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Increased runoff rates and fingered flow after fire-induced changes in soil water repellency

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Water repellency (WR) from fire-affected soils can affect infiltration processes and increase runoff rates. The effects of fire-induced changes in soil WR and the related soil hydrological response after one of the largest wildfires in Spain in recent years have been investigated in this research. The vertical distribution of WR in soil profiles was studied under oak and pine forests and the wetting pattern was analyzed after rainfall simulations. After burning, the persistence of WR in soils under oaks increased in the upper 0-5 cm of soil in comparison with pre-fire WR, but no significant changes were observed under pines. A hydrophilic layer was not observed at the soil surface, but the thickness of the water repellent layer was considerably enlarged after fire. After fire, WR was stronger and the thickness of the water repellent layer was greater in soils under pines in the upper 0-16 cm of soil. The hydrophobic layer was thinner under oaks, where no strong to extremely water repellent samples were observed below 12 cm (in burnt soils) and 8 cm (in unburnt soils). Fire increased subsurface WR after translocation of hydrophobic substances into the soil during burning. This suggests that soil temperature did not exceed the critical threshold for repellency destruction in the first 16 cm. In long unburnt and burnt soils under oaks and pines, the severity of WR was commonly higher at the soil surface, where the presence of hydrophobic organic substances is common after low intensity burning and it decreased with depth up to 16 cm.

Uniform wetting was observed through soil depth in burnt and unburnt soils under oaks, as a consequence of the prevailing matrix flux infiltration. Water was mostly stored in the upper few centimetres and soil became rapidly saturated, favouring a continuous rise in the runoff rate during the experiments. Preferential flow paths were observed in unburnt and burnt soils under pines, with highly irregular wetting fronts, as a result of wettable and water repellent three-dimensional soil patches. In this case, runoff rates on burnt plots increased with relation to unburnt plots, but runoff generation reached a steady state after 25-30 minutes of simulated rainfall at intensity of 85 mm/h. Rainfall water infiltrated over a small part of the ponded area, where the vertical pressure of the water column overcame the WR. After burning, runoff rates were enhanced in soils under both studied species, but the increase was much larger under oaks. Higher runoff rates in burnt plots under oaks may be related with uniform wetting patterns and prevailing matrix flux infiltration. These factors favoured rapid saturation in the few upper centimetres of soil and delayed infiltration. In burnt plots under pines, part of ponded water infiltrated rapidly through preferential flow paths.