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Discussions

Interactive comment on "Tree height integrated into pan-tropical forest biomass estimates" *by* T. R. Feldpausch et al.

T. R. Feldpausch et al.

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Response to Reviewer 1: "Tree height integrated into pan-tropical forest biomass estimates" by T. R. Feldpausch et al.

Feldpausch et al provide a detailed analysis on the effect on including tree height in allometric models used to estimate tropical biomass. Their analysis shows three critical insights that have relevance for tropical biogeography, carbon management, and satellite remote sensing of tropical biomass. First, at plot level, uncertainty in aboveground biomass is reduced considerably when tree height (from measurements or from diameter-height allometry) is included (on average, 52 Mg biomass ha-1). Second, biogeographic differences in biomass distributions were significant; with biomass skewed toward large diameter trees in Africa and smaller diameter trees elsewhere, reflecting

the importance of stand density. And third, scaling of new plot level biomass estimates reduces pan-tropical biomass by 13%, within implications for REDD+ and a new benchmark for satellite-derived and model-based biomass estimates.

The manuscript is very clearly written, and the figures are especially informative with the spatial and stand-level patterns of allometric bias clearly shown. The discussion on the recent pan-tropical GLAS/MODIS biomass estimates of Baccinni and Saatchi is timely because bias in spatial patterns in satellite derived biomass may be partly explained by this study.

Comments The authors appear to suggest that wood density is a much smaller source of error (Section 4.1.6) than constraining tree height. Can an error range be estimated to clarify this from either the current study or from published studies?

Response: We thank the reviewer for the helpful comments to improve the manuscript. It was not our intention to suggest that wood specific gravity was a much smaller source of error than tree height. Wood specific gravity has been shown to be an important factor in reducing uncertainty in biomass estimates, e.g., Baker et al. (2004) modified the Chambers et al. (2001) Amazonian biomass models to include wood density. More importantly, in developing pantropical biomass models, wood specific gravity was a more important predictor of AGB than tree height (the most important predictors of AGB in declining order of important were tree diameter, wood specific gravity, height, and forest type) (Chave et al. 2005). We comment in the introduction that, "wood speciïňĄc gravity is highly variable across regions and is a key determinant of larger-scale tree biomass spatial patterns (Baker et al., 2004b; Chave et al., 2006), and therefore accounting for it holds a central role in reducing uncertainty in biomass estimates." It is for this reason that we included wood specific gravity in both of our pantropical biomass models, with and without height, reformulated from newly published destructive data (including data from Africa). In this section we now included the reference to the Chave et al. (2005) study to note the importance of wood specific gravity over tree height.

In Section 4.2, how might the inclusion of wood density improved satellite derived estimates of aboveground biomass? This comment is partly related to my previous comment.

Response: Wood specific gravity is currently included in some satellite-based estimates of above-ground biomass during model calibration. For example, the recent remote-sensing-based pantropical biomass estimates of Baccini et al. (2012) and Saatchi et al. (2011) include wood specific gravity through the use of the Chave et al. (2005) biomass model in calibrating space-borne GLAS height measurements to ground-based estimates of aboveground biomass. Our study examines how regional parameterisations of biomass estimates that include height (in addition to wood specific gravity) improve biomass estimates. Such steps may lead to improvements in biomass estimates based on satellite-derived estimates of AGB.

In Section 4.3, Saatchi et al estimate belowground biomass as a function of their aboveground biomass estimates. When describing implications for carbon sinks, do the revised biomass estimates (including tree height) alter the belowground relationship – can some insight be made on this difficult measurement from the current study?

Response: There are few studies quantifying root:shoot ratios and with differences in measurement approaches (e.g. Mokany et al. 2006; Saatchi et al. 2011). As a result, current large-scale estimates of total tree biomass of live above-ground (BAG) and below-ground (BGB) are generally estimated based on a root fraction of 0.25 of the above-ground biomass (e.g. see Lewis et al. 2009) or by using a regression equation based on above-ground biomass data collected across biomes (e.g. BGB = 0.489*BAG0.89; Saatchi et al. 2011). Our results indicate that above-ground biomass estimates that do not include height are approximately 13% higher than those that include height. This would imply that current estimates of carbon in roots that are based on biomass estimates that do not include height would likewise be on average 0.13 lower after inclusion of height.

The more complex question of whether the fraction of above- to below-ground carbon changes as a result of our down-scaling due to height is beyond the scope of our study, as we lack the required below-ground data. This question may also be beyond the current capacity of the literature, as we are unaware of any studies that indicate whether this scaling relationship varies with tree height. There is a reported negative relationship ($p<0.001$, $R2=0.21$) between the root:shoot ratio and forest stand height. However, it is unclear if this relationship holds for individual tree height. If the relationship holds, the greater biomass attributed to forests which are on average taller would be offset by proportionally less below-ground biomass. This again highlights the need for additional destructive data, both above- and below-ground.

Some minor comments P2572, line 4-7: this sentence is somewhat unclear and would be helpful is it was re-written. Response: Done.

P2588, line 22: check grammar Response: Fixed.

P2591, line 8: check grammar Response: Fixed.

P2595, line 16: I suggest confirming whether height was used from Chave's allometric equations with Baccini et al

Response: We contacted Baccini et al. (2012) and they informed us that height was not used in the Chave et al. 2005 equation used to estimate biomass. Based on the suggestion from reviewer 2, we have decided to remove this text since there is not enough space here to explore this in detail.

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