Carbon, forest structure, soil and hydrological relationships in a primary forest undergoing reduced impact logging in southern Amazonia

ND-11

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1. Introduction

Record rates of deforestation in 2004 in the frontier regions of Amazônia, and a consistent increasing trend since 1996 (INPE 2005), have led to major changes in land-cover/land-use. We examined the effect of reduced impact logging (RIL) on soil nutrients, forest structure and coarse woody debris (CWD) in NW Mato Grosso and compared damage caused by RIL to conventional logging (CL). We also studied relationships between primary forest vegetation, biogeochemistry and hydrology. We asssessed how hydrology affects the harvestable area, and examined the abiotic controls of timber and species distribution.

Fig 2.1

Fig 2.2

2. Methods

Study Site

•Rohden Lignea Ltda forest in southern Amazonia, selectively logged at a rate of ~1200 ha yr^{-1}.
•Annual rainfall: 2,200 mm with a strong dry season from June to September.
•Soils: predominately Ultisols and Oxisols, deep, acidic, and highly weathered.
•Study area: three ~1200 ha blocks (Fig 2.1).

2.1 Commercial Timber Inventory, Hydrology, and Harvestable Area:

•Biomass estimates were made from:
1) a 100% forest timber inventory of trees ≥ 45 cm diameter at breast height (DBH).
2) transects to inventory all trees ≥ 10 cm DBH and all vines.
•Mapped, measured DBH, bole height, and species.
•Calculated commercial biomass, stem density, and basal area for 50x50 m cells (Brown eq. 3.2.3).
•Used kriging interpolation to estimate density and biomass across the 3 blocks.
•Generated a topographic index (TI) from ASTER data.
•Estimated the area in 50 m stream buffers where logging is prohibited.

2.2 Abiotic Controls of Biomass, Density and Species Distribution

•Used canonical correspondence analysis (CCA) to relate tree, palms and lianas to soil and topographic variables.
•Analyzed the relationship between timber species, slope, and drainage using a topographic index.
•In three vegetation types (*campinarana*, palm and upland forests):
•Excavated soil pits.
•Measured soil moisture, water table fluctuations, and throughfall.

2.3 RIL Damage and CWD

•Measured canopy opening LAI, stems damaged and CWD in skid trails, 54 gaps and intact forest (Fig 2.2).

2.4 Total Soil N and Nitrate in Logged-Gaps

• Nitrate to 8 m depth below 9 logged gaps.
•Soil water depletion over 1-year in gaps and intact forest.
•Total soil N to 20 cm depth 2 to 12 years after logging.

2.5 RIL versus CL

•Compared estimates of ground disturbance between RIL and CL.

3. Results

3.1 Commercial timber inventory, hydrology, and harvestable area

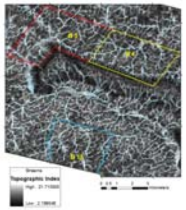

Fig 3.1-1

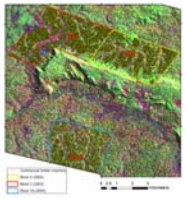

Fig 3.1-2

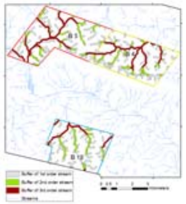

Fig 3.1-3

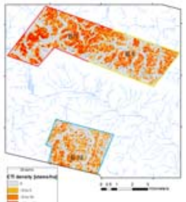

Fig 3.1-4

•Streams network generated from 50 convergence cells corresponded to streams in the field (Fig 3.1-1).
•37 species were harvested, with 48% of the total exported C in three of the most common species.
•Commercial timber species were significantly clustered, with a mean density of 6 trees ha^{-1} and volume from 15.3 to 21.6 m^3 ha^{-1} (Fig. 3.1-2).
•Areas protected from logging under RIL as 50-m stream buffers around 1st to 3rd order streams and greater represented 28 to 7% of the total area (Fig 3.1-3).
•An additional 27% of the area had no timber species, resulting in up to a 55% reduction of the total harvestable area (Fig 3.1-4).

3.2 Abiotic controls of biomass, density and species distribution

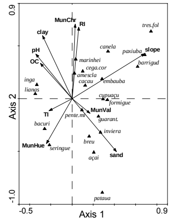

Fig 3.2-1

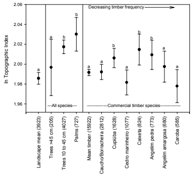

Fig 3.2-2

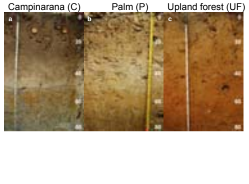

Fig 3.2-3a,b,c

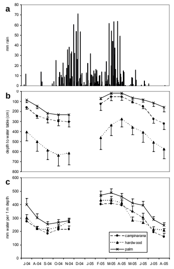

Fig 3.2-4

•Fig 3.2-1: CCA biplot relating vegetation to edaphic and topographic variables. Arrows represent vectors of environmental variables which are shown in bold. Solid triangles represent species which are shown in italics. **Axis 1 describes an environmental gradient in topography from steep areas to low-lying convergence zones. Axis 2 describes a soil color/texture gradient which serves as a proxy for soil fertility. Some species show clear niche preferences for environmental conditions.**
• Fig 3.2-2: Some timber species were located in areas with significantly higher topographic index values, indicating preferential habitat selection.
•Fig 3.2-3a,b,c: Soil pits excavated in (a) campinarana [C], (b) palm [P], and (c) upland forests [UF]. **C-areas all had an impeding layer at ~50 cm depth and were extremely sandy. P-areas had gleyed soils from fluctuating water table conditions. UF had darker soils with iron accumulation and good root distribution throughout the profile.**
•Fig 3.2-4: Time series hydrological data for 3 vegetation types and canopy through-fall from July 2004 through August 2005 showing (a) water storage per 1 m soil depth, (b) depth to water table, and (c) daily canopy through-fall in the study area. **Palm sites had prolonged surface saturation during the wet season; C sites restricted rooting zone, surface saturation during wet season and drought stress during dry season; UF sites essentially released from hydrologically imposed constraints on colonization.**

3. Results – cont.

3.3 Selective Logging Damage

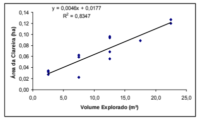

Fig 3.3-1

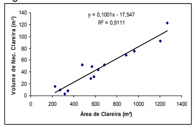

Fig 3.3-2

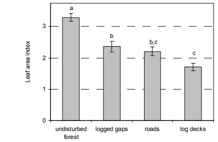

Fig 3.3-3

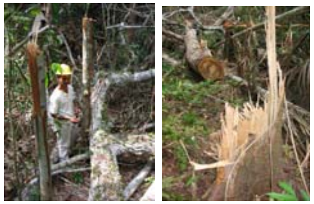

Fig 3.3-4

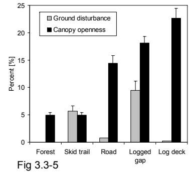

Fig 3.3-5

Fig 3.3-6

•There was a strong relationship between the clearing size and volume of necromass and volume harvested (m^3) (Fig 3.3-1,2).
•Logging reduced LAI from undisturbed forest levels (Fig 3.3-3).
• Logging damage (Fig 3.3-4,6) produced 4.9-8.8 Mg C ha^{-1} logged of CWD from all phases of the operation.
•Logging disturbed ~17% of the forest surface area (Fig 3.3-5).
•Carbon export in whole logs (2.1-3.7 Mg C ha^{-1} logged) represented 1-3% of the total standing forest carbon ≥ 10 cm DBH (138 Mg C ha^{-1}).

3.4 Total Soil N and Nitrate in Logged Gaps

•Nitrate concentrations in logged gaps 1-year after logging were only significantly higher in the surface 60-100 cm depth compared to intact forest (Fig 3.4-1).
•With a harvest rate of 2.6 tree ha^{-1}, logging activities resulted in an addition of 91 kg N ha^{-1} forest to the soil and an export of 19 kg N in boles.
•Total nitrate storage to 8 m was the same between gaps (613) and intact forest (636 kg ha^{-1}-8m) (Fig 3.4-2).

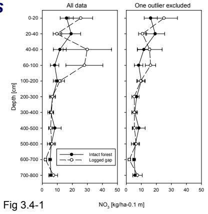

Fig 3.4-1

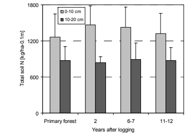

Fig 3.4-2

3.5 RIL versus Conventional Logging

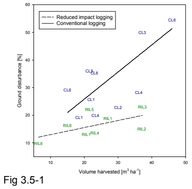

Fig 3.5-1

• RIL results in less total ground disturbance than CL only at higher volumes of timber harvest (Fig 3.5-1).

4. Acknowledgements

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