

Supplementary Information for Shear layer over floodplain vegetation with a view on bending and streamlining effects

Gerardo Caroppi* & Juha Järvelä

Aalto University School of Engineering, Department of Built Environment, Espoo, Finland

*corresponding author: gerardo.caroppi@aalto.fi

1 Introduction

This supplementary information file contains additional data for Caroppi & Järvelä [1]. Details on the experimental facility and the model canopy, with information on spatial arrangement of plants and measurement positions are reported in Section 2. The determination of the characteristic areas of the plants is described in Section 3. Information on the hydrodynamic behavior of the plants is reported in Section 4. In Section 5, the vertical distribution of turbulent kinetic energy is reported.

2 Experimental facility and vegetation model

The top view of the flume is shown in Figure S1. The position of the vegetated area and the measurement section are indicated. The spatial arrangement of the plants and the relative position of the verticals for ADV measurements are also indicated.

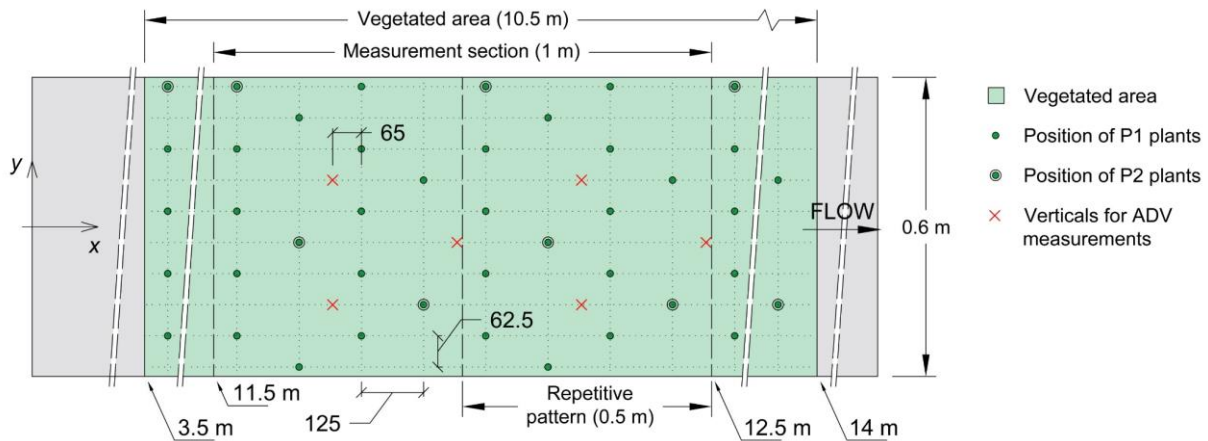


Figure S1. Top view of the flume showing the 10.5 m long vegetated area, the 1 m long measurement section, and the 0.5 m long repetitive vegetation pattern. The position and the spacing between plants is indicated together with the positions of the verticals for ADV measurements. Dimensions are in millimeters unless otherwise indicated.

The two plant types constituting the model canopy are shown in Figure S2, a and b. The plants and the bed grasses as arranged in the model vegetation are shown in Figure S2, c.

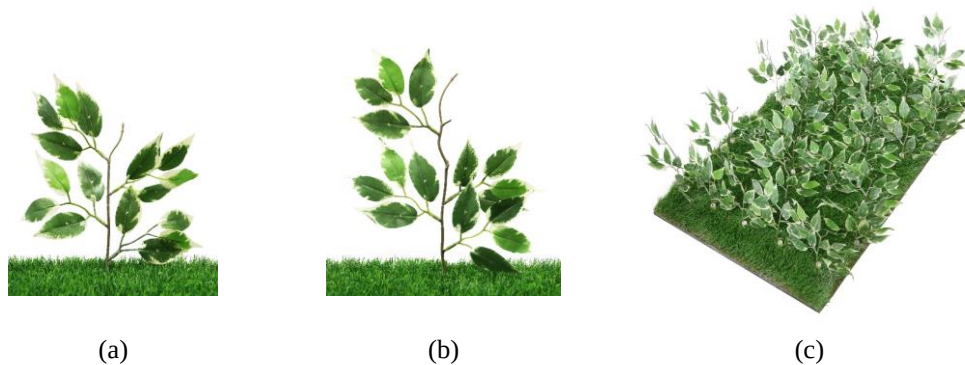


Figure S2. Pictures of plant P1 (a) and plant P2 (b) composing the model canopy (c).

A mat of artificial polyethylene grass was used to reproduce the bottom grasses (Figure S2). The dense grass was 40 mm tall with a density of 20000 blades per m^2 . Each blade had a rectangular cross section, with a width of 0.5 mm and a thickness of about 0.1 mm. The plants constituting the model vegetation, Figure S2, were prepared from modular elements. The stems (Figure S3, a) were made of a steel wire coated with polyethylene, with short lateral branches to which leaves could be attached. The average diameter of the stem was 3.8 mm. The leaves (Figure S3, b) were made of polyester fabric and were connected to short polyethylene petioles.

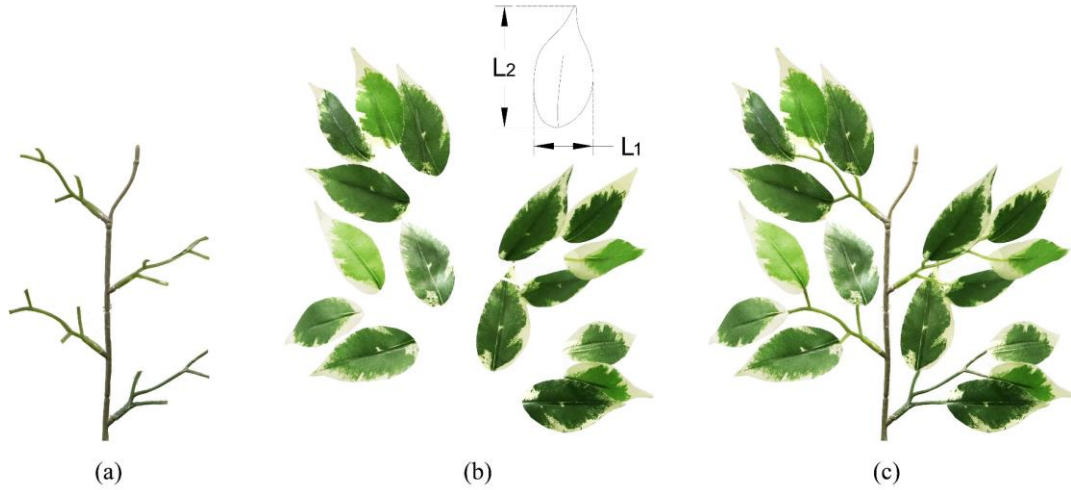


Figure S3. Picture of stems (a) and leaves (b) of one P1 plant (c).

3 Characteristic areas of plants

The leaves had an average width L_1 of 29 mm and an average length L_2 of 63 mm (Figure S3, b). The frontal area of individual plants in dry conditions was measured using image analysis. For plant P1 and plant P2 (Figure S2, a and b, respectively), presenting the same number of leaves, the total one-sided area of leaves A_L (Figure S3, b) was equal to 200 cm^2 . The total frontal stem area A_S (Figure S3, a) was equal to 5.2 cm^2 and 7.3 cm^2 for plant P1 and plant P2, respectively. The leaf to stem area ratio A_L/A_S was equal to 38.5 and 27.4 for P1 and P2, respectively.

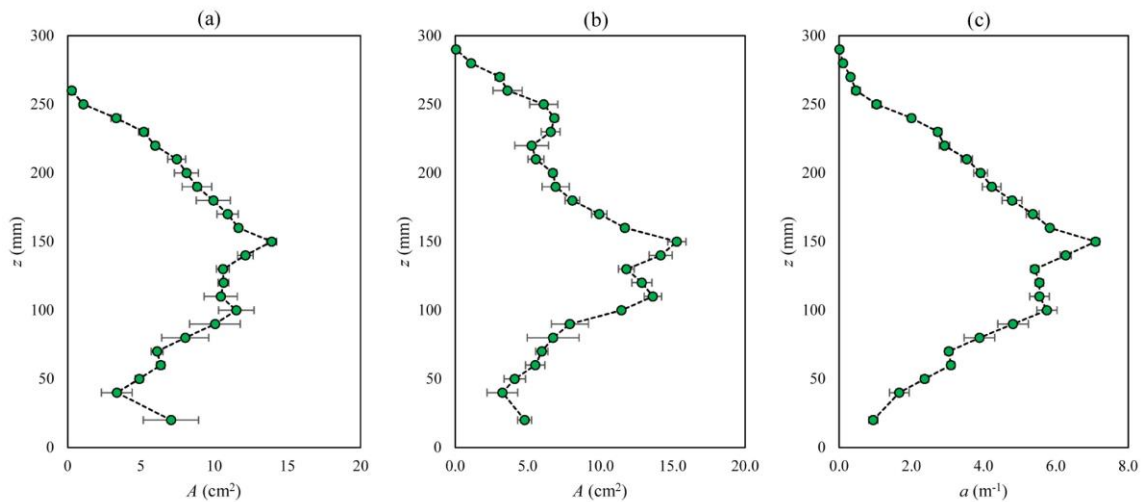


Figure S4. Vertical distribution of frontal area for P1 plant (a) and P2 plant (b). Horizontal bars indicate the variability among the three plants considered. Vertical distribution of frontal area per unit volume for the model canopy (c).

With reference to the repetitive vegetation pattern (Figure S1 and Figure S2, c), the frontal area of the model canopy was evaluated considering the number of P1 and P2 plants within the pattern, 12 and 3, respectively. The total one-sided frontal area of the leaves was equal to 3000 cm^2 , while the total frontal area of stems was equal to 87.9 cm^2 . Consequently, the bulk A_L/A_S of the model canopy was equal to 35.6.

The vertical distribution of the frontal area of plants in dry conditions was evaluated using image analysis. Three plants for each type (P1 and P2) were photographed against a uniform background with a ruler. The images were calibrated and analyzed with CAD software to determine the frontal area. The vertical distribution of the frontal area $A(z)$ evaluated within 10 mm vertical intervals is shown in Figure S4 a and b, for plant P1 and plant P2, respectively. The horizontal bars indicate the variability among the three plants. The vertical distribution of frontal area per unit volume $a(z)$ of the model canopy was evaluated accounting for the number of P1 and P2 plants within the pattern (0.6 m wide and 0.5 m long) and is shown in Figure S4, c.

4 Hydrodynamic behavior of the plants

Drag force measurements carried out for P1 and P2 plants of Figure S2 demonstrated similarity in terms of plants' hydrodynamic response between the model plants and common riparian species [2, 3]. In Figure S5, the drag force divided by the leaf area measured at different velocities is reported for the model plants and for common riparian species (reference data derived from [4]).

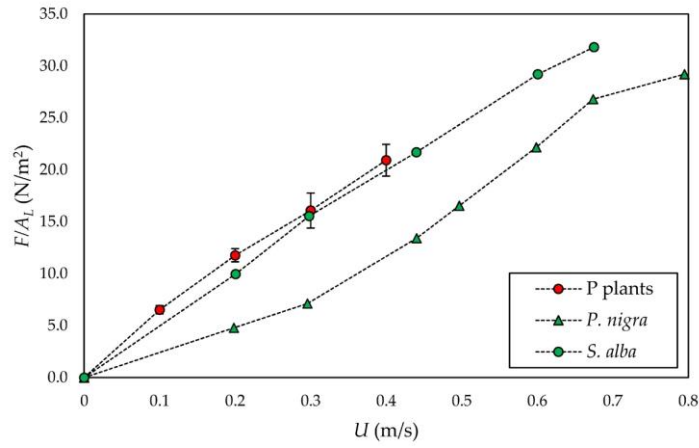


Figure S5. Variation in drag force with flow velocity for the model plants and common riparian species. Vertical bars indicate the variability between P1 and P2 plant.

5 Turbulent kinetic energy

In Figure S6 the vertical profiles of the spatially averaged turbulent kinetic energy k are shown for the four test cases.

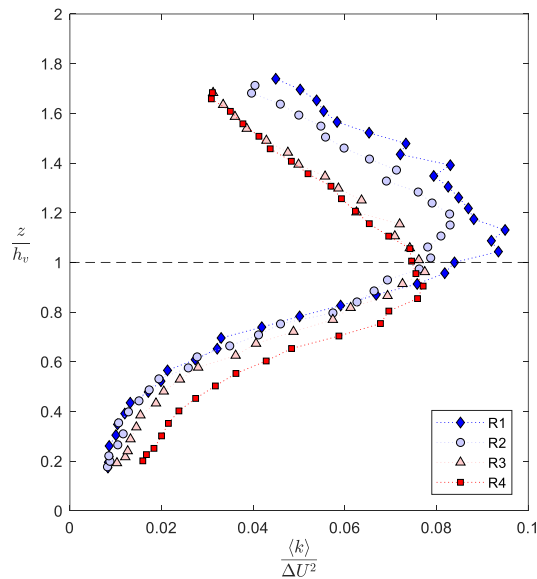


Figure S6. Vertical distribution of normalized turbulent kinetic energy.

References

1. Caroppi G, Järvelä J (2022) Shear layer over floodplain vegetation with a view on bending and streamlining effects. *Environ Fluid Mech.* <https://doi.org/10.1007/s10652-022-09841-w>
2. Andelin M (2019) Development of experimental methods for investigating sediment and nutrient transport in vegetated flows. Aalto University
3. Caroppi G, Västilä K, Gualtieri P, Järvelä J, Giugni M, Rowiński PM (2021) Comparison of Flexible and Rigid Vegetation Induced Shear Layers in Partly Vegetated Channels. *Water Resour Res.* <https://doi.org/10.1029/2020wr028243>
4. Whittaker P (2014) Modelling the Hydrodynamic Drag Force of Flexible Riparian Woodland. Cardiff University