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Development and assessment of a model for vegetated planform dynamics in braided rivers

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River planform results from the complex interaction between flow, sediment transport and vegetation, and can evolve following a change in these controls. The braided planform of New Zealand's Lower Waitaki River, for instance, is endangered by artificially-introduced alien vegetation. This vegetation, by encouraging flow concentration into the main channel, would likely promote a shift towards a single-thread morphology if it was not artificially removed within a central fairway.

The purpose of this work is to study the evolution of vegetated braided rivers through two dimensional numerical modelling. In previous work, we have constructed a suitable model starting off the physics-based GIAMT2D model (Siviglia et al., 2013), which solves two-dimensional shallow flows and bedload transport in wet/dry domains. This enhanced model further includes (i) a rule-based bank erosion module inspired by that of Sun et al. (2015) and (ii) a riparian vegetation dynamics module that develops the concepts put forward by Bertoldi et al. (2014). Biomass density evolves in time following vegetation growth and removal rules, and adjusts the local flow roughness, bank erodibility and critical shear stress for sediment transport accordingly.

Here we test the numerical model in a case study inspired to the flume experiments of Tal and Paola (2010). The experiments began with self-formed a braided morphology. Then, the planform transitioned to single-thread when this discharge was repeatedly cycled with periods of low flow and vegetation growth, however, still displaying shifts of flow paths driven by vegetation removal and reoccupation of previously abandoned channel, that happened over longer spatial and temporal scales compared to the initial braiding development phase.

Assessing model calibration and developing guidance on the optimal parameter value is a key step to make the model a predictive tool ready for use in real-world cases such as the Waitaki River. As widely known, a numerical model cannot be considered as an exact replica of a real-world case; hence, the model is assessed on its ability of producing similar morphological shapes and overall trends and statistics that well compare with the prototype. In our numerical experiments, very different vegetated planform styles and speed of planform reworking can be achieved depending on the set parameters for roughness, erodibility and shear stress due to vegetation, and no specific reference on values to be used in different application types have been found from the literature.

Here, we perform 81 simulations with different combinations of flow roughness, critical shear stress and bank erodibility associated with vegetation presence. In detail, vegetated flow resistance appears to be by far the most influential parameter, as it controls reworking (i.e. determines if a vegetated planform is still active, or becomes "fossil", and the speed of such transition) through controlling the vegetation removal ability of the flow during flood periods. The critical shear stress associated with vegetation presence has a less pronounced, but still measurable effect on vegetation removal. Conversely the increase in bank resistance associated with vegetation presence does not produce clear trends in the analysed metrics, although it visually contributes to producing different planform shapes.