Long-term variability of litterfall nitrogen and phosphorus in a tropical dry forest of Mexico

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INTRODUCTION

Litterfall in tropical dry forest (TDF) ecosystems represents a relatively short-term pulse that responds to the seasonality of rainfall, the main controlling factor of ecosystem dynamics in TDF. Also, TDF may display a high degree of heterogeneity, due to both plant species distribution and landscape features.

Long-term studies of litterfall nutrient fluxes in TDF are scarce, despite their relevance for the understanding of the impact of changing climate on ecosystem dynamics.

Available evidence from nutrient studies in tree leaves of the TDF in the Chamela region of Mexico, allow us to hypothesize that litterfall N and P should show differing responses to variation in rainfall and sites.

The main objective of this work is to study the dynamics of litterfall nutrients (N and P) over a period of 9 years with contrasting precipitation, in sites located within different small watersheds in the landscape.

MATERIALS and METHODS

Study Site (Fig. 1)
- Chamela-Cuixmala Reserve
- Mean annual ppt: 736 mm, mostly July to November
- Tropical Dry Forest: dense 4-15 m tall, with a well-developed shrub understory and a strongly seasonal phenology
- Poorly developed soils: regosols, luvisols and cambisols, rarely deeper than 1 m

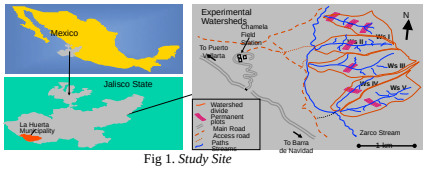

Fig 1. *Study Site*

Data collection - Litterfall samples are collected in littertraps in seven permanent sites within five small watersheds (Fig. 1).
Study period: 1995 – 2003
Seasons: dry (March-June), rainy (July-October) and transition (November-February)

Nutrient determination - Total N and P concentrations were determined by a semi-Kjeldhal method.

Data Analyses
- Site factor: single factor ANOVA; post-hoc Tukey test (p = 0.05)
- Relationship between mean annual rainfall and mean annual nutrient concentrations: linear regression
- Long-term trends: multiple mean time series model (lv=3, with seasonal means)

RESULTS and DISCUSSION

Mean N and P concentrations in litterfall and N:P ratios are consistent with values previously reported for the Chamela TDF, for a smaller number of years and sites.

Table 1. Nutrient concentrations (mg/g) in litterfall averaged over years and sites. Variation is indicated by the range and the coefficient of variation (CV).

	Among years			Among sites		
	N	P	N:P	N	P	N:P
Mean ± SE	17.6±1.7	1.6±0.3	13.4±2	18±2.0	1.5±0.3	14.4±0.5
Range	16.6-20.3	1.1-2.6	9.6-19.0	17.7-18.8	1.3-1.7	12.6-16.5
CV (%)	23.8	41.2	35.3	28.1	51.9	44.9

Variation as expressed by the CV is greater among sites than among years in all cases. Also, P is more variable than N.

AMONG SITES

When averaged over years, litterfall N concentrations are similar (p = 0.44) among sites (Fig. 2), whereas litterfall P differs among sites (p < 0.001). There is a "high concentration" site (3), two "low concentration" sites (2 and 6) and four sites with "intermediate" values (1, 4, 5, 7).

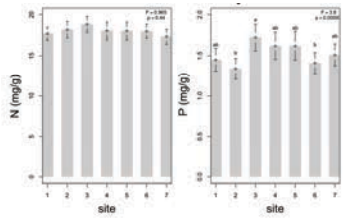

Fig 2. Litterfall N concentrations (left) and P concentrations (right) in the different sites averaged over the years of study. P values test differences among sites after ANOVA. Columns with the same letters are not statistically different (p > 0.05)

To explore potential causes of among-site variation in litterfall nutrients, especially for P, we use soil N and P data collected for the sites and use linear regression to establish possible relationships (Fig. 3).

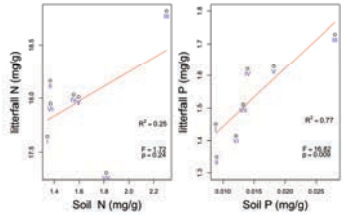

Fig 3. Regression models relating soil and litterfall nutrients at the sites. Soil N is total N and soil P is available P (PO_4).

Soil total N and litterfall N are not statistically related, which is consistent with the lack of site differences in litterfall N concentrations (Fig. 2).

Soil available P and litterfall P concentrations show a strong relationship (R^2 = 0.77); the "high and low" litterfall P concentration sites (Fig. 2) correspond to "high and low" available soil P sites.

AMONG YEARS

Litterfall mean annual N concentrations for all sites (Fig. 4) show less variation than litterfall P. Averaged over site for each year, litterfall P is related to annual rainfall (p = 0.06, R^2 = 0.4), but not litterfall N (p = 0.98, R^2 = 0.0002). Litterfall N is similar at all sites most years, whereas litterfall P shows greater among-site differences in wet (e.g. 1999) and smaller differences in dry (e.g. 2001) years.

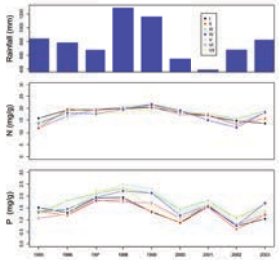

Fig 4. Annual rainfall (top) and mean annual N (center) and P (bottom) concentrations (mg/g) in litterfall in each site.

SEASONAL VARIATION

Litterfall N and P for each season are averaged over the sites and rainfall values are summed up for each 4-month period (Fig. 5).

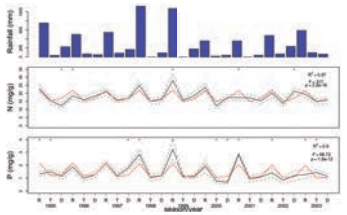

Fig 5. Seasonal variation of rainfall (top), litterfall N (middle) and P concentrations (bottom). Observed values (black solid line), confidence intervals (dashed line) and time-series fitted values (red line). * = seasons where data are different from model predictions. Seasons = rainy (r; July-October), transition (t; November-February) and dry (d; March-June).

Litterfall N and P vary in response to rainfall seasonality. As expected, N displays less variation than P. More rainy-season litterfall P values are greater than expected than litterfall N and show a higher number of significant discrepancies with seasonal model predictions (Fig. 5).

Table 2. Percentage prediction of the seasonal litterfall N and P concentrations by the time series model. R = rainy, T = transition, D = dry

	Total	R	T	D
N	81%	66%	100%	77%
P	59%	33%	66%	77%

Litterfall N can be highly predicted by the season means for the full data set (Table 2); differences among seasons are consistently similar. This suggests that litterfall N responds mostly to rainfall seasonality.

Litterfall P concentrations in the transition and dry seasons seem highly predictable (66% and 77%, respectively), but rainy season values are not (33%). This suggests that litterfall P responds to both rainfall seasonality and amount.

CONCLUSION:

The differing patterns, spatial and temporal, in litterfall N and P are consistent with previous findings with live and senesced leaves in the Chamela TDF and at smaller spatial and temporal scales. Litterfall N exhibits seasonal variation, small differences among sites and no relationship to annual rainfall. Also, litterfall N is not related to soil N. In contrast, litterfall P responds to both the seasonality and amount of rainfall, differences among sites are greater (especially in wet years) and is related to available soil P.

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