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Quantifying river's response over plant life stages during a sequence of floods

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With river flooding being more frequent due to climate change, the interaction between fluvial morphodynamics and riparian vegetation may depend in part on the sequence of the flood events. We report a laboratory study on the mechanism of bed morphology adjustment in response to vegetation growth and flood sequencing. A set of 60 runs was performed in a mobile bed flume (10 m x 2.5 m), with constant longitudinal slope (0.015) and uniform grain size (0.46 mm) in the Total Environment Simulator at the University of Hull, UK, to identify the critical role played by vegetation (alfalfa) during the release of a sequence of low and high magnitude flood events. Our setting did not allow recovery of neither morphology nor vegetation in between floods, as the goal was to model the situation where the subsequent event occurred before the system had fully recovered from the previous perturbation. Sediment conditions included runs with equilibrium loads and floods with sediment deficit (in which transport capacity exceeded supply) to quantify the sensitivity of the river's response to sediment variations within the supply. In the runs with vegetation, four different growth periods for the alfalfa were investigated (4,8,14 and 20 days) along with a dying phase, to get insights into the relative role of the plant's age (size) in the geomorphic impact of the sequential floods. The outcomes of each run were characterized by a detailed digital elevation model, digital imagery and continuous monitoring of the sediment transported through the flume outlet.

Observations indicate that both the removal of plants by bank undercutting and sediment transport efficiency at the river reach scale adjust with the life stage of the plants. The braiding intensity (computed directly from topographic data) increases as the flood-survival plants growth, and it becomes less sensitive to flow variability. Under this configuration, the impact of vegetation patchiness becomes more important since it leads to localized erosion by obstructing the flow and encouraging bar development. To some extent, the antecedent flow conditions are important on the system response (filling/eroding), and the same low-magnitude flood impacts differently if it is before or after the high-magnitude flood. Further, an elevation-based distribution function approach (Redolfi et al., 2016) is used to quantify the complexity, and explaining the dynamic response of the channels to plant's age at the reach scale. In particular, the cross-section shape of the rivers computed by the b(D) curve (where b: width, D: depth) illustrates how higher vegetation might mimic the effect of channel confinement.

Overall, results indicate that vegetation growth can have a significant influence on channel pattern and planform dynamics, and a threshold in plant's size can enhance the impact of the variations in flood sequencing and reduce the resilience of the system. This knowledge is particularly important for restoration and risk management of fluvial environments when contemplating changes in flood magnitude and frequency due to climate change or other long-term drivers.