The Effects of Light Availability and Soil Type on Forest Structure

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Abstract: Forest structure- measured as the proportion of individual plants in multiple growth form categories- was compared between shale and clay soils in the Lambir Forest CTFS plot, and among sites with different canopy openness. It was found that clay soils supported a higher proportion of understory growth forms compared to shale soils, and that these soil type effects were independent of canopy openness.

Introduction: The species composition of the Lambir Hills Forest has been found to vary between the different soil types present at the site, which differ in their nutrient availability and water retention properties (Palmiotto 2004). Aerial surveying has suggested that these soil types also host different forest structures, which affects their light availability, animal niches, and microclimate. However, the relationship between species composition, abiotic factors, and forest structure on these soil types is largely unknown (Ashton and Hall, 1992). The differences in forest structure due to soil type are investigated here, as well as the effects of canopy openness on this structure. It is predicted that the nutrient-poorer clay soils and plots with lower light availability will support more climbers and epiphytes, because they can possibly obtain nutrients from their host plants and reach light in the canopy.

Methods: Within the 52 hectare CTFS plot, five 5m x 5m plots were sampled in both clay-sandstone and shale soils. The area sampled within the two soil types was standardized for similarity in topography and density of the most abundant tree species, *Dryobalanops aromatica,* although plots were chosen randomly within those areas. In each plot, the number of individuals was recorded in each category of growth form, namely overstory tree (at or near maximum canopy height), understory tree (above 10 feet tall), tree seedling at shrub height (3-10 feet tall), tree seedling at low growth height (below 3 feet tall), climber, epiphyte, low growth (mature height less than 3 feet tall), and shrub (branching from the ground, usually below 5 feet tall). Tree seedlings were recorded separately from other understory species because of their eventual role in replacing the current overstory. Canopy openness was measured by photographing the plots in each corner and the center, then determining the light levels using the light level scale in GIMP software and averaging the levels for each plot. (Multiple photographs were used to reduce variation in light level observed within the plot area.) All photographs were taken between 10:30- 11:00 AM in similar weather conditions. The proportion of each growth form within the plots was compared between the two soil types using a chi-square test, and correlated with light levels. The association was also examined between tree proportions (both overstory and understory) and the proportion of the other growth forms, to see how tree composition affected other components of forest structure between the two soil types.

Results: The proportion of growth forms (Fig.1) was found to be significantly different between the two soil types ($p = 0.04691$, $\alpha = 0.05$). The clay soil forest contained more understory trees, climbers, shrub-size seedlings, and low-growth plants, while the shale soil forest had more shrubs. There was no difference between soil types for low growth-size seedlings, overstory trees, or epiphytes, which were uncommon in this forest (Fig. 2). There was also no significant correlation between light level and the proportion of any growth form, or between the frequency of overstory or understory trees and any other growth form consistently on both soils (Fig. 3). However, a significant correlation was found between overstory tree and shrub-height seedling frequency in the shale soil, and between understory tree and low-growth-height seedling frequency in the clay soil.

Discussion: The clay soil forest had more individuals concentrated in the understory than the shale soil forest, independent of canopy openness. The similarity in low-growth seedling level between the two

soil types suggests that lower seedling mortality may account for the increased understory trees and shrub-sized seedlings in the clay soil, possibly because the higher water content of the clay soil may allow more shallow-rooted young seedlings and low-growth plants to survive the cyclical Lambir forest drought events. The abundance of climbers was uncorrelated with light levels and overstory and understory tree frequency. The overall lack of correlation between growth form proportion and light level is difficult to account for, but this could be the result of the sampling method- the number of individuals may be a less sensitive measure for response to light than growth rate or biomass per growth form. Overstory and understory tree frequency did not correlate with the proportion of most growth forms, possibly because their dominant effect on the understory - decreasing light availability- was found to be unassociated with growth form frequency. It was found that increasing overstory frequency in the shale soils correlated with a decrease in shrub-height seedlings, suggesting that shading effects may have been present but measured incorrectly, or that another overstory density-dependent effect was taking place, like increased pathogen frequency or overly high root density. In the clay soils, a negative correlation was found between understory trees and low-growth seedlings, again suggesting shading or understory density-dependence effects.
Overall, specialization into certain growth forms was found to differ between the two soil types but not to correlate to light levels, indicating that understory growth forms have a better survival ability on the clay soils independent of light availability. This suggests that the water and nutrient properties of the clay soil are better able to support understory and low growth plants, which may contribute to the differences in species composition between the two soil types by favoring the survival of different species. Further research in this area could address what properties of the clay soil and its ecosystem favor understory and low growth species, and how the differences in forest structure between the two soil types affect the ecology of higher trophic levels in the two areas.

References

Aiba, S. & Kitayama, K. (2002), 'Effects of the 1997-98 El Nino drought on rain forests of Mount Kinabalu, Borneo', *Journal of Tropical Ecology* 18(02), 215-230.

Palmiotto, P.; Davies, S.; Vogt, K.; Ashton, M.; Vogt, D. & Ashton, P. (2004), 'Soil-related habitat specialization in dipterocarp rain forest tree species in Borneo', *Journal of Ecology* **92**(4), 609-623.

Figures

Soil Type	Overstory	Understory	Shrubs	Low-growth	Epiphytes	Climbers	Seedling-shrub	Seedlings-low growth
Shale	0.03191	0.12766	0.15957	0.03191	0.00000	0.07447	0.29787	0.27660
Shale	0.00000	0.05820	0.10582	0.04233	0.00000	0.04233	0.47090	0.28042
Shale	0.03797	0.06962	0.05696	0.01899	0.00633	0.06962	0.29114	0.44937
Shale	0.03509	0.06140	0.07895	0.03509	0.00000	0.18421	0.30702	0.29825
Shale	0.01538	0.03077	0.05769	0.04615	0.00000	0.05769	0.31923	0.47308
Clay	0.01724	0.17241	0.05172	0.06034	0.00000	0.07759	0.40517	0.21552
Clay	0.02256	0.06015	0.04511	0.07519	0.00000	0.07519	0.28571	0.43609
Clay	0.02424	0.06667	0.02424	0.04242	0.00000	0.13333	0.30909	0.40000
Clay	0.04651	0.09302	0.05814	0.02326	0.00000	0.10465	0.22093	0.45349

Figure 1. The prorpotion of each growth form in each soil type.

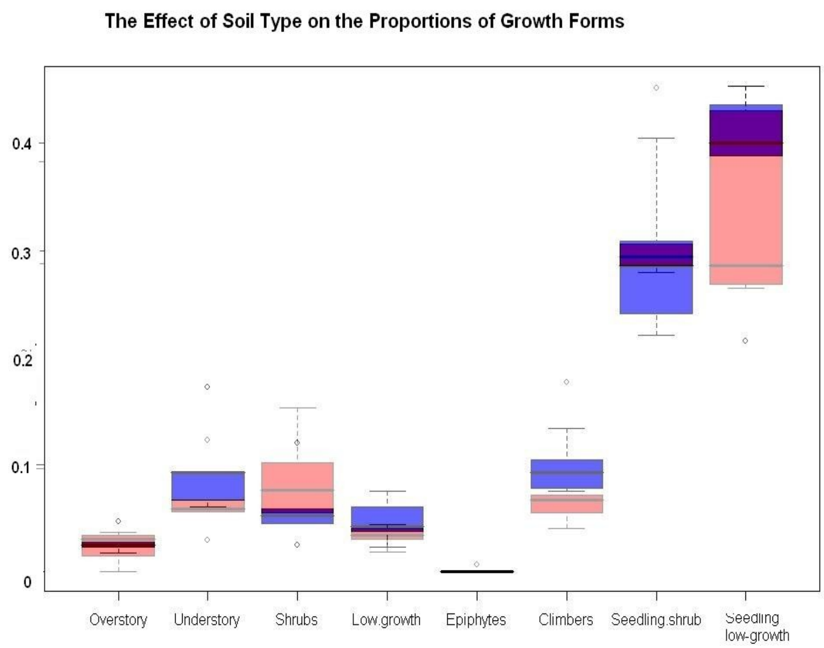

Figure 2: The proportion of each growth form compared between the two soil types. (Clay soil is indicated in red, shale soil in blue).

Shale					Clay				
x	y	Estimate	P-value		x	y	Estimate	P-value	
Light level	Overstory	0.00002190	0.9660		Light level	Overstory	0.00009239	0.8345	
	Understory	0.00124100	0.3446			Understory	0.00184200	0.2341	
	Shrubs	0.00039340	0.7723			Shrubs	-0.00091840	0.5025	
	Low growth	0.00005801	0.8631			Low growth	-0.00045370	0.5606	
	Epiphytes	-	-			Epiphytes	-	-	
	Climbers	-0.00160700	0.3299			Climbers	0.00045000	0.6240	
	Seedlings-shrub height	-0.00148800	0.5213			Seedlings-shrub height	0.00213600	0.4270	
	Seedlings-low growth height	0.00226000	0.4414			Seedlings-low growth height	-0.00314900	0.3648	
Overstory	Climbers	1.99878000	0.3175		Overstory	Climbers	0.66406000	0.6074	
	Shrubs	-0.13147000	0.9373			Shrubs	0.51118000	0.7990	
	Low growth	-0.50350000	0.1299			Low growth	-1.42736000	0.12	
	Seedlings-shrub height	-4.21270000	0.0395	**		Seedlings-shrub height	-5.08551000	0.1122	
	Seedlings-low growth height	0.81593000	0.8289			Seedlings-low growth height	5.47280000	0.2395	
Understory	Climbers	0.02405000	0.9807		Understory	Climbers	-0.22167000	0.4837	
	Shrubs	1.02529000	0.0661			Shrubs	0.09380000	0.8524	
	Low growth	-0.13729000	0.4309			Low growth	0.03061000	0.9144	
	Seedlings-shrub height	-0.56407000	0.6650			Seedings-shrub height	1.09450000	0.2079	
	Seedlings-low growth height	-1.54058000	0.3213			Seedings-low growth height	-1.92606000	0.0335	**

Soil Type Kruskal-Wallis chi-squared = 14.25, df = 7, p-value = 0.04691

Figure 3: The correlation between light level, proportion of overstory, and proportion of understory trees and proportion of each growth form category in both soil types. There was no significant association between light level and proportion of growth form, or most growth form categories and overstory and understory proportion (significant exceptions, such as that between understory and low growth height seedlings in clay soil and between overstory and shrub height seedlings in the shale, are marked on the table).