A comparison of tropical forest structure among four sites in Costa Rica

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Abstract: We studied forest structure and life-form composition in dry forest, pre-montane cloud forest, seasonal wet forest and wet rainforest in Costa Rica, CA. We recorded basal area, diameter at breast height, height class, life form, buttresses, bark type, liana load, bark microepiphyte load, macroepiphytes, the presence of termite nests, and whether individual trees were leguminous. We found differences in basal area and several compositional characteristics among sites. This data set can be augmented in future years, and will serve as a baseline to study and quantify the differences among Costa Rica's diverse tropical forests.

Key Words: basal area, dry forest, elevation, forest composition, pre-montane cloud forest, precipitation, prism method, rainforest, seasonality

Introduction

Climate, soil type, and elevation influence the distribution, abundance, and growth forms of plants. These factors ultimately determine the structure of forests, which then influences the plants, animals, fungi and microorganisms that contribute to the great diversity of tropical communities.

We sought to quantify and compare simple measures of forest structure over four very different tropical forests in Costa Rica. We included tropical dry forest, pre-montane cloud forest, seasonal wet rainforest forest and wet rainforest. Exploring the structural differences between these forest types will increase our understanding of the sources of diversity in tropical communities. Our work can serve as the first data set in an ongoing comparative study of forest structure between these sites.

Methods

We conducted our survey in primary forest at four sites in Costa Rica: Palo Verde National Park (tropical dry forest), Monteverde Biological Station (tropical pre-montane cloud forest), Corcovado National Park (tropical seasonally wet rainforest), and La Selva Biological Station (tropical wet rainforest).

We established two parallel transects 100 – 150 m apart at each study site. We sampled between five and ten points along each transect at 50 m intervals. To estimate basal area at each survey point, we used prism sampling as described by Marty (1999). For each tree included in the variable radius prism plot, we also measured diameter at breast height and noted the following characteristics: (1) height class as shrub, sapling, subcanopy, canopy, or emergent; (2) alive or dead; (3) life form as dicot, monocot, tree fern, hemiepiphyte, or liana; (4) buttressed, not buttressed, or stilt rooted; (5) bark type as smooth, flaky/peeling, or rough; (6) visible macro-epiphyte load as none, < 5, 5 – 20, or > 20; (7) bark microepiphyte load as none, < 20% cover, > 20% cover; (8) liana load (including vines) as none, one, 2 – 5, or > 5; (9) termite nest as none or 1 or more; (9) legume or not.

Results

Basal Area: Basal area differed significantly between sites ($F = 10.21$, $df = 3,47$, $P < 0.001$). Monteverde had significantly higher basal area than both La Selva and Palo Verde. Corcovado had significantly higher basal area than Palo Verde, but not La Selva (Fig. 1). The remainder of the results (below) have not yet been tested statistically.

Composition: In the results that follow, the percent basal area of trees in the various categories is equivalent to the percent of trees sampled, because the sample of

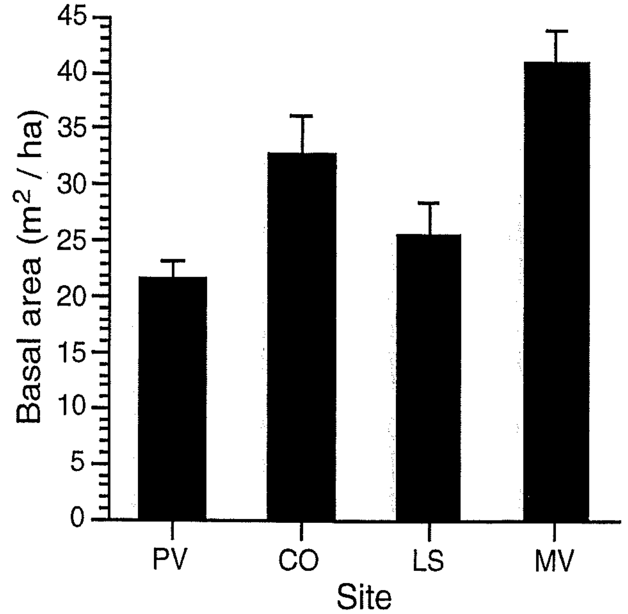

FIG. 1. Basal area (mean ± SE) for four forest sites in Costa Rica ($F = 10.21$, $df = 3,47$, $P < 0.001$). See Table 1 for sample sizes.

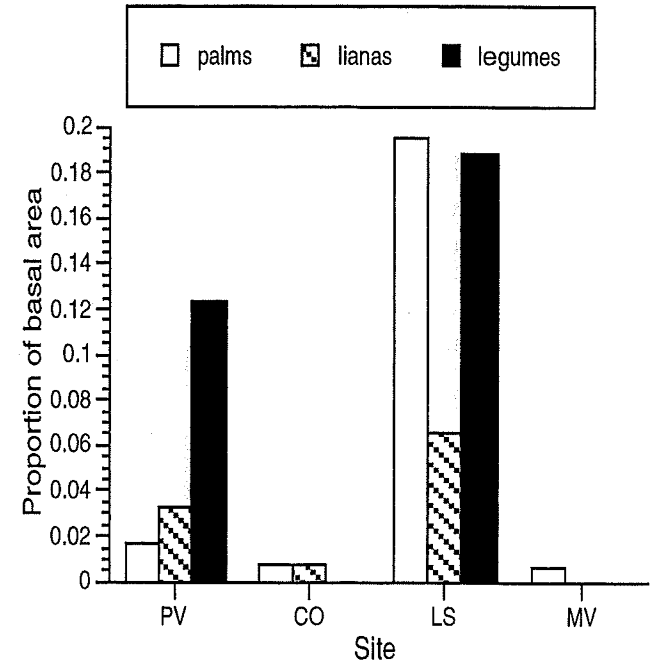

FIG. 2. Percent of live basal area in palms, lianas and legumes across four forest sites in Costa Rica. See Table 1 for sample sizes. Legumes were recorded only at Monteverde and La Selva. Values are also the proportions of individual trees in prism samples.

trees was obtained using prisms.

Of the two sites where we identified legumes, we found a higher percentage of basal area in leguminous trees at La Selva (19%) than at Palo Verde (12%) (Fig. 2). There was a much higher percentage of palms at La Selva (20%) than in any of the other sites (Fig. 2). Percent basal area contributed by lianas was highest at La Selva (7%) but was low at all sites (Fig. 2). There was approximately the same percentage basal area in standing dead wood across sites (~5%, expressed as a % of live basal area; Fig. 3). We found the greatest percentage of live basal area in large trees (> 50 cm diameter) at La Selva (27%), followed by Monteverde and Corcovado (20%); Palo Verde was the lowest at 12% (Fig. 3).

Buttresses: The proportion of trees with buttresses increased with both height and diameter. Overall, we found a higher proportion of buttressed trees at Corcovado, Monteverde, and La Selva than at Palo Verde. Across all sites, large trees (> 50 cm diameter) had many more buttresses than small trees (< 50 cm in diameter; Fig. 4). At Corcovado, 100% of the large trees and 56% of the small trees had buttresses. Across all sites, the greatest proportion of buttressed trees occurred in the emergent height class (Fig. 5). At Corcovado, 100% of emergent trees had buttresses, compared to only 31% at Palo Verde. We also found a large proportion of trees in the subcanopy with buttresses both at Corcovado (37%) and La Selva (36%).

Epiphytes: La Selva and Monteverde had similar abundances of macroephiphytes and were the only sites that had more than 20 on a single tree (Fig. 6). We found a high proportion of trees with no macroepiphytes at both Corcovado (87%) and Palo Verde (100%).

TABLE 1. Sample sizes (number of trees and number of prism points sampled at each location) in a comparative study of forest structure at four sites in Costa Rica.

Location	Abbreviation	Tree Sample Size (n)	Prism Point Sample Size (n)
Palo Verde	PV	121	14
Corcovado	CO	118	9
La Selva	LS	154	15
Monteverde	MV	163	10

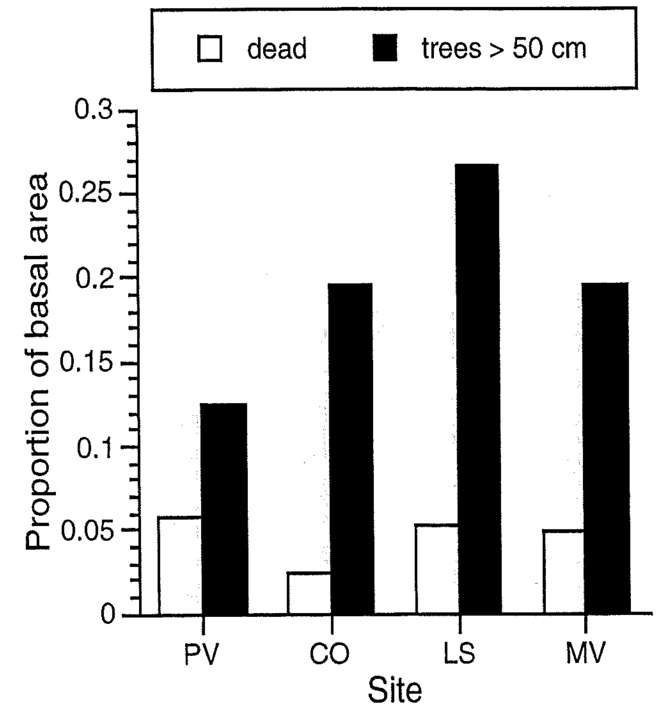

FIG. 3. Proportion of basal area in dead trees and trees > 50 cm at four sites in Costa Rica. See Table 1 for sample sizes. Values are also the proportions of individual trees in prism samples.

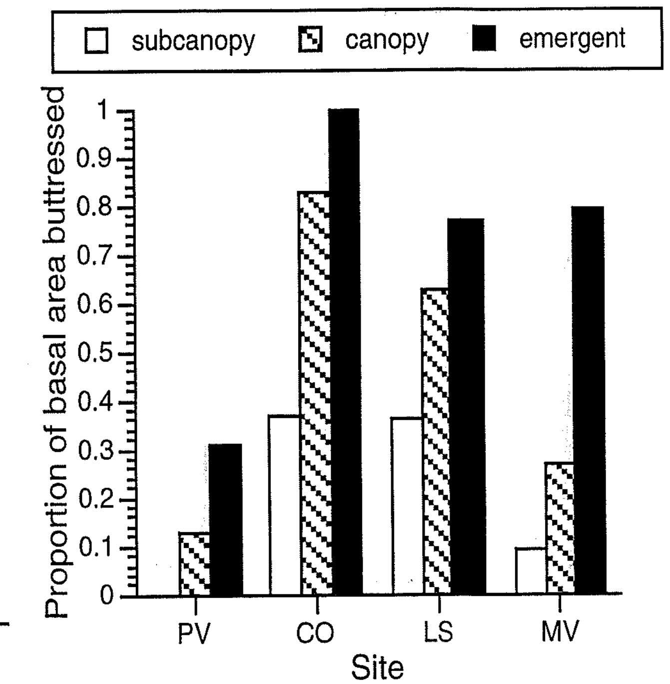

FIG. 5. Proportion of total live basal area buttressed, by height class, for four sites in Costa Rica. See Table 1 for sample sizes. Values are also the proportions of individual trees in prism samples.

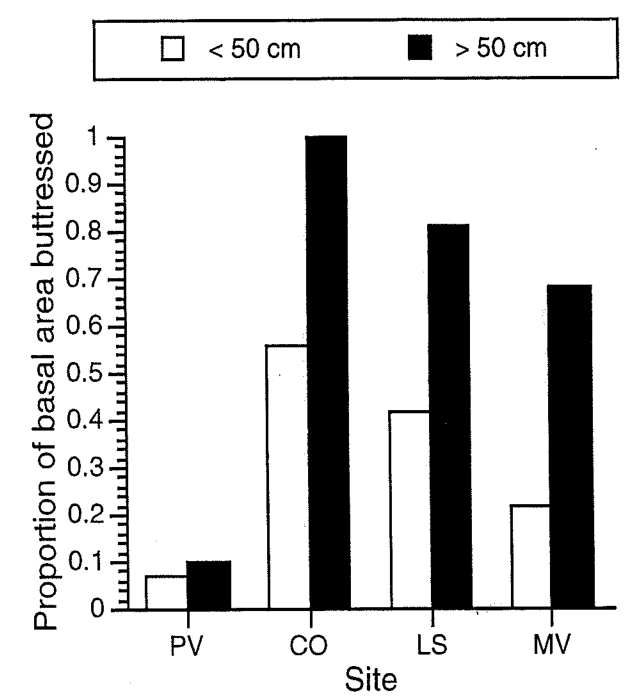

FIG. 4. Percent of total live basal area in buttressed trees in two size clasess (greater and less than 50 cm diameter) for four sites in Costa Rica. See Table 1 for sample sizes. Values are also the proportions of individual trees in prism samples.

At Palo Verde 99% of the sampled trees had no epiphytes on the bark (Fig. 7). In contrast, most trees had > 20% bark epiphyte cover at the other three sites, with mean values of 69% at Corcovado, 73% at La Selva and 64% at Monteverde.

Lianas: Liana loads were remarkably similar among sites, with the exception of Corcovado, where the frequency distribution was distinct, and skewed toward the high load categories. At Corcovado, only 12% trees had no lianas, and 35% trees had > 5 lianas (Fig. 8).

DISCUSSION

We found a host of differences in forest structure and composition across

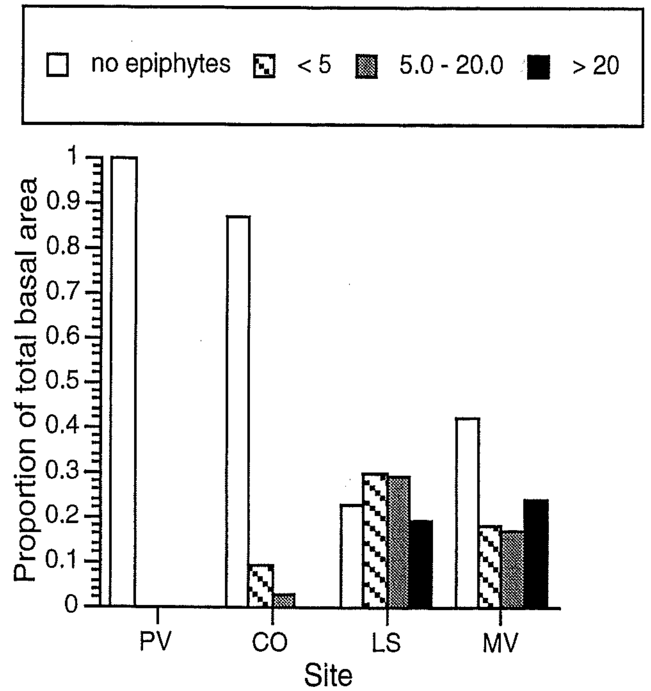

FIG. 6. Proportion of total live basal area for trees in each macroepiphyte growth class (0, < 5, 5 - 20, > 20 visible epiphytes) at four sites in Costa Rica. See Table 1 for sample sizes. Values are also the proportions of individual trees in prism samples.

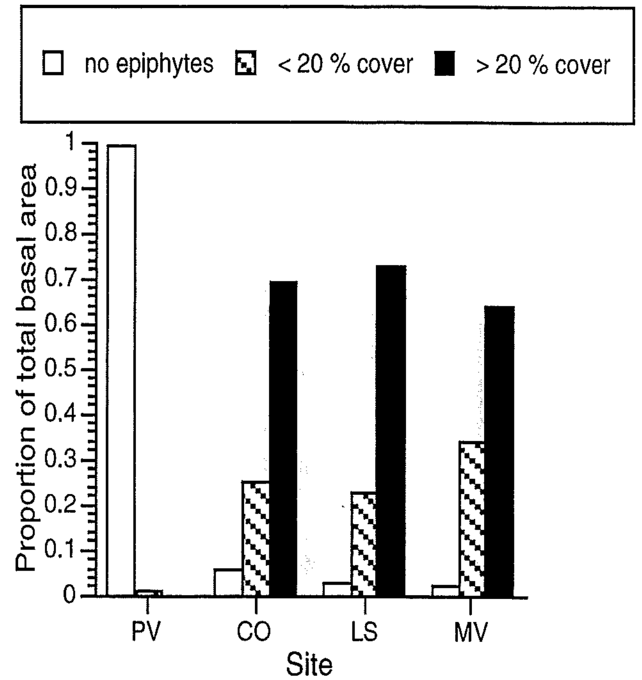

FIG. 7. Proportion of total live basal area for trees in each bark epiphyte class at four sites in Costa Rica. See Table 1 for sample sizes. Values are also the proportions of individual trees in prism samples.

sites, reflecting differences in rainfall, seasonality, soil depth.

Basal Area: Basal area (Fig. 1) was lowest at Palo Verde, which is the driest site, with probably the lowest overall biomass production. Slightly higher basal area at Monteverde than at Corcovado and La Selva may reflect the deeper soils at Monteverde. We measured the Monteverde forest on the leeward side of the continental divide, where the relatively low physical stress from wind may contribute to higher basal area.

Composition: La Selva had a higher percentage of legumes than Palo Verde (Fig. 2) (there were no data for Corcovado or Monteverde). The dominant canopy tree at La Selva is the legume *Pentaclethra macroloba*. The reasons for legume dominance at La Selva are unclear, but nitrogen limitation could possibly be greater there than at other sites.

La Selva also had a higher percentage of palms than the other sites (Fig. 2). Most palms are moisture demanding, so La Selva's consistently high rainfall makes it especially amenable to palm growth. The cool conditions at Monteverde may be detrimental to palms.

We also found that tree diameter increased across the moisture gradient at the four sites (Fig. 2), suggesting that moisture is a limiting factor in the diameter growth or survival of trees.

Buttressing: Across all sites, buttressing was positively associated with tree diameter (Fig. 3). Bigger trees need more support to avoid tipping over in shallow soils. Decreasing percent buttressing from Corcovado and La Selva to Monteverde to Palo Verde may be explained by increasing soil depth across those sites, a key limiting factor for tree stability. We also found a positive association between percent buttressing and tree height (Fig. 4), which suggests that taller trees that are exposed to stronger winds need more structural support. Corcovado and La Selva had high buttress frequency in the subcanopy compared to the other sites, which may reflect

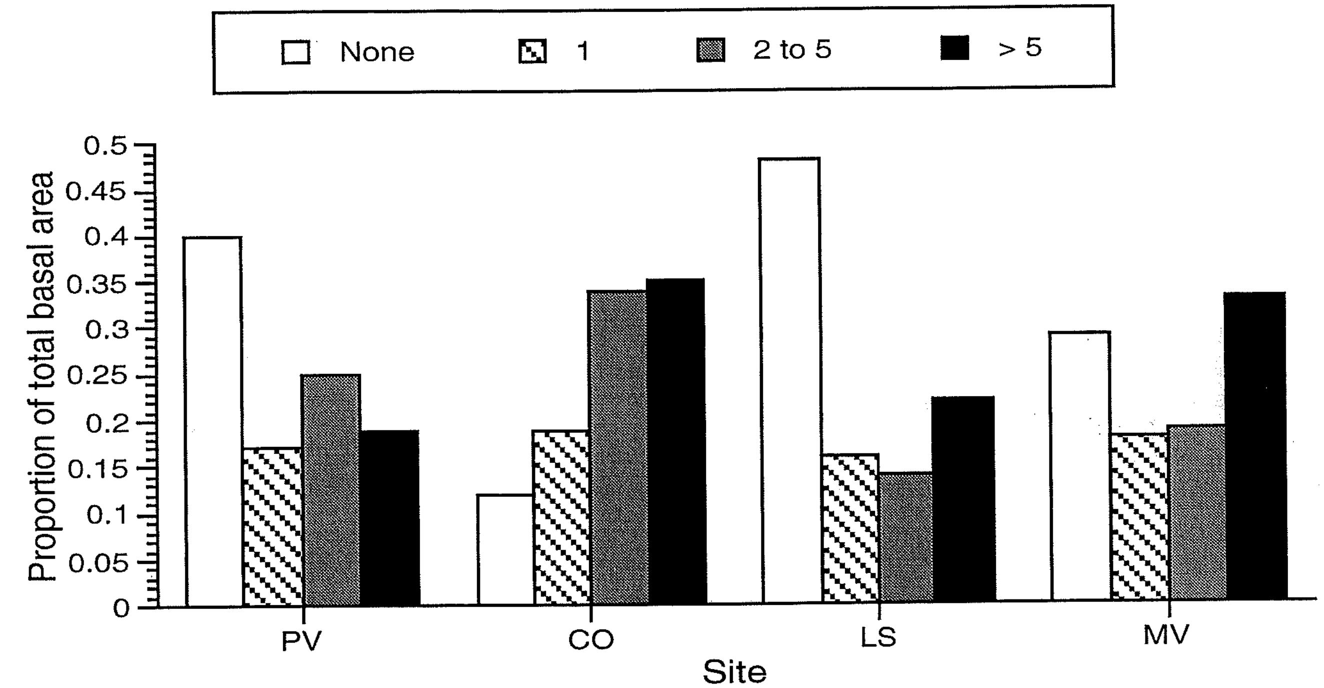

FIG. 8. Proportion of total live basal area for trees in each class of liana load (0, 1, 2 to 5, or > 5 lianas per tree) at four sites in Costa Rica. See Table 1 for sample sizes. Values are also the proportions of individual trees in prism samples.

the numbers of canopy recruits necessary to sustain these very dynamic forests. It may also reflect shallow soils at these two sites.

Macroepiphytes: The abundance of macroepiphytes on trees followed the moisture gradient across sites (Fig. 5). Because macroepiphytes get their moisture from rainfall, they require frequent precipitation or cloud water input. Many macroepiphytes may not be able to survive the prolonged dry season at Corcovado, even though it is wet for much of the year.

Bark epiphytes: The lack of bark epiphytes at Palo Verde again reflects the dry climate there (Fig. 6). Unlike the trend for macroepiphytes, trees at Corcovado had a similar abundance of bark epiphytes to La Selva and Monteverde. This suggests that soil moisture and the forest canopy may buffer moisture fluctuations in the subcanopy, allowing bark epiphytes to survive in forests like Corcovado with less consistent rainfall.

Lianas: Trunk liana loads were highest at Corcovado and lowest at La Selva (Fig. 8). Reasons for these differences are unclear, and may be an interesting subject for future study if the patterns are confirmed when this data set is expanded.

Literature Cited

Marty, Robert. 1999. *Aids to Professional Forestry Practice: Point sampling.* Michigan State University Extension Bulletin E – 1757.