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Data-driven approaches to delineating morphodynamically distinct vegetation communities in deltas and floodplains

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Typically, vegetation is represented in morphodynamic models using just a single set of rules, often involving vegetation's role in inhibiting erosion, promoting deposition, and slowing or steering flow. However, in many floodplain or deltaic environments where vegetation is a key geomorphic agent, diverse vegetation communities coexist and may participate in distinct ecogeomorphic feedbacks. In addition to determining how to formulate adequate ecogeomorphic models, it is also important to resolve these differential feedbacks to strategize plantings for more effective restoration or to assess the ecogeomorphic consequences of proliferation of invasive species. Here we illustrate two approaches for resolving and quantifying the strength of ecogeomorphic feedback processes within different communities, using the Wax Lake Delta, Louisiana, USA, and Big Spring Run floodplain, Pennsylvania, USA as case studies.

In the Wax Lake Delta, one of the only actively prograding parts of the Louisiana coastline, vegetation varies along age and elevation gradients from upstream to downstream and near-channel to interior portions of deltaic islands. We used information-entropic measures, computed from bed elevation and canopy structure data from lidar data obtained in 2009 and 2013, together with remote sensing vegetation classification maps, to quantify the existence and strength of bidirectional feedbacks between topography and vegetation canopy characteristics within individual vegetation communities. Essentially, these measures quantify whether knowledge of historical vegetation canopy characteristics at a location significantly reduces uncertainty in future elevation, given knowledge of past elevation, and vice-versa. We find that bidirectional feedback between vegetation canopy characteristics and topography is resolvable only within low-elevation emergent vegetation communities, and that canopy characteristics have a statistically significant effect on topographic change only in native vegetation communities that develop biofilm coatings. Invasive vegetation communities, on the other hand, responded significantly to elevation but did not exert significant influence on future elevation change.

In Big Spring Run, a stream-wet meadow complex restored in 2011 is notable for having a known "initial condition" (i.e. bare floodplain devoid of vegetation). Its floodplain geomorphology is dynamic, characterized by rapid rates of change of vegetation communities and channel planform morphology. To resolve morphodynamically distinct feedback processes within this floodplain, we repeatedly sampled abiotic and biotic characteristics (e.g., grain size, sediment organic matter content, sediment erodibility, vegetation canopy characteristics) at sites within different vegetation communities in a 16-m x 24-m study plot. We then used traditional multivariate statistical techniques (e.g., ANOVA, principal components analysis) to evaluate which vegetation communities had distinct ecogeomorphic roles. We found that, in this floodplain, communities' influences on geomorphology were not cleanly separable in temporally agnostic analyses, yet differences emerged in their promotion of fine sediment deposition or erosion over time, with watercress, clonal giants, and grasses emerging as the main classes. Over time, transitions in vegetation communities were significantly different from random and attributable to deterministic sediment and biotic drivers.