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Floodplains and wood

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ABSTRACT

Interactions between floodplains and wood date to the Carboniferous, when stable, multithread channel deposits appear with the evolution of tree-like plants. Foundational geologic texts, such as Lyell's, 1830 *Principles of Geology*, describe floodplain–wood interactions, yet modern technical literature describes floodplain–wood interactions in detail for only a very limited range of environments. This likely reflects more than a century of deforestation, flow regulation, and channel engineering, including instream wood removal, which has resulted in severe wood depletion in most of the world's river networks.

Instream wood affects floodplain form and process by altering flow resistance, conveyance and channel–floodplain connectivity, and influencing lateral and vertical accretion of floodplains. Instream wood reflects floodplain form and process as the floodplain influences wood recruitment via bank erosion and overbank flow, and wood transport and storage via floodplain effects on stage-discharge relations and flow resistance. Examining turnover times for instream wood at the reach scale in the context of a wood budget, floodplain characteristics influence fluvial transport and dynamics (wood recruitment), valley geometry (wood transport and storage), and hydraulics and river biota (wood decay and breakage).

Accumulations of wood that vary from in situ jams and beaver dams in small channels to transport jams and log rafts in very large rivers can create stable, multithread channels and floodplain wetlands. Floodplain–wood interactions are best understood for a subset of small to medium-sized rivers in the temperate zone. We know little about these interactions on very large rivers, or on rivers in the tropical or boreal regions.

This review suggests that most, if not all, channels and floodplains within forested catchments in the temperate zone historically had much greater wood loads and consequently much more obvious and important influences from wood than do heavily modified contemporary catchments. For many rivers in the temperate zone, direct and indirect removal of instream wood very likely caused a fundamental shift in channel and floodplain process and form, as has been demonstrated in detail for specific rivers of diverse size in several regions. Failure to explicitly include floodplain–wood interactions creates a misleading conceptual model of floodplain dynamics in forested catchments.

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1. Introduction

> "After the flood season, when the river subsides within its channel, it acts with destructive force upon the alluvial banks …. Several acres at a time, thickly covered with wood, are precipitated into the stream …. Islands arrest the progress of floating trees, and they become in this manner reunited to the land; the rafts of trees, together with mud, constituting at length a solid mass …. One of the most interesting features in this basin [the Mississippi] is "the raft." The dimensions of this mass of timber were given by Darby, in 1816, as ten miles in length, about two hundred and twenty yards wide, and eight feet deep, the whole of which had accumulated, in consequence of some obstruction, during about thirty-eight years, in an arm of the Mississippi called the Atchafalaya …. The mass of timber in the raft is continually increasing, and the whole rises and falls with the water…. Notwithstanding the astonishing number of cubic feet of timber collected here in so short a time, greater deposits have been in progress at the extremity of the delta in the Bay of Mexico." (Lyell, 1830, vol 1, pp. 186–188) "Lake Bistineau, as well as Black Lake, Cado Lake, Spanish Lake, Natchitoches Lake, and many others, have been formed, according to Darby, by gradual elevation of the bed of the Red River, in which the alluvial accumulations have been so great as to raise its channel, and cause its waters, during the flood season, to flow up the mouths of many tributaries, and to convert parts of their courses into lakes."
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> [Lyell, 1830, vol. 1, p. 190]

Charles Lyell's classic textbook *Principles of Geology* contains one of the earliest scholarly descriptions of the great log rafts that occupied substantial portions of rivers in North America when people of European descent first entered the continent. Lyell, and the original sources he quotes, such as William Darby's 1816 book on the geography of Louisiana, clearly recognized the geomorphic effects of large quantities of instream wood, describing what we would now call increased flow resistance, aggradation within the channel, enhanced overbank flow and channel–floodplain connectivity, channel avulsion and floodplain erosion and deposition. Recognition of the interactions between instream wood and floodplains thus extends back to some of the foundational writings in geomorphology. Subsequent generations of scientists have to some extent forgotten the importance of these interactions (Francis et al., 2008; Chin et al., in press), however, as a result of centuries of deforestation, wood removal, and channel engineering. Recent advances in understanding the geologic and historical importance of wood–floodplain interactions, as well as quantifying contemporary examples of these interactions, make this an opportune time to review the scope and nature of wood–floodplain interactions, and to highlight remaining knowledge gaps relevant to this topic.

Several geologists have noted that the nature of fluvial sedimentary facies suites changes dramatically with the evolution or temporary removal of woody terrestrial vegetation (Schumm, 1967, 1968; Ward et al., 2000; Montgomery et al., 2003). Davies and Gibling (2011) compiled a list of outcrops indicating the first appearance of a sedimentary facies suite that reflects river systems with low energy, organic matter accumulation, multiple channels, and stable alluvial islands. These anabranching or anastomosing rivers first appear during the Carboniferous period, synchronous with the evolution of tree-like plants presumably capable of blocking channels with logjams (Gastaldo and Degges, 2007). The synchroneity of plant evolution and changes in channel sedimentary facies suggests that floodplain–wood interactions of the type described in this paper have been occurring for hundreds of millions of years.

The association between plant evolution and stable multithread channels creates an interesting pairing with recent work on braided versus meandering channels. Braided channels – rapidly shifting, multithread, alluvial channels – appear to be the default planform in the absence of vegetation that stabilizes channel banks sufficiently to permit meandering, and predominantly braided fluvial facies give way to other fluvial strata starting with the evolution of land plants approximately 415 million years ago (Paola, 2001; Tal and Paola, 2007). In contrast to braided channels, stable multithread alluvial channels and associated floodplain development may require either living vegetation to enhance bank erosional resistance and flow resistance (Nanson and Knighton, 1996; Wende and Nanson, 1998; Tooth and McCarthy, 2004; Jansen and Nanson, 2010), or channel obstructions and flow resistance created by instream wood.

An extensive geomorphic and ecological literature documents the interactions between living vegetation and floodplain process and form. This review focuses primarily on downed, dead wood. Living vegetation is discussed only to the extent that it provides a recruitment source for instream wood, influences hydraulic patterns that control the dynamics of wood in transport, or traps wood in transport. I first review how instream wood influences floodplain dynamics and floodplain turnover time at the scale of a valley segment, as well as how wood responds to floodplain dynamics across different spatial scales of channel and floodplain size, and the controls on wood turnover time at the reach scale. I then discuss the effects of climate on floodplain–wood interactions. I draw on a series of case studies to explore details of how spatial scale, geomorphic setting, and climate govern contemporary floodplain–wood interactions on small and medium-sized rivers and the historical evidence of much greater instream wood volumes prior to extensive deforestation and channel modification. The review concludes with a discussion of gaps in our understanding of floodplain–wood interactions.

2. Interactions between floodplains and wood

Interactions between floodplains and instream wood occur in at least two directions: instream wood driving floodplain dynamics, and wood responding to floodplain dynamics. These interactions are closely intertwined via feedbacks and complex, nonlinear behavior. The specific details of floodplain–wood interactions vary in relation to channel size, sediment load, channel planform and dynamics, volume of instream wood, methods of wood recruitment, and storage or transport of wood.

Floodplain–wood interactions are particularly important along rivers with forested floodplains, but can also occur in reaches where the floodplain is too dynamic to permit mature woody vegetation to develop. In the latter case, instream wood can be transported from upstream portions of a channel network, or from adjacent uplands via tributaries or hillslope mass movement. Forested floodplains can be longitudinally discontinuous because of downstream variations in valley geometry (here, valley gradient, valley bottom width relative to channel width, and channel planform), channel stability, and biotic activities that limit tree growth, such as dam building by beaver or heavy grazing by ungulates (McKenney et al., 1995; Hughes, 1997; Wohl, 2011c). Within forested floodplain segments, however, wood influences floodplain dynamics in diverse ways.