

Supplementary material

Table S1. Stand characteristics and mean values of field measurements in the study area. Where: *Dbh* = mean diameter at 1.3 m above ground; *H* = mean height; *V* = tree outside-bark mean volume; *N* = mean number of trees per hectare.

Stand	Area (ha)	Regeneration	Spacing	Age class	<i>Dbh</i> (cm)	<i>H</i> (m)	<i>V</i> (m ³ ha ⁻¹)	<i>N</i> /ha
S1	10.41	Clearcut	3x3	Mature	19.5	32.0	441.33	1028
S2	25.00	Clearcut	3x3	Mature	34.6	25.4	654.62	1179
S3	25.65	Clearcut	3x3	Mature	33.7	25.0	601.02	1178
S4	37.91	Clearcut	3x3	Mature	35.7	27.4	662.34	1075
S5	37.56	Clearcut	3x3	Mature	34.0	27.9	547.78	954
S6	18.31	Clearcut	3x3	Mature	17.1	26.3	318.41	1167
S7	22.01	Clearcut	3x3	Mature	18.9	31.2	424.15	1074
S8	10.06	Clearcut	3x3	Mature	17.0	26.6	305.56	1108
S9	37.80	Clearcut	3x3	Intermediate	28.7	19.9	311.43	1060
S10	16.21	Clearcut	3x3	Intermediate	16.0	22.4	194.45	953
S11	8.22	Clearcut	3x3	Intermediate	15.7	23.0	213.75	1056
S12	17.12	Clearcut	3x3	Intermediate	16.8	22.0	247.19	1101
S13	27.39	Clearcut	3x3	Intermediate	15.4	22.7	244.43	1259
S14	24.03	Coppice	4x3	Intermediate	32.4	24.5	412.87	956
S15	11.20	Coppice	4x3	Intermediate	16.0	23.5	192.90	953
S16	24.31	Coppice	3x3	Intermediate	47.5	24.9	714.02	1101
S17	22.56	Coppice	4x3	Intermediate	31.6	24.5	391.58	939
S18	57.40	Clearcut	3x3	Young	13.4	21.5	152.85	1056
S19	38.33	Coppice	3x3	Young	13.6	19.7	113.36	900

Table S2. Plot characteristics and mean values of field measurements in the study area. Where: *Dbh* = mean diameter at 1.3 m above ground; *H* = mean height; *V* = tree outside-bark mean volume; *N* = mean number of trees per hectare. Partition stands for the data sets used for training (60%) and test (40%) of the volume estimation models.

Stand	Plot	Regeneration	Spacing	Age	<i>Dbh</i> (cm)	<i>H</i> (m)	<i>V</i> (m ³ ha ⁻¹)	<i>N</i>	Partition
S1	P1	Clearcut	3x3	Mature	19.53 ± 2.98	32.04 ± 2.2	441.33 ± 5.26	1028	Training
S2	P2	Clearcut	3x3	Mature	16.69 ± 3.68	23.7 ± 3	304.67 ± 3.84	1268	Training
S2	P3	Clearcut	3x3	Mature	17.97 ± 4.58	27.12 ± 4	349.95 ± 5.38	1090	Training
S3	P4	Clearcut	3x3	Mature	17.33 ± 1.99	27.73 ± 1.3	363.14 ± 2.66	1241	Test
S3	P5	Clearcut	3x3	Mature	16.44 ± 2.12	22.29 ± 1.2	237.88 ± 2.12	1114	Training
S4	P6	Clearcut	3x3	Mature	17.97 ± 2.34	27.91 ± 1.7	342.64 ± 2.75	1079	Training
S4	P7	Clearcut	3x3	Mature	17.75 ± 1.81	27.04 ± 1.2	319.7 ± 1.97	1070	Test
S5	P8	Clearcut	3x3	Mature	16.73 ± 1.11	25.98 ± 0.6	238.54 ± 1.48	937	Training

S5	P9	Clearcut	3x3	Mature	17.34 ± 2.88	29.85 ± 2.2	309.24 ± 4.3	971	Test
S6	P10	Clearcut	3x3	Mature	17.12 ± 2.29	26.33 ± 1.6	318.41 ± 2.71	1167	Test
S7	P11	Clearcut	3x3	Mature	18.93 ± 2.9	31.26 ± 2.2	424.15 ± 5.43	1074	Training
S8	P12	Clearcut	3x3	Mature	17.02 ± 3.1	26.63 ± 2.8	305.56 ± 3.29	1108	Training
S9	P13	Clearcut	3x3	Intermediate	14.05 ± 1.34	19.44 ± 0.8	146.41 ± 1.01	1072	Test
S9	P14	Clearcut	3x3	Intermediate	14.69 ± 2.27	20.35 ± 1.4	165.02 ± 1.96	1047	Test
S10	P15	Clearcut	3x3	Intermediate	16.03 ± 1.63	22.48 ± 0.8	194.45 ± 1.74	953	Test
S11	P16	Clearcut	3x3	Intermediate	15.79 ± 1.24	23.03 ± 0.7	213.75 ± 1.56	1056	Training
S12	P17	Clearcut	3x3	Intermediate	16.84 ± 2.89	22.06 ± 2.3	247.19 ± 2.82	1101	Training
S13	P18	Clearcut	3x3	Intermediate	15.49 ± 2.31	22.7 ± 1.4	244.43 ± 2.72	1259	Training
S14	P19	Coppice	4x3	Intermediate	16.11 ± 2.99	23.5 ± 1.8	201.43 ± 2.5	1005	Test
S14	P20	Coppice	4x3	Intermediate	16.35 ± 3.33	25.63 ± 2.6	211.44 ± 2.7	907	Training
S15	P21	Coppice	4x3	Intermediate	16.05 ± 3.54	23.58 ± 2.5	192.9 ± 3.09	953	Test
S16	P22	Coppice	3x3	Intermediate	15.34 ± 3.74	25.7 ± 2.8	242.04 ± 3.88	1149	Training
S16	P23	Coppice	3x3	Intermediate	14.89 ± 3.01	22.74 ± 2.1	181.33 ± 2.14	1084	Training
S16	P24	Coppice	3x3	Intermediate	17.32 ± 3.92	26.52 ± 2.9	290.65 ± 3.66	1068	Training
S17	P25	Coppice	4x3	Intermediate	14.97 ± 3.28	22.82 ± 2.1	166.16 ± 2.69	974	Test
S17	P26	Coppice	4x3	Intermediate	16.72 ± 3.31	26.34 ± 2.3	225.42 ± 3.2	903	Training
S18	P27	Clearcut	3x3	Young	14.02 ± 2.37	21.24 ± 2.1	140.74 ± 1.79	909	Training
S18	P28	Clearcut	3x3	Young	13.67 ± 1.67	20.3 ± 1	135.99 ± 1.22	986	Test
S18	P29	Clearcut	3x3	Young	12.55 ± 2.42	23.03 ± 2.2	181.83 ± 1.88	1271	Training
S19	P30	Coppice	3x3	Young	13.92 ± 2.02	19.31 ± 1	114.11 ± 1.4	891	Test

S19	P31	Coppice	3x3	Young	12.36 ± 2	19.96 ± 1.6	119.18 ± 1.61	1094	Training
S19	P32	Coppice	3x3	Young	13.9 ± 3.32	20.38 ± 2.2	112.81 ± 2.69	803	Test
S19	P33	Coppice	3x3	Young	14.29 ± 1.51	19.15 ± 0.8	107.32 ± 0.85	813	Training

P21	22.89	24.10	-1.21	-5.04
P22	26.26	27.17	-0.90	-3.33
P23	24.92	23.30	1.62	6.97
P24	24.68	27.43	-2.76	-10.04
P25	24.22	23.43	0.78	3.34
P26	20.07	27.17	-7.09	-26.11
P27	18.49	19.23	-0.75	-3.89
P28	17.65	20.57	-2.92	-14.20
P29	18.81	20.97	-2.15	-10.28
P30	17.55	18.97	-1.41	-7.46
P31	19.45	21.40	-1.95	-9.10
P32	18.40	20.17	-1.77	-8.78
P33	19.44	24.80	-5.36	-21.62

Table S3. Description of soil types by plot and stand. Soil types classified in the Brazilian Soil Classification System [1].

Stands	Plots	Soil description
S19	P30, P31, P32, P33	Yellow Latosol: Typical dystrophic, very clayey texture, A prominent, allic, kaolinitic, mesoferic.
S12, S15, S16, S2	P17, P2, P21, P22, P23, P24, P3	Yellow Latosol: Typical Acrylic, clayey texture, moderate A, allic, kaolinitic or kaolinitic-oxidic, mesoferic.
S18	P27, P28, P29	Cambisols: Dystrophic latosolic, very clayey texture, A prominent or moderate, allic, kaolinitic, hypoferric or mesoferic.
S1, S17, S7	P1, P11, P25, P26	Cambisols: Dystrophic latosolic, medium / clayey texture, A prominent or moderate, kaolinitic, hypoferric or mesoferic.
S10, S13, S14, S3, S4, S9	P13, P14, P15, P18, P19, P20, P4, P5, P6, P7	Cambisols: Dystrophic latosolic, medium / clayey texture, A prominent or moderate, kaolinitic, hypoferric or mesoferic. + Cambisols: Dystrophic lithic, clayey or very clayey texture, A moderate, allic, kaolinitic or kaolinitic-oxidic, mesoferic.
S6	P10	Cambisols: Dystrophic latosolic, very clayey gravel texture, moderate A, allic, kaolinitic, hypoferric or mesoferic.
S11, S5, S8	P12, P16, P8, P9	Red Latosol: Typical Accric, clayey texture, moderate A, allic, kaolinitic or kaolinitic-oxidic, mesoferic. + Red Yellow Latosol: Typical Accric, clayey texture, moderate A, allic, kaolinitic or kaolinitic-oxidic, mesoferic.

Table S4. Parameters used to estimate volume in the ITD approach using Schumacher and Hall (1933) model. Stand names following Table 1. RMSE = Root Mean Square Error; RMSE(%) = relative RMSE.

Stand	b0	b1	b2	r_{yy}	RMSE (m ³ /tree)	RMSE(%)
S(1-13)	-10.082876	1.961099	0.978704	0.9955	0.0182	7.9
S(14-17)	-10.853507	1.811935	1.325494	0.9971	0.0230	11.8
S18	-10.300613	1.689753	1.292432	0.9920	0.0301	12.4
S19	-10.327244	1.820607	1.175653	0.9924	0.0320	13.2

Table S5. Most frequently held LiDAR metrics as input variables in an estimation method by the Recursive Feature Elimination algorithm (RFE) based on its importance. Metrics within the dashed box were used as input variables in the estimation methods.

Metric	Frequency (%)		
	ANN	RF	SVM
H.P95	99	99	100
H.P50	91	91	70
Hmod	73	73	77
H.P10	46	46	68
H.P05	12	26	48
H.Admod	7	8	43
Ccover	6	26	18
Hkurt	5	3	27
H.Admed	1	7	16
Hcv	0	4	10
CRR	0	4	7
H.P01	0	3	4
Hmin	0	2	0

Table 6. Statistics for training, tuning and validating non-parametric methods. Method's performance was assessed with leave-one out cross validation resample method. r_{yy} = Pearson's correlation coefficient between observed and estimated volume; RMSE = Root Mean Square Error; RMSE(%) = relative RMSE.

Method	r_{yy}	RMSE	RMSE(%)	Bias	Bias(%)
RF	0.97	25.75	11.39	-2.576	-1.02
SVM	0.89	32.79	16.24	-2.098	-0.83
ANN	0.95	28.17	12.08	0.413	0.16

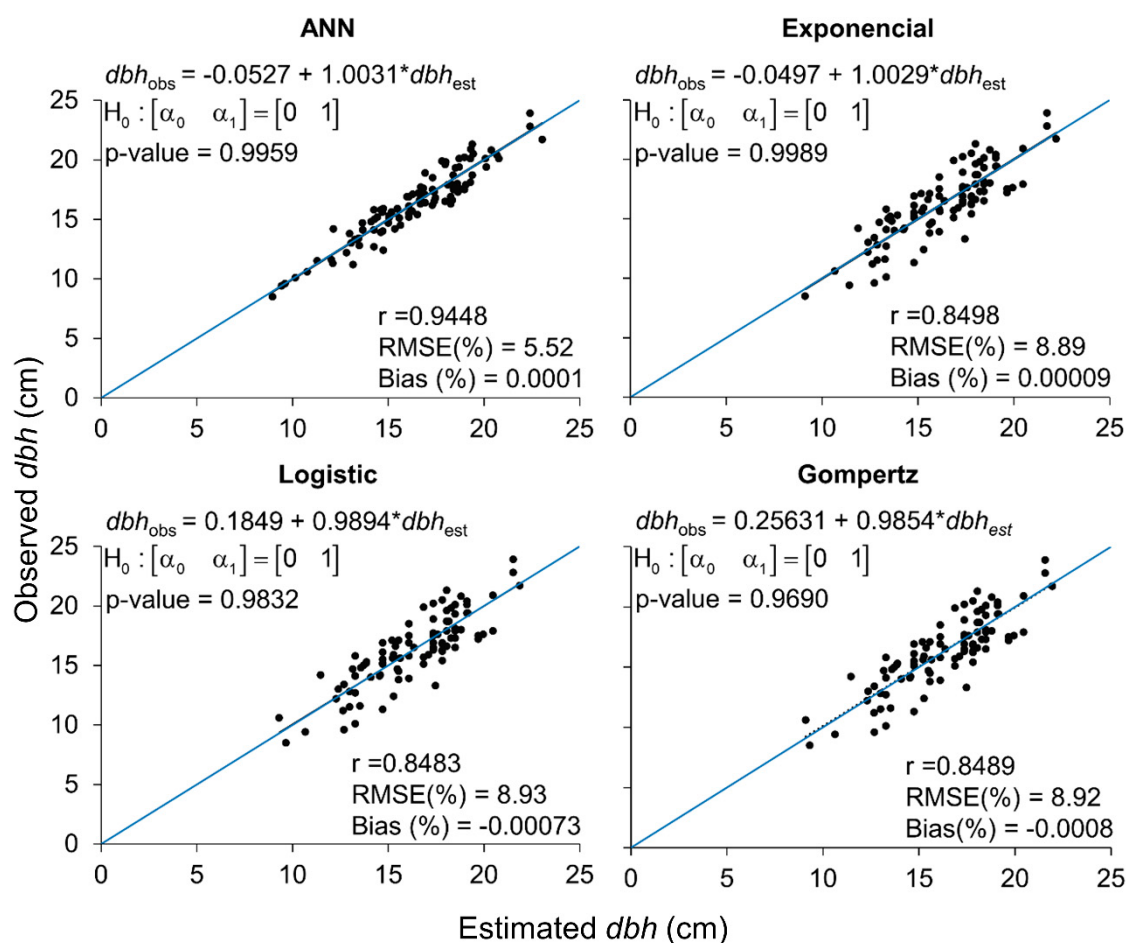


Figure 1. Estimates of diameter at breast height (*dbh*). P-values within plot are for the Graybill (1976) F-test. Parametric methods:

$$dbh = b_0 e^{-e^{b_1 - b_2 H}} + \varepsilon \text{ (Gompertz)}$$

$$dbh = \frac{b_0}{1 + b_1 e^{-b_2 H}} + \varepsilon \text{ (Logistic)}$$

$$dbh = b_0 e^{\frac{b_1}{H}} + \varepsilon \text{ (Exponential)}$$

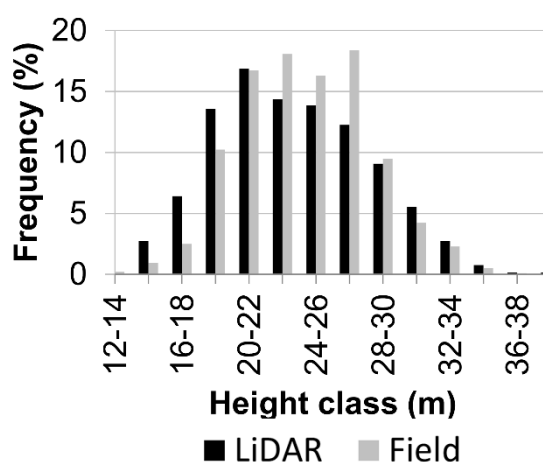


Figure 2. Height distribution of sample plot field measured trees in 33 plots and the nearly 520 thousand trees detected with LiDAR.

1. Santos, H.G., Jacomine, P.K.T., Anjos, L.H.C., Oliveira, V.A., Lumberras, J.F., Coelho, M.R., Almeida, J.A., Araujo Filho, J.C., Oliveira, J.B., Cunha, T.J., 2013. Brazilian Soil Classification System, 3rd ed. Embrapa, Brasília, 353 p.



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