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Graph theory as a tool for the analysis of cascading systems in geomorphology

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From a systems perspective, catchments can be regarded as cascading systems consisting of components (e.g. rock faces, talus, channel subsystems, but also specific landforms) which are linked by a variety of geomorphic processes. Two components are linked if sediment transport is possible between them; this condition is referred to as geomorphic coupling, e.g. from a particular hillslope to a channel reach (lateral coupling) or among channel reaches (longitudinal coupling). The degree to which the components of a system are coupled, and hence the potential of sediment of moving through the system, is called (sediment) connectivity. Connectivity is governed by the structure of the system, i.e. the location and topology of its components, and by properties of the respective geomorphic processes (e.g. magnitude and frequency of sediment transport).

We argue that graph theory is a suitable mathematical framework for the analysis of sediment connectivity in geomorphic systems. In a graph model of a geomorphic cascading system, landforms or other system components are represented by graph nodes, and the linkages between them are formed by graph edges. Coupling and connectivity can be assessed by establishing a graph model of the cascading system in a catchment or parts of it at various scales, the local (i.e. referring to single nodes or edges) or global (i.e. referring to the whole graph) properties of which can be analysed using graph theory.

In the present study, numerical GIS-based models are used to create a graph model of the cascading system by identifying the process domains of important geomorphic processes (rock fall, debris flows, slope aquatic and fluvial processes) and by simulating the potential pathways of sediment transport. This is an extension to previous approaches of 'predictive geomorphological mapping' and should enable the analysis of geomorphic systems in large areas without the need of extensive area-wide field mapping.