A landscape-scale assessment of nutrient limitation in the tropical forests of Luquillo, Puerto Rico

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Summary

We deployed a fertilized root ingrowth core experiment across a contrast in topographic position (ridge vs. slope) on two soil parent materials (volcaniclastic and quartz diorite) in the Luquillo Mountains of eastern Puerto Rico.

• Neither nitrogen (N) nor phosphorus (P) stimulated root ingrowth relative to control cores in either topographic position on either parent material.

• Cores on ridges had 1.5x more root biomass than those on slopes, regardless of parent material or fertilizer treatment.

Introduction

The nature and extent of nutrient limitation in tropical forest primary production has been explored for decades, but empirical data of growth responses to nutrient additions remains sparse [1]. In lieu of full forest fertilization, several proxies for nutrient limitation have been developed, each with its own caveats [2].

Fertilized root ingrowth cores have shown promise as a proxy for nutrient limitation to NPP. Nitrogen fertilized cores stimulated more root growth than controls in a Hawaiian montane forest where N limits net primary production [3,4]. We found a similar result using a slightly different method, though we found no difference in ingrowth among treatments (or relative to control) in a Hawaiian forest where P limits NPP (L. Schreeg, unpubl. data).

In this context, we explored how fine roots responded to fertilization in the Luquillo Mountains of Puerto Rico. We hypothesized root ingrowth on stable, highly-weathered ridges would respond most to P, whereas the response to N would be higher on slopes, as a result of the rejuvenation of P via erosion [5].

Ingrowth Core Design

We filled 10cm x 7.5cm cylindrical perforated plastic cores (32% void) with a mixture of silica sand, clay-sized silica, perlite, and either weak anion or cation resin beads loaded with NH_4Cl or H_3PO_4 (equivalent to 30-50 g m^{-2}) [6]. This produced elevated levels of available N (100 ±20 ppm) and P (160 ±10 ppm) in cores relative to controls (N = 0.4 ±0.06 ppm and P = 0.16 ±0.02 ppm) after two months.

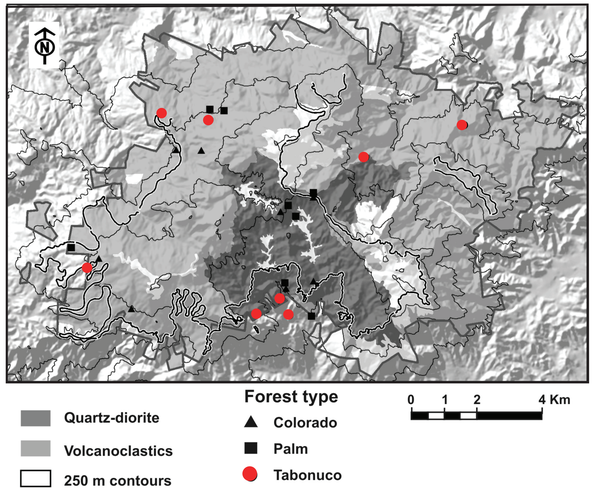

Figure 1. Geologic map of the luquillo mountains and the location of our sites (red circles). Sites ranged from 350-650m in elevation, were in tabonuco-type forest, and had map 3-3.5 m y^{-1}.

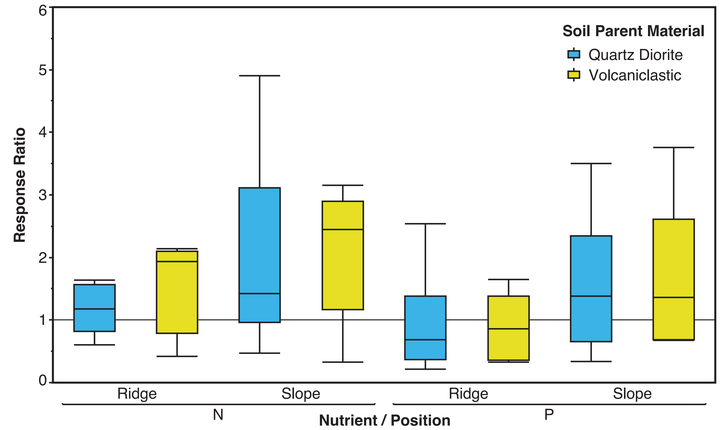

Figure 3. Response ratio (treatment/control) across the sub-watersheds. N(QD) = 54, N(VC) = 26.

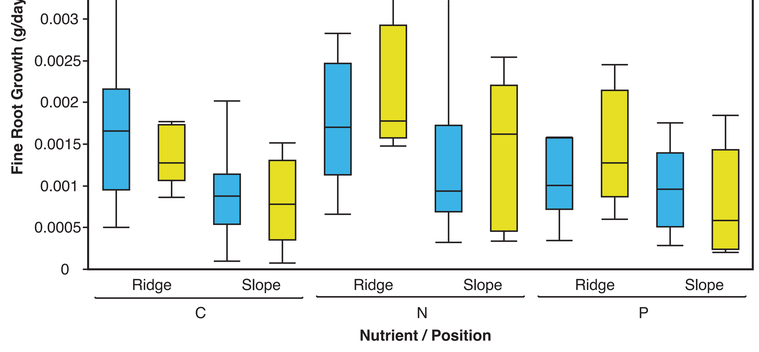

Figure 4. Response ratio (treatment/control) across the sub-watersheds. N(QD) = 92, N(VC) = 47.

Ingrowth Core

Experimental Design

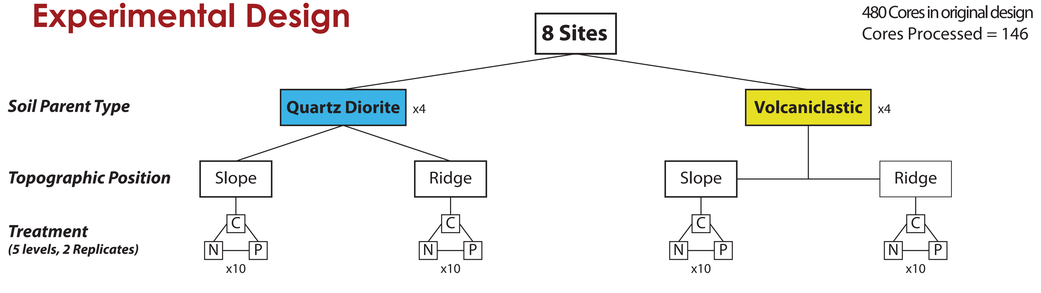

Figure 2. In June 2012, we placed 30 cores in 10, 1m triangles on a ridge and a slope in each of 8 sub-watersheds (4 on quartz diorite, 4 on volcaniclastic). Each triangle contained one core of each treatment (C, N, P). The original experiment had five levels of fertilization for each nutrient (each replicated twice at each topographic position) but here we report only results from the most heavily fertilized cores (30-50 g m-2). Thus N=4 for each nutrient in each topographic position, with four replicates of that topographic position on each rock type.

Sample Processing

We estimated fine root biomass (<2mm) by picking roots for 5, 8-minute sessions. We plotted cumulative root mass against time, fit a logarithmic curve, and estimated total mass as the mass at which the increment between consecutive intervals was below 1% of the total mass (mean r2 = 0.97, SD = 0.025) [7].

Data Analysis

• We calculated the ratio of root mass in each treatment core to the control core in the same triangle. We tested for fertilizer and topographic effects using a mixed model ANOVA with topographic position, treatment (N, P; N, P, Control), and nutrient x position as fixed effects and site as a random factor.

• We evaluated cores from quartz diorite and volcaniclastic parent material separately. We are still processing cores from the volcaniclastic parent material, so results from volcaniclastic are preliminary.

Discussion

Response Ratio:

Our result of no increased growth into N or P-fertilized cores relative to control leads us to infer a lack of N limitation in this landscape. This interpretation is consistent with the result of a nearby plot-scale fertilization experiment that showed no change in NPP with N fertilization 8.

Root Production:

A recent meta-analysis suggests root production in montane tropical forests is correlated with total soil N 9 and fine root production and turnover increase with soil N-availability 10. Across our sites, however, total N does not vary between ridges and slopes (A.H. Johnson, unpubl. data), and neither does net N mineralization or nitrification (M. Almaraz, unpubl. data). We attribute the higher root ingrowth on ridges to greater surface stability, rather than a strong signal of different nutrient status.

References

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