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Mechanistic modelling of macropore evolution

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Preferential flowpaths appear to be ubiquitous features in most hydrogeomorphic systems. While these networks present themselves in different forms, one commonly described form is laterally downslope. These may greatly contribute to the (lateral, effective) saturated hydraulic conductivity at the hillslope scale. Direct biogenic action (root channels, animal burrows) have been hypothesized to be responsible for the formation of lateral macropores. While these have been extensively studied, one other possible mechanism has not been examined to date in detail: mechanic erosion, that might subsequently enlarge biogenic macropores. Part of the reason for this is that such a process is difficult to observe, model or characterize.

In this paper we explore the explanatory power of mechanic, shear stress-driven enlargement of lateral macropores. We find that as long as subsurface sediment transport capacity is not a limiting factor (i.e. detachment limited), the process of pore erosion and flow is self-enhancing. A realistic process-response model thus requires an additional pore destruction mechanism to prevent the system from runaway behaviour. Threshold based collapse of pore walls, or bioturbation are two likely destructive processes. Because the time integrated effect of pore erosion is proportional with the total duration of saturated conditions, detachment-limited pore erosion is hypothesized to be more effective lower in the soil profile (e.g. directly on top of an impervious layer). This is consistent with some observed forms of lateral macropore networks only. The other variant of subsurface macropore evolution, i.e. transport-limited, results in pore network growth upwards, starting from the hillslope foot, very much like described for the development of soil piping.