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Wood recruitment and retention: The fate of eroded trees on a braided river explored using a combination of field and remotely-sensed data sources

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ABSTRACT

This paper investigates wood recruitment and deposition dynamics in a large gravel-bed, braided river (Tagliamento River, Italy). We used a combination of field measurements, automatically repeated ground images, and remotely sensed surveys to quantify wood input through bank erosion and associated downstream deposition. Two sites were investigated where floods caused the erosion of vegetated island edges. A lidar survey preceding the erosion events provided data on the morphology and vegetation structure of the eroded areas, allowing estimation of the number of trees that were uprooted. Sequences of ground-based images acquired automatically (and supported by field measurements) showed the time, number, and location of deposited trees. Results show that the complex morphology of braided rivers induces specific deposition patterns. We observed wide dispersal of wood on gravel bars, with jams characterised by a small number of logs (on average 2–3) and, in many cases, only a single log. A large proportion of the eroded trees (up to 40%) were deposited on the nearest downstream bar. This illustrates significant wood retention close to the recruitment site, with the remaining wood dispersed widely downstream. Differences in the observed level of local wood retention were associated with the proximity of the erosion site to the main channel and differences were also observed in retention between the peak and the falling limb of flood events, confirming that water depth and probably flow velocity are the crucial parameters controlling wood deposition.

1. Introduction

Over three decades ago, a conceptual framework for evaluating wood recruitment, in-stream processing, and transport was proposed by Keller and Swanson (1979). Based on their field observations, they summarised the controls on wood stored in river channels, including the driving variables (tree mortality, precipitation, wind, ice, and runoff events), input processes (blow down, bank erosion, direct fall of large wood pieces, debris avalanches, and flotation from upstream), in-stream processes (decomposition, abrasion, leaching, and consumption), and output processes (debris avalanches, flotation, transport of dissolved material, and respiration). More recently, this conceptual framework has been extended by Swanson (2003) by considering how the dominant wood input processes (fire; wind throw; landslides; and lateral erosion, particularly on the outer bank of bends in meandering channels and around island margins on multithread channels) and transport processes (earth flows, debris flows, and floods) and their interactions with human interventions (forestry, check dams, reservoirs, channelisation, embanking, riparian tree clearance, and channel reinforcement) might change in a downstream direction.

Whilst a conceptual framework has been in place for some time, progress in quantifying the relevant processes has been gradual. Over the last three decades, numerous studies have quantified the amount and styles of wood retained in fluvial systems (e.g. see review by Gurnell, in press), but direct measurements of wood recruitment and transport/retention remain relatively rare across all sizes and styles of river. Field measurements of wood recruitment have concentrated on extreme events such as floods (Palik et al., 1998; Johnson et al., 2000; Hering et al., 2004; Golladay et al., 2007; Oswald and Wohl, 2008), debris flows (May and Gresswell, 2003; Reeves et al., 2003; Bigelow et al., 2007), fire (Zelt and Wohl, 2004; Arsenault et al., 2007; Jones and Daniels, 2008; Comiti et al., 2009), and beetle infestation (Bragg, 2000). Field measurements of the processes of wood transport/retention have employed a variety of largely indirect techniques, for example detailed mapping of the changing locations of tagged, naturally occurring wood pieces (e.g., Elosegi et al., 1999; Daniels, 2006; Warren and Kraft, 2008; Curran, 2010) and also experimental releases of wood mimics (usually wooden dowels), resulting in measures of the distance moved and retention locations of mimics of different dimensions following specific time periods or flow events (Crowl and Covich, 1990; Ehrman and Lamberti, 1992; Braudrick et al., 1997; Millington and Sear, 2007). Air photograph interpretation of changes in sources and stores of wood (Latterell and Naiman, 2007), the use of helicopter surveys (Lassettre et al, 2008), and an

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intensive field study revisiting fixed plots to assess changes in wood storage (van der Nat et al., 2003) have extended these indirect methods into larger river systems.

To date, analysis of wood dynamics in large multi-thread rivers has shown that complex river morphology and flow patterns play a crucial role in determining potential sites of wood retention (Piégay et al., 1999; Gurnell et al., 2000; Abbe and Montgomery, 2003). In large braided rivers, large wood is most likely to be retained on the top of gravel bars, often forming 'bar apex jams' as defined by Abbe and Montgomery (2003), showing highly variable orientation and mobility (Piégay et al., 1999; Piégay, 2003). Among the various wood input processes, bank erosion has been identified as the dominant driver of wood supply in large rivers (Gurnell et al., 2000; Downs and Simon, 2001; Moulin and Piégay, 2004; Lassettre et al., 2008), with a notable correlation between the size of the eroded area and quantity of in-channel deposited trees. This relationship has so far been explored mainly at a reach rather than a local scale and at relatively coarse timescales, and no data currently exists on the proportion of wood pieces (uprooted trees) that are retained close to erosion sites, although new methods of actively tracking wood in transport have the potential for obtaining direct measurements of wood piece movements, particularly in larger river systems (MacVicar et al., 2009; MacVicar and Piégay, 2012).

This paper contributes some new approaches to measuring wood recruitment and retention at a local scale with relatively high temporal resolution by combining information from repeat automatic photography (up to hourly resolution), airborne lidar surveys, and field measurements. Based on the detailed information extracted from these data sources on the structure of the riparian woodland and the spatial and temporal dynamics of uprooted trees, it has been possible (i) to derive mechanistic understanding of wood delivery by bank erosion to a large braided river during single flood events and (ii) to investigate the fate of the delivered wood in terms of local storage on braid bars, linking wood dynamics to the bed elevation of deposition sites.

2. Methods

2.1. Study sites and data sets

Information on wood recruitment from the riparian forest and wood storage within an active river channel was obtained from two study sites (named Cornino and Flagogna) of the middle reaches of the Tagliamento River, NE Italy (Fig. 1A and B). The Tagliamento is a large, gravel-bed, braided river that drains from the Alps to the Adriatic Sea. The river is bordered by riparian woodland along most of its course, and it also supports wooded islands in many reaches. Within the two study sites, more than 90% of the basal area of trees in the riparian forest and on established islands belongs to one species, *Populus nigra* (Karrenberg et al., 2003). The two sites are located 6 km apart and have similar flow conditions (no major intervening tributaries), longitudinal bed slope, and bed sediment grainsize. The Flagogna site is characterised by a larger number of vegetated patches (islands) and therefore shows a slightly smaller number of anabranches and a larger main channel (Bertoldi et al., 2011). During the 2008–2010 period, bank erosion during high flows was observed at two locations, within a secondary braid channel on the left of the braid plain at the Cornino study site and within the main braid channel at the Flagogna study site. This main channel carries approximately 60% of the discharge, whereas the secondary anabranch at Cornino carries no more than 20% of the discharge.

Four data sources were used to evaluate wood recruitment from the bank erosion of two islands, one at each of the Cornino and Flagogna sites, and in-channel storage of the recruited wood: (i) airborne lidar surveys collected in May 2005 and August 2010; (ii) oblique photographs captured every hour by cameras overlooking the two study sites; (iii) field measurements of standing and deposited trees gathered during June 2010; and (iv) continuous records of river stage obtained from a gauging station located immediately upstream of the two sites.

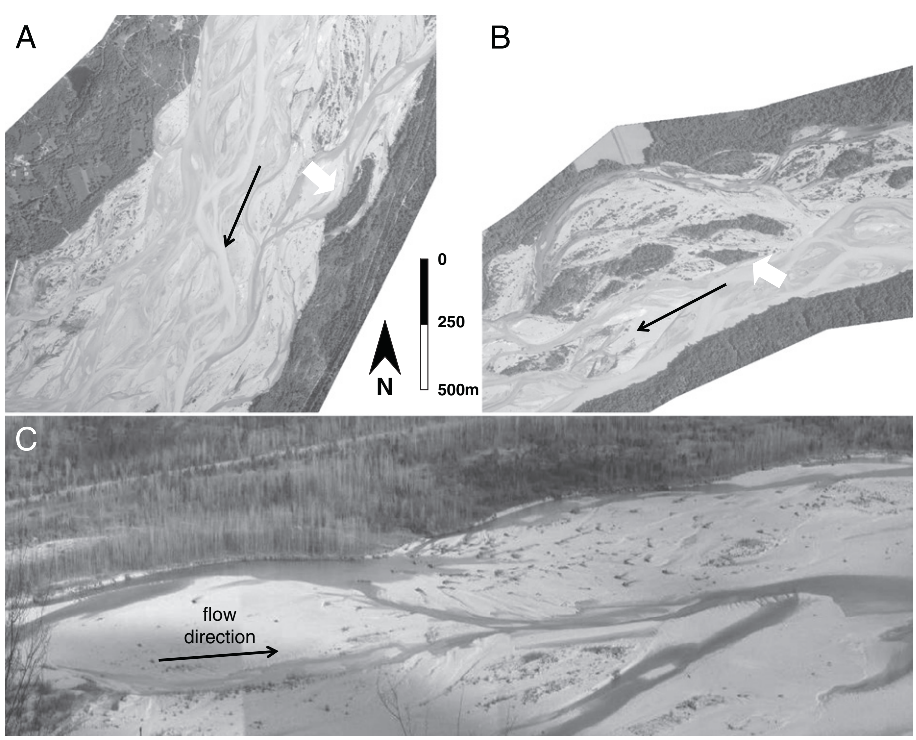

Fig. 1. Aerial image of the two studies sites (acquired in 2009, courtesy of Nicola Surian) (A) Cornino; (B) Flagogna. The white arrow indicates the eroded bank. (C) Oblique photograph showing bank erosion (left) and tree deposition within the active channel (centre and right) at Cornino, 24 March 2010.