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Evolving soils and hydrologic connectivity in semiarid hillslopes

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Soil moisture availability is essential for the stability and resilience of semiarid ecosystems. In these ecosystems the amount of soil moisture available for vegetation growth and survival is intrinsically related to the way water is redistributed, that is from source to sink areas, and therefore prescribed by the hydrologic connectivity of the landscape. Recent studies have shown that hydrologic connectivity is highly dynamic and linked to the coevolution of geomorphic, soil and vegetation structures at a variety of spatial and temporal scales.

This study investigates the effect of evolving soil depths on hydrologic connectivity using a modelling framework. The focus is on Australian semiarid hillslopes with patterned vegetation that result from coevolving landforms, soils, water redistribution, and vegetation patterns. We present and analyse results from simulations using a coupled landform evolution-dynamic vegetation model, which includes a soil depth evolution module and accounts for soil production and sediment erosion and deposition processes. We analyse the effect of soils depths on surface connectivity for a range of biotic (plant functional type strategies) and abiotic (slope and erodibility) conditions. The analysis shows that different plant functional types, through their varying facilitation strategies, have a profound effect on soils depths and therefore affect hydrologic connectivity and soil moisture patterns. This interplay becomes particularly important for systems that coevolve to have very shallow soils. In this case soil depth becomes the key factor prescribing surface connectivity and available soil moisture for plants, which affect the recovery of the system after disturbance. Conditions for the existence of threshold behaviour for which small perturbations can trigger a sudden increase in hydrologic connectivity, reduced soil moisture availability and decrease in productivity leading to degraded states are investigated. Critical implications for effective restoration efforts are discussed.