# SOIL CRUSTING EFFECTS ON INFILTRATION UNDER EXTREME RAINFALL IN SEMIARID ENVIRONMENTS

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## Introduction

Soil crusting is a common and widespread phenomenon in arid and semiarid soils which cover about 40% of the earth's land surface (Dregne, 1991). Although physical and biological crusts are an almost negligible portion of the soil profile (from less than one to a few millimetres in thickness), they play a significant role in ecosystems: affect the local hydrological regime dramatically, decrease the infiltration rate, reduce the available water, increase runoff and affect evapotranspiration and interception (Mualem, 1996; Belnap, 2006). Their influence on erosion processes is complex: crusts may reduce detachment, but they can also build up runoff, suggesting that downstream erosion may actually be increased (Zhang and Miller, 1996) or favour water harvesting to vegetated areas (Valentin *et al.*, 1999). To improve the modelling capabilities of runoff and water erosion in arid and semiarid catchments it is necessary to take into account the response of crusted areas (Stolte *et al.*, 1997; Cerdan *et al.*, 2002). This work constitutes the first results of a project about the incorporation of soil crusting dynamics into runoff and erosion modelling at catchment scale in semiarid ecosystems. The infiltration on physical and biological soil crusts under simulated rainfall in two small semiarid catchments is analysed. Disturbance treatments were applied to evaluate the hydrological response of crusts just after crust disruption and later, in future experiments, during crust reconstitution, colonization and succession processes

## Methods

Two experimental areas representative of soil crusting processes in Mediterranean semiarid environments located in Almeria (SE Spain) were selected: a) El Cautivo, a badlands area developed on gypsiferous marls, with steep slopes (from 9 to 40º for the studied plots), located in Tabernas desert. Physical and biological soil crusts cover more than 80% of soil and appear as unique soil cover in many landforms; b) Amoladeras (Cabo de Gata Natural Park), over an exhumed and dissected caliche area in the distal, flat part of an alluvial fan system, consisting of disperse shrubs and biological soil crust in open areas.

Extreme rainfall of 50 mm $h^{-1}$ (maximum precipitation in 1 h for return period of 10 years) was simulated on the main soil crusts at micro-plot scale (0.25$m^2$) during one hour. In El Cautivo five types of crusts representing the different stages in crust succession were considered: 1) Structural crust over marl (SC); 2) Depositional silty crust (DC); 3) Depositional crust with incipient cianobateria colonisation (BIC); 4) Biological soil crust dominated by cianobacteria (BCC) and 5) Biological soil crust dominated by lichens (BLC). BCC, BLC and a biological soil crust dominated by moss (BMC) were the representative soil crusts in Amoladeras. SC and DC are physical crusts. The rest are biological soil crusts with BIC-BCC-BLC and BMC sequence of evolution.

Three treatments were applied on each crust type: a) no disturbance; b) trampling (consisting in stepping 100 times over the 0.25 m² plot) and c) scraping. Four plots for each treatment, as repetitions were considered.

Rainfall was applied in two events of 30 minutes each: the first on dry conditions and the second on wet conditions (30 minutes after the first rain). Runoff was collected at one to three minutes intervals.

## Results and discussion

The influence of the different parent materials and topography explains the contrasted infiltration rates at both areas. As it can be observed in Table 1, infiltration rates are lower in badlands, where crusts appear covering very incipient silty soils, whereas in Amoladeras, soils have a higher development and coarser texture. For the same material and topographic conditions, infiltration rate in undisturbed crusts increases with the evolution of the crust: a) in Amoladeras the infiltration rate increases in this sequence BCC-BLC-BMC and b) in El Cautivo, to ensure comparable topographic conditions, two sequences have to be distinguished: SC or DC-BLC with the highest infiltration rates in lichens crusts (late successional crust) and BIC-BCC.

Significant differences in infiltration rates (considering all crust types) were found for the undisturbed and trampling treatment, in each site separately, but no for the scraping treatment, as expected, because crusts are on the same type of soil in each site and once the crust is removed infiltration is controlled by soil properties and the new seal properties.

Table 1. Total infiltration rate ($mm{\cdot}h^{-1}$) (average from 4 repetitions) after 1 hour at both studied sites and in each crust type

| Site | Crust type | Undisturbed | Trampling | Scraping |
|---|---|---|---|---|
| Cautivo | SC | 13.27 | 8.68 | 16.67 |
| | DC | 8.11 | 8.90 | 15.86 |
| | BIC | 18.50 | 16.53 | 20.75 |
| | BCC | 22.96 | 19.63 | 34.32 |
| | BLC | 13.52 | 11.20 | 17.61 |
| Amoladeras | BCC | 21.48 | 23.09 | 26.49 |
| | BLC | 33.45 | 29.99 | 32.33 |
| | BMC | 42.84 | 40.57 | 30.86 |

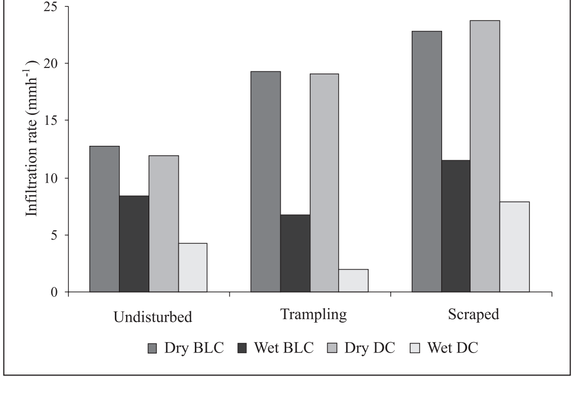


Figure 1. Infiltration rates recorded for the first rain (dry) and the second (dry)

For all crusts types, in both sites, the trampling treatment promoted a decrease in infiltration (Table 1). This treatment applied to the soil surface breaks soil aggregates, crushes macropores, disrupts physical and chemical crusts, and compacts soil reducing infiltration. However, the effect of this treatment was less evident in Amoladeras where soils have a coarser texture which provides a higher resistance to soil compaction. Nevertheless, in general, the trampling effects on runoff are lower than the found by other authors applying similar management (Barger *et al.*, 2006).

Differences between the first and second simulated rains were found for all crusts as can be observed in Figure 1 for BLC (lichen crust) and DC (physical crust) in El Cautivo (Tabernas).

In all cases, the crust removal treatment showed the highest infiltration rate, however the difference is more evident during the first 30 minutes rainfall, because during the second rainfall, soil surface is already sealed and runoff increases reaching similar rates to those measured on the undisturbed plots. When the infiltration curve is analysed in detail (Figure 2), it can be observed that during the first minutes the trampling treatment showed high infiltration rates, as higher as the scraping treatment, because the crust disruption caused by trampling enhances infiltration in the first soil millimetres. However, after the first minutes, the soil compaction caused by trampling restricted infiltration and induced the highest runoff rates.

Figure 2 also shows the reduction in the difference between undisturbed and scraping treatments in the second 30 minutes rainfall. This

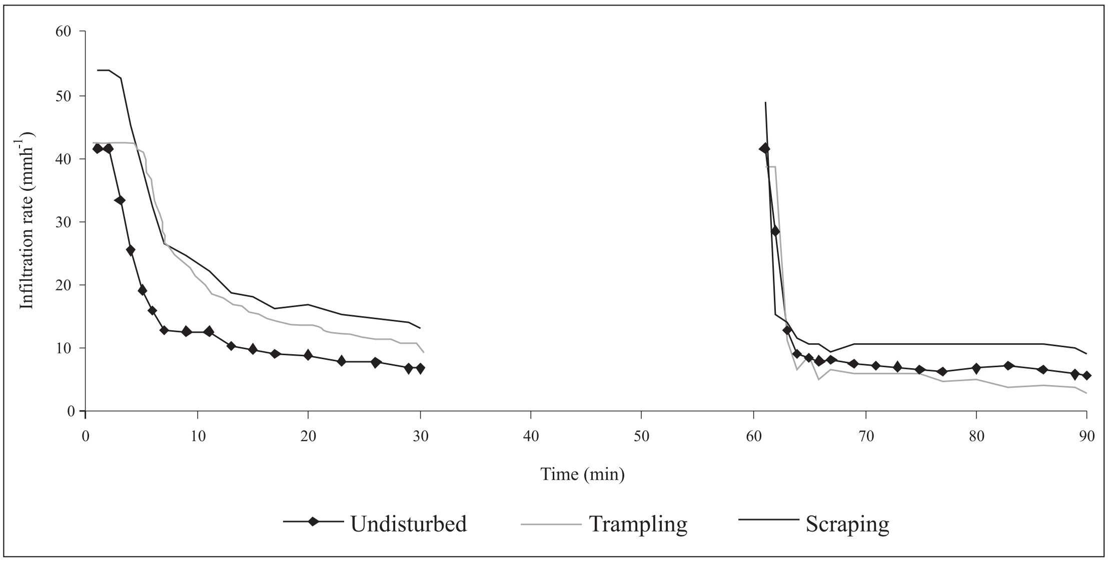


Figure 2. Infiltration curves in BLC (lichen crust) plots. The two rains (30 minutes duration) are presented

pattern is also observed in the rest of crusts at both sites. However, the differences in the infiltration rate between crust types are more marked in the second rain, suggesting that these differences will become accentuated for extreme events.

## Some conclusions

Crust types in both sites showed different infiltration rates, and the infiltration rate increased with the evolution of the crust (stage of succession) but only when the rest of conditions (soil properties, slope, etc.) are the same.

Crust disturbance affected infiltration. Trampling promoted the highest reduction in infiltration. Crust removal leaded to an increase of infiltration rates, especially at the beginning of the rain, though the difference between removed and correspondent undisturbed soil crust decreased during second rain event as a consequence of the new physical crust development. The main consequence of the enhanced infiltration just after crust removal is the reduction of runoff to be redistributed towards shrub mounds, which support the highest plant diversity and productivity in arid and semiarid environments.

These results suggest that the effects of crust removal on infiltration will be lower during extreme events with regard to small events: under extreme events the soil surface with a removed crust will behave similarly to an undisturbed crust, though under normal events the differences in infiltration behaviour are enhanced. However, the differences in infiltration rates among undisturbed crust types would be accentuated during extreme events. Therefore the incorporation of the response of undisturbed crust types in rainfall-runoff modelling is critic for extreme events.

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