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When big trees fall: Damage and carbon export by reduced impact logging in southern Amazonia

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Abstract

We examined carbon export in whole logs and carbon accumulation as coarse woody debris (CWD) produced from forest damage during all phases of the first and second year of a certified reduced impact logging (RIL) timber harvest in southern Amazonia. Our measurements included a 100% survey of roads and log decks, assessment of canopy damage and ground disturbance in skid trails and tree-fall gaps, and measurement of carbon exported from the site in logs. Log deck and road construction crushed one and five trees in the 10–60 cm diameter at breast height (DBH) class per hectare logged, disturbed areas of 24 and 100 m^2 ha^{-1}, respectively, and together disturbed about 1% of the forest. On average 1.1–2.6 trees ha^{-1} were harvested over the two years. Logged gaps constituted the greatest disturbance on an area basis (4–10% of the forest) and CWD generation (1.9–4.4 Mg ha^{-1} logged). In gaps, felled trees severed or crushed 10 trees $\geq$10 cm DBH per tree logged, which corresponded to 1.7 Mg ha^{-1} of CWD per tree logged. Crown height – measured from the first bifurcation to the top of the crown – rather than tree height was the better predictor of gap size formed from tree felling ($R^2 = 0.41$). Logging activities significantly reduced leaf area in roads, log decks and gaps, with the greatest reduction (48%) in log decks and least in logged gaps and roads (28–33%) compared to undisturbed forest. A total of 37 species were harvested, with 36% of the total trees harvested and 48% of the total carbon exported from the site in three of the most common species. Logging damage produced 4.9–8.8 Mg C ha^{-1} logged of CWD from all phases of the operation. Carbon export in whole logs (2.1–3.7 Mg C ha^{-1} logged) represented 1–3% of the total standing forest carbon $\geq$10 cm DBH (138 Mg C ha^{-1}). The mean carbon ratio (per hectare logged) of C in CWD to C exported in logs was 2.4. The disturbance, damage, carbon export and CWD data we present advances understanding of the effect of selective logging on tropical forest dynamics of the Amazon Basin. Our results indicate that certified timber harvest in Amazonia under RIL is a viable forest management option to reduce damage and CWD production compared to conventional logging (CL) practices; however, the benefits of disturbance reduction from RIL relative to CL are only realized at greater volumes of timber extraction.

Keywords: Gap; LAI; Deforestation; RIL; Selective logging; Forest certification; Primary forest; Amazon; Brazil

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1. Introduction

Carbon flux as necromass is an important component of the regional carbon cycle for mature undisturbed (Chambers and Schimel, 2001) and selectively logged tropical forests (Keller et al., 2004). Selective logging contributes to necromass fluxes through forest damage as well as a net export of carbon as logs. Forest management provides opportunities both to reduce necromass fluxes and to retain carbon stocks in vegetation and soils (Pinard and Putz, 1996). Improved harvest methods such as reduced impact logging (RIL) can lessen damage to the forest (Johns et al., 1996; Pinard and Putz, 1996) and reduce course woody debris (CWD) accumulation (Keller et al., 2004) relative to conventional selective logging (CL). In addition, per volume harvested, RIL may provide an economic advantage to CL (Healey et al., 2000). Few studies have explicitly related ground damage, canopy reduction and log export to carbon fluxes and export on a tree by tree and operation by operation basis. Such values would improve estimates across the Amazon Basin of the level of damage the forests sustain, carbon lost and potential understory and canopy regeneration after selective logging.

In Amazonia, logging intensity (5–90 m^3 ha^{-1}) and forest disturbance vary by region (Barros and Uhl, 1995; Johns et al., 1996; Nepstad et al., 1999; Pereira et al., 2002; Fredericksen et al., 2003). Selective logging, a dominant form of land use in Amazonia, affected 9000–15,000 km^2 in 1996–1997 (Nepstad et al., 1999). Logging and deforestation assume many forms in the frontier regions, including small-scale tree felling opening new areas for subsistence food production and pasture, predatory logging in indigenous reserves and state and national parks, deforestation by ranchers to create large pastures and well-managed forests that closely follow federal logging guidelines and minimize forest perturbations.

Conventional selective logging leaves the forest standing, but no planned efforts are made to reduce residual stand damage. Improved extraction methods such as certified reduced impact logging use reconnaissance and planned logistics to reduce damage to the forest and streams from road and log deck building and tree extraction. Commercial timber inventories of all harvestable trees $\geq$45 cm diameter at breast height (DBH) provide a tool for forest engineers to plan road and log deck density and find desired species quickly, reducing inefficient tree searching common to conventional methods. RIL prescribes vine cutting one or two years prior to logging (e.g. Pinard et al., 1995), which reduces unintentional tree-fall from vine-linked canopies and injury to workers. RIL also employs directional felling to minimize both damage to surrounding vegetation and the size of gaps. Well-planned RIL operations attempt to limit the number of skidder extraction pathways to reduce damage from moving logs to consolidation decks.

Improved extraction methods, such as RIL, result in less canopy damage and lower gap fraction than CL (Pereira et al., 2002), and differences are persistent for several years (Asner et al., 2004a). Logging intensity, species selection and canopy damage from logging have direct effects on stand structure, which in turn influences stand development and subsequent logging cycles. Following selective logging there may be major shifts in species dominance and vine densities, which can reduce tree productivity and the future timber value (Pinard and Putz, 1994).

Market demands by international consumers for sustainably harvested timber has lead to the certification of some forests in Amazonia. Certification places additional management guidelines on forest managers to improve upon RIL methods and further minimize forest damage. Certified timber provides a direct economic incentive to timber companies through premiums paid for timber harvested according to environmentally and socially sustainable guidelines. By adhering to forest management, environmental impact and worker safety guidelines established by certifying agencies, timber companies benefit financially and workers are safer. Forest management improvements under certified RIL may reduce damage and carbon turnover as CWD.

We studied sources of damage in each phase of timber cutting and extraction during two years of a certified RIL timber harvest. Our objectives were to: (1) quantify ground disturbance and tree damage caused by reduced impact logging operations in a forest in southern Amazonia; (2) relate logging damage, including CWD generation from canopy and understory disturbance and tree mortality from tree felling, machine maneuvering, and road and log deck building to carbon export as whole logs; (3) compare carbon export and damage to logging operations in other regions of Amazonia.