Physical modelling of in-channel wood dynamics in braided rivers

Modélisation physique des dynamiques du bois flotté sur des fleuves anastomosés

Welber M., Bertoldi W., Tubino M.

University of Trento, Department of Civil and Environmental Engineering, Trento, Italy matilde.welber@ing.unitn.it

RÉSUMÉ

Les plaines inondables anastomosées sont le produit de puissantes interactions entre le courant, le transport de sédiments et la végétation. Le bois flotté représente un élément clé de ces environnements fluviaux, car il joue un rôle essentiel dans leur morphodynamique et leur écologie. Notre étude se concentre sur la dispersion du bois dans ce milieu complexe en constante évolution et propose une description quantitative du transport, du dépôt et de la remobilisation du bois, ainsi que de ses principes directeurs. Une modélisation physique a été réalisée dans un laboratoire de 3 m de large et de 25 m de long à l'université de Trente en Italie. Le canal de flottage a été construit de sorte à reproduire le débit et l'inclinaison des fleuves anastomosés naturels à lit de gravier, des goujons de bois servant de bûches de substitution. Un profileur LASER, ainsi qu'un appareil photo reflex ont permis d'offrir une caractérisation haute résolution du réseau. Le rôle de la taille et de la forme du bois, de son dépôt et de la géométrie du réseau a fait l'objet de recherches par le biais de simulations d'écoulements permanents et transitoires. Des modèles de dépôt ont été analysés pour connaître les distances de parcours et le style d'accumulation, avant d'être comparés à des modèles de tresses. Nous avons découvert que la remobilisation était liée aux dynamiques d'inondation et à la dégradation/l'alluvionnement local du lit du fleuve. Le modèle physique a permis de reproduire des phénomènes de dispersion de bois particuliers, pertinents sur le plan écologique, observés dans des cours d'eau à échelle réelle, tels que l'accumulation de débris dans les tresses, les modèles d'affouillement et de dépôt caractéristiques autour des bûches ou la remobilisation de bois au cours d'inondations.

ABSTRACT

Braided floodplains are the product of strong mutual interactions between flow, sediment transport and vegetation. Driftwood is a key feature of these riverine environments, playing a significant role in their morphodynamics and ecology. Our study focuses on wood dispersal in this spatially complex, rapidly evolving context and provides a quantitative description of wood transport, deposition and remobilisation and their governing factors. Physical modelling was performed in a 3 m wide, 25 m long laboratory facility at the University of Trento, Italy. The flume was set up to reproduce typical discharges and slopes of natural gravel-bed braided rivers and wooden dowels were used as surrogate logs. A laser profiler and a reflex camera provided high resolution characterisation of the network. The role of wood shape and size, discharge and network geometry were investigated through steady and unsteady flow simulations. Deposition patterns were analysed in terms of travel distances and accumulation style and compared with the bar pattern. Remobilisation was linked to inundation dynamics and local aggradation/degradation of the riverbed. The physical model was able to reproduce peculiar, ecologically relevant wood dispersal phenomena observed in real-scale streams, such as the accumulation of debris jams on bars, the characteristic scour and deposition patterns around logs and the remobilisation of wood during floods.

KEYWORDS

Braided rivers, driftwood, morphodynamics, physical modelling.

1 INTRODUCTION AND AIM OF THE WORK

Driftwood in riverine systems has been widely investigated during the last few decades and strong mutual interactions linking wood dynamics with river morphodynamics and ecology have been identified. On one hand, driftwood influences river processes by interacting with water flow, sediment transport and standing vegetation; on the other hand, its dispersal is governed by river morphology and flow regime (Gurnell et al., 2000).

Little information is available about driftwood dynamics in braided corridors. Here, the spatial complexity and the intense, rapid evolution of the network are expected to produce very specific wood dispersal phenomena. Our laboratory study addresses wood transport, deposition and remobilisation processes in braided rivers. The main research aims are 1) to achieve a detailed, quantitative description of wood dispersal and 2) to identify and analyse the main governing factors of wood-related processes. Target river systems are gravel-bed braided rivers characterised by low-management, deciduous riparian vegetation.

2 METHODS

Physical modelling was performed in a 3x25 m laboratory facility located at the University of Trento, Italy. The flume was set up to reproduce typical discharges and slopes of natural gravel-bed braided rivers. Laboratory runs included an initial phase of network development starting from a straight rectangular channel. Planform and bed topography evolution were monitored using a laser profiler and a reflex camera and channel properties were evaluated at multiple cross-sections by employing a simple 1-D stationary flow model.

Two sets of wood dispersal simulations were carried out over self-organised braided networks. Cylindrical wooden dowels were used as surrogate logs, with cross-shaped bases to reproduce root boles. The first set of 180 runs (“input runs”) was designed to reproduce local, rapid wood inputs caused by the erosion of a vegetated bank. The goal was the investigation of the main factors governing wood dispersal, namely 1) the physical properties of the woody elements; 2) the discharge and 3) the spatial structure of the braided network. As for wood properties, the analysis focused on element size (length and diameter) and shape, represented by the percentage of elements with roots. Four different values of these parameters, as well as four values of discharge, were tested. The role of the spatial structure of the network was investigated by comparing wood dispersal patterns, braid bar patterns and bed elevation maps.

The second set of runs (“flood runs”) was designed to reproduce wood remobilisation due to flood events. Wood deposits were produced by adding dowels to the network under constant flow conditions ranging from 50 to 100 % of the formative discharge. The relative elevation and position of the accumulations with respect to the bar pattern was surveyed. After a rapid increase in discharge, wood mobilisation was assessed and linked to inundation dynamics and morphological evolution of the network.

3 RESULTS AND DISCUSSION

Model runs provided information on typical wood transport distance and accumulation style, i.e. the tendency for wood to form jams. Data were collected by mapping the dowels on a 5x5cm grid and recording the size of each jam. Transport distance decreases with increasing diameter and percentage of wood with roots and peaks for intermediate element lengths. Braudrick and Grant (2001) also highlighted the dual effect of wood length. Large pieces are more likely to encounter low depth, low velocity retentive areas, but also fast, deep channels ensuring transport. The percentage of dowels stored in jams, as well as the average size of jams, were found to be independent from wood diameter. On the contrary, both parameters decrease with discharge and increase sharply for long elements and high percentage of wood with roots.

Driftwood mobility and accumulation style were linked to the relative size of dowels, namely the wood length / channel width ratio and the wood diameter / channel depth ratio. Transport distance was found to drop for wood diameters larger than 50% of the median channel depth, while wood longer than 50% of the median channel width shows a greater tendency to form large jams.

The comparison between runs carried out over the same morphology but under different flow conditions shows that travel distance does not necessarily increase with discharge. In a relevant number of cases, intermediate flow conditions correspond to a minimum in mobility. This is most likely due to the larger amount of potential wood retention sites (such as bar heads, Abbe and Montgomery, 1996) activating at moderate flows with respect to low flows, where discharge tends to concentrate few deeper, faster channels. This hypothesis is confirmed by analyses of inundation dynamics in real-scale braided rivers. Braiding index and shoreline length, which can be assumed as indicators of the availability of retentive sites, have been shown by the authors to peak at intermediate flow.

To analyse the influence of braidplain structure, main network features were mapped and characteristic wavelengths were identified for the longitudinal distribution of main braid bars. Wood dispersal was linked to the bar pattern at two different spatial scales by aggregating wood accumulations over fractions of bar wavelength and over single wavelengths, respectively. At the smaller scale, wood retention peaks at the bar apex, while at reach scale the first bar downstream of the input point hosts a large part of driftwood (up to 30%). Figure 1 shows an example of the prevalence of wood deposition at bar heads. These results match real-scale observations of wood input due to bank erosion on the Tagliamento (NE Italy), especially in terms of retentiveness of the first bar.

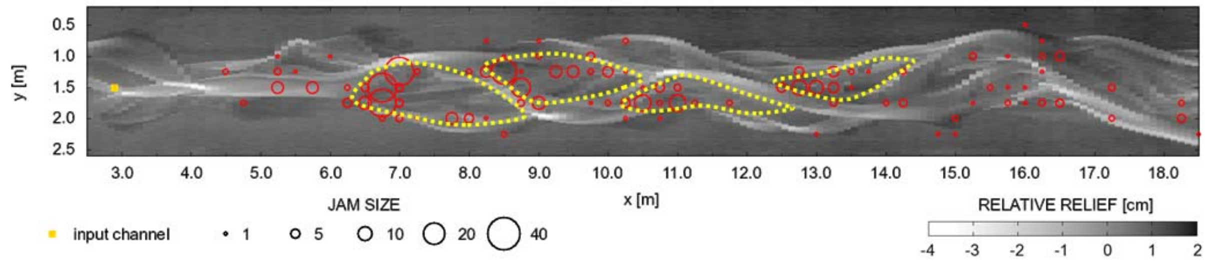

Figure 3: Wood deposition map over a DEM of the braided network. Dashed lines highlight main braid bars

LIST OF REFERENCES

Abbe, T.B., Montgomery, D.R. (1996). *Large woody debris jams, channel hydraulics and habitat formation in large rivers*. Regulated Rivers: Research & Management 12 (2): 201-222.

Braudrick, C.A., Grant, G.E. (2001). *Transport and deposition of large woody debris in streams: a flume experiment*. Geomorphology 41: 263–283.

Gurnell, A.M., Petts, G.E., Harris, N., Ward, J.V., Tockner, K., Edwards, P.J., Kollmann, J. (2000). *Large wood retention in river channels: the case of the Fiume Tagliamento, Italy*. Earth Surface Processes and Landforms 25: 255–27.