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Using rainfall simulation to monitor the effect of fire on overland flow and erosion through time

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The Mediterranean region is highly susceptible to wildfires, which can lead to serious soil degradation as a result of physico-chemical soil property changes. Soil reacts in a complex way to changes brought about by fire, but removal of much or all of the vegetation cover and heating effects on the soil usually cause increased overland flow and increased losses of sediment and nutrients. The consequences may be not only loss of minerogenic material, organic matter and nutrients from the soil leading to loss of soil productivity but also reduced downstream water quality.

In Portugal, one of the most popular techniques used in recent years by the forestry service to limit wildfire occurrence is the control of the fuel load using prescribed fire. The aim is to reduce the biomass whilst minimising impacts on the soil. Although there have been many studies focusing on wildfire effects on soil properties and overland flow, there has been less interest in prescribed fire effects.

To assess changes in hydrology and soil losses caused by prescribed fire, an experimental burn was carried out in a small (9 ha) catchment (Vale Torto) in central Portugal in February 2009. The catchment has steep slopes (up to c. 25º) on schist bedrock and the soil is water-repellent, thin (<10cm) and stony. The mean annual rainfall is about 1000 mm. Rainfall simulation experiments were carried out before the fire (under dry and wet antecedent conditions) and at intervals after it (immediately after the fire, three months later and one year later). The simulations were performed on five small plots 0.25 m2 in size. Each plot has straight upper end and sides with a tapered lower end with incorporated outlet to facilitate runoff collection. The plots were installed with the top and bottom parts removed between measurements to allow natural overland flow and soil redistribution processes to occur.

Each simulation experiment was performed for 1 hr at a rainfall intensity of 45 mm/hr. Soil moisture content was measured every minute, and overland flow volume at 5-minute intervals. Sediment transported by overland flow (slopewash) and its organic content were also measured.

The results show a slightly lower pre-fire mean infiltration capacity during dry than wet antecedent conditions (runoff coefficients of 37% and 42%, respectively), which can be attributed to higher water repellency under dry conditions. However, erosion rates were higher under these dry water-repellent conditions (4.6 g/m2 compared with 1.2 g/m2), which is probably a consequence of the greater efficacy of rainsplash detachment when the soil is dry. Immediately after the fire, the mean runoff coefficient was approximately the same as during wet antecedent conditions before the fire, but the erosion rate was eight times higher (14.2 g/m2). Three months after the fire, despite a lower runoff coefficient (36%, almost the same as in the dry period before the fire), the erosion rate increased sharply (35.2 g/m2), which can be attributed to the continued exposure of unvegetated erodible sediment within the plots (provided by inwash from upslope between measurements; such an erosion rise would not have been recorded if the plot had remained bounded between measurements These results show that this fire continued to have a significant impact on soil loss for a relatively long period.

As regards the methodology adopted, the ability to keep the plots in fixed positions minimised soil disturbance due to plot installation and meant that results carried out at the same sites were directly comparable. Removing the upper and lower boundaries of the plots between measurements ensured that soil in the plots underwent processes similar to those experienced on the surrounding slope and avoided the ‘oasis’ effect associated with bounded plots. It can be concluded that rainfall simulation experiments provide a good method for monitoring and assessing spatial and temporal differences in overland flow and erosion rates through time.