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Toward understanding causal interrelationships between stormflow and erosion processes in a steep zero-order basin

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Stormflow generation and soil-erosion process on a steep zero-order basin have close interdependencies though their timescales are far different. This study pays attention to a difference in interdependences of stormflow and erosion processes between a near-ridge nose and a concave hollow within a zero-order basin.

Due to strong erosional forces in an active tectonic region, soil moves down by the gravity force throughout the basin. In a convex nose near the ridgeline, soil moves gradually by diffusive processes, and the curvature of bedrock surface controls the soil depth (Heimsath, Geomorphology 27, 1999). On the other hand, in a concave hollow, soil layer suddenly collapses as a landslide and a long-term soil-layer evolution at a timescale of 10^2 - 10^4 years continues unless a landslide occurs (Tsukamoto et al., IAHS Publ. 137, 1982). In the nose, the soil layer may move downslope with vegetation on it without disturbances. The recovery of soil layer after a landslide occurrence in a hollow is supported by the soil supply from the nose by the diffusive movement. The diffusive process near nose and the recovery process near hollow are closely related each other.

In order to ensure these processes, saturation excess overland flow should be suppressed both in a nose and a hollow because it is a trigger of landslide initiation. We can assume that the drainage capacity through pipe-like preferential paths (McDonnell, Water Resour. Res. 26, 1990) plays an important role in the suppression.

One hydrological analysis for addressing the assumption is attempted from estimating the expansion of stormflow contribution areas from rainfall-runoff responses in a small catchment. In the wet conditions when most of all the rainfall contributes to the stormflow, a hydraulic continuum under a quasi steady state is created and a single tank model can well simulate rainfall-runoff responses (Tani: Hydrol. Earth Syst. Sci., 17, 2013). This simple characteristic was utilized to estimate the contribution-area expansion with rainfall increases inversely from the runoff responses.

Results show that except a short dry period at the beginning of a storm, the waveform transmission of rainfall to runoff was simulated well by the same model parameters of our tank model though the contribution area only increased. This result suggests the waveform transmission was originated mainly from the vertical water movement instead of the downslope subsurface flow or the overland flow. As suggested from a conceptualized model (Montgomery and Dietrich, Water Resour. Res. 38, 2002), rainwater may be confined within the soil layer due to a large drainage capacity of the pipe-like preferential paths. This strongly encourages the soil-layer evolution process against strong erosional forces not only in a nose but also in a hollow.

Runoff and erosional processes are certainly linked, and collecting field evidences is expected. In addition, however, reanalyzing the existing hydrological data may also provide a new interesting finding from the linking point of view.

Keywords: erosion, hillslope hydrology, soil-layer evolution, stormflow, variable contribution area, zero-order basin