Stochasticity controls and the central role of “internal variability” in soil erosion system

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Accurate prediction of soil loss rates remains a problem because erosion exhibits a non-unique behavior given the same rainfall/runoff forcing. The effects and causes of uncertainties in soil surface erodibility resulting in such a behavior have not been fully addressed from a mechanistic perspective in previous research. We use a large database of empirical data on soil loss and a comprehensive physical model of runoff –overland flow –erosion –transport processes that dynamically updates the mass and composition of soil substrate at the hydrologic-event scale to address reasons of unpredictability in soil erosion. We explain the role of micro-scale erodibility (referred to here as ‘geomorphic internal variability’) on geomorphic response, which acts as an intermediary between larger-scale forcings and soil loss response. Accounting for a possible range of internal variability illustrates the high sensitivity of erosion response to initial conditions of soil bed, resulting in extremely large uncertainties in short-term predictions. Furthermore, the reduction of geomorphic response variability at larger temporal scales is primarily attributed to a ‘compensation effect’: temporal alternation of events that exhibit either ‘source-limited’ or ‘transport-limited’ regimes. We relate this reduction to a novel stochasticity index that reflects the degree of variability of intra- and inter-event hydrometeorologic conditions. A higher stochasticity index implies a larger reduction of soil loss variability (higher predictability) at the aggregated temporal scales with respect to the mean hydrologic forcing.

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