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Modeling groundwater-driven morphodynamic evolution of a gravel bed river in presence of riparian vegetation

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The morphological trajectory of gravel bed rivers is often dictated by the interaction between riparian vegetation, flow and sediment transport. Vegetation encroachment on riverbed can significantly reduce channel mobility, preventing bank erosion and ultimately confining the river to a single-thread planform. The rate at which plants can encroach the riverbed has been mainly associated to the frequency and magnitude of flooding removing vegetation. However, recent observations indicate that the groundwater dynamics can drive distinct morphological patterns, because of its effect on the spatial distribution of vegetation and growth. However, the quantification of the processes that links groundwater to river morphological changes through vegetation remains unclear.

Here we aim at investigating the ecomorphodynamics of a gravel bed river induced by spatial variations in vegetation density by means of numerical simulations. Our case study is a 3 km long reach of the Allondon river, Switzerland, characterized by a wandering river morphology and that underwent spatially contrasting river planform changes in the last decades. Field observations suggest that deep groundwater in the upper part of the reach limited vegetation growth over years, with the main channel keeping a larger active width and dynamic behavior. On the other hand, a shallower groundwater in the downstream part provided accessible water resources for plants, which encroached the riverbed and confined the channel into a single-thread type of morphology. We performed numerical simulations with the 2D shallow water model BASEMENT, considering a mobile bed composed by uniform sediment and including the main feedbacks between vegetation growth and erosion, the flow field, and the sediment transport processes. We set up the model parameters to reproduce different vegetation spatial distributions, associated with different groundwater depths, and investigated the effect of a 10-years return period flood on the river planform change.

Model results highlight that a low vegetation biomass density, particularly at lower riverbed elevations, caused no significant effect on scour and deposition processes, favoring channel mobility and plant removal by uprooting. This behavior is in line with the observations in the groundwater-deep part of the reach. In contrast, the occurrence of high biomass density at low

elevations reduced significantly the channel mobility and the river active width. In this case, vegetation was able to trigger sedimentation on bars and reduce scouring in the main channel, which are key processes for the formation of vegetated, stable riverbeds.

This study represents a step forward to the understanding of the role of the complex link between vegetation dynamics and gravel bed rivers morphodynamics and shows the potential of ecomorphodynamic modeling to interpret river morphological trajectories.