The Role of Long Term Ecological Research in Understanding Dynamic Geomorphological Systems: Insights from Mountain Environments and Highland Watersheds

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This theoretical paper explores the new concept of integrating research on geomorphological processes and landscape ecology in order to understand dynamic and large geomorphic systems. Ever since the seminal work of Chorley (1962) that analyzed the essentially multivariate nature of geomorphic processes, whole landscape assemblages, heterogeneity, and evolutionary patterns; the idea of open systems is considered important in geomorphology. This approach was later fine- tuned by Thornes and Ferguson (1981: ‘systems of complex disorder’ approach) and Odoni and Lane (2011). A key ongoing debate within this paradigm is: whether concepts of ‘equilibrium’ and ‘equilibrium states’ as descriptors of geomorphic systems are inadequate and should be replaced with the concept of ‘systems in perpetual flux’ (Gregory and Lewin 2014). Another important question is on ‘universality’ versus ‘uniqueness’ of such system properties, with von Elverfeldt (2012) noting that such complex geomorphic systems could be ‘self-referential’. This paper invokes processes in mountain environments and highland watersheds—disturbance regimes in hillslopes, sediment transport in rivers, differential erosion and interplay with biotic and abiotic agents—to illustrate key points of this ongoing debate. Back in the 1970s, it was already asserted that reductive logic would fail to provide meaningful understanding of very complex systems due to the property of ‘synergy’ (Monod 1970). As for equilibrium in large geomorphic systems; Scheidegger (1983) contended with his ‘instability principle’, based on the study on the development of cirques, that the ‘equilibrium’ of geomorphic systems is inherently unstable. Those ideas resonate well with recent research on ‘emergence’ in landscape ecology; where it has been contended that Long Term Ecological Research (LTER) based on monitoring and accounting for change in a landscape over time is fundamental to understand complex system pathways, emergence, and resilience. 'Forward and backward loops' whereby the landscape undergoes periodic energy-buildup, storage, release, and reorganization phases (natural disturbance regime) is another key concept that has emerged from landscape ecological research. Recently, the sub-discipline ‘Biogeomorphology’ (Stallins 1996) has emerged to put the idea of the ‘landscape’ (with its often-chaotic patchwork of sub-components) as a fundamental unit for geomorphic system analysis; with empahsis on the key role of ‘ecological memory’ (i.e. how a set of abiotic and biotic factors is engaged in complex, at times recursive feedback between components) in describing processes. Through his 4R (Response, Resistance, Resilience, Recursion) concept, Philips (2011) has described how geomorphic systems co-evolve with climate, soil, ecosystems and other drivers. In mountain environments and highly active (dynamic) watersheds, abrupt threshold change has been noted for sediment transport and channel formation processes. Eaton et al. (2010) have observed that change- thresholds could be fundamentally ‘fuzzy’ and ‘overlapping’; posing yet more challenge for predictive science. While such developments could appear as erosive for the authority of geomorphology as a descriptor of land-formation, in reality they offer an exciting new vista for geomorphological research. Especially for highland watersheds, river geomorphologists’ long-standing preference for ‘stability’ (under which any change is an ‘anomaly’ and must be ‘normalized’) is increasingly untenable, in the light of recent advances in the understanding of active channel formation and mountain-river-plains interactions. By drawing on the seminal work of Stirling (2010) this paper proposes that understanding large and complex geomorphic

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systems (or processes) need to switch to 'recursive understanding', and possibly abandon 'predictive understanding' which has functioned as a longstanding goal for geomorphologists.

Keywords: Dynamic and large geomorphic systems, Geomorphic processes, Equilibrium vs. Flux, Disturbance regimes, Highland watershed , LTER

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