Tropical forest recovery following human disturbance in central Amazônia: post-pasture forest structure, canopy cover, biomass and nutrient dynamics

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1. Abstract

Over 80% of the estimated 588,000 km^2 reforested in Brazilian Amazônia was converted to pasture or secondary forest (SF). These land-use change practices altered above- and below-ground biogeochemical processes. We examined post-pasture forest recovery in a ten-forest chronosequence (0-14-years after abandonment). After 12-14-years of regrowth following pasture abandonment, the forests accumulated up to 124 Mg ha^{-1} of dry aboveground biomass. Soil exchangeable Ca (20±24 kg ha^{-1}) was low, extractable soil P stocks declined as forest biomass increased, and both were rapidly translocated from soil to plant pools. Total soil N stocks increased with forest age (117.8 kg ha^{-1} yr^{-1}), probably due to N-fixation, atmospheric deposition, and/or subsoil mining. Total soil C storage to 45-cm depth ranged between 42 and 84 Mg ha^{-1}, with the first 15 cm storing 40-45% of the total. Compared to mature forest values leaf area index was about 60%, canopy cover and stem frequency were similar, and the rapid tree-dominated biomass accrual was 25-50% after 12-14-years growth.

Figure 1: Deforestation and pasture establishment in Amazônia.

2. Objective

Our goal was to determine rates of recovery and potential nutrient limitations to regrowth, and develop management recommendations to rehabilitate degraded areas to speed SF recovery in central Amazônia.

3. Methods

Research sites

- 46–72 km north of Manaus, Amazonas, Brazil.
- The area was upland *terra-firme* primary forest before pasture clearing. Soils are nutrient-poor, acidic Oxisols, with 80-85% clay.
- 3 cattle ranches with 10 secondary forests (SF) regrowing from degraded pastures (Figure 3).
- SF age ranged from 0 to 14 years since pasture abandonment; 4 plots within each forest (100 to 400 m^2).

Sampling

Soil and plant tissue

- Composite soil samples to 45 cm depth collected within each plot.
- Analyzed leaf and wood macronutrients (sampled 15 trees per forest).

Forest structure

- Measured tree, vine and shrub DBH, stem density, and basal area.
- Calculated dry biomass by life-form and diameter class using allometric equations (trees: Nelson et al. 1999 and R. Mesquita *in preparation*; vines: Putz 1990).
- We reported stand-level biomass and nutrient stock estimates for these forests (Feldpausch *et al. in press*).

Leaf area index

- Digital handheld hemispheric (fisheye) lens.
- 3 random locations within each of the four plots per forest; photographed at 5 and 150 cm height.
- Calculated LAI and canopy openness from 240 digital images (Figure 2).

a.

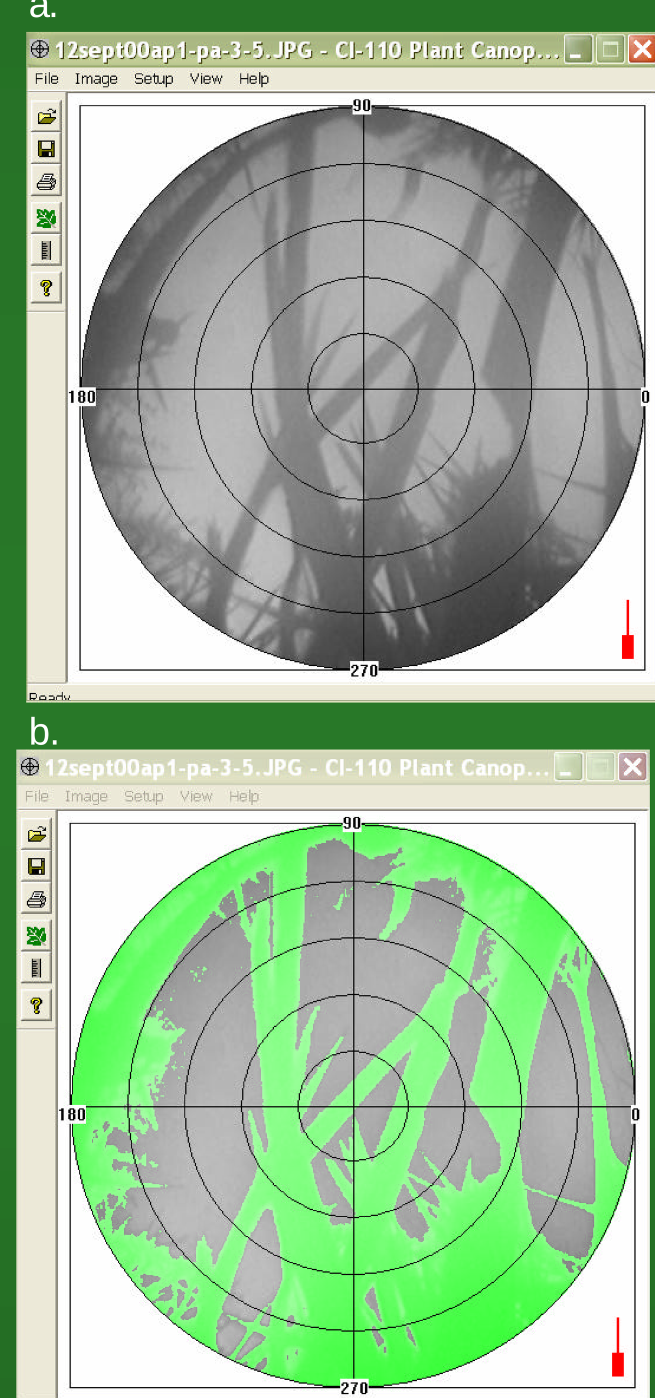

Figure 2: LAI image analysis a) pre and b) post image processing. Using the software CI-100 3.2 we differentiated between leaf and open space and used inverse gap-fraction analysis to estimate LAI.

Figure 3: In 2001 and 2002- area with colonizing *Borreria, Rolandra, Vismia, Bellucia*, and *Cecropia* spp. beginning to emerge from *Brachiaria* spp. pasture grasses.

4. Results

4.1 Nutrients

- •Total soil N stocks rapidly increased with forest age (118 kg ha^{-1} yr^{-1}) (Figure 3b).
- •Extractable soil (plant-available) P stocks declined as biomass accumulated (Figure 3c).
- •Leaf carbon:P ratios increased with time, while C:N did not (Figure 3d).

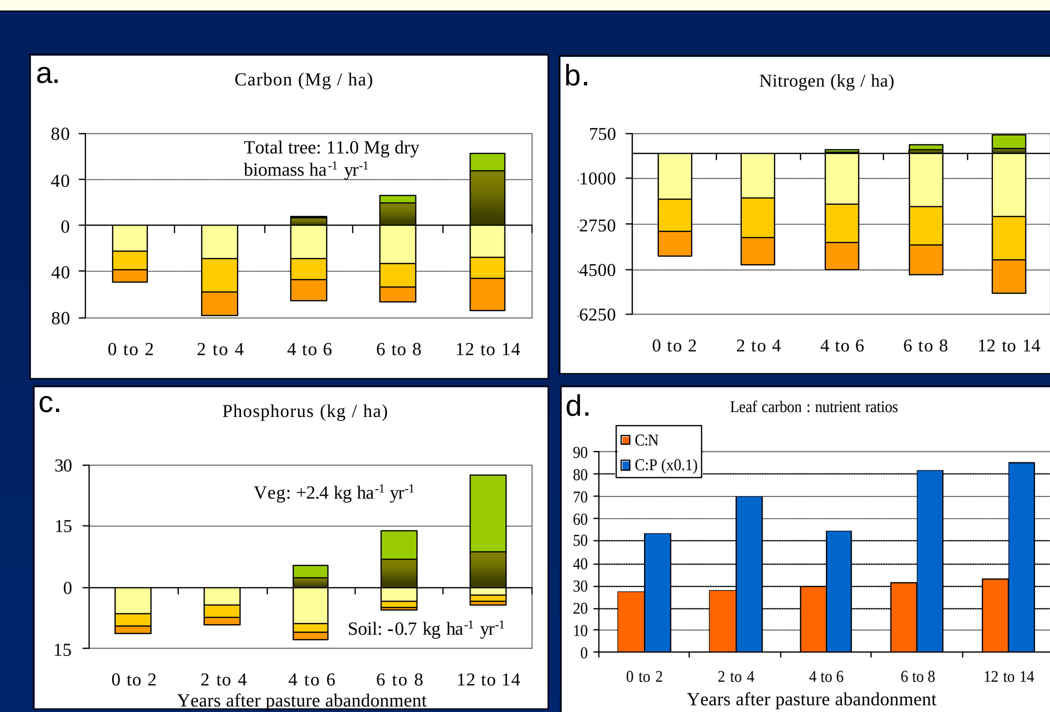

Figure 3: Vegetation and soil stocks of a) carbon b) nitrogen and c) phosphorus. d) leaf carbon to nutrient ratios by year after pasture abandonment in ten SF regenerating from degraded pastures.

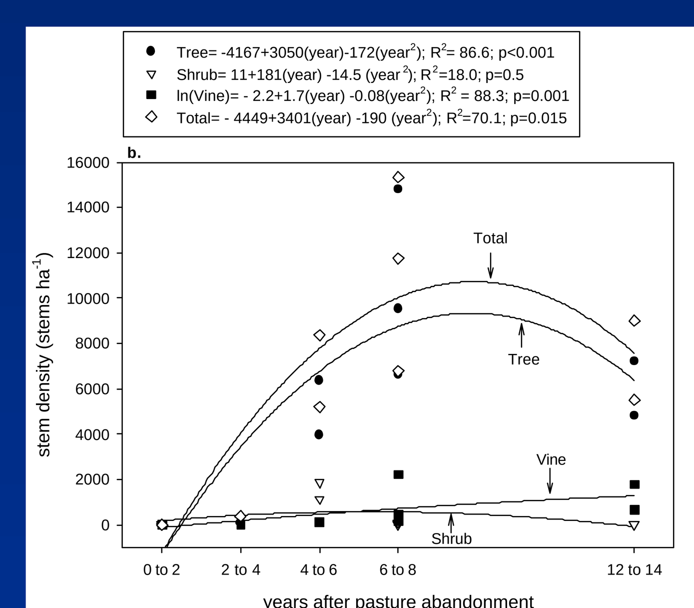

Figure 4: Stem density (stems ha^{-1}) by growth-form for 10 secondary forests near Manaus, Brazil

4.2 Forest Structure

- •Trees rapidly colonized the abandoned pastures, producing 124 Mg ha^{-1} of biomass in 12 to 14 years (Figure 3a).
- •Total vine biomass increased with forest age (r^2=85; p=0.001)
- •Tree stem density peaked after 6 to 8-years (10,320 stems ha^{-1}) (Figure 4).

4.3 Leaf Area Index

- •Total LAI (>5 cm height) ranged from 3.2 to 3.7 (Figure 5).
- •Canopy LAI (=150 cm height) ranged from <0.1 to 3.3.
- •Canopy (=150 cm height) and ground vegetation (5-150 cm height) contributed equally (~45% each) to total foliar cover between 2 to 4 and 4 to 6-years following pasture abandonment.

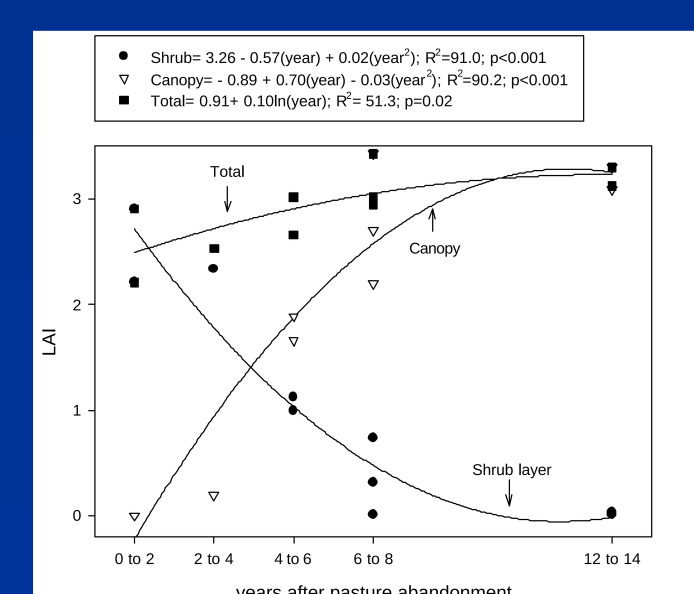

Figure 5: LAI for the shrub layer (< 150 cm) and tree canopy (=150 cm height) in 10 SF regenerating from degraded pastures..

5.Discussion

•Compared to primary forests values, after 12 to 14-years of secondary forest growth:

- •LAI was about 60%.
- •Canopy cover and stem density were comparable.
- •Tree-dominated biomass accrual was 25-50%.

•Pasture establishment, grazing and fire result in a cost to regeneration via impacts on nutrients, seed banks, and selection of sprouting species that gave rise to:

- •uniform "clonal" stands of a few species (e.g. Vismia).
- •Monospecific, 'simple-structured' stands.
- •even-aged, dense forests.

6. Conclusions

Following pasture abandonment:

1) Translocation of some nutrients from deep soil (>45-cm depth) may be important to sustaining productivity and biomass accumulation.
2) Increasing leaf C:P ratios indicate soil nutrient deficits may limit future productivity.
3) Uniform stand structure affects both LAI and biomass accumulation relative to the species rich forests regenerating after cropping, which may influence long-term recovery.

The widespread area of SFs regrowing from pastures in the Amazon Basin may become increasingly important in the regulation of local, regional and global biogeochemical cycles and also providing socio-economic services for the landholders.

7. Acknowledgements

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