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A Dynamic Eco-Geomorphogic View of Surface Connectivity in Semi-Arid Areas: Modelling Approach and Observations

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We study the dynamics of runoff connectivity patterns in semi-arid areas with patchy vegetation using a modelling approach and field data. Runoff connectivity emerges from the interaction between hydrologic, vegetation and erosion patterns. These patterns are spatially and temporally dynamic as they respond to a variety of processes acting at various temporal and spatial scales. For example, soil moisture patterns, which prescribe runoff production due to infiltration excess mechanisms, dynamically change exhibiting a relatively fast response to temporal changes in rainfall rates, but are also influenced by a slower response to spatial and temporal changes in vegetation cover that alter infiltration rates.

We use a modelling framework that couples a landform evolution model with a dynamic vegetation model for water-limited ecosystems. The model captures the dynamics of spatially variable infiltration rates that are responsible for the development of a runoff–runon system, which determines the surface connectivity of the landscape and modulates the resulting sediment erosion and depositional areas. Therefore the amount of water and sediments retained by the landscape is linked to the dynamic surface connectivity between the upslope and downslope areas. We analyse and compare the patterns of surface connectivity resulting from hillslopes with varying slopes, and varying soil erodibilities and diffusivities. We also investigate the effect of different vegetation covers, with varying degrees of soil-cover protective effect, which give rise to both banded and striped vegetation patterns. We present and analyse the modelling results, which are found to be in good agreement with field observations in both Australia and Spain. These simulations suggest that the appearance of rills in areas with higher slope or soil erodibility, and/or vegetation with lower soil-protective effect dramatically alters connectivity patterns. Results show that in these areas, small disturbances can dramatically increase the connectivity above a threshold value that leads to severe degradation.