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Response of the N and P cycles of an old-growth montane forest in Ecuador to experimental low-level N and P amendments

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Abstract

Atmospheric nitrogen (N) and phosphorus (P) depositions are expected to increase in the tropics as a consequence of increasing human activities in the next decades. In the literature, it is frequently assumed that tropical montane forests are N-limited, while tropical lowland forests are P-limited. In a low-level N and P addition experiment, we determined the short-term response of N and P cycles in a north Andean montane forest on Palaeozoic shists and metasandstones at an elevation of 2100 m a.s.l. to increased N and P inputs. We evaluated experimental N, P and N + P additions (50 kg ha^{-1} yr^{-1} of N,

10 kg ha^{-1} yr^{-1} of P and 50 kg + 10 kg ha^{-1} yr^{-1} of N and P, respectively) and an untreated control in a fourfold replicated randomized block design. We collected litter leachate, mineral soil solution (0.15 and 0.30 m depths), throughfall and litterfall before the treatment began (August 2007) until 16 months after the first nutrient application (April 2009). Less than 10 and 1% of the applied N and P, respectively, leached below the organic layer which contained almost all roots and no significant leaching losses of N and P occurred to below 0.15 m mineral soil depth. Deposited N and P from the atmosphere in dry and wet form were retained in the canopy of the control treatment using a canopy budget model. Nitrogen and P retention by the canopy were reduced and N and P fluxes in throughfall and litterfall increased in their respective treatments. The increase in N and P fluxes in throughfall after fertilization was equivalent to 2.5% of the applied N and 2% of the applied P. The fluxes of N and P in litterfall were up to 15% and 3%, respectively, higher in the N and N + P than in the control treatments. We conclude that the expected elevated N and P deposition in the tropics will be retained in the ecosystem, at least in the short term and hence, N and P concentrations in stream water will not increase. Our results suggest that in the studied tropical montane forest ecosystem on Palaeozoic bedrock, N and P are co-limiting the growth of organisms in the canopy and organic layer.

Research highlights

▸ Low-level repeated N and P additions to tropical montane forest remain in the ecosystem. ▸ N and P additions reduce canopy uptake of these elements from the atmosphere. ▸ N and P additions increase internal N and P fluxes with throughfall and litterfall. ▸ N and P seem to be co-limiting canopy and organic layer organisms. ▸ Low-level N and P additions do not increase N and P concentrations in surface water at the short run.

Keywords

- Tropical montane forest;
- Nutrient cycle;
- Leaching losses;
- N deposition;
- P deposition;
- Environmental change

Figures and tables from this article:

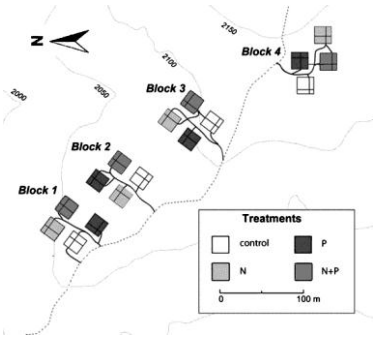

Fig. 1. Location of the study sites. Dotted lines within plots represent transects and continuous lines between the plots represent the access roads.

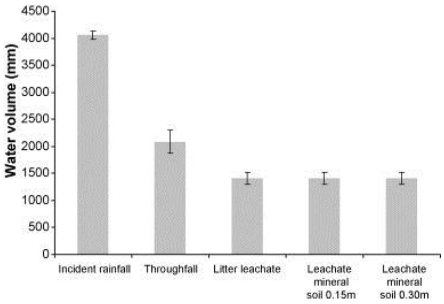

Fig. 2. Water budget during the study period (19/08/2007–25/04/2009). Error bars represent standard deviation.

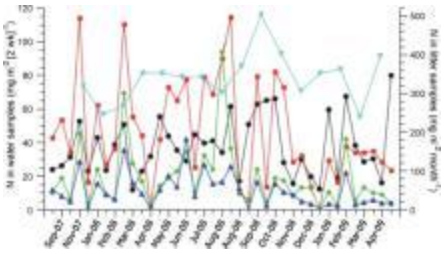

Fig. 3. Total N fluxes with throughfall (●), litter leachate (■), soil solution at 0.15 m (◆), soil solution at 0.30 m (▲) and litterfall (▼) in the control treatment.

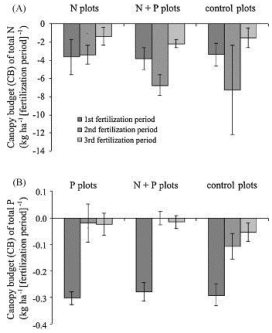

Fig. 4. Canopy budget (CB) of (A) total N and (B) total P for the three fertilization periods. Negative values of CB indicate net retention in the canopy. Error bars represent standard deviation.

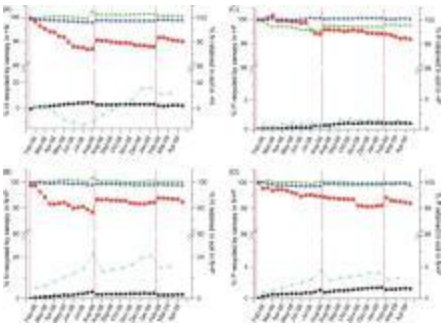

Fig. 5. Cumulative losses of N or P from the canopy with throughfall (●) and litterfall (▼) and cumulative retention of applied N and P in soil: litter leachate (■), soil solution at 0.15 m (♦), and soil solution at 0.30 m (▲). (A) N in N plots, (B) N in N + P plots, (C) P in P plots, (D) P in N + P plots. The shown values were calculated as differences between fertilized and unfertilized control treatments. Fertilizer application dates are indicated by vertical red lines.

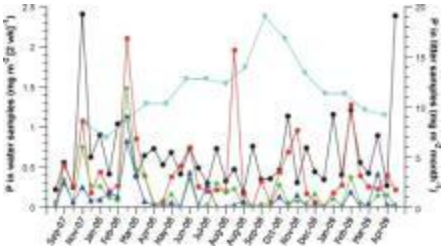

Fig. 6. Total P fluxes with throughfall (●), litter leachate (■), soil solution at 0.15 m (♦), soil solution at 0.30 m (▲) and litterfall (▼) in the control treatment.