Leaching of essential nutrient cations and anions from undisturbed lowland forests across the Brazilian Amazon Basin

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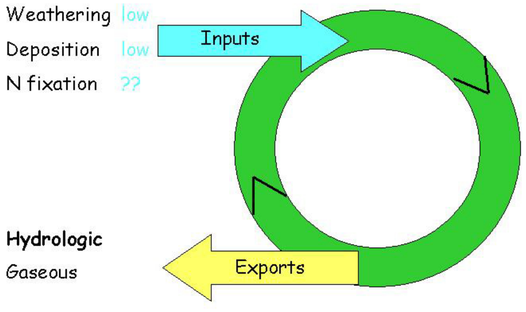
Introduction:

Losses of essential nutrients can feed back to control both storage and availability of nutrients in terrestrial ecosystems (Hedin et al. 2003; Vitousek et al. 1999; Hedin et al. 1995). This mechanism is especially relevant for nutrients that exist in complex dissolved organic forms, which (in contrast to inorganic nutrients) can be exported from ecosystems unaffected by immediate plant and microbial assimilation. Such dissolved organic forms of nitrogen (DON) or phosphorus (DOP) can represent major losses of nutrients from ecosystems (Perakis and Hedin 2002; Hedin et al. 2003). Together with external inputs, such losses define nutrient balances and cycling in terrestrial ecosystems, which, in turn, defines how these systems respond to climate change, CO2 fertilization, N deposition, land clearing, and other disturbances.

We know very little, however, about how losses of dissolved organic and inorganic nutrients are organized in ecosystems unaffected by modern human influences (Hedin et al. 1995). And yet, such information is critical in order to better understand the initial, pre-industrial, conditions of natural ecosystems - a kind of *baseline* against which it is possible to better judge trajectories of change in modern ecosystems (Hedin et al. 1995). We here expand upon earlier efforts to develop such a baseline for temperate forests throughout unpolluted areas of southern Chile and Argentina (Hedin et al. 1995; Perakis and Hedin 2001). We consider old-growth and unpolluted temperate forested watersheds across the Brazilian Amazon Basin. The largely unpolluted nature of these forests, offers a unique opportunity to examine nutrient losses in ecosystems that are naturally N rich and P limited.

Figure 1



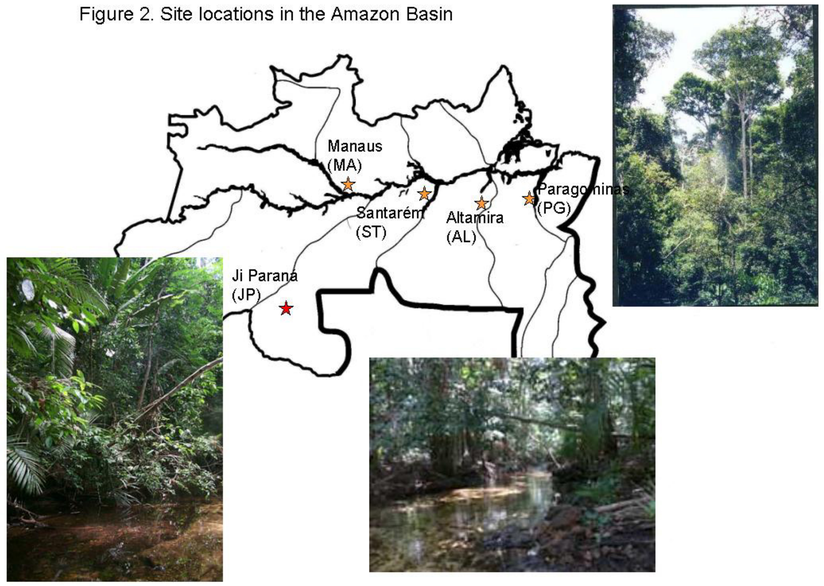
Research Questions:

What is the baseline variability in stream nutrient chemistry under mature tropical lowland forests?

Do stream nutrient concentrations vary with soil nutrient availability?

To address such a spatially extensive question, concerning variations in ecosystem properties across the entire Amazon Basin, we adopted the approach of Perakis and Hedin (2002), which substitutes geographically extensive sampling of the chemistry of watershed streams across broad forested regions for intensive studies of single watersheds. This approach includes natural variations owing to differences in environmental factors between streams (e.g., climate, slope, flow paths, etc.) and time. The approach assumes that internal variations in nutrient chemistry of single ecosystems, by and large, remain small relative to trends that appear across strong environmental gradients. While the approach is designed to capture more residual variation than intensive, single watershed studies, it is precisely this variation that we seek to evaluate for evidence of structure across gradients in key state factors.

Figure 2. Site locations in the Amazon Basin



Sites	Soil pH	Soil C (%)	Soil N (%)	Basal area (m^2 ha^{-1})
Altamira	5.2	1.46	0.20	50
Ji-Parana	4.9	1.26	0.11	39
Paragominas	4.4	2.39	0.22	28-30
Santarem	4.2	2.26	0.17	24.4
Manaus	4.4	1.00	0.07	33-40

Altamira: Moran et al. 00 , Lu et al. 02

Ji- Parana: Alves et al. 97, Neill et al. 97

Paragominas: Markewitz 01, Moran et al. 00

Santarem: Silver et al. 00, Williams et al. 02

Manaus: Luizão 89, Luizão et al. 04

Figure 3. Base cation concentrations in first-order streams (data for Ji Parana in open symbols from ND-03)

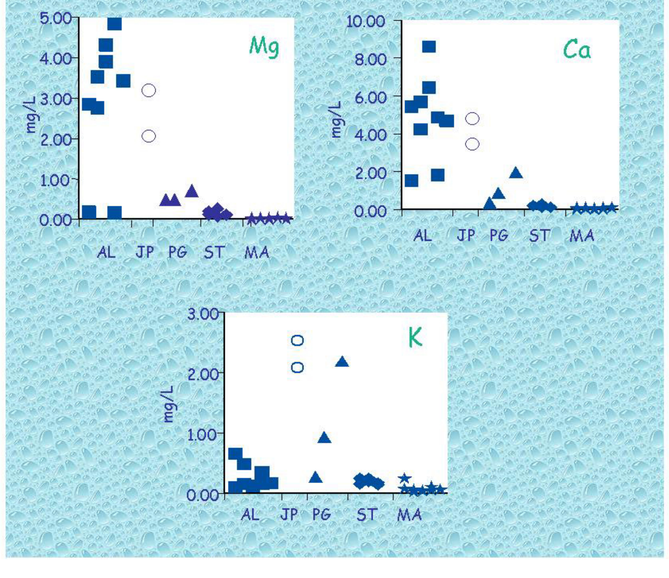
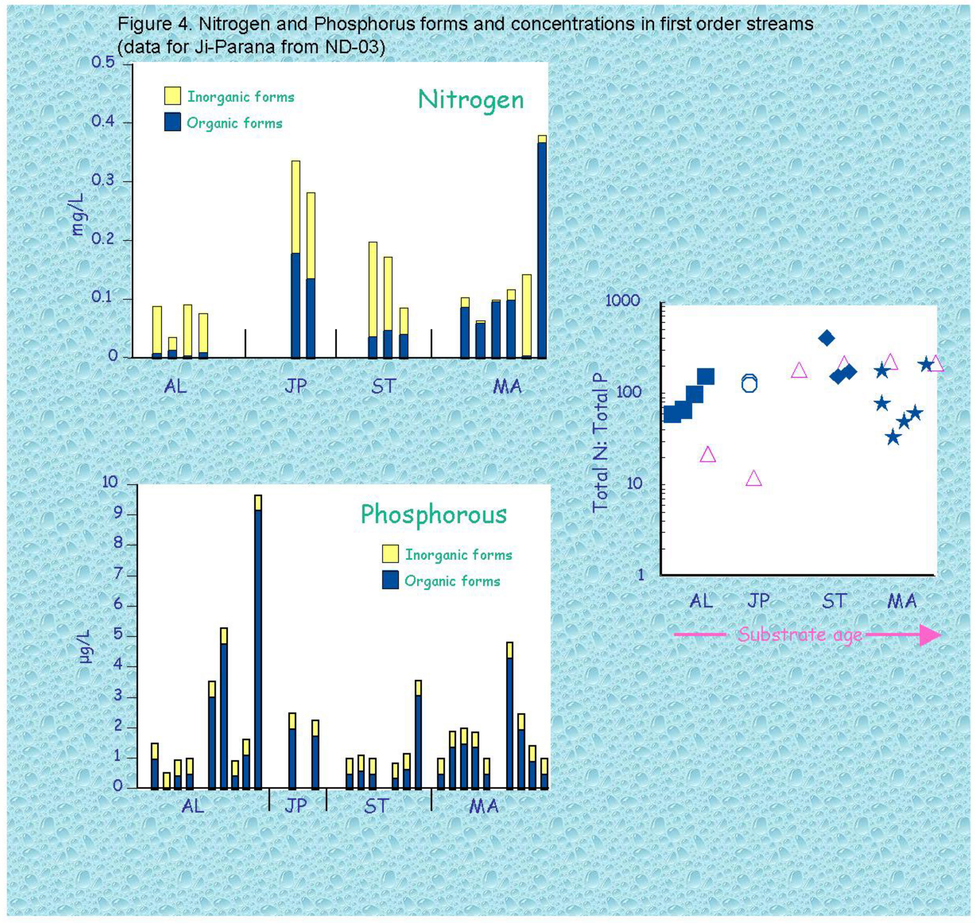


Figure 4. Nitrogen and Phosphorus forms and concentrations in first order streams (data for Ji-Parana from ND-03)



Results:

- Streamwater Ca, Mg and K concentrations all follow the fertility gradient proposed by literature values for soil characteristics and basal area.
- Nitrogen concentrations at most sites were largely dominated by inorganic forms (particularly NO3--N) with the exception of Manaus where organic forms dominated streamwater N concentrations
- Streamwater phosphorus concentrations were, in contrast, always dominated by organic forms, in fact no inorganic P was detected in any streamwater samples.
- Total N to P ratios from the Amazonian streams sampled were consistently > 30, suggesting P limitation to productivity. As a comparison, data from the Hawaiian Islands Long Substrate Age Gradient are also graphed (in pink symbols). Fertilization studies have shown that the older sites on the Hawaiian gradient are P limited while the younger sites N-limited.

Summary:

- Strong differences in base cation concentrations appear to be linked to soil nutrient status
- N and P concentrations in streamwater do not appear to correspond to variations in soil nutrient status
- As predicted N concentrations are relatively high and dominated by NO3-N and P concentrations are low and dominated by organic forms
- PO_4-P below detection limits for > 90% of samples - a trend to higher concentrations in the wet season

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