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A conceptual model for quantifying connectivity using graph theory and cellular (per-pixel) approach

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The concept of connectivity is being increasingly used for understanding hydro-geomorphic processes at all spatio-temporal scales. Connectivity is defined as the potential for energy and material flux (water, sediments, nutrients, heat, etc.) to navigate within or between the landscape systems and has two components, structural connectivity and dynamic connectivity. Structural connectivity is defined by the spatially connected features (physical linkages) through which energy and materials flow. Dynamic connectivity is a process defined connectivity component. These two connectivity components also interact with each other by forming a feedback system. This study attempts to explore a method to quantify structural and dynamic connectivity.

In fluvial transport systems, sediment and water can flow in either a diffused manner or in a channelized way. At all the scales, hydrological and sediment fluxes can be tracked using a cellular (per-pixel) approach and can be quantified using graphical approach. The material flux, slope and LULC (Land Use Land Cover) weightage factors of a pixel together determine if it will contribute towards connectivity of the landscape/system. In a graphical approach, all the contributing pixels will form a node at their centroid and this node will be connected to the next 'down-node' via a directed edge with 'least cost path'. The length of the edge will depend on the desired spatial scale and its path direction will depend on the traversed pixel's slope and the LULC (weightage) factors. The weightage factors will lie in-between 0 to 1. This value approaches 1 for the LULC factors which promote connectivity. For example, in terms of sediment connectivity, the weightage could be RUSLE (Revised Universal Soil Loss Equation) C-factors with bare unconsolidated surfaces having values close to 1. This method is best suited for areas with low slopes, where LULC can be a deciding as well as dominating factor. The degree of connectivity and its pathways will show changes under different LULC conditions even if the slope remains the same.

The graphical approach provides the statistics of connected and disconnected graph elements (edges, nodes) and graph components, thereby allowing the quantification of structural connectivity. This approach also quantifies the dynamic connectivity by allowing the measurement of the fluxes (e.g. via hydrographs or sedimentographs) at any node as well as at any system outlet. The contribution of any sub-system can be understood by removing the remaining sub-systems which can be conveniently achieved by masking associated graph elements.