**"Hydrogeomorphic Processes – the Challenge of Scaling"**

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Hydrogeomorphology is defined as the study of the interaction of hydrological processes with landforms and earth materials, and the interaction of geomorphic processes with surface and subsurface water in temporal and spatial dimensions. In this lecture, hydrogeomorphology is discussed in the context of surface and mass erosion processes across spatial and temporal domains, including the role of hydrologic linkages, with an emphasis on research gaps, pathways forward, and implications for land management.

Understanding integrated hydrological phenomena in hillslopes, and especially in catchments, is difficult because of the fragmented nature of soil physical and hydrological data, typically derived from pedons or small plots. Typical soil physics measurements, as well as runoff plot, lysimeter, and pedon-scale studies do not capture the complexity of surface and subsurface flowpaths in hillslopes. Because pedon/plot scale results are not easily transferable to hillslope and catchment scales, theoretical and empirical approaches to quantify these hydrology-driven dynamics tend to over- or underestimate parameters and fluxes. When included in catchment models, such soil physical parameters often yield unrealistic results, necessitating parameter calibration.

Surface erosion typically decreases from small plots to hillslopes owing to sediment deposition and re-infiltration of overland flow in localized areas, underlining the need to evaluate spatially heterogeneous soil surface and vegetation conditions. At broader scales, re-entrainment of previously stored sediment complicates this generalization, as may the development of rill and gully systems facilitated by overland flow concentration. Subtle changes or patterns of ground cover, infiltration, antecedent moisture, and land use (e.g., roads and trails) play important roles in overland flow concentration and rill and gully initiation and expansion. Advances in remote sensing can help understand and quantify the connectivity of these overland flow paths in erodible terrain, thus informing active or potential sources of erosion and management practices to reduce overland flow concentration.

Rainfall-triggered landslides and debris flows pose even greater challenges related to spatial and temporal water routing in soils and regoliths. Geotechnical approaches to mass wasting have typically focused on hydraulic behavior in small soil cores or disturbed soil samples. While these studies may elucidate physical phenomena controlling slope failure, such homogeneous conditions are rare in the field where landslides and debris flows occur. Preferential flow is common in unstable hillslopes, particularly vegetated terrain, and can contribute to or mitigate slope failure depending on interconnectivity of subsurface flow pathways. This process is usually investigated in the laboratory (core samples) or in soil pedons. Understanding interconnectivity of various preferential flow paths across large hillslopes is important for assessing and modelling slope stability, in both spatial and temporal dimensions. Models based on steady-state infiltration and migration of rainfall (i.e., Richards equation) may erroneously estimate the timing of landslides in heterogeneous regoliths. Quantifying mass wasting and sediment interactions in channels presents different temporal and spatial challenges, and must be assessed at the catchment scale where ecological and channel morphology/floodplain effects are considered.

Process-based scaling requires an over-arching integration of different hydrogeomorphic concepts and approaches. Nested catchment studies, where processes are monitored at different scales, can elucidate diverse spatial and temporal patterns of water and sediment behavior. The spatial scale dependence inherent in many pedology and catchment hydrology studies can be overcome by incorporating hydrogeomorphic, pedological, ecological, and connectivity concepts that demonstrate how soil hydraulic parameters, geomorphic controls, and water/sediment routing change from pedon to plot to hillslope to catchment scales. The resulting self-organization generates spatial and temporal dependencies and provides a paradigm to better understand, model, and assess management effects on water and sediment fluxes and pathways in the continuum from pedons to catchments.