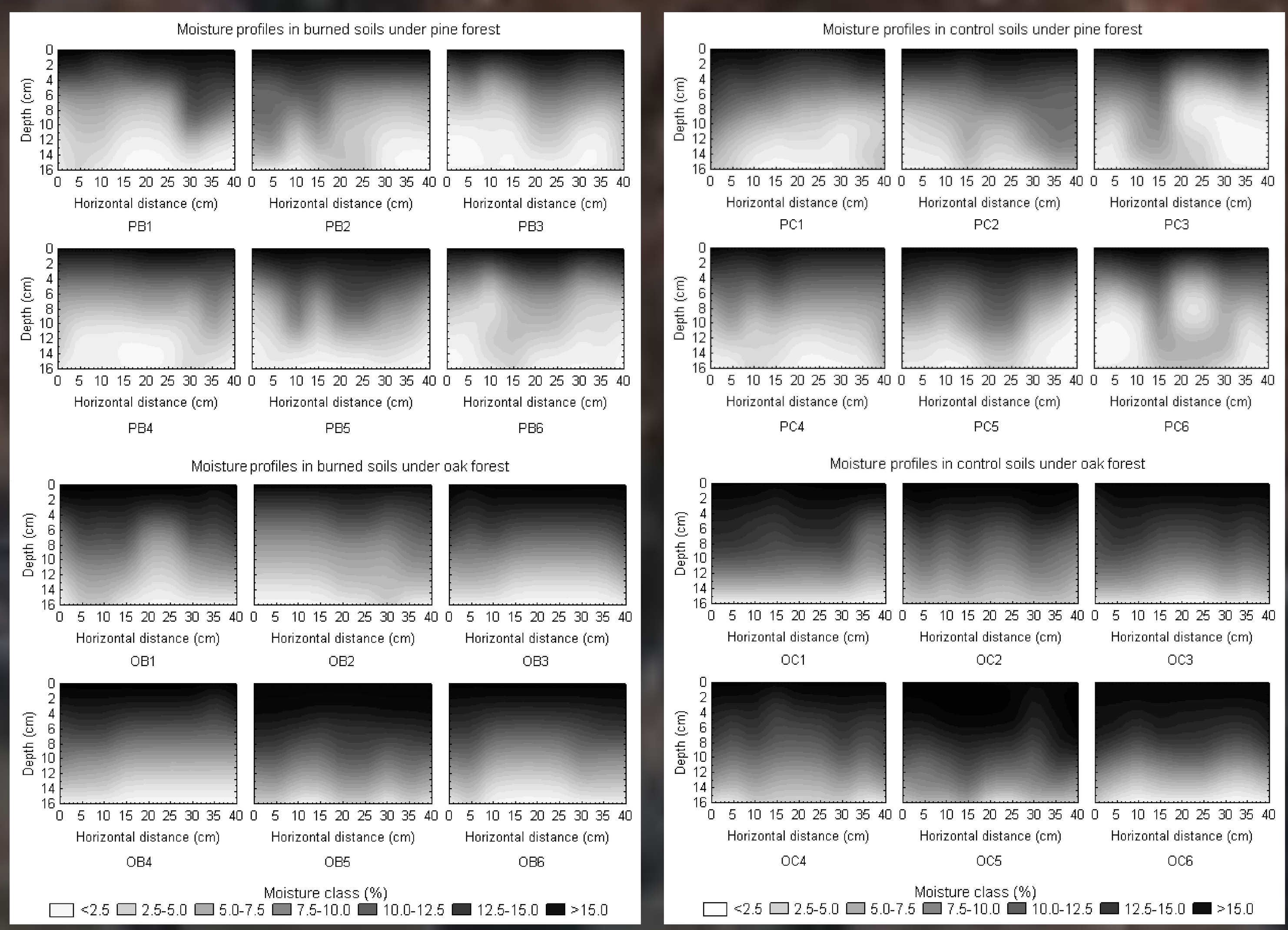



Figure 2. Location of study area. Squares correspond to pines burned (white) and unburned (black) plots. Circles represent oaks burned (white) and unburned (black) plots.

## Results



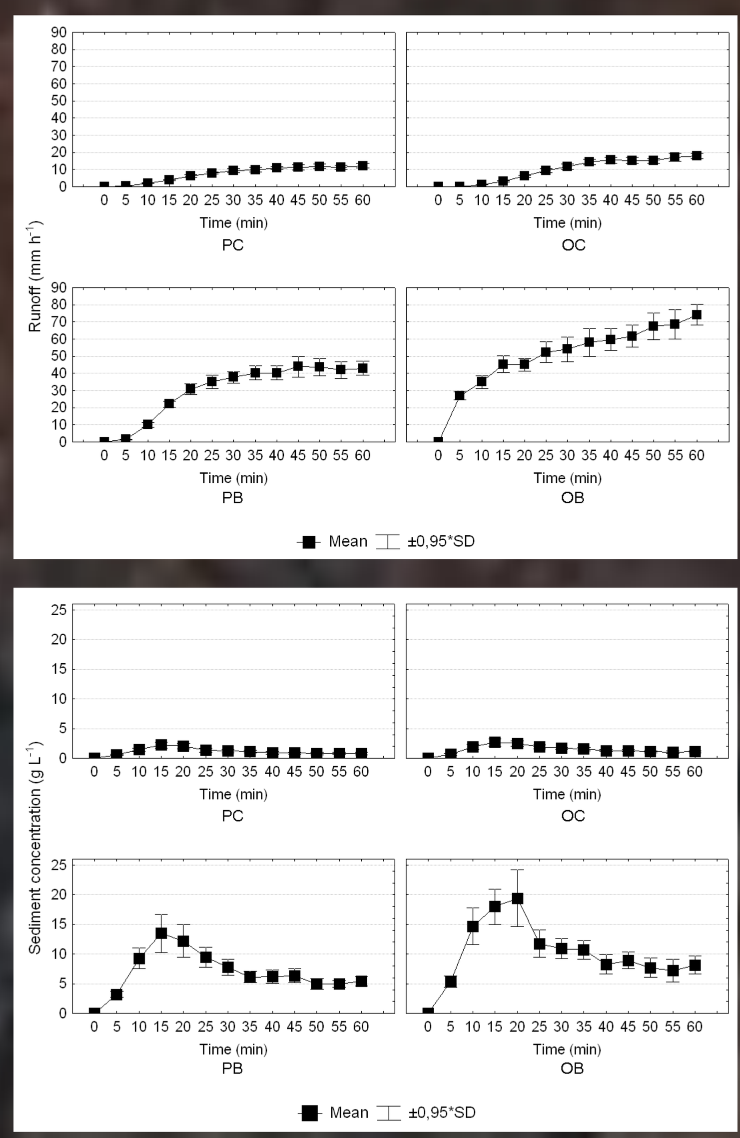




**Fig. 4. Soil water repellency profiles from unburned control (left) plots under pine forest (PC1-PC6) and oak forest (OC1-OC6), and burned (right) plots under pine forest (PB1-PB6) and oak forest (OB1-OB6),**

**Fig.5. Moist profiles from unburned control (left) plots under pine forest (PC1-PC6) and oak forest (OC1-OC6), and burned (right) plots under pine forest (PB1-PB6) and oak forest (OB1-OB6).**

**Figure 3. Runoff rate and sediment concentration in runoff for control unburned (C) and burned (B) plots under pine (P) and oak (O) forest. Some standard deviation bars are hidden by plots.**

Runoff flow was observed in all the experiments after the first 5 minutes of rainfall. Unburned plots (pine and oak) shoed lower average of runoff flow than burned soil. Nevertheless the dynamic was different depending on pine and oak plots. The runoff rate in plots under pine forest increased rapidly and linearly in the first 5-25 minutes after rainfall started, approaching a limit value, while mean runoff from soils under oaks 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 (Fig.3). Sediment concentration in runoff also showed great differences among plots (Figure 3). Generally, sediment yield increased linearly during the first 15-20 minutes of rainfall, reaching a peak of sediment yield for all plots, relatively low at control unburned plots (pines and oaks) and higher in the case of burned soils. After these peaks of sediment concentration in runoff, a steady decrease of sediment concentration was observed.

The proportion of wettable samples in control unburned soil plots under pine forest 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. In the case of unburned control plots under oak forest, the proportion of wettable samples ranged between 4 % (0 cm) and 54 % (14 and 16 cm). WDPT class profiles from burned plots under pines and oaks show a higher degree of repellency. Under pines, the proportion of wettable soil samples from burned plots did not differ from control plots. WDPT class profiles from burned plots under oak forest show stronger WR and more thickness of the hydrophobic layer respect to unburned plots.

A quite irregular moisture pattern was observed at control unburned plots under pine forest (Fig. 5 a). No dry soil 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 control unburned plots under oaks showed a deeper and more homogeneous infiltration, although the proportion of dry soil samples increased rapidly below 12 cm (13 % at 14 cm and 59 % at 16 cm).
Under burned pine forest (Fig. 5 b), 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

1) 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.
2) 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.
3) In unburned/burned soils under oaks and pines, the severity of WR was commonly higher at the soil surface, where the presence of hydrophobic organic substances is normal after burning, and it decreased with depth in the first 16 cm.
4) 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.
5) 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-.