Do secondary forests of Amazonia conform to the soil genesis paradigm of N and P limitation in terrestrial ecosystems?

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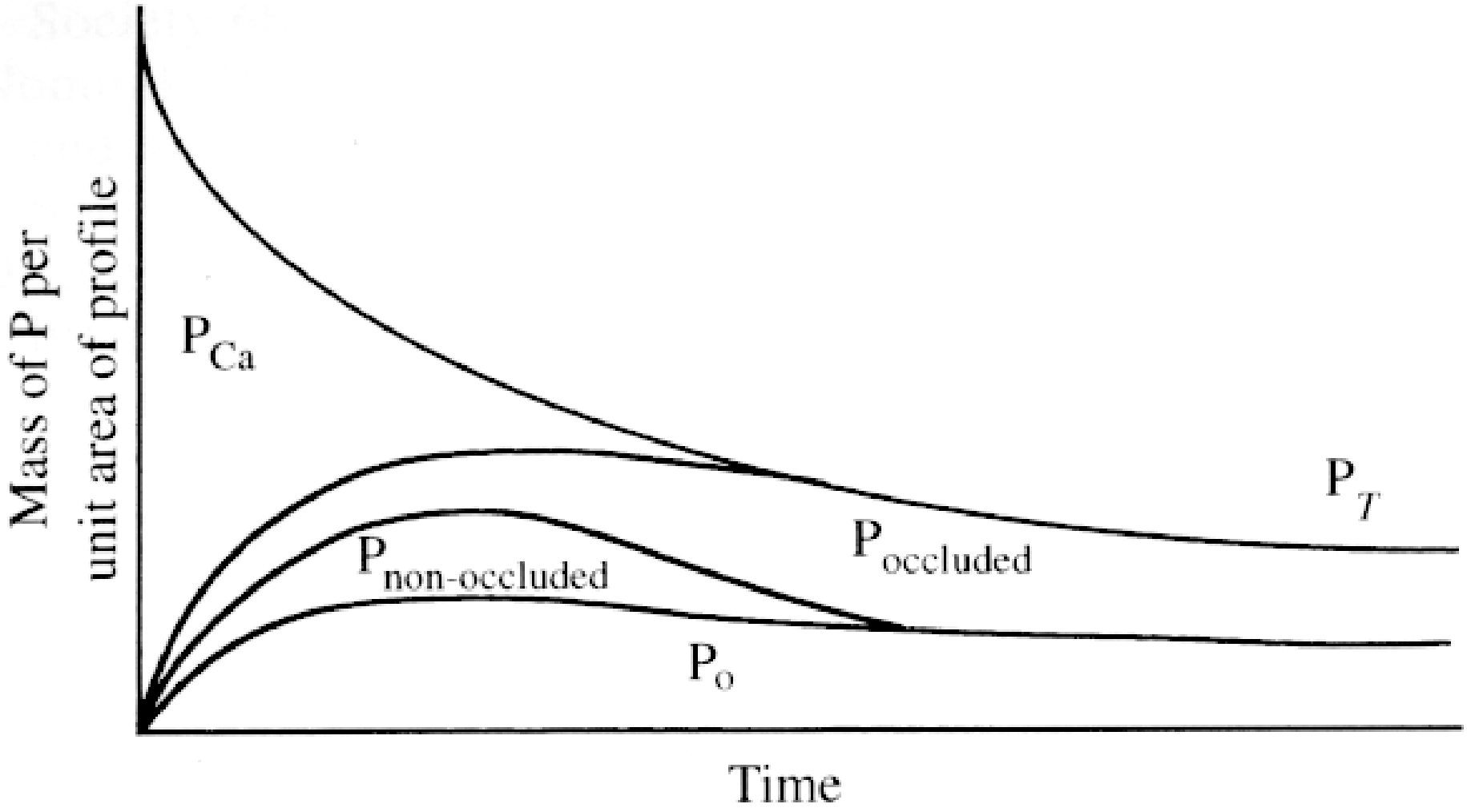
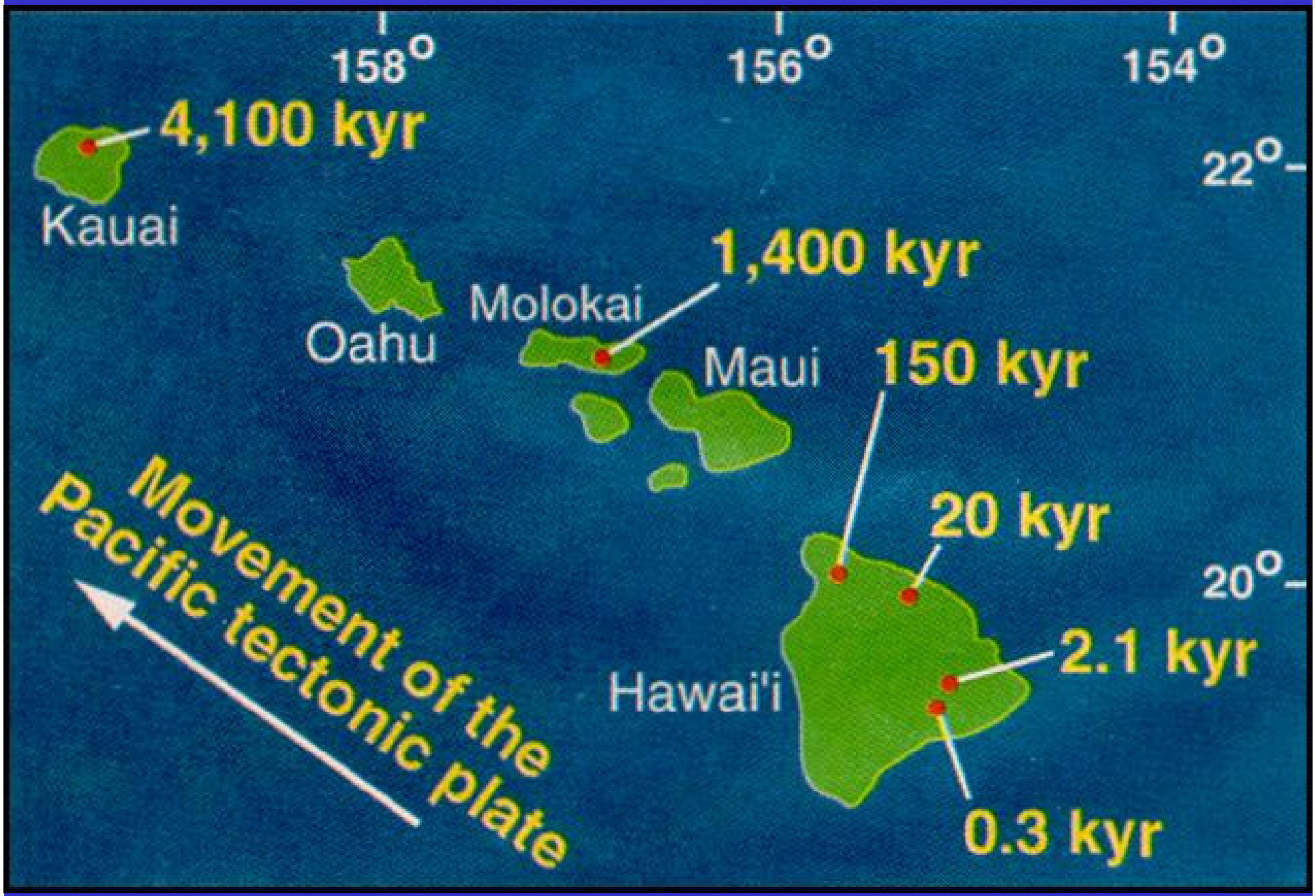
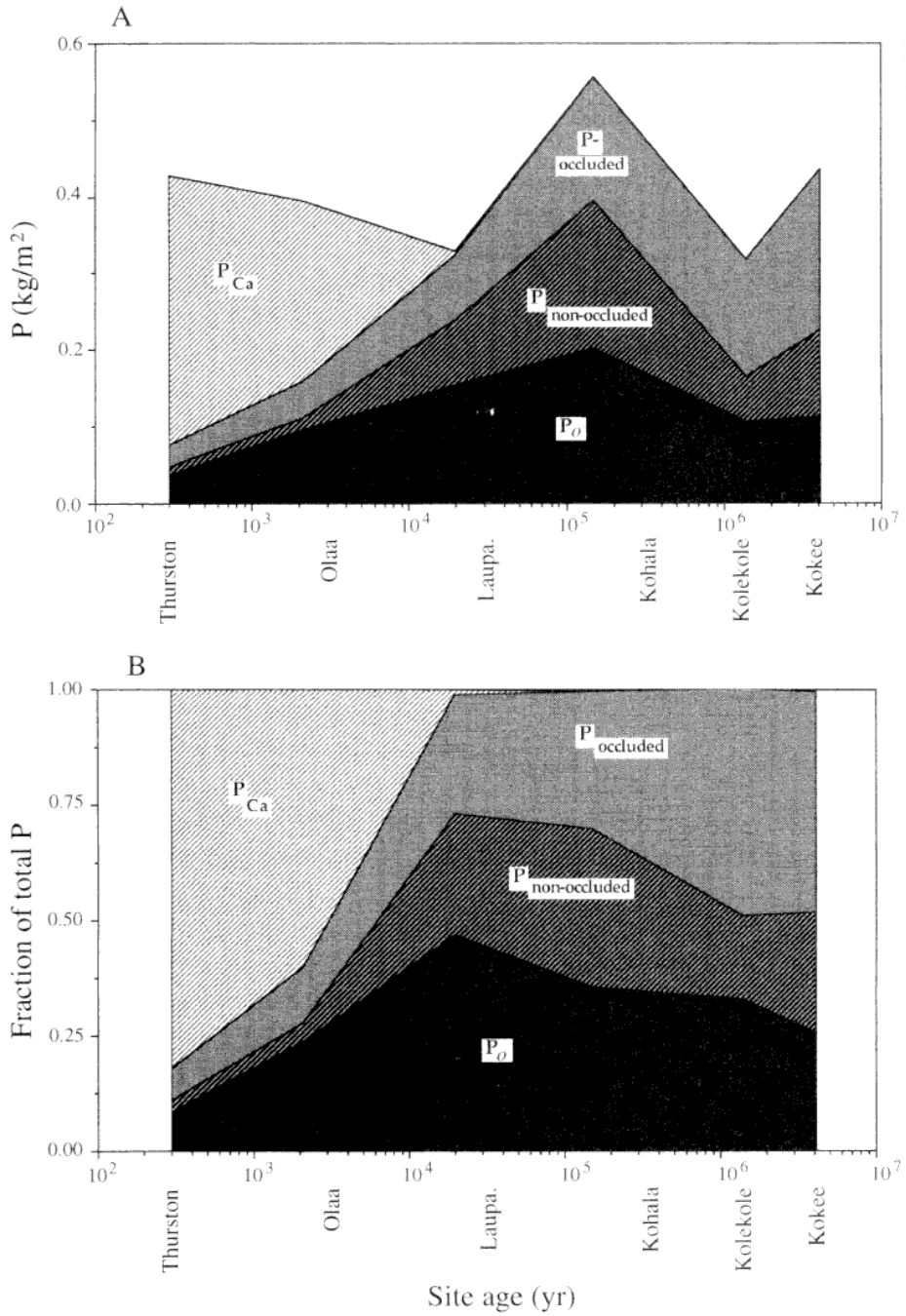
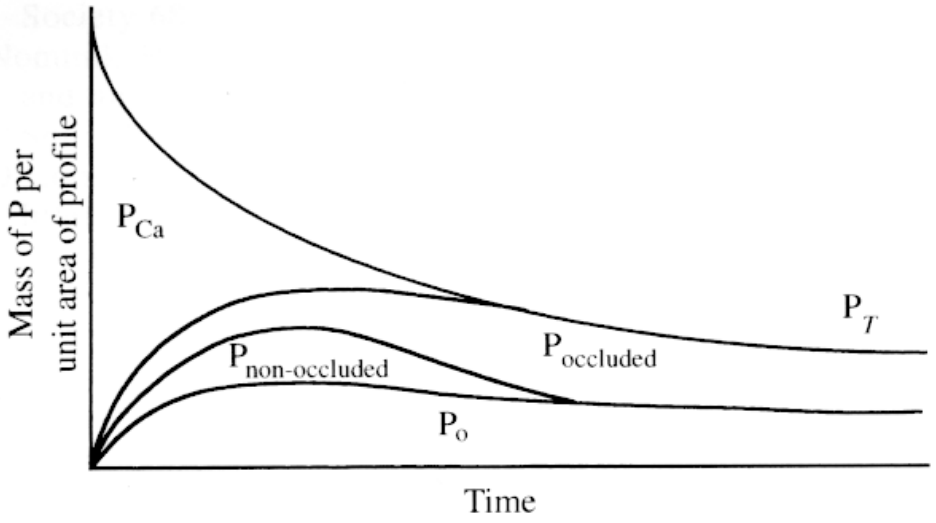


Walker and Sykes model; from Crews et al. (1995; Ecology 76:1407:1424).


158°
156°
154°
22°
20°
4,100 kyr
Kauai
Oahu
Molokai
1,400 kyr
Maui
150 kyr
20 kyr
2.1 kyr
Hawai'i
0.3 kyr
Movement of the Pacific tectonic plate





Crews et al.

(1995; Ecology 76:1407:1424).

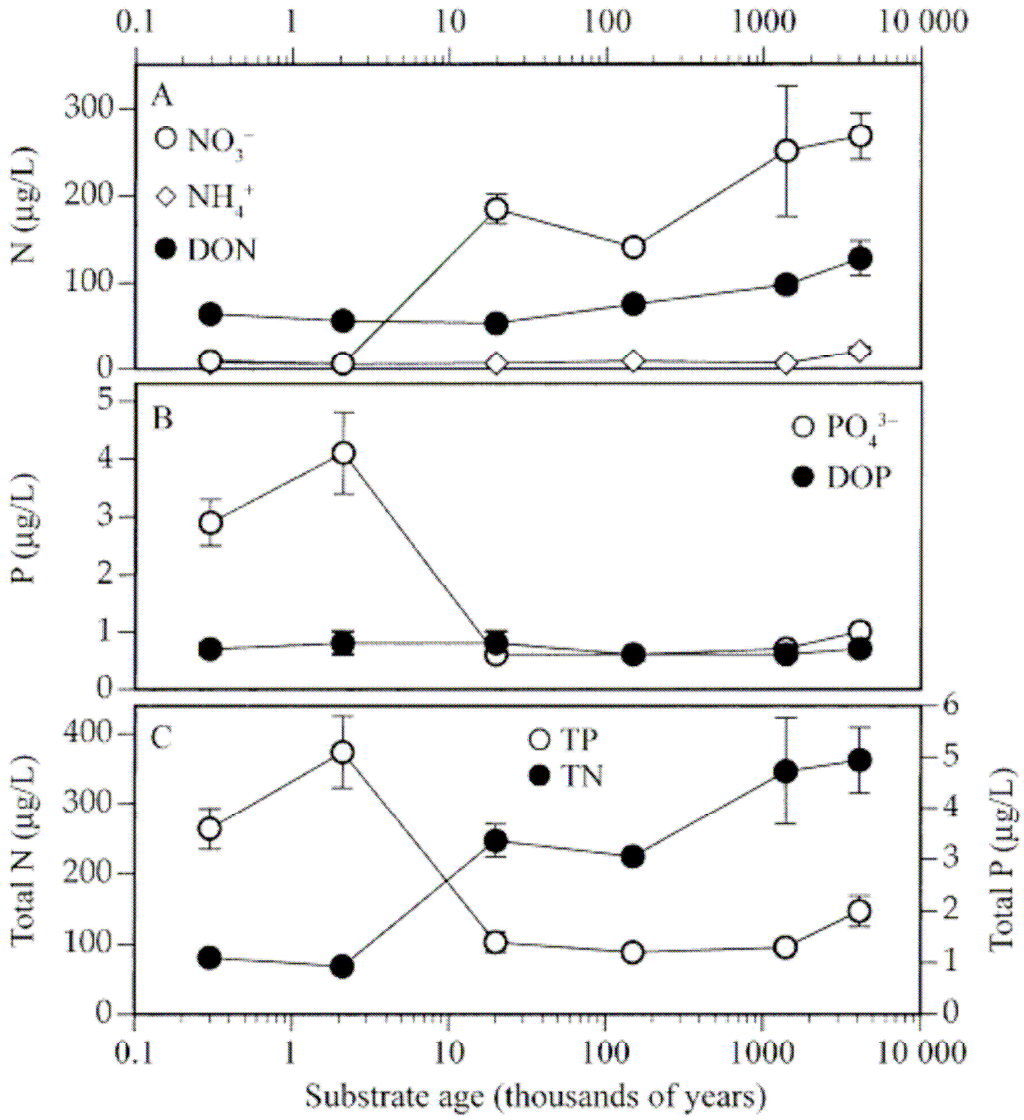


FIG. 3. Concentrations of different forms of N and P in soil waters below the active rooting zone across the age gradient of study sites. Each value is the long-term arithmetic mean based on 10–22 monthly sample efforts, from 6–12 lysimeters at the different sites (see Appendix B). Error bars identify 1 SE of the means; the absence of error bars indicates that errors were too small to be differentiated from individual symbols (A) Concentrations of NO_3^-, NH_4^+, and DON (dissolved organic nitrogen). (B) Concentrations of PO_4^{3-} and DOP (dissolved organic phosphorus). (C) Concentrations of total N (sum of NH_4^+, NO_3^-, and DON) and total P (sum of PO_4^{3-} and DOP) Note the *x*-axis logarithmic scale.

Hedin

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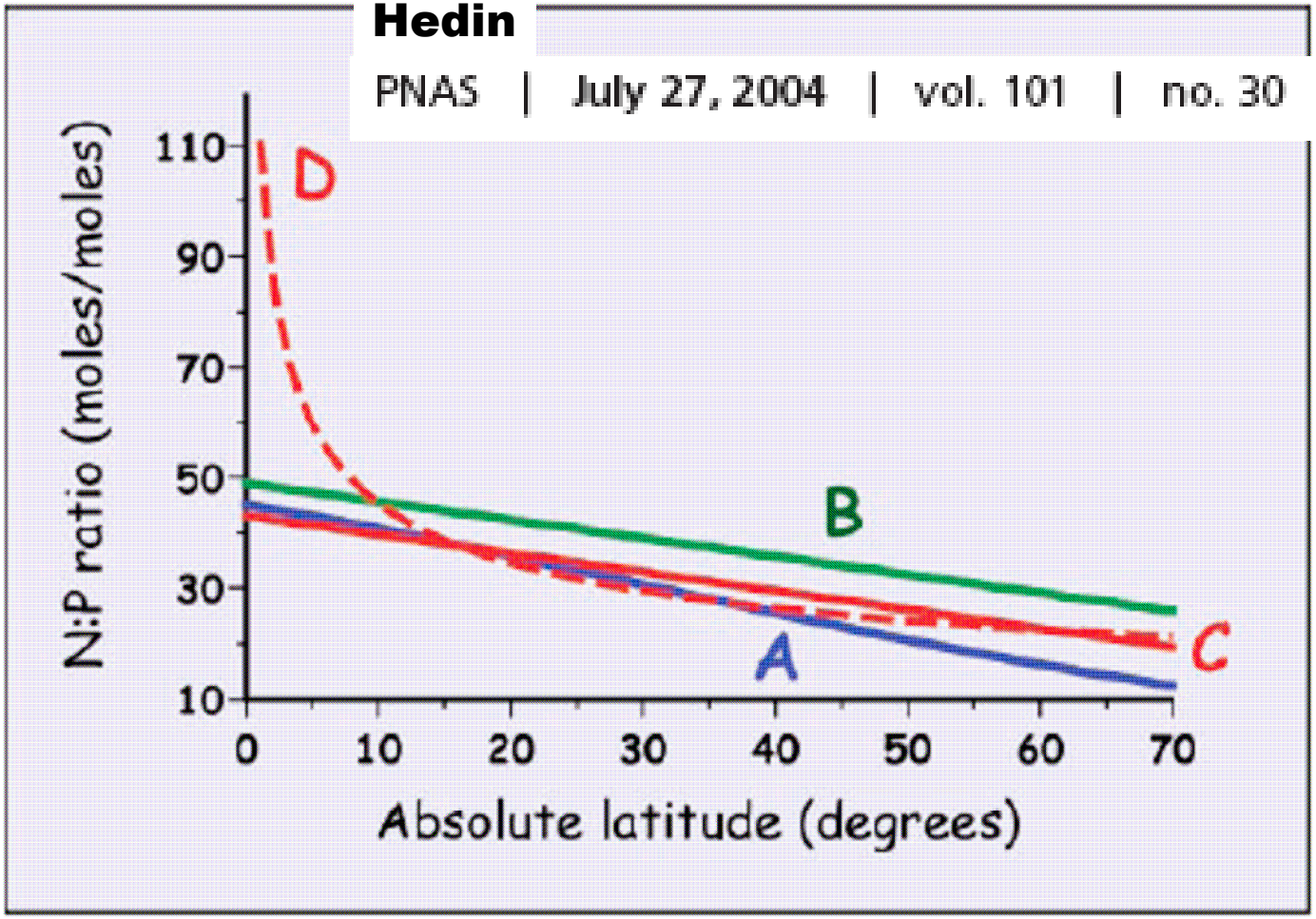
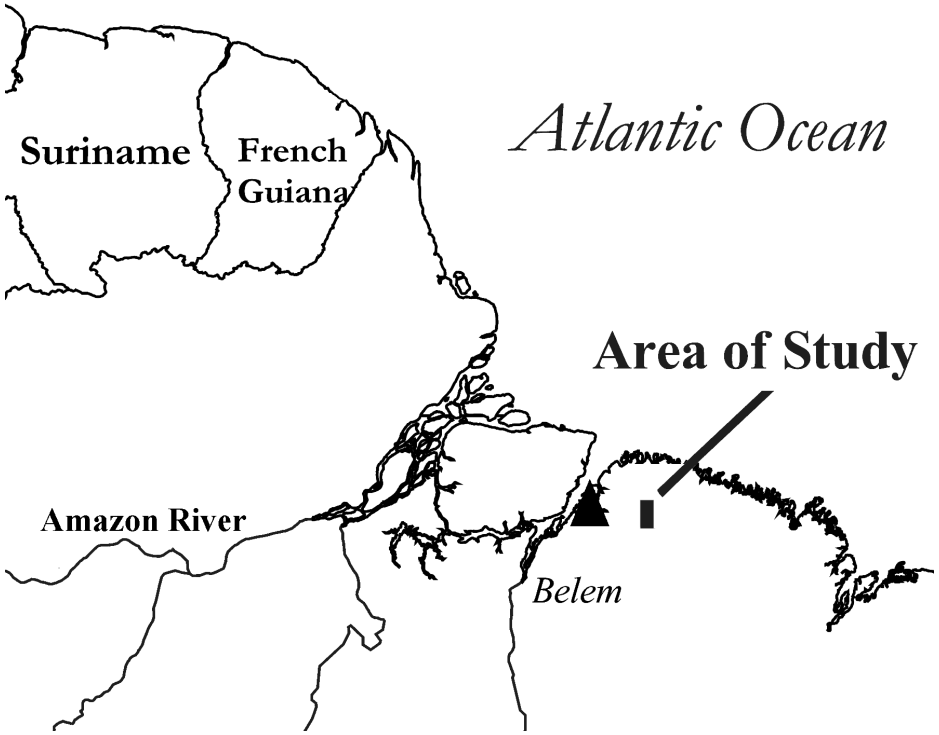
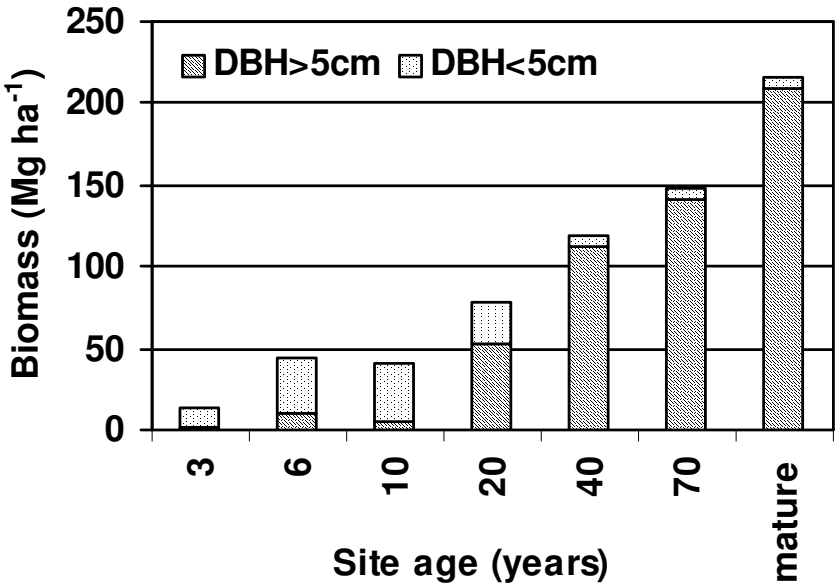


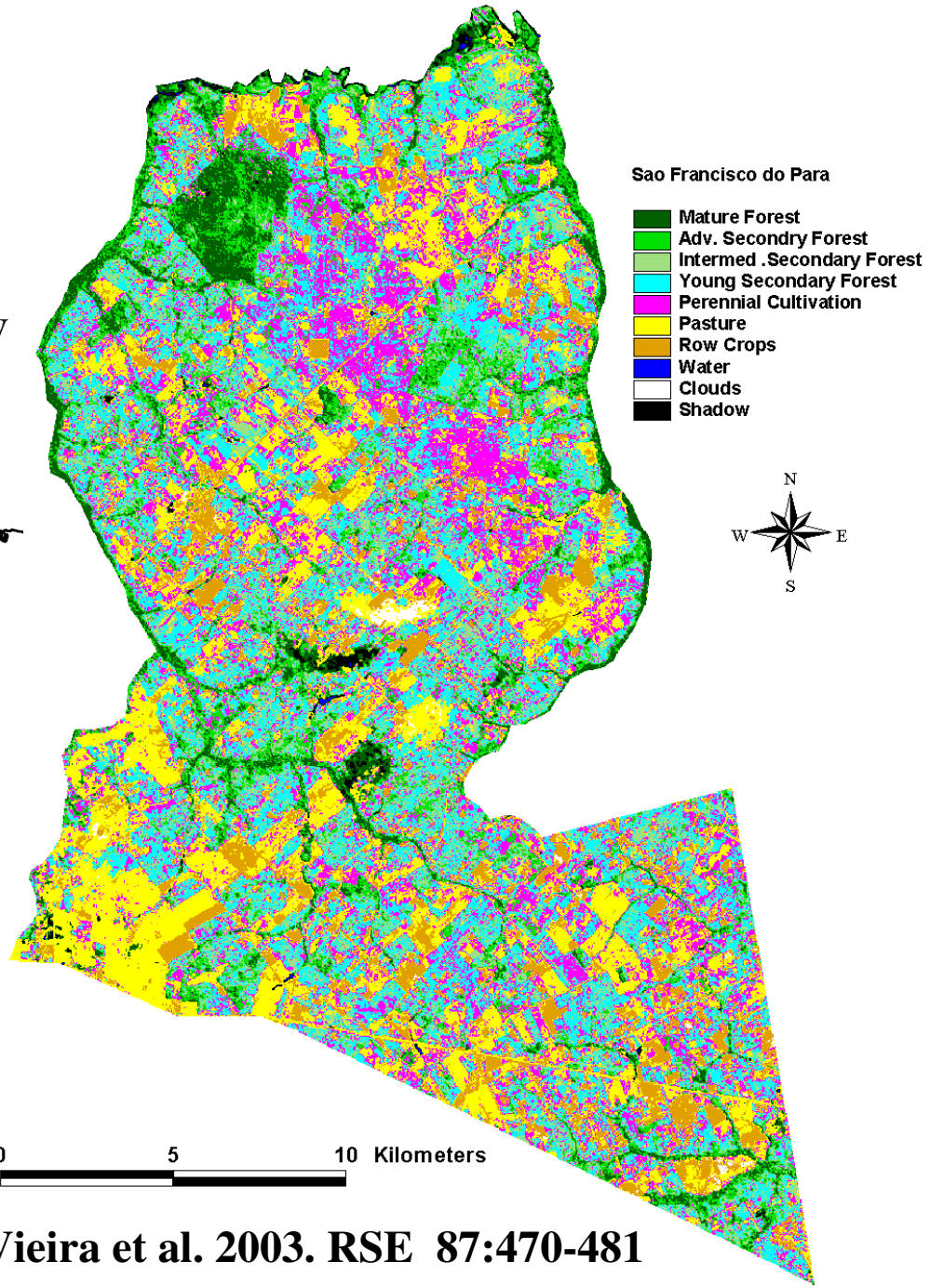
Fig. 1. Regression trends of plant N:P ratios (molar basis) as a function of absolute latitude (degrees): Reich and Oleksyn (ref. 8; blue), Kerkhoff's group (green), and McGroddy *et al.* (ref. 9; red). Line A, Reich and Oleksyn's (8) study of leaf nutrient content in 1,280 plant species from 452 locations worldwide (log N:P = 1.30985 − 0.00377 · latitude − 0.00006 · latitude^2; $r^2 = 0.78$; $P < 0.005$). Line B, Kerkhoff's group's study of leaf nutrient content in 1,054 plant species worldwide, binned across 16 latitudes (N:P = 49 − 0.33 · latitude; $r^2 = 0.55$; $P < 0.001$). Line C, McGroddy *et al.*'s (9) study of foliage nutrient content across 59 undisturbed forests worldwide (N:P = 43.1 − 0.338 · latitude; $r^2 = 0.28$; $P < 0.0001$). Line D, McGroddy *et al.*'s (9) study of litterfall nutrient content across 106 undisturbed forests worldwide (N:P = 111.1 · latitude$^{-0.389}$, $r^2 = 0.43$; $P < 0.0001$).

Secondary Forests in Amazonia

- About 16% of the original forest area has been cleared [*INPE*, 2004]
- As much as 30-50% of cleared land has been estimated to be in some stage of secondary forest succession following agricultural abandonment [*Hirsch et al., 2004. GCB 10, 908-924*].
- The area of secondary forests in the Amazon increased from ~30,000 km^2 (1978) to 160,000 km^2 (2002), the latter figure representing about 20% of deforested land and about 4% of the natural forest area [*Neeff et al., 2006. Ecoystems 9, 609-623*].
- The mean age of Amazonian secondary forests has been estimated to vary only between 4.4 and 4.8 years during the last three decades [*Neeff et al., 2006*].







Vieira et al. 2003. RSE 87:470-481

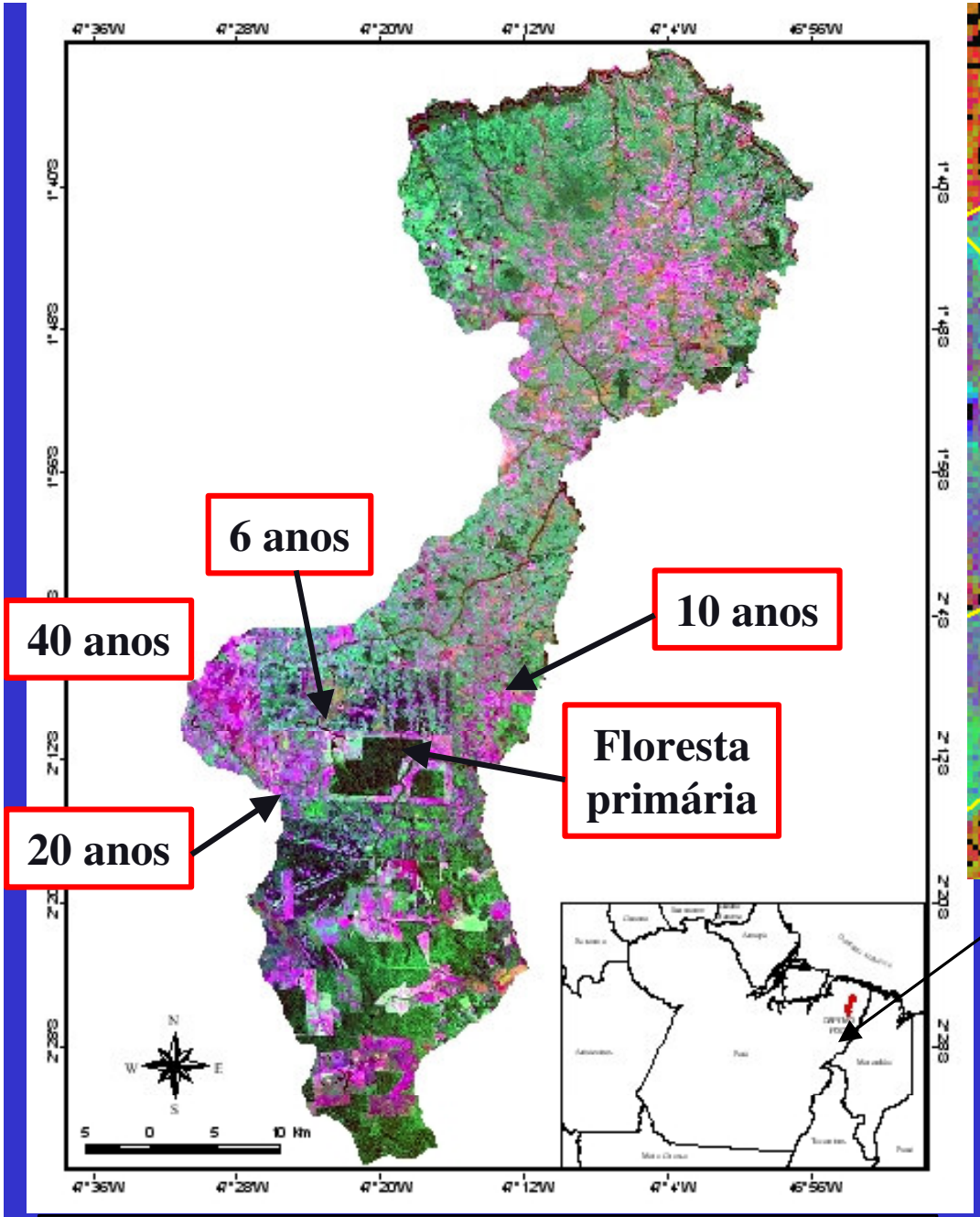
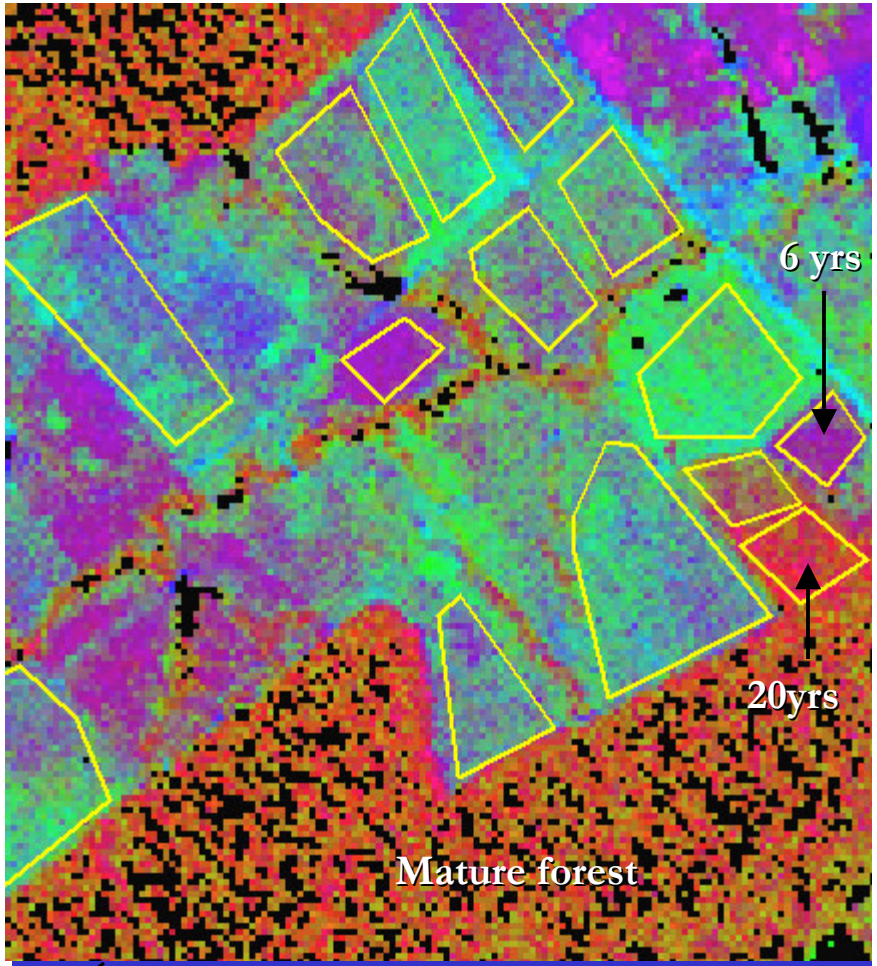


Figure 5. Map of Capitão Poço municipality and study sites based on Landsat imagery.

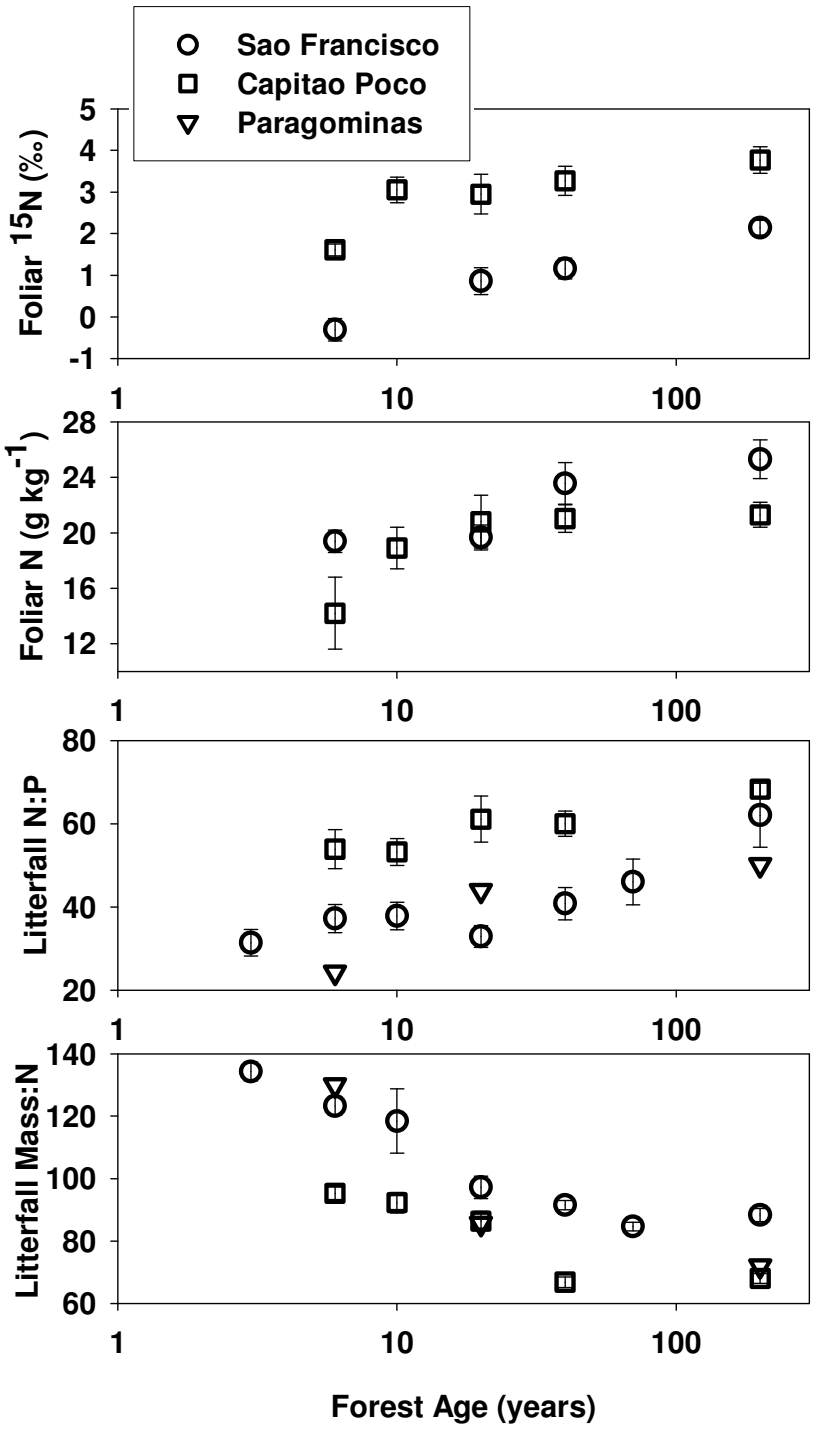


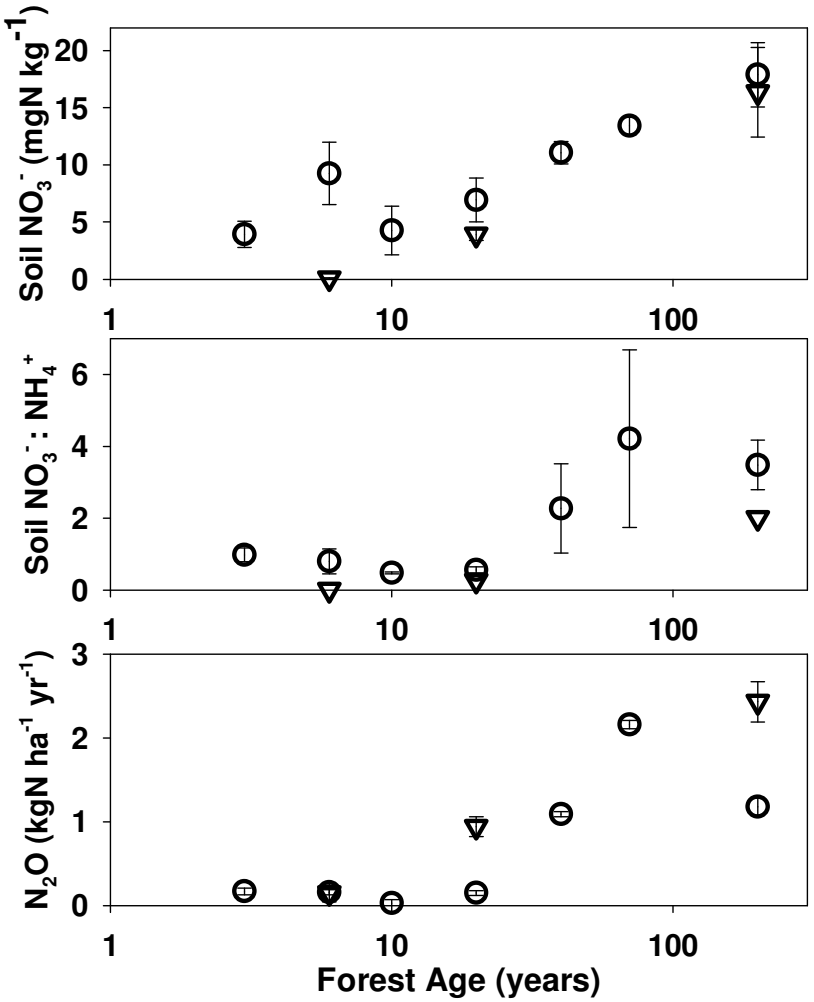
Paragominas:

Markewitz et al. 2004Ecol. Appl. 14:S177-S199

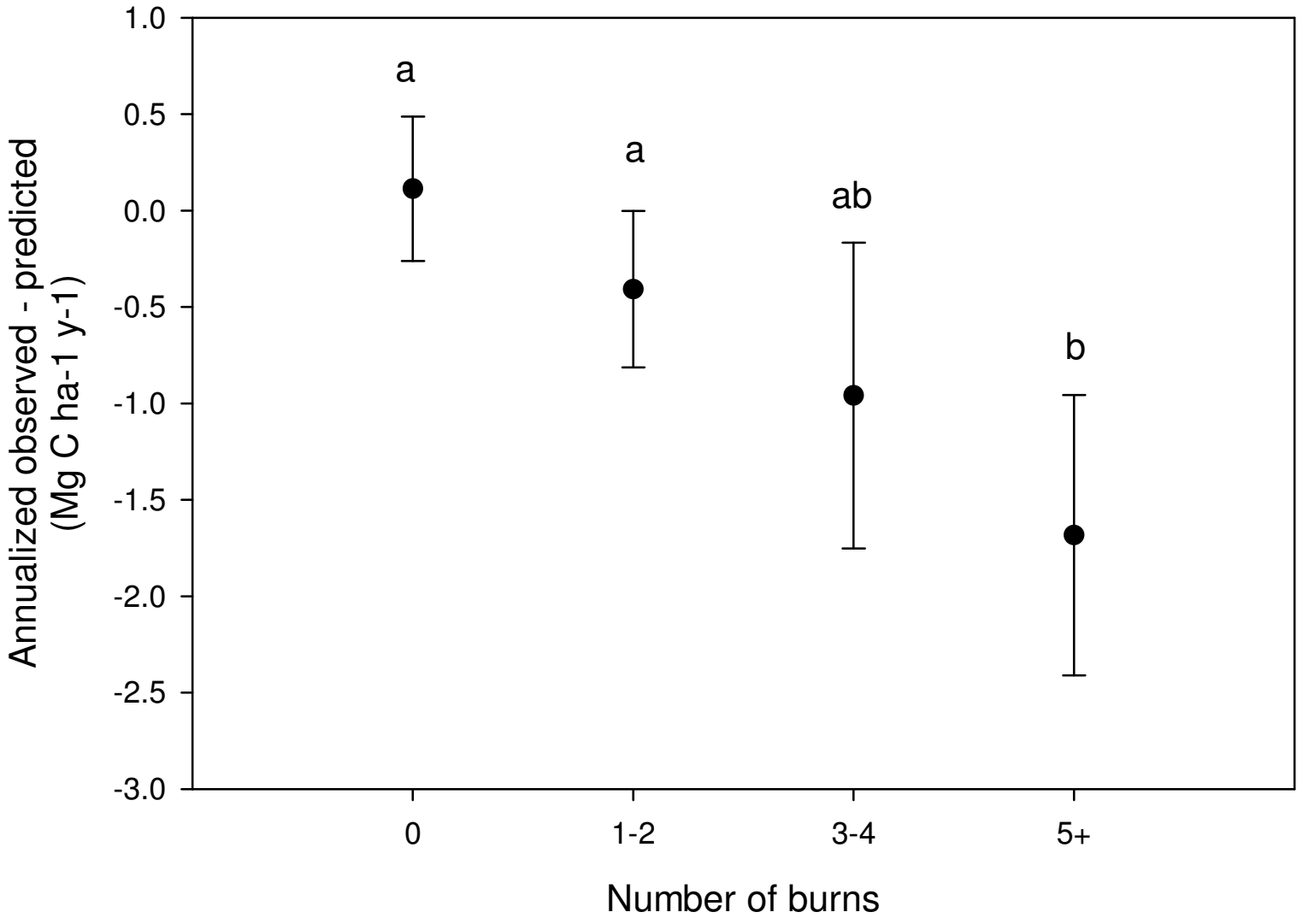
Davidson et al. 2004 Ecol. Appl. 14:S150-S163

Almeida, Vieira, Stone, Davidson, Hayashi, Leal, unpublished

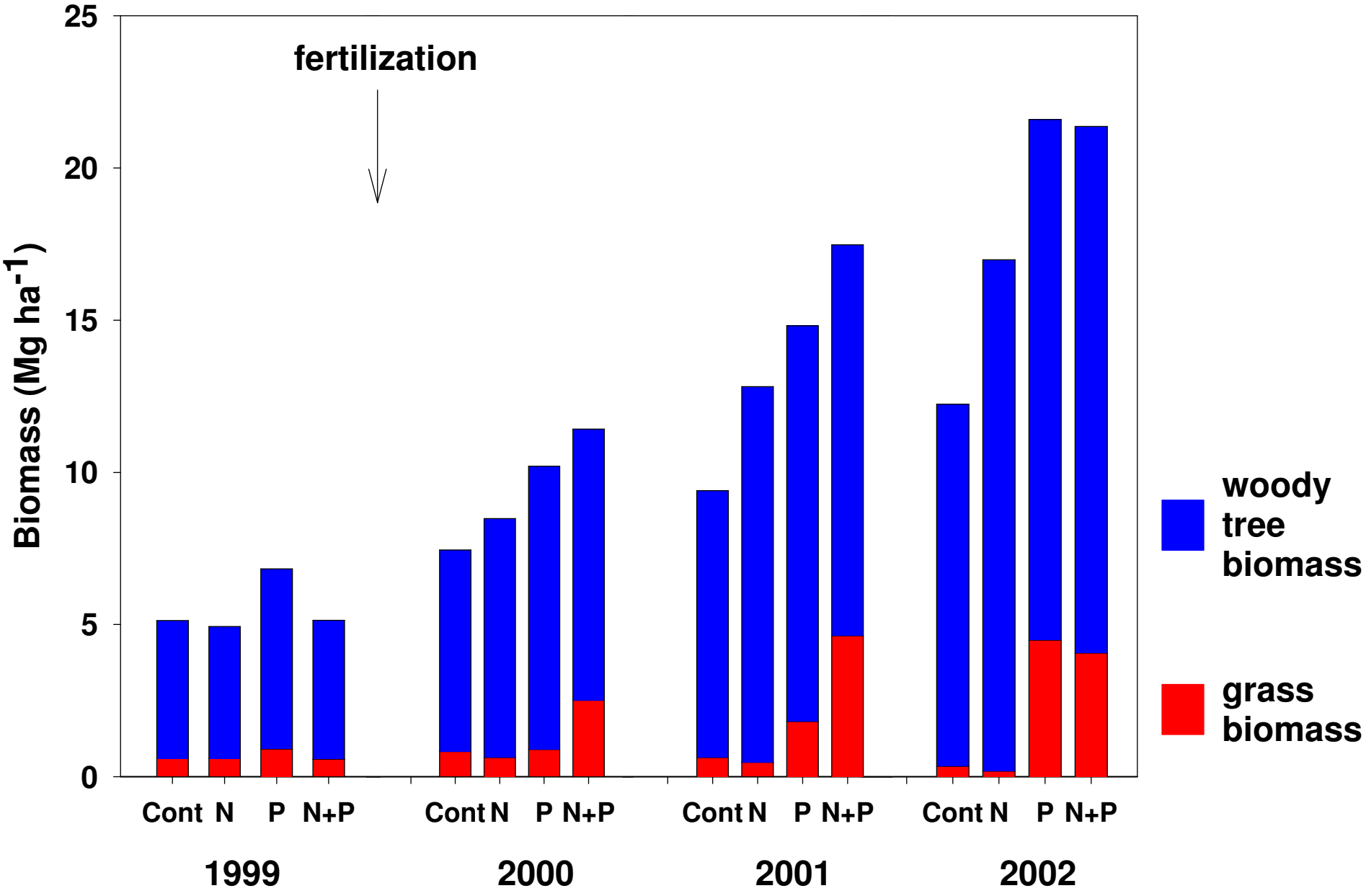




Davidson et al. 2007.
Nature 447:995-998



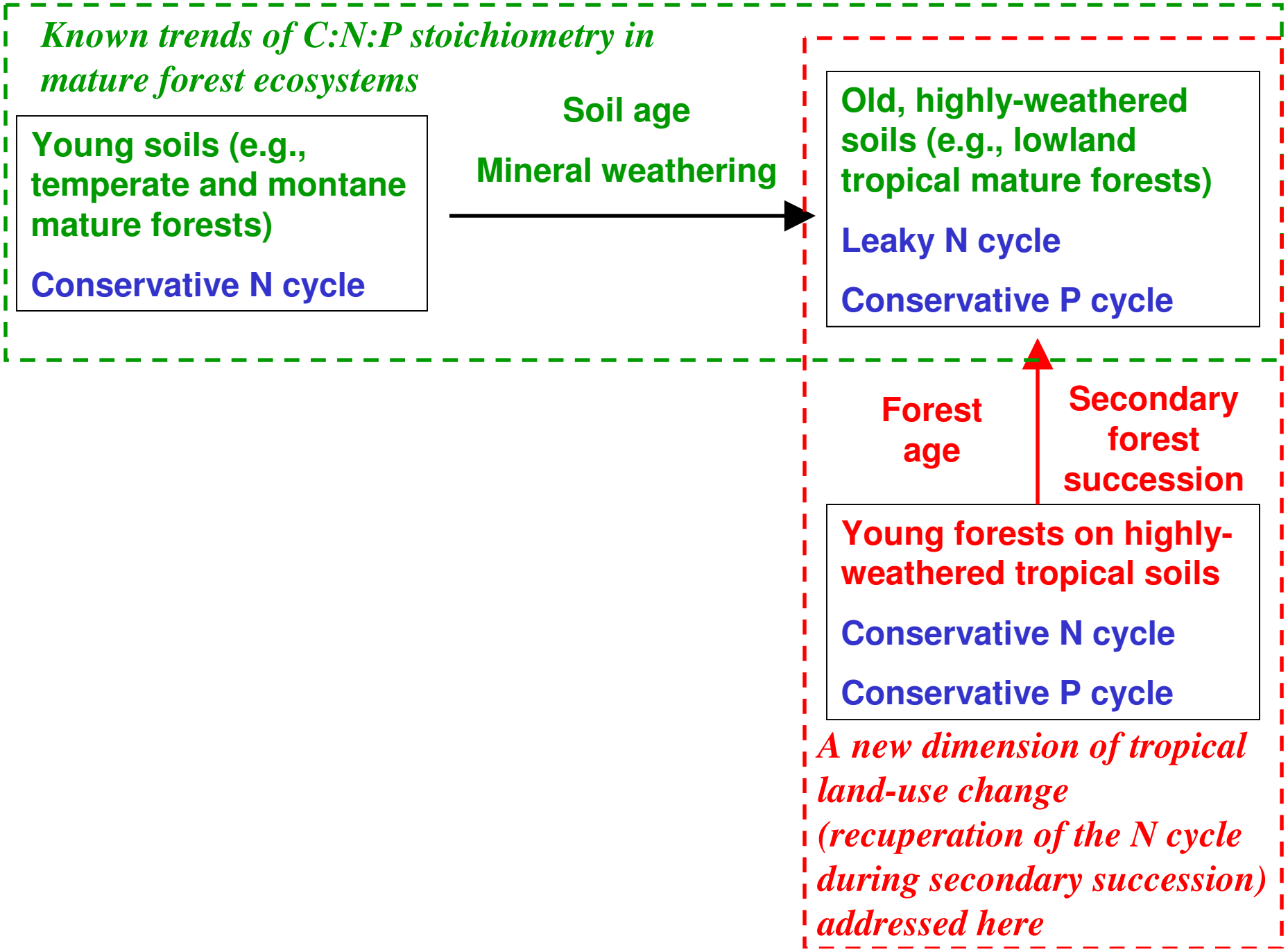
In sites that have burned repeatedly, the observed rates of secondary forest regrowth fall below expectations based on a previously validated empirical model that predicts growth from climate and soil properties. From Zarin et al. Front. Ecol.& Environ. 2005. 3:365-369



Davidson et al. 2004. Ecological Applications 14:S150-S163

- Atmospheric deposition inputs: 2-6 kg N ha^{-1} yr^{-1}
- Biological N fixation?
- Accumulation in woody biomass: 3-8 kg N ha^{-1} yr^{-1}
- Accumulation in canopy foliage: 11 kg N ha^{-1} yr^{-1}
- About 100 kg N ha^{-1} accumulates within the litter layer within the first 6 years.
- Mineral soil (top 30 cm) N stocks: 2000-3000 kg N ha^{-1})

The rate of recuperation of N cycling processes during secondary succession may reflect, in part, the kinetics of mobilization of recalcitrant forms of soil N to an actively cycling N pool.


Known trends of C:N:P stoichiometry in mature forest ecosystems
Young soils (e.g., temperate and montane mature forests)
Conservative N cycle
Soil age
Mineral weathering
Old, highly-weathered soils (e.g., lowland tropical mature forests)
Leaky N cycle
Conservative P cycle
Forest age
Secondary forest succession
Young forests on highly-weathered tropical soils
Conservative N cycle
Conservative P cycle
A new dimension of tropical land-use change (recuperation of the N cycle during secondary succession) addressed here