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Impact of soil surface sealing on Rainfall-Runoff Processes in semi-arid areas

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Water resources are vital for arid and semi-arid land ecosystems. Temporal and spatial distribution of water resources may significantly impact the development and sustainability of these ecosystems. One of the major elements in the water budget is the rainfall-runoff relationship. The response of semi-arid regions to short but intense rainfall events has not been fully understood yet due to complex feedbacks between water, vegetation patches, topography and soil characteristics variability. The widely observed soil surface sealing is an important complicating factor in this system. Soil surface sealing involves the formation of a compact seal layer at the vicinity of the soil surface, inducing a drastic reduction of the soil infiltrability, thus affecting the local rainfall-runoff relationship. This study aims to quantitatively examine the role of surface sealing in semi-arid region hydrology. A modeling approach is developed including a two-dimensional surface runoff model and a two-layer conceptual infiltration model to study the rainfall-runoff process with the formation of a seal layer. The two-dimensional surface runoff model solves the diffusion wave equation with a Total Variation Diminishing (TVD) scheme to enhance accuracy and minimize numerical effects. The model is able to resolve details of runoff routing pattern on an irregular surface. The two-layer infiltration model applies the approach developed by Smith et al. (1999) and is able to describe the rainfall infiltration process in a sealed soil profile. The combination of the two models can simulate the rainfall-infiltration-runoff process on a heterogeneous surface with spatially varying soil and landscape properties. The modeling results show that, as expected, when a seal layer exists, the chance of runoff occurrence can dramatically increase. On a vegetated surface, the seal layer can enhance the effects of heterogeneous soil properties and surface features and lead to a highly heterogeneous pattern of runoff and soil moisture distribution. Water allocation can favor vegetation patches through surface runoff. This implies that more water resources may be available for plants when a seal layer develops at the soil surface.