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Sediment connectivity: addressing the non-linearity of erosional processes within spatially and temporally variable environments

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A major challenge for geomorphologists is to scale up small-magnitude erosional processes to predict landscape form and landscape-scale sediment flux. Here, we present a sediment connectivity framework, showing the controls and dynamics of sediment transport which govern erosional processes across multiple scales. This framework is based on the concept that the interplay of structural components (morphology) and process components (flow of energy/transport vectors and materials) determines the long-term behaviour of the sediment flux, which is manifest as a change in landform. The sediment connectivity framework therefore incorporates all aspects of the geomorphic system that control sediment flux. Because of the link between process (flux) and form, sediment connectivity is a product of sediment entrainment and sediment-transport distance and the emergent characteristics of sediment deposition and sediment residence times. Therefore, depending on the dominant processes in operation and their spatial and temporal configuration, the scaling of erosion differs in form and extent. Sediment-transport distances are an integral component of this sediment connectivity framework, as they provide a means of addressing the non-linearity of erosional processes within spatially and temporally variable environments.

We apply this sediment-connectivity framework to test how structural and process components of a system alter sediment flux. Specifically, we use a modelling-based approach to investigate how antecedent soil-moisture content and rainfall characteristics affect hydrological and sediment connectivity over a shrub-encroachment gradient in the southwest USA; a region that is undergoing rapid vegetation transitions. We carried out scenario-based runoff and erosion modelling using MAHLERAN to investigate the impact of changes in runoff and erosion to soil moisture and rainfall characteristics. Using outputs from these simulations, we quantify hydrological and sediment connectivity metrics, which proportion the length of simulated connected flow paths and pathways of connected sediment transport to the maximum potential length of pathways.

Results show that there are critical thresholds of hydrological connectivity and sediment connectivity for large flow and sediment-production events, but that thresholds of sediment connectivity are not directly related to thresholds of hydrological connectivity. The sediment-connectivity framework explains how this difference can arise as a function of different degrees of control of hydrological connectivity on sediment flux. By applying this sediment-connectivity framework to a modelling-based study, we are able to identify relevant processes and variables that control the spatial and temporal dynamics of sediment transfers through geomorphic systems.