Linkages between flow, morphodynamics and vegetation

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Introduction

Although it is well known that riparian vegetation alters flow characteristics and resistance, there is still a lack of knowledge regarding the linkages between flow, sediment transport, and vegetation, especially when dealing with plants of more complex morphology. Common models for predicting flow resistance are developed without considering mutual interactions between vegetation and bedforms. This assumptions deviate from the reality of natural environments where shrubs, brushes and woody trees and river dunes might coexist interacting with each other. Thus, it is of fundamental importance to increase our knowledge of such physical processes to design efficient and sustainable river management solutions and to improve the ecological value of natural water bodies.

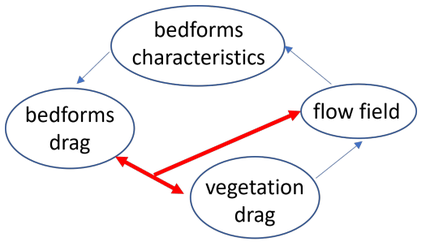

Figure 1: The complex interplay between flow, vegetation and sediment processes

Research goals

→ to study the effect of vegetation with different leaf mass on flow field, sediment transport and bedforms characteristics;
→ to investigate the interplay between bed conditions (mobile or fixed) and flow field in vegetated channels and in presence of large-scale bedforms (river dunes).

Experimental activities

Experimental activities were conducted in the hydraulic laboratories of the University of Florence and Braunschweig (Germany) in both mobile and fixed bed conditions and in both presence and absence of leafy flexible vegetation with the aim to understand the impact of leaf mass on flow field and sediment transport. The employed vegetative elements, known from previous studies [1], can be modified to vary the leaf mass, e.g., from fully foliated to bare stem.

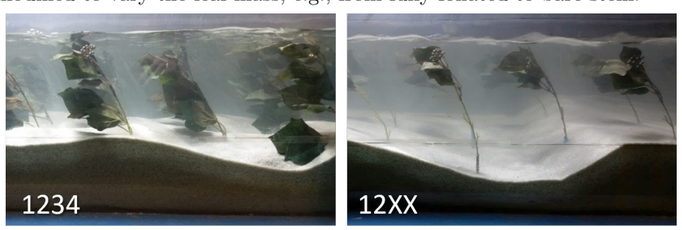

Figure 2: Side-view photos taken during mobile-bed experiments.

Additional experiments were carried out in fixed bed conditions to direct measure the resistances exerted by both bedforms and leafy flexible. For this purpose, a physical model representing the final morphology of the mobile-bed experiments was built using the Structure-from-Motion technique.

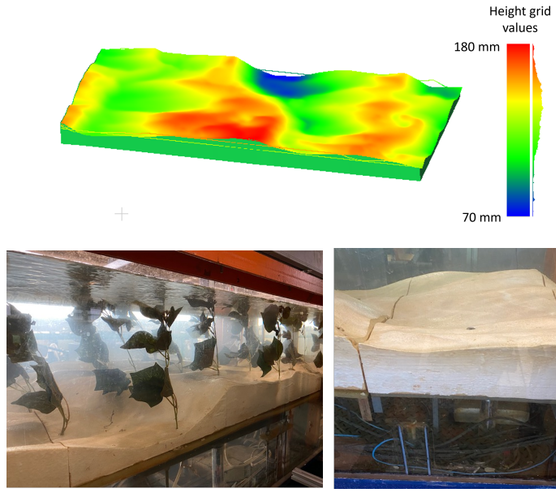

Figure 3: On the left: vegetation connected to the drag force sensors. On the right: printed fixed-dunes model connected to the shear plate.

Results

Classical sediment transport models [3, 4] resulted valid in absence of leaves, whereas the presence of leafy vegetation seems to enhance sediment transport Q_s, suggesting that leaves-generated turbulence should be considered. This result is in contrast with other studies that claim that vegetation diminishes Q_s [5].

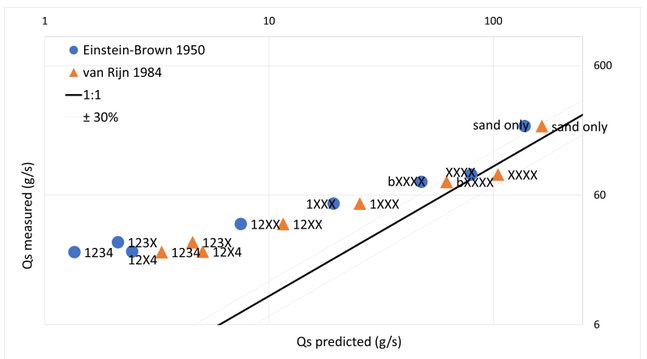

Figure 4: Measured and predicted sediment transport by means of classical models. X in the setup name refers to the missing branch.

The linear superposition principle [2], is usually used to estimate the total shear stress as the sum of friction associated with the channel bed and form drag, in this case, associated with vegetation and dunes. Results collected during the experiments showed that the linear superposition might deviate from linearity (up to 40 %) when leaf mass is added.

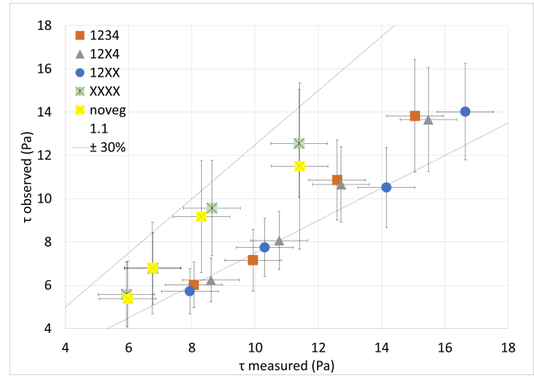

Figure 5: Bed shear stress observed (estimated with the depth-slope product $\tau = \rho g H S$) and the sum of the independent measures of bed shear stress related to plants and dunes.

Conclusions

These results revealed the need to revise models to predict flow resistance and sediment transport in presence of realistic vegetation. Further studies investigating different hydraulic conditions might be useful to better understand the intrinsic linkages between flow, vegetation and sediment processes.

References

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