Geomorphology 259 (2016) 119–133

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Simulated wood budgets in two mountain streams

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ARTICLE INFO

Article history:
Received 28 September 2015
Received in revised form 9 February 2016
Accepted 10 February 2016
Available online 13 February 2016

Keywords:
Wood budget
Wood decay
Wood recruitment
Wood simulation
Large wood

ABSTRACT

Large wood (LW) recruitment, transport, and storage were evaluated over a century in Gregory and Riley creeks (Haida Gwaii, British Columbia) by modeling a reach-scale LW budget using two frameworks for output: LW loss through decay and downstream transport, and loss through depletion. At reach and at watershed scales, mass movement and bank erosion dominated inputs, and fluvial transport was an important flux term in several reaches. Large wood recruitment by mortality was relatively minor in comparison. Large proportions of the in-channel LW were stored in jams with a mean age of 40–50 years. Overall, both modeling approaches yielded reasonable stored LW predictions in the study creeks, with the omission/inclusion of transport responsible for the largest differences between models. Modeled storage generally was within 30% of that measured in the field, and our results illustrate the large temporal variation in storage resulting from episodic inputs of LW from hillslopes.

1. Introduction

In forested regions, within-channel large wood (LW) constitutes an important geomorphic, hydraulic, and ecological component of stream systems (Keller and Tally, 1979; Hogan, 1986, 1987; Bilby and Ward, 1989; Gurnell et al., 2002; Abbe and Montgomery, 2003; Phillips, 2012; Wohl, 2013). Large wood is recruited to a stream channel network through a variety of processes including mass movement, bank erosion, and mortality and is transported and redistributed from upstream through fluvial and mass movement processes (Martin and Benda, 2001; Benda and Sias, 2003; May and Gresswell, 2003; Kasprak et al., 2012; King et al., 2013; Benda and Bigelow, 2014, Ruiz-Villanueva et al., 2014; Lucia et al., 2014). Once in the stream, LW can (i) promote sediment storage and regulate bed material sediment transport (Keller and Tally, 1979; Hogan, 1986; Roberts and Church, 1986; Gippel, 1995; Wilcox and Wohl, 2006; Andreoli et al., 2007; Eaton et al., 2012; Davidson and Eaton, 2013); (ii) alter channel morphology and promote pool formation (Bilby and Ward, 1989; Jackson and Sturm, 2002; Bocchiola, 2011; Faustini and Jones, 2003; Wohl and Jaeger, 2009; Thompson, 2012; Davidson and Eaton, 2013); (iii) produce local channel scouring (Smith, 1992); and (iv) modify channel width, gradient and channel-floodplain connectivity by triggering bank erosion and avulsions (Nakamura and Swanson, 1993; Brummer et al., 2006; Sear et al., 2010; Wohl, 2011, 2013; Phillips, 2012; Davidson and Eaton, 2013). Changes to the delivery, storage, and transport of LW therefore lead to changes in sediment storage, stream morphology, and aquatic habitat (McHenry et al., 1998, Gurnell et al., 2002; Benda and Bigelow, 2014).

Timber harvesting operations change the supply and nature of LW entering a stream (e.g., Hogan, 1986, 1987; Hogan et al., 1998a, 1998b; McHenry et al., 1998; Benda and Bigelow, 2014) by removing the standing timber stock, and regulations are widely applied to this industry in order to maintain a supply of LW to streams (e.g., Forest and Range Practices Act, 2004). In addition, many watershed restoration efforts have focused on returning LW to logging-affected channels in order to improve aquatic habitat (e.g., Roni et al., 2002) and to mitigate any logging-related stream channel disturbance (e.g., Faustini and Jones, 2003; Czarnomski et al., 2008). It is therefore of interest to scientists and watershed managers to develop management practices that sustain LW volumes in managed streams while still allowing access to commercial timber resources. This requires a detailed understanding of LW input and flux.

The sources of LW delivered to a given stream will vary with geology, topography, forest type, management and landscape history, floodplain configuration, character of flood events, channel network structure, and the geomorphic coupling between hillslopes and channels (May and Gresswell, 2003; Wohl, 2013; Benda and Bigelow, 2014). Two types of linkages are defined (Brunsden, 1993; Whiting and Bradley, 1993): (i) coupled — in which there is a free transmission of material and energy from hillslope to channel, and (ii) decoupled — in which there is (temporarily) no interaction between hillslope and channel given the presence of barriers such as floodplains. Temporal and spatial variations in hillslope-channel connectivity (coupling) have a significant influence on the evolution of forested landscapes, channel dynamics in mountain streams, habitat diversity and quality, and LW recruitment processes (Montgomery and Foufoula-Georgiou, 1993;

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http://dx.doi.org/10.1016/j.geomorph.2016.02.010
0169-555X/

Montgomery, 1999; Jakob et al., 2005; Savi et al., 2013). Similarly, the character and quantity of stored LW along channels can vary with channel morphometry. A controlling factor of downstream change in LW storage is channel geometry: as channel width and depth increase, flows are more capable of transporting recruited LW material (Hassan et al., 2005; Eaton et al., 2012; Rigon et al., 2012).

Some studies have suggested that, in steep terrain, mass movement can dominate the delivery of LW to channels (Lienkaemper and Swanson, 1987; Nakamura and Swanson, 1993; May and Gresswell, 2003; Benda et al., 2005; Rigon et al., 2012). Other studies, conducted for the most part in relatively low-relief terrain, have suggested that hillslope input plays only a minor role in delivery of LW to streams and that inputs of LW from mortality and bank erosion are most significant (e.g., Murphy and Koski, 1989; Martin and Benda, 2001; Benda et al., 2002; Benda and Bigelow, 2014). Furthermore, most LW budget studies are either purely synoptic in design or are relatively short-term case studies (e.g., Lienkaemper and Swanson, 1987). In summary, there remains a lack of understanding as to the relative importance of different LW recruitment processes within and between basins in steep terrains over timescales sufficient to capture the episodic nature of hillslope input.

Utilizing a unique data set, in this paper we investigate LW dynamics using two approaches to develop reach-scale budgets in paired watersheds over a century-timescale. The specific objectives of the study are: (i) to compare LW recruitment processes between reaches within the same watershed and between watersheds, and (ii) to evaluate and contrast the LW budget using depletion and decay/transport frameworks. A comparison between these two frameworks will help identify the dominant processes controlling reach-scale LW dynamics.

2. Watersheds and study reaches

This study focuses on the Gregory and Riley Creek watersheds in Rennell Sound, on the west coast of Graham Island in the Haida Gwaii (formerly Queen Charlotte Islands) archipelago (Fig. 1). Riley and Gregory Creeks drain an area of 27.6 and 35.0 km^2, respectively, of steep terrain (Table 1). The region is moist and temperate, with mean annual precipitation of 3400 mm (Wang et al., 2012). The most intense storm events typically occur in the fall and the winter with maximum precipitation in October (Hogan and Schwab, 1990). The watersheds have been shaped dramatically by repeated glacial episodes, and valley walls tend to be steep and covered with unstable glacial drift material (Roberts and Church, 1986). The region is composed of weak, highly erodible sedimentary and volcanic rock (Sutherland Brown, 1968; Roberts and Church, 1986). The combination of high precipitation, unstable surficial materials, weak lithology, and steep hillslopes contributes to extensive mass movement in the region (Hogan et al., 1998a, 1998b).

Forest cover in the basins is typical of the Coastal Western Hemlock biogeoclimatic zone (CWHvm) with high forest density (Meidinger and Pojar, 1991; Hassan et al., 2005) and infrequent, localized disturbance that create canopy gaps (e.g., Daniels and Gray, 2006). In 2005, the Province of British Columbia performed an inventory of forest resources on all public lands, collecting data to describe forest composition, age,

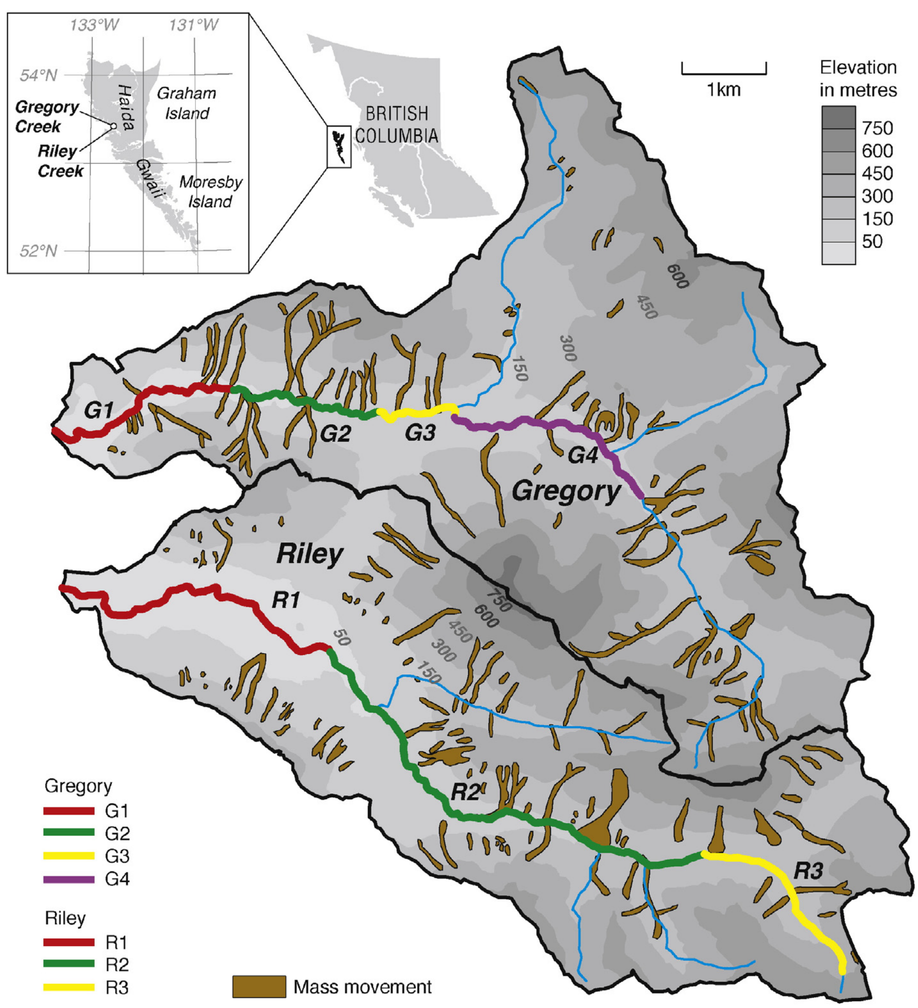

Fig. 1. Location map, watershed, and study reaches of Riley and Gregory creeks.