Spatial partitioning of biomass and diversity in a lowland Bolivian forest: linking field and remote sensing measurements

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Introduction

Large-scale inventories of forest biomass and structure are necessary for both understanding carbon dynamics and conserving biodiversity. High resolution satellite imagery is starting to enable structural analysis of tropical forests over large areas, but we lack an understanding of how tropical forest biomass links to remote sensing. Excellent results are being found using LiDAR (light detection and ranging systems) systems (Drake et al. 2002), and headway is being made on both manual and automated interpretation of high-resolution optical satellite imagery (Asner et al. 2002; Clark et al. 2004; Palace et al. *in press*). A better understanding of tree species spatial distribution and visibility to nadir sensors is relevant both for improving biomass estimations through better tree crown delineations using species specific spectral signatures and for forest management and biodiversity conservation.

In this study we quantified the three-dimensional partitioning of forest biomass and species diversity in a tropical moist forest in lowland Bolivia by developing high-resolution, three-dimensional spatial maps of trees and their structural attributes within four 1-ha study plots. Principal questions addressed in our study were:

(1) how is biomass distributed throughout tree-diameter and crown-position classes?
(2) how is tree diversity distributed through these same classes?
(3) how are tree stems and crowns spatially distributed throughout the stand?
(4) what implications do these results have for remote sensing of fine-scale forest structure and biomass?

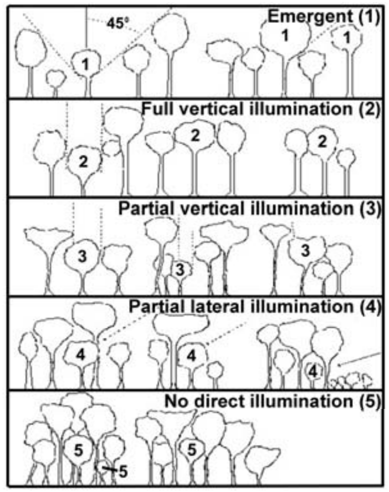

Figure 1. Five crown position classes used in this study.

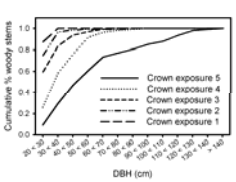

Fig. 1. Cumulative proportion of total woody stems ≥ 20 cm in diameter (DBH) by DBH class and crown exposure class. Crown exposure classes 1-5 are completely shaded to fully exposed tree crowns.

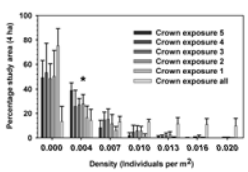

Fig. 2. Tree stem density by crown exposure class and for all exposure classes combined. Error bars represent standard deviation of the mean among the 4 one ha study plots. The asterisk represents significant differences among crown positions ($p < 0.05$).

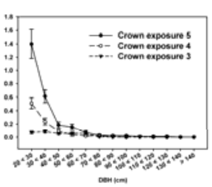

Fig. 4. Mean number of stems covered by trees belonging to crown exposure class 5, 4 and 3. Error bars represent standard errors of the mean.

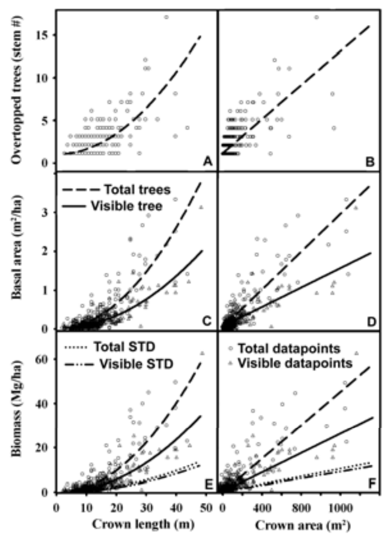

Fig. 5. Correction factors for obscured understory trees for: tree abundance (A, B), basal area (C, D) and biomass (E, F) for trees with DBH ≥ 20 cm using crown length and crown area. Equations are provided in Appendix 3. STD represents the standard deviation of the 5 biomass equations used in the analysis and is provided to indicate the potential error in the biomass estimation.

Results

Emergent and canopy dominant trees, being those directly visible from nadir remote sensors, comprised the highest diversity of tree species, represented 86% of all tree species found in our study plots, and contained the majority of forest biomass. Emergent trees obscured 1-15 trees with trunk diameters (at 1.3 m, DBH) ≥ 20 cm, thus hiding 30-50% of forest biomass from nadir viewing. Allometric equations were developed to link remotely visible crown features to stand parameters, showing that the maximum tree crown length explains 50-70 % of the individual tree biomass. We then developed correction equations to derive aboveground forest biomass, basal area, and tree density from tree crowns visible to nadir satellites. We applied an automated tree crown delineation procedure to a high-resolution panchromatic Quickbird image of our study area, which showed promise for identification of forest biomass at community scales, but which also highlighted the difficulties of remotely sensing forest structure at the individual tree level.

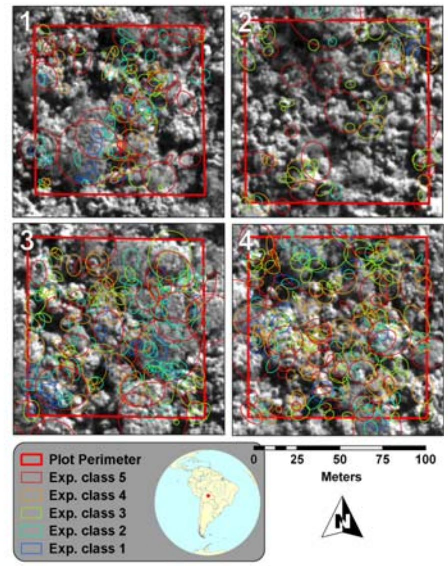

Fig. 3. Field geolocated tree crowns (DBH ≥ 20 cm) in crown exposure classes 1 (shaded understory) through 5 (emergent) for the 4 study plots. Crown delineations are overlaid on the panchromatic Quickbird satellite image. Areas within each plot but outside delineated tree crowns represent crowns of trees not meeting our DBH ≥ 20 cm threshold.

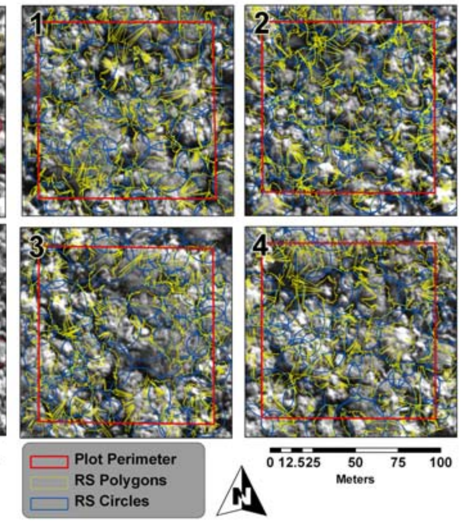

Fig. 6. Automated circle and polygon crown delineations in study plots 1-4 (top left corner) overlaid on the panchromatic Quickbird satellite image.

Summary

Results from this study are pertinent for assessing current and developing future remote sensing approaches of forest biomass and tree diversity. An improved capability for large scale, fine resolution and cost effective quantification of biomass and diversity via remote sensing is relevant for forest management and biodiversity conservation throughout all tropical forests. Although the automated crown detection algorithm employed here requires continued development, it did show promise in delivering high-resolution maps of forest structure.

Asner, G. P., M. Palace, M. Keller, R. Pereira Jr, J. N. M. Silva, and J. C. Zweede. 2002. Estimating canopy structure in an Amazon forest from laser range finder and IKONOS satellite observations. Biotropica **34**:483-492.

Drake, J. B., Dubayah, R. O., Clark, D. B., Blair, J. B., Hofton, M. A., Chazdon, R. L., Weishampel, J. F., and S. Prince. 2002. Estimation of tropical forest structural characteristics using large-footprint lidar. Remote Sensing of Environment. **79**: 305-319

Palace, M., M. Keller, G. P. Asner, S. Hagen, and B. Braswell. in press. An analysis of Amazonian forest structure using an automated tree crown detection algorithm and IKONOS imagery. Biotropica.