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Sediment and wood accumulations in humid tropical headwater streams: Effects of logging and riparian buffers

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Abstract

The amount of sediment, wood, and detritus (leaves and small branches) accumulations were examined in four headwater tributaries subjected to different treatments (unlogged, logged with riparian buffer, and logged with no buffer) 16 and 40 months after timber harvesting in the Bukit Tarek Experimental Watershed, Peninsular Malaysia. Sediment transport from hillslope logging roads and skid trails resulted in large sediment storage in the stream channels. Riparian reserves appear to mitigate logging impacts to streams; however, more sediment was found in a tributary channel with a 20-m buffer than an unlogged channel because some of the nearby roads and skid trails were connected to the stream. Sediment storage in channels declined within 40 months after logging in catchments with and without riparian buffers. Vegetation recovery on skid trails and logging roads reduced both sediment supply and delivery. The volume of large wood was 1.5 to 2-times greater in the stream without riparian reserves than the stream of an unlogged catchment or in a stream with a riparian buffer. No consistent change in detritus accumulations was found among streams in 2001 and 2003, although more detritus was present in 2003 in all streams. The effects of logging and the effectiveness of riparian buffers appear to depend on the hydrologic connections between hillslopes and headwater streams.

Keywords: Timber harvest; Riparian buffer; Wood; Sediment storage; Hillslope and stream linkages; Tropical headwater streams

1. Introduction

In the past decade numerous studies have examined the effects of logging activities in tropical rain forests on hydrologic and geomorphic processes (e.g. Baharuddin, 1988; Malmer, 1996; Douglas, 1999; Hartanto et al., 2003; Sidle et al., 2004; Bruijnzeel, 2004). Logging roads and skid trials in the tropics cause soil disturbance, compaction, and decrease the infiltration capacity of soils (Malmer and Grip, 1990; Baharuddin, 1995; Pinard et al., 2000; Noguchi et al., 2003), thereby increasing surface erosion. The sediment delivery to streams depends on the hydrologic connectivity between hillslopes and channels (Malmer, 1996; Douglas et al., 1999; Sidle et al., 2004). Excess sedimentation in channels reduces water quality and habitat availability in stream ecosystems (Heartstill-Scalley and Aide, 2003).

Riparian reserves (i.e. buffer zones) are often left along logged streams to filter sediment and reduce near-channel soil disturbance (e.g. Phillips, 1989). Riparian buffer zones also can mitigate stream temperature increases and reduce the fluxes of runoff, nutrients, chemicals and bacteria, as well as enhancing aquatic habitat (Beschta et al., 1987; Barton et al., 1985; Belt and O'Loughlin, 1994; Hill, 1996; Ziegler et al., 2006). Various widths of riparian reserves have been prescribed depending on stream size, contributing hillslope area, presence of certain biota (e.g. fish), filtering of sediments and nutrients, recruitment

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of wood and organic matter, and potential increases in stream temperature (e.g. Bren, 1998; Young, 2000).

The effectiveness of riparian buffers for maintaining wood recruitment and sediment dynamics has been studied in western North America and elsewhere (see reviews by Gomi et al., 2005; Hassan et al., 2005). The effectiveness of buffer zones depends largely on the linkages between the disturbed areas and streams (Bren and Turner, 1980; Belt and O'Loughlin, 1994; Gomi et al., 2005). However, few studies have focused on the efficacy of riparian buffers to change rates and processes of sediment deposits related to logging activities in humid tropical forests (Ter Steege et al., 1995; Douglas et al., 1999).

Wood and detritus (leaves and small branches) from riparian forests exert important physical and biological functions in headwater streams (Gomi et al., 2002). Leaves and small branches are the major mass of accumulated detritus within channels (Casas, 1997). Large wood pieces can form channel steps and pools, which modify channel morphology (Montgomery and Buffington, 1997; Gomi et al., 2003) and aquatic biota (e.g. Wright and Flecker, 2004). Sediment transport in small streams is affected by the amount of in-channel storage behind pieces of large wood (Gomi and Sidle, 2003). The type of riparian stand (e.g. deciduous or coniferous) is one factor that determines the amounts and sizes of large and fine woody debris in both temperate and tropical streams (e.g. Harmon et al., 1986; Heartstill-Scalley and Aide, 2003). Channel size also controls the accumulations of wood and detritus along headwater streams (Bilby and Ward, 1989; Gomi et al., 2006). However, no studies have assessed how logging activities and riparian management affect the accumulation of wood and detritus in humid tropical streams. Because of the high temperature, humidity, species richness, and hydrologic responses (e.g. frequent intense squalls), the rate of wood recruitment and residence time of wood and detritus in humid tropical streams may differ from that in temperate forest streams (e.g. Vogt et al., 1996; Pyron et al., 1999). The persistence of wood and detritus in humid tropical headwater channels also may differ from temperate headwater streams because they decompose more quickly in the tropics (Richards, 1996).

Given the sparse research on riparian vegetation–stream interactions in the tropics, the objectives of this study were to: (1) evaluate the effects of logging and riparian management on sediment, wood, and detritus accumulations in four humid tropical headwater channels, (2) investigate changes in sediment and organic matter accumulations with time, and (3) evaluate the effectiveness of riparian buffers for mitigating some of the impacts of logging on humid tropical headwater streams. The results are used to suggest riparian management practices in tropical headwater catchments.

2. Study site

Four headwater channels in three small catchments were studied in the Bukit Tarek Experimental Watershed in Selangor Darul Ehsan, Peninsular Malaysia (Fig. 1). Mean channel gradient in the study reaches of perennial streams ranged from 2.7 to 3.1%, and mean bankfull width ranged from 2.5 to 3.5 m (Table 1). Dominant channel reach types are pool-riffle, step-pool, and plane bed in all channels (Montgomery and Buffington, 1997). The area is covered by lowland tropical rain forest and the dominant vegetation consists of *Koompassia malaccencia*, *Canarium* spp., *Santiria* spp. and *Eugenia* spp. (Saifuddin et al., 1991). The riparian zones are dominated by

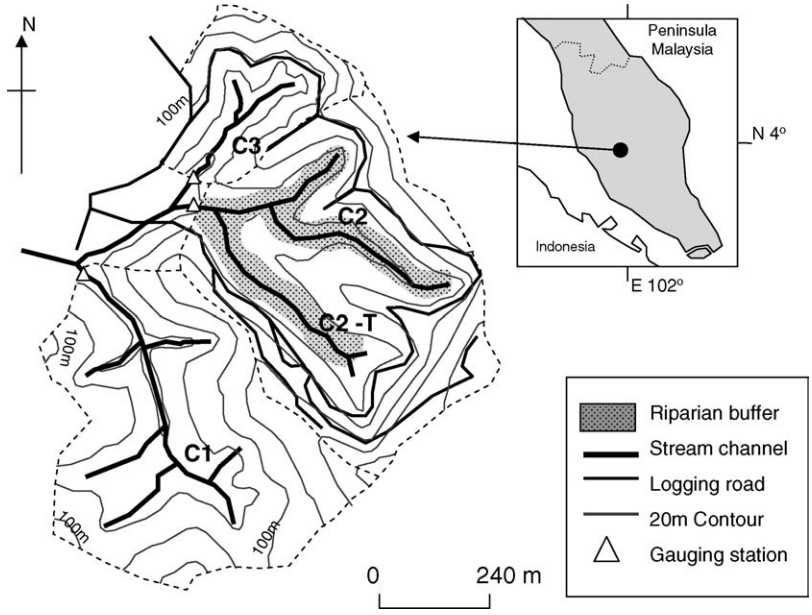

Fig. 1. Location and topography of study areas in the Bukit Tarek Experimental Watershed. Large commercial timber was selectively harvested in Catchments C2 and C3 in late 1999 and early 2000. A 20-m riparian buffer was left along the main C2 and tributary (C2-T) channels. Both C2 and C3 catchments have an extensive logging road network, especially at mid-slope locations. Skid trails (not shown) are present in the C2 and C3 catchments. The C1 catchment has not been logged since the 1960's and is covered by dense second-growth forest.