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Effects of vegetation on gravel-bed river channel formation

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Highlights

- The channel formation is strongly influenced by vegetation in addition to the river water and sediment discharge regimes
- Pluvial forest and taiga affect the channel development in different ways depending on sediment supply and discharge regime
- Without sediment supply both types of floodplain forest strongly reduce the river planimetric changes and the channel width

Overview

Gravel-bed rivers are extremely dynamic systems. They are characterized by alluvial coarse material, relatively steep slopes, high velocities and display a development of recurring bars transforming the river into a braided system. In addition to water and sediment supply, both flood plain vegetation and riparian vegetation play a role in determining the river planform due to their capacity of retaining sediment and stabilize bars and river banks. However, vegetation is often not considered for the river channel formation and does not appear in most regime formulas describing the equilibrium river width and depth.

This research aims to establish the effects of vegetation on the river channel formation focusing on the development process and, in particular, to determine if the final characteristics of vegetated channels retain the footprint of their initial conditions. The tool of investigation is a 2-dimensional morphodynamic model developed using the Delft3D-4 code (https://oss.deltares.nl/web/delft3d). It is based on the model developed by Paudel et al. (2022) who simulated the formation of gravel-bed rivers without vegetation, and on Baptist's (2005) approach to reproduce the effects of vegetation. Plants are represented as rigid cylinders, and the parameters such as height, diameter and spatial density are determined based on the features of pluvial and taiga forests described in the literature.
Scenarios with a different type of floodplain forest (pluvial or taiga), initial channel width, discharge regime and sediment input rate are simulated based on the previous simulations carried out by Paudel et al. (2022). The relationship between vegetation characteristics and river morphology development is analysed focusing on channel width and bar characteristics. The results of this study are finally compared with the previous the non-vegetated ones obtained by Paudel et al. and other previous works.

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Model set up and simulation scheme

The model reproduces the evolution a hypothetical straight river channel 3.5 km long and 500 m wide. The simulations include bank erosion and accretion, the latter obtained by introducing vegetation on emerging bars and point bars. Here we compare the preliminary results of the scenario with an initial width of 30 m and 235 m wide floodplains on both sides and a constant discharge of 300 m^3/s. The bed sediment is made of cobbles with a D_{50} of 8 cm, the same as in the model of Paudel et al. (2022), the sediment input from the upstream boundary being 0.1 m^3/s. Three scenarios with different types of vegetation conditions are designed. In Scenario A, vegetation is set to mimic a generic pluvial forest. Scenario B is without floodplain vegetation (base-case model), whereas in scenario C vegetation is set to represent a generic boreal forest, a taiga. The vegetation characteristics for each scenario are listed in Table 1.

Table 1. Description of the three Scenarios

Input Description	Scenario A	Scenario B	Scenario C
Representative Vegetation	Pluvial	No Vegetation	Taiga
Plant Height (m)	5.0	N/A	16.0
Intensity (m^{-2})	10.2		0.055
Plant Diameter (m)	0.015		0.28
Density (m^{-1})	0.153		0.015

Preliminary results

Figure 1 shows the final water depth for the three scenarios.

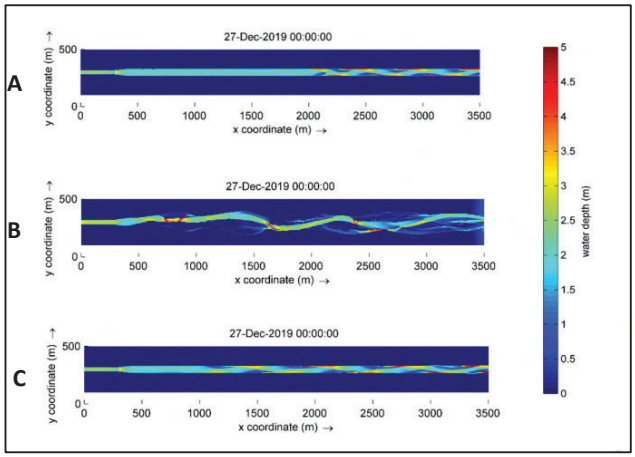

Figure 1: Water depth for scenario A (pluvial forest), B (no vegetation) and C (taiga)

The results profiles show that floodplain forests strongly restrict bank erosion. In both scenarios A and C the channel remains straight with free migrating alternate bars (Crosato and Mosselman, 2020). Pluvial forest and taiga result in different bar wavelengths and celerity, the latter being higher in scenario A (pluvial forest). The case without floodplain vegetation (B) presents bank erosion, with the main river channel becoming sinuous, and the formation of numerous side channels, transforming the straight river into a braided system.

Conclusions

Vegetation plays a significant role in the evolution of river channel as it provides a stabilising factor to the river banks. Studies of Allmendinger, et al. (2005) and Zong and Nepf (2011) have found that flood plain vegetation influences the river formation at both the local and the cross-sectional scale. Preliminary results indicate that boreal and pluvial forests reduce bank erosion in a similar way, but the different types of vegetation result in different bar characteristics.