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Drivers of Tree Species Effects on Phosphorus and Cation Cycling in Plantations at La Selva Biological Station, Costa Rica

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Introduction

Regenerating forests comprise a rapidly increasing proportion of humid tropical forests and can sequester large amounts of carbon, thereby playing an important role in global carbon cycling. The question becomes:

How does nutrient cycling keep pace with rapid C cycling?

Our focus is on the belowground drivers, using differences among four tropical tree species to evaluate mechanisms.

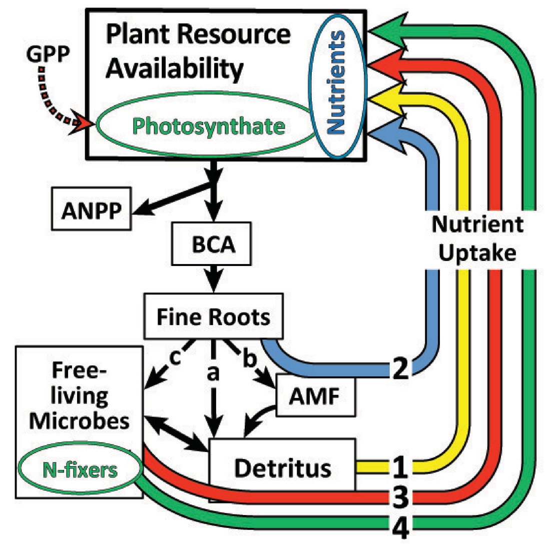
Conceptual Framework & Hypotheses

Carbon fixed during photosynthesis is transported from leaves to roots via at least three alternative anabolic pathways, with belowground carbon allocation (BCA) to:

a) Fine root (FR) growth and FR detrital production, which support free-living microbes
b) Arbuscular mycorrhizal fungi (AMF)
c) Root exudates that support rhizosphere heterotrophs. (Fig. 1)

The quantity and partitioning of BCA could influence plant nutrient uptake via at least four distinct mechanisms (Fig. 1). Greater partitioning to:

Figure 1



1) **Fine roots** ⇨ >Exploration and scavenging of soil ⇨ >Cation uptake
2) **AMF** ⇨ Symbiosis with fine roots ⇨ >Phosphorus uptake
3) **Heterotrophs** ⇨ Mineralization, priming of soil organic matter ⇨ >N uptake
4) **N-fixing microbes** ⇨ Mineralization of soil organic matter ⇨ >>N uptake

Hypothesis regarding cations: Cation stocks in aboveground biomass will be correlated with fine-root growth. Rationale: Fine roots allow for greater exploration of elements on exchange sites of mineral soil.

Study Site and Methods

Climate: MAP: 4000 mm; MAT = 25.8°C

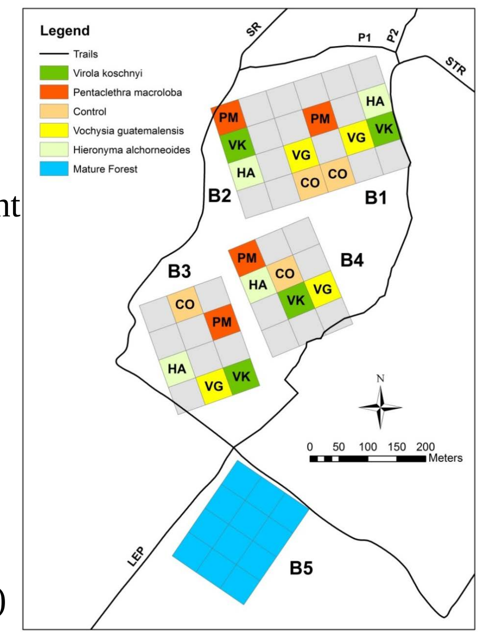
Soil: Acidic, highly weathered Oxisol

Site history: Deforested in 1955, pastured until1987. Experimental plantations established in 1988. All plots had similar climate, relief, parent material, time of development & human factors: only the tree species differed.

Experimental Design: Randomized complete block (RCB):

4 tree species (+ Control = no planted trees) x 4 Blocks

+ 1 Block of Mature forest = Incomplete RBC (to the right)



Tree Species:
Hieronyma alchorneoides (HIAL); *Pentaclethra macroloba* (PEMA)
Virola koschnyi (VIKO); *Vochysia guatemalensis*, Vochysiaceae (VOGU)

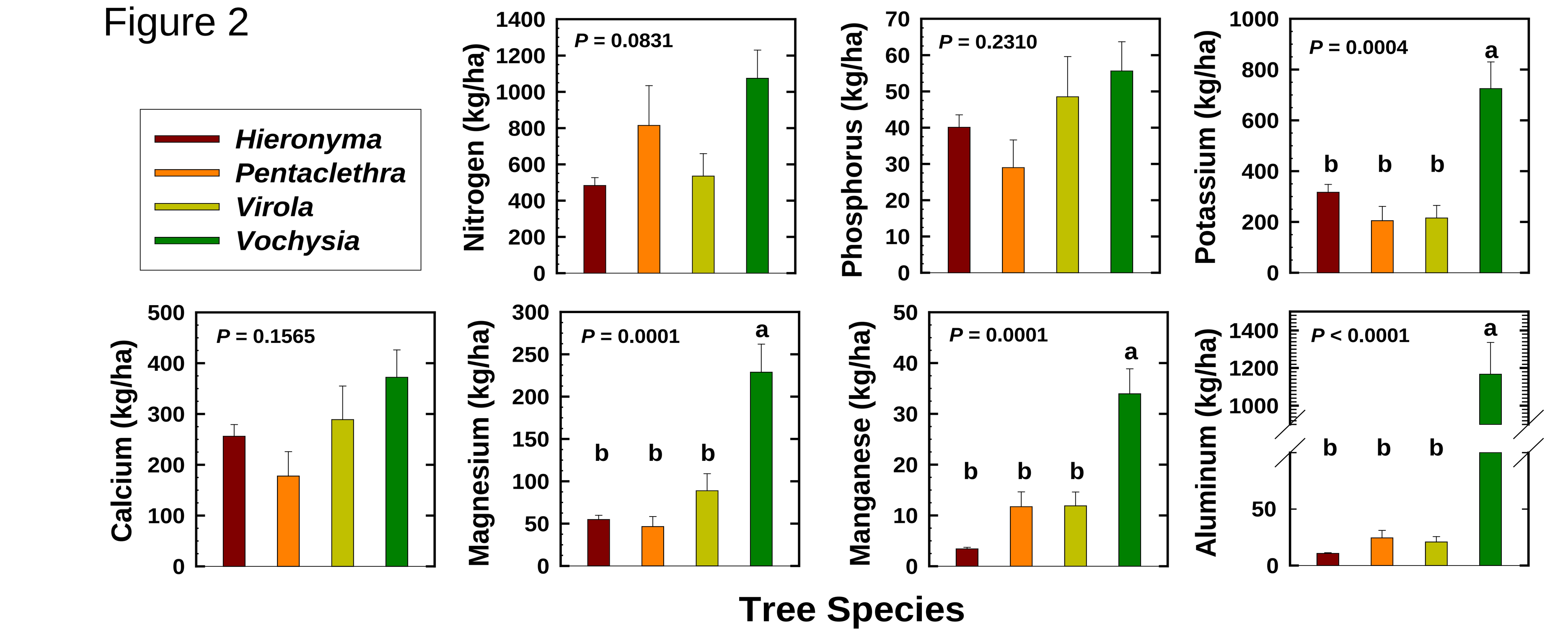
Methods, Field & Lab: *Biomass, fine root ingrowth , BCA* measured as in Russell et al. (2010). Cation (Ca, K, Mg, Mn) and P concentrations in plant tissues measured by microwave-assisted acid digestion and analyzed using ICP (Kingston et al., 1997); N determined by dry combustion using a using a Thermo-Finnigan EA Flash.

Results

Element Stocks in Aboveground Tree Biomass

Tree species differed significantly in stocks of magnesium, manganese, potassium, aluminum and iron (not shown) accumulated in aboveground biomass at 25 years of age (Fig. 2). However, the species did not differ (α = 0.05) in stocks of nitrogen, phosphorus or calcium.

Figure 2



Mechanisms of Influence

- **Storage capacity:** Element stocks were **not** significantly correlated with aboveground tree biomass.
- **Concentrating potential:** Foliar concentrations of elements were **not** correlated with aboveground tree biomass, with the exception of aluminum.
- **Litterfall fluxes of elements** were **not** correlated with element stocks in tree mass, exc. for Al.
- **Fine root ingrowth** differed among species (Fig. 3) and **was** correlated with element stocks (Fig. 4).

Figure 3

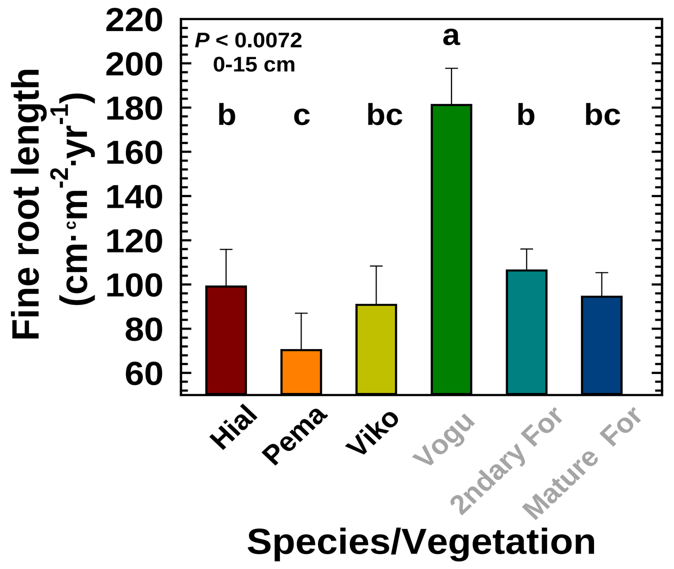
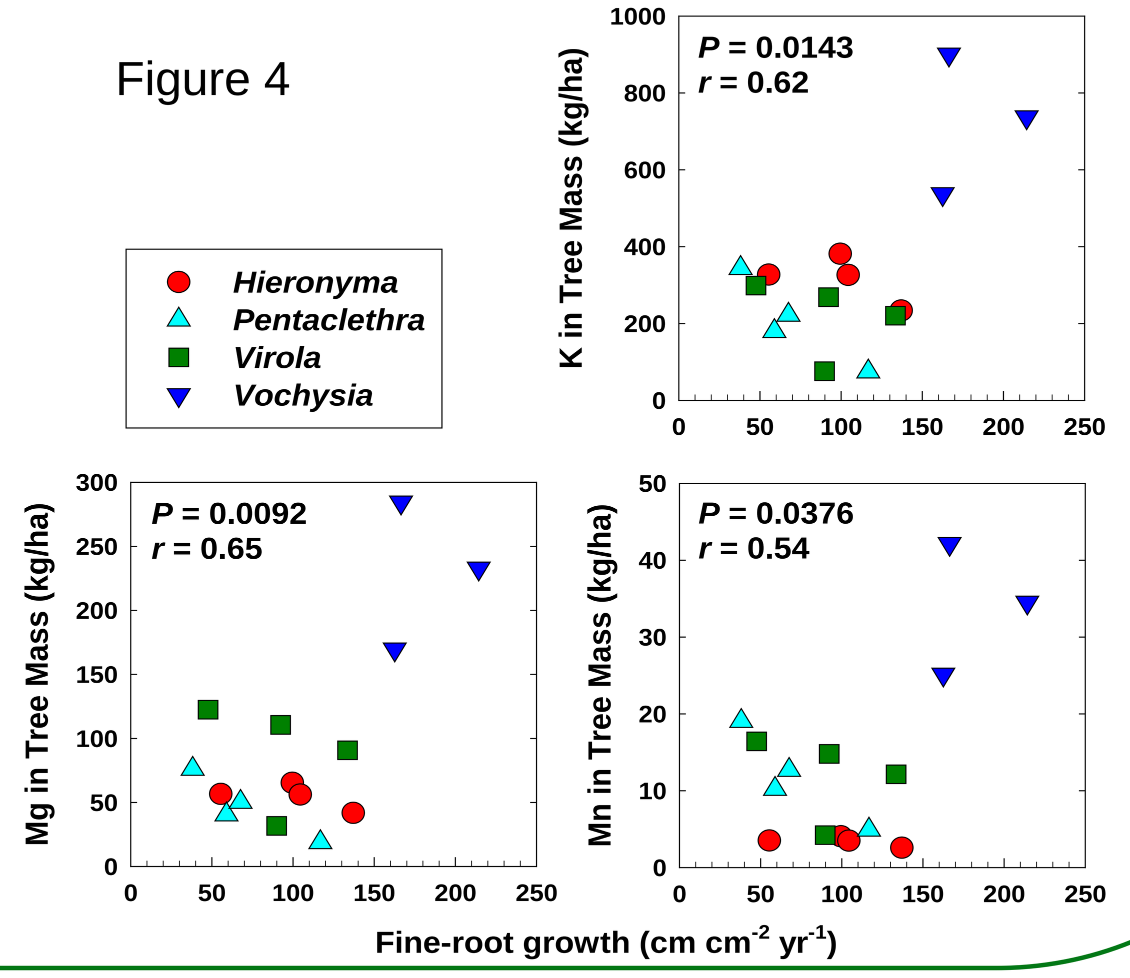
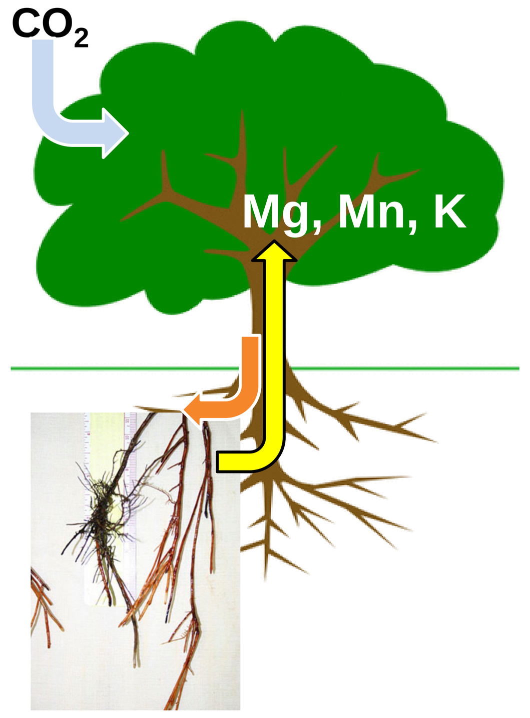


Figure 4



Conclusions

Allocation to fine roots (Pathway 1) was correlated with differences in cation accumulation in biomass



Results indicate that differences among tree species in fine-root growth translated into differences in:

- Scavenging and acquisition of cations, except for Ca.
- Accumulation in biomass of mineral-associated nutrients, i.e., K, Mg, and Mn.

Allocation to AMF & exudates (Pathways 2, 3, & 4 in Fig. 1) are undoubtedly important, but species did not differ significantly in N and P accumulated in aboveground tree mass. While mechanisms of acquisition and use of these nutrients may differ among species, this did not result in differences in accumulation in biomass.

References:

Kingston et al. 1997. In Microwave-Enhanced Chemistry: Fundamentals, Sample Preparation, and Applications. American Chemical Society, Washington, DC. pp. 223-349.

Russell et al. 2010. Ecol Applications 20:1087-1100

Acknowledgements

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