Supplementary material

A Universal Airborne LiDAR Approach for Tropical Forest Carbon Mapping

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In previously published and forthcoming papers, we developed equations to estimate aboveground carbon density (ACD; Mg C ha^{-1}) from LiDAR-derived Mean Canopy Profile Height (MCH; m) for tropical forests in Hawaii, Peru, Panama, and Madagascar (see main text; Asner et al. 2011; Asner et al. 2010; Mascaro et al. 2011). These were fit in two forms: (1) using linear regression on ln-transformed ACD and MCH data, and applying a correction factor to account for the back-transformation of the regression error (Baskerville 1972), or (2) using non-linear regression in the form of a power-law model (Table S1). For a given region, the fitting approach that provided the more consistent distribution of residuals was used.

We also previously generated diameter-to-height models using 2nd or 3rd-order polynomial models fit to ln-transformed diameter (D; cm) and height (H; m) data, again applying a correction factor. For the present study, we related both basal area (BA; m^2 ha^{-1}) and wood density (WD; g cm^{-3}) to LiDAR MCH using linear regression; in the case of BA, the model was forced through the origin to provide a ratio of BA to MCH. Additional relationships between WD and ACD are provided for congruity with previous studies (Table S2).

For all trees globally, ACD is approximately proportional to D^2*H*WD (Chave et al. 2005), and because H is typically related to D^2 with in a power model with an exponent between 0.46 and 0.65 (Feldpausch et al. 2010), ACD is approximately proportional to $D^{2.5}$ or $BA^{1.25}$. At the plot scale, we found that this was the case for the sites considered in this study (Figure S1).

Table S1: Summary of equations used to develop a universal approach to LiDAR-based carbon monitoring. For parameters, the estimated value is followed by its standard error in parentheses.

Equation/Region	a		b_1		b_2		b_3		r^2	n	RMSE	CF
$\ln(ACD) = a + b_1*\ln(MCH)$												
Hawaii	1.8520	(0.0870)	1.2400	(0.0410)					0.86	149	0.3795	1.0747
$ACD = a*MCH^{b1}$												
Panama	1.1162	(0.0787)	1.4498	(0.0310)					0.85	157	17.5377	
Peru	0.3530	(0.1110)	1.9250	(0.1010)					0.85	130	23.6566	
Madagascar	3.9288	(1.6263)	1.2158	(0.1445)					0.68	46	35.4286	
$BA = b_1*MCH$												
Hawaii			3.5299	(0.0740)					0.77	149	9.1768	
Panama			1.4888	(0.2200)					0.84	157	4.9523	
Peru			1.5329	(0.0220)					0.82	130	4.8536	
Madagascar			2.2295	(0.3170)					0.55	46	10.4597	
$\ln(H) = a + b_1*\ln(D) + b_2*\ln(D)^2 + b_3*\ln(D)^3$												
Hawaii	0.5120	(0.0200)	0.7580	(0.0190)	-0.0320	(0.0040)			0.86	2257	0.2828	1.0408
Panama	0.8620	(0.0320)	0.6110	(0.0470)	0.0510	(0.0200)	-0.013	(0.0030)	0.91	1218	0.2236	1.0253

							0					
Peru	0.5690	(0.1100)	0.9890	(0.0650)	-0.0720	(0.0090)			0.68	1681	0.2191	1.0243
Madagascar	-0.5900	(0.6530)	1.9790	(0.6750)	-0.3620	(0.2210)	0.0270	(0.0230)	0.83	250	0.2191	1.0243
WD = a + b_1*MCH												
Hawaii	0.6699	(0.0110)	-0.0024	(0.0011)					0.03	149	0.0656	
Panama	0.5549	(0.0081)	-0.0009	(0.0004)					0.03	157	0.0346	
Peru	0.4551	(0.0170)	0.0049	(0.0009)					0.20	130	0.0608	
Madagascar	0.5750	(0.0210)	-0.0001	(0.0010)					0.00	46	0.0566	

Table S2: Relationships between wood density and aboveground carbon density . For parameters, the estimated value is followed by its standard error in parentheses.

Equation/Region	a		b_1		r^2	n	RMSE
WD = a + b_1*ACD							
Hawaii	-6.93E-05	(6.94E-05)	0.6560	(0.0090)	0.01	149	0.0660
Panama	-5.23E-05	(4.86E-05)	0.5440	(0.0060)	0.01	157	0.0340
Peru	5.44E-04	(8.97E-05)	0.4860	(0.0110)	0.22	130	0.0600
Madagascar	2.03E-04	(1.32E-04)	0.5530	(0.0160)	0.05	46	0.0550

References

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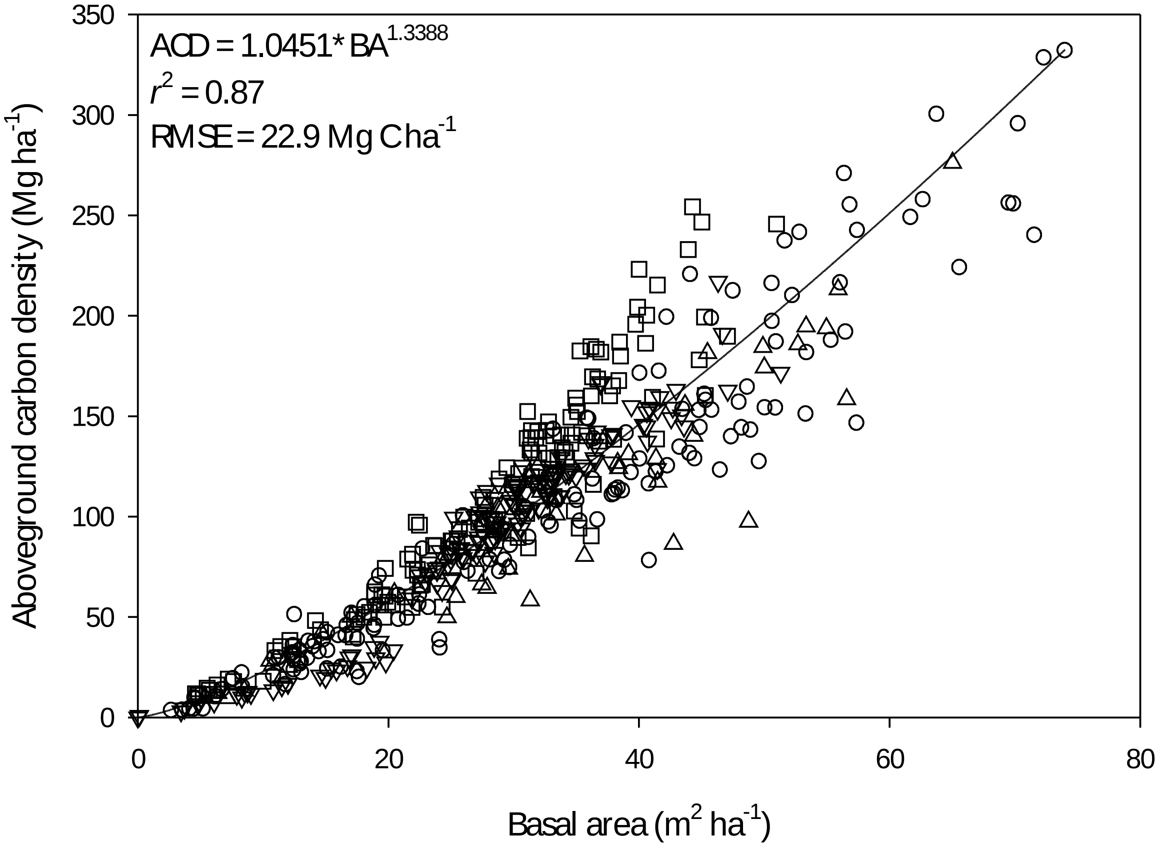

Figure S1. Relationship between aboveground carbon density and basal area across 482 plots in four tropical ecoregions: Hawaii, Panama, Peru and Madagascar.