18th World IMACS / MODSIM Congress, Cairns, Australia 13-17 July 2009
http://mssanz.org.au/modsim09

Evolution of surface connectivity and patchiness in semi-arid areas: the role of slope and plant response times

Saco, P.M. [1], **and G.R. Willgoose** [1]

[1] *School of Engineering, University of Newcastle, Callaghan, NSW, 2308*
Email: patricia.saco@newcastle.edu.au

Abstract: In arid and semi-arid regions distinct patterns of vegetation emerge from the interaction between plants, soils, topography and water re-distribution. Generally, the vegetation of these regions consists of a mosaic or pattern composed of patches with high biomass cover interspersed within a low-cover or bare soil component. In many areas, the development of these patterns has been associated with the emergence of a spatially variable infiltration field with low infiltration in the bare areas and high infiltration in the vegetated areas which gives rise to the development of a runoff–runon system. The enhanced infiltration rates under vegetated patches are due to improved soil aggregation and macroporosity related to biological activity (e.g., termites, ants, and earthworms are very active in semi-arid areas) and vegetation roots.

We present simulations from a modelling framework that couples evolving landforms, dynamic vegetation and hydrology to explore the co-evolution of landforms and vegetation patterns at the hillslope scale in those regions. The dynamics of vegetation patterns in water limited ecosystems is simulated using a new model developed as an extension of that described in Saco et al. (2007). The dynamic vegetation model describes the dynamics of three state variables: overland runoff depth (h), soil moisture (M; volume/area), and plant biomass density (P; mass/area). This model captures the emergence of the spatially variable infiltration field mentioned above and observed in large areas of Australia and the world. The runoff–runon system not only determines the surface connectivity of the hillslope but also modulates the resulting sediment erosion and depositional areas (obtained from the coupled landform evolution model) that lead to observed characteristic patterns of micro-topography.

We use the model to analyse the spatial and temporal dynamics of runoff and sediment re-distribution in arid areas with banded vegetation. We run the model with different parameter choices to simulate the fast response of grasses and slow dynamics of shrubs for long term climate fluctuations. We compare the patterns of surface connectivity resulting from hillslopes with different initial topographies and with varying vegetation in response to observed daily rainfall from arid eastern New South Wales (Australia). We find that the amount of water retained by the landscape is related to the surface connectivity between the upstream and downstream areas which depends on the (evolving) vegetation cover.

Modelled results agree with experimental observations suggesting that, in disturbed hillslopes, there is a threshold slope gradient below which runoff and erosion will eventually return to pre-disturbance levels and above which runoff and erosion will remain higher. This threshold varies with hillslope soil-type (that is, depends on soil erodibility) and vegetation type. The main controlling effect of vegetation type is manifested through differences in response times and resilience to drought periods. We also find that the simulations that incorporate rainfall variability give rise to vegetation patterns that are less regular and therefore look more realistic than the patterns typically obtained from previous models that use a (constant) mean daily rainfall. This result is due to the effect of rainfall variability in both vegetation growth rates and erosion rates. The principles of this dynamics have important consequences for restoration efforts in arid areas.

Saco P.M, G.R. Willgoose and G.R. Hancock, 2007, Eco-geomorphology of banded vegetation patterns in arid and semi-arid regions, Hydrol. Earth Syst. Sci., 11, 1717–1730.

Keywords: *Eco-hydrology of Arid Areas, Eco-geomorphology, Runoff–Runon System, Soil erosion.*

Abstract only