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Redistribution Processes Create Multiple Challenges for the Prediction of Storm Runoff and Soil Loss from Semiarid Hillslopes

Matthias M. Boer (1,2) and Juan Puigdefabregas (3)

(1) Bushfire Cooperative Research Centre (2) Ecosystems Research Group, School of Plant Biology, University of Western Australia (3) Estación Experimental de Zonas Áridas (CSIC), Almería, Spain. (email: mboer@plants.uwa.edu.au, puigdefa@eeza.csic.es)

Semiarid hillslopes are often characterised by a patchy vegetation cover consisting of clumped or banded formations of grasses or shrubs amongst a matrix of bare soil areas. Typically, the bare soil areas respond more readily to rainfall and generate more runoff and sediment than the vegetated patches, but these differences may vary dynamically during a storm or from one season to another. Whenever bare soil areas and vegetated patches are responding differently there is a probability that runoff and sediment generated in the former (sources) is intercepted and (partially) retained in the latter (sinks). The redistribution from sources to sinks creates multiple challenges for models that seek to predict water and sediment fluxes at the hillslope scale. The net loss of water or sediment over a period of time is a function of the frequency and duration of continuous flows from sources areas to the base of the slope. Prediction of this process for a large number of simultaneously operating source-sink systems under rainfall of variable intensity seems a complex task indeed. With how much detail do we need to model these redistribution processes to make accurate predictions at the hillslope scale?

We aimed at firstly gaining a better understanding of the interaction between spatial variability of vegetation and soil attributes and temporal variability in rainfall intensity and its effects on the net loss of water and sediment. A series of simulation experiments was performed with a spatially-distributed process-based soil erosion model (i.e. LISEM). The model was parameterised and verified for a small catchment with discontinuous vegetation cover at Rambla Honda, SE Spain, and then used to predict water and sediment fluxes on 1 ha hypothetical hillslopes with simulated spatial distributions of vegetation and soil parameters. Both, storms of constant and variable rainfall intensity were applied. After quantifying the contribution of spatio-temporal patterning to variation in water and sediment outputs, the same set-up was used to explore how much detail of those patterns is required as input by the model to "correctly" predict the hillslope fluxes. To that end the simulation experiments were repeated with increasingly coarser representations of the same vegetation/soil patterns and rainfall time-series.

The results suggest that variation in spatio-temporal patterns of land attributes or rainfall may have substantial effects on discharge and soil loss rates from semiarid Mediterranean hillslopes. The effects were found to be transient and to be most pronounced when runoff generation or sediment transport thresholds were (just) exceeded in bare soil areas but not (yet) in vegetated patches. The temporal correlation structure of rainfall intensity contributed more to variation in discharge and soil loss rates than spatial correlation structure of vegetation cover and related soil attributes.

For high-intensity storms, LISEM predictions of storm discharge or soil loss showed to be more sensitive to changes in the temporal resolution of the rainfall time-series than to the spatial resolution of the vegetation and soil input maps. During storms of moderate rainfall intensities, temporal and spatial resolution effects were observed to interact causing either over- or under-prediction of water and sediment yields.