LITERATURE CITED

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Differences in soil properties between primary and secondary forests

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Abstract: Soil composition should differ between primary and secondary forests because of differences in plant communities and land use history. I predicted that tighter nutrient cycling in primary forests would produce a smaller litter layer and O horizon and a higher root/shoot ratio than secondary forest sites. I found instead that the secondary forest sites had a smaller litter layer and O horizon and a greater root/shoot ratio than the primary forest sites. This implies that the secondary forest soils I sampled were more nutrient limited than primary soils. The difference could be due to different soil textures, with the secondary soils being sandier than the primary soils, and to nutrient depletion that occurred in the secondary forest following deforestation.

Keywords: Inga sp, *nutrient cycling, root/shoot ratios, root biomass*

INTRODUCTION

Primary and secondary forests tend to have different soil characteristics. These can be influenced by different plant communities or by land use history. Primary forests often have tighter nutrient cycling patterns, with organic matter being broken down quickly and the nutrients being sequestered by plants. In addition, primary forests are usually more nutrient efficient, a result of being nutrient limited (D. Peart, *pers comm*). In nutrient limited soils, plants tend to put out more roots in an effort to obtain below-ground resources necessary for development. This results in greater root/shoot ratios.

Near the Estacíon Sirena in Corcovado National Park, C.R., land that is now secondary forest was used for farming until 1978. I hypothesized that these secondary forests would have different soil properties. Specifically, I predicted that the secondary forest would have greater litter layer and O horizon depths due to slower decomposition and less developed nutrient cycling there, and that the plants would have a smaller root/shoot ratio because of less nutrient limitation than in the primary forests.

METHODS

Seven random points at least 10 m apart were chosen along the Sendero Sirena, which passes through land that was farmland until 1978 and is now forested, and seven along the Sendero Espavales, which passes through mostly primary forest. Transects were walked from each point on 6 February 1999, starting five paces into the forest, until the first seedling (< 20 cm tall) of *Inga sp.* (Fabaceae) was found. *Inga* was chosen as the focal plant because it was common in both forest types. Percent canopy cover above each plant was measured using a spherical densiometer. pH and soil moisture were measured using a Demetra E.M. System Soil Tester. Litter and O horizon (decomposed organic material layer) depths next to each plant were measured to the nearest mm. Soil texture was classified on a scale from 1 to 5, with 1 being sand, 3 being clay, and 5 being loam. Each *Inga* seedling was carefully dug up, washed clean of dirt, and dried in the sun for 5 hrs. Root/shoot biomass was measured by cutting the plant at the root collar and weighing both roots and shoots to 0.05 g on a 5 g Pesola scale.

RESULTS

There was a trend for greater root/shoot ratios of *Inga* in the secondary (0.55 ± 0.04, mean ± SE) than primary forests (0.37 ± 0.08) (Fig. 1; t=1.97, df=12, P=0.07). Soil texture was significantly different between secondary (sandy-clay; rank 2.2 ± 0.2) and primary forests (loamy-clay; rank 3.9 ± 0.2) (X^2=10.4, df=1, P=0.001). Soil from secondary forest sites also had significantly less soil moisture than primary forest sites (Table 1, X^2=9.5, df=1, P=0.002). Canopy cover and pH did not differ significantly at *Inga* seedling sites in primary and secondary forests (Table 1; t=1.08, df=12, P=0.303, and t=-0.3, df=12, P=0.80 respectively).

Secondary forest sites had significantly smaller litter and O horizon depths than primary (Table 1, X^2=5.9, df=1, P=0.015 and X^2=5.7, df=1, P=0.017 respectively). There was no significant difference in temperature between primary and secondary forest sites when soil temperature was subtracted from air temperature (to account for differences due to sampling time) (Table 1, X^2=0.016, df=1, P=0.90).

Table 1. Physical characteristics around randomly selected *Inga* seedlings in primary (n=7) and secondary (n=7) forest sites at Corcovado N.P., Costa Rica. Differences in litter depth, O horizon depth, and soil moisture were significant (P<0.05, mean ± SE, see text).

Forest Type	Litter Depth (cm)	O horizon depth (cm)	Soil moisture (%)	Canopy Cover (%)	pH	Soil minus air temp °C
Primary	3.4 ± 0.7	2.7 ± 0.64	88.6 ± 0.9	79.6 ± 1.3	6.3 ± 0.07	1.4°C ± 0.1
Secondary	1.0 ± 0.4	0.7 ± 0.35	68.1 ± 3.7	77.6 ± 1.3	6.4 ± 0.08	1.3°C ± 0.2

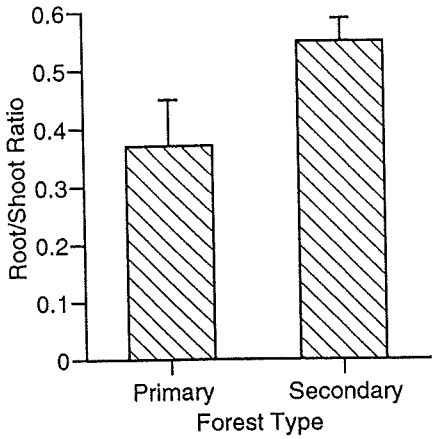

Fig. 1. Root/shoot ratio of *Inga sp.* seedlings in primary (n=7) and secondary (n=7) forest sites at Estacíon Sirena, Corcovado N.P., Costa Rica (mean ± 1 SE, P=0.07).

Discussion

The higher root/shoot ratio of *Inga* in the secondary compared to the primary forest was probably due to differences in the soil environment. Sunlight did not seem to be a factor differentially affecting seedling growth in the two forests, as the canopy cover over *Inga* did not differ significantly between secondary and primary forests. Therefore, *Inga* seedlings in the secondary forest were probably either nutrient or water limited, and required more roots per shoot mass than plants in the primary forest.

The difference in soil texture between forest types (sandy soil in secondary sites and loamy-clay in primary forest sites) probably is the main reason for the difference in root/shoot ratios. Sandy soils have a lower cation exchange capacity, and so hold fewer nutrients than clay. Therefore, the secondary soils may be more nutrient limited than the primary forest soils. In soils with low pH, base cations such as K^+, P^+, Ca^{2+}, and Mg^{2+}, which are important nutrients for plants, are replaced with protons and leached out of the soil. pH did not differ significantly between soils, so acidity did not seem a likely cause of differences in nutrient levels in these two tropical forests soils.

Greater soil moisture in the primary forest could be due to the greater litter layer and O horizon compared to the secondary forest, which would prevent water from evaporating. As well, clays dry out more slowly than sandy soils, thereby increasing soil moisture. Temperature did not differ significantly between sites, and thus could not affect soil moisture levels.

Differences in soil type may partially be the result of differences in past usage and geological history. Unlike the primary forest sites, the secondary forest sites I sampled were farmed until 1978, and therefore cleared of trees, which in tropical areas often results in nutrient leaching (D. Peart, *pers comm*). Also, the secondary forest sites I sampled were on flat land < 500 m from the ocean, which could explain the sandy soils there. The primary forest, however, was farther from the ocean and likely on volcanic or alluvial soils.

The deeper litter layer and O horizon in the primary compared to the secondary forest could be due to greater organic input rates. However, if the decomposition rates differ between forest types, then inputs might be equal. Slower decomposition, perhaps due to tougher leaves that resist decomposition, returns nutrients to the soil less quickly, implying that the primary forest could be less nutrient limited than the secondary forest.

In conclusion, significant differences in soil characteristics existed between sites, with the primary forest having a deeper litter layer and O horizon, greater soil moisture, and more clay-like soils than in the secondary forest. *Inga* seedlings in the secondary forest had a greater root/shoot ratio than in the primary forest. These findings suggest a lower nutrient availability in the secondary forests, which may be related to past use and geological history.