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Comparison of formulae for biomass content determination in a tropical rain forest site in the state of Pará, Brazil

Thaís Maia Araújo[a], Niro Higuchi[b], João Andrade de Carvalho Júnior[a,*]

[a] *INPE, Instituto Nacional de Pesquisas Espaciais, Rodovia Presidente Dutra km 40, 12630-000 Cachoeira Paulista SP, Brazil*
[b] *INPA, Instituto Nacional de Pesquisas da Amazônia, Alameda Cosme Ferreira 1756, 69083-000, Manaus AM, Brazil*

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Abstract

The aboveground biomass content of a region can be estimated by either direct or indirect methods. The direct method corresponds to sampling the biomass content by weighing and extrapolating results to larger areas. It is a destructive and very laborious procedure. The indirect method utilizes formulas whose predictor parameters are obtained from forest inventories. Forest inventories are conducted with the purpose of planning exploitation and land use, and the data derived from inventory are frequently not suitable for biomass estimation. Problems with both these methods increase in the Amazon region, where little information is available on forest biomass. The objective of this paper is to compare a number of biomass equations taken from previous studies and establish an appropriate mathematical formula to estimate the vegetation weight of a particular region in the Amazon forest. A 0.2 ha area of 'terra firme' forest was chosen for the comparison. This effort was part of a major forest clearing experiment conducted in Tomé Açu, a town located 250 km south of Belém, the capital of the Brazilian state of Pará. The entire biomass in the 0.2 ha area was weighed. A detailed inventory was carried out in the area prior to the cut and then the biomass was estimated with the inventory data inserted in the selected equations. Fourteen different biomass equations taken from previous studies were used. A comparison of the data of real mass and the mass obtained through the application of the fourteen formulas indicated that the two formulas more suitable for the region are given by (a) $FW=\alpha D^{\beta} H^{\gamma}$, where FW is total fresh weight (kg), D the diameter at breast height (cm), H the total height of the tree (m) and α, β, and γ the regression coefficients, equal to 0.026, 1.529, and 1.747, respectively, and (b) $FW=\alpha D^{\beta}/(1-M)$, where α and β are 0.465 and 2.202, respectively, and M the moisture content, defined in terms of mass of moisture per unit mass of fresh biomass. The aboveground fresh biomass weight predicted by the above equations were within $\pm$0.6% of the weight determined in the field.

Keywords: Amazon forest; Biomass; Diameter at breast height (DBH)

1. Introduction

Biomass is defined as the quantity, expressed in mass units, of the vegetal material content per unit area in a forest. In general, the estimated biomass components are: vertical aboveground biomass or standing alive aboveground biomass, composed of trees and shrubs (not considering the roots), dead aboveground biomass, composed of litter and fallen trunks, and the belowground biomass, composed of roots. The sum of all considered components provides

*Corresponding author. Tel.: +55-12-560-9345; fax: +55-12-561-1992; e-mail: joao@yabae.cptec.inpe.br

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the total biomass. In this paper, equations for determination of the vertical biomass are considered and compared in a test site located in the northern state of Pará, Brazil.

The total vertical aboveground biomass can be estimated by direct and indirect methods. Both methods present advantages and disadvantages (Martinelli et al., 1994). The direct method is destructive, consisting of the cutting and weighing of the aboveground material in an established area. However, the choice of the area to be cut down and weighed is, in many instances, biased and simple extrapolation leads to inaccurate results. In general, the chosen area is thought to be homogeneous, but it frequently contains very large trees, resulting in over-estimated data (Higuchi and Carvalho, 1994).

The indirect method utilizes mathematical models. It relates the tree variable parameters obtained from forest inventories, such as diameter at breast height (DBH, the trunk diameter at $\approx$1.3 m from the soil level), trunk height, crown diameter, total tree height, tree species, etc. Also, the application of this method can be inaccurate. For example, trees can have a hollow inside, and, in case of large trees, the error in the calculation of biomass can be significant. In general, the forest inventory is carried out with the exclusive objective of planning land exploitation and use, for which the variable of greatest interest is wood volume. Forest inventory is also the first step to start much of the basis of research concerning natural resources and decisions related to land use (Higuchi et al., 1982).

In this work, a set of fourteen different biomass equations were applied to calculate the biomass weight per hectare in a test area located in the Brazilian Amazon region. The weights, thus determined, were then compared with the results obtained from felling and weighing the material in the area. The most suitable equations were determined.

2. Study site and experimental procedure

A 0.2 ha (20×100 m^2) area was selected for the experiment. The test site was located in a small village, named Igarapé do Vinagre, about an hour-and-a-half by boat from the town of Tomé Açu, 250 km from Belém, the capital of the state of Pará. Fig. 1 shows the location of the experiment area. The geographic coordinates of the area are: $48^\circ0.8'$W longitude and $2^\circ30'$S latitude.

One hundred and twenty seven trees with DBH$\geq$10 cm were present in the test area. All 127 trees were felled and weighed. Once cut down, the trees were divided into trunk and crown, the latter being considered as starting from the first line branch.

Without exception, the crowns of all trees were weighed. First, the leaves and thin branches were removed and weighed. Then, the gross branches were cut in pieces that could be put on the scales and also weighed one by one.

For 54 trunks with DBH$\geq$10 cm (54 out of 127), a method, based on the formula for a cylinder (Higuchi and Carvalho, 1994), was utilized to estimate the total volume. As shown schematically in Fig. 2, the method consists of dividing the trunk in four equal size parts in such a way that each part could be regarded as approximately cylindrical. Then, disks were removed from each end and weighed. The diameter and thickness of the disks were measured. From these data, the total volume of the trunk was calculated by summing the volumes of the four pieces. The fresh weight biomass was then obtained from the volume and average wood density. The remaining 73 trunks, whose DBH's lay between 10 and 20 cm, were weighed directly.

Fourteen mathematical formulae developed for typical vegetation of the Amazon region were used to calculate biomass indirectly. The corresponding expressions and regression coefficients of these equations are presented in Table 1, where FW_n(n=1–14) is the fresh weight (kg), H the total tree height (m), D the DBH (cm) and $\bar{\rho}$ the average density of fresh biomass (0.995 g cm^{-3}, for the vegetation in the test site, as determined by Araújo, 1995). The first seven equations (n=1–7) were developed using 335 trees randomly selected from a dense tropical moist forest sited near Manaus, Amazonas State, Brazil (Higuchi and Carvalho, 1994). The remaining seven equations of Overman et al. (1994), for the prediction of dry weight, were applied to the data using the average moisture content of the area (40%, in terms of mass of moisture per unit mass of fresh biomass, also determined by Araújo, 1995). The test site of Overman et al. (1994) was located in a region in the Colombian Amazon, classified as a mature tropical rain forest,

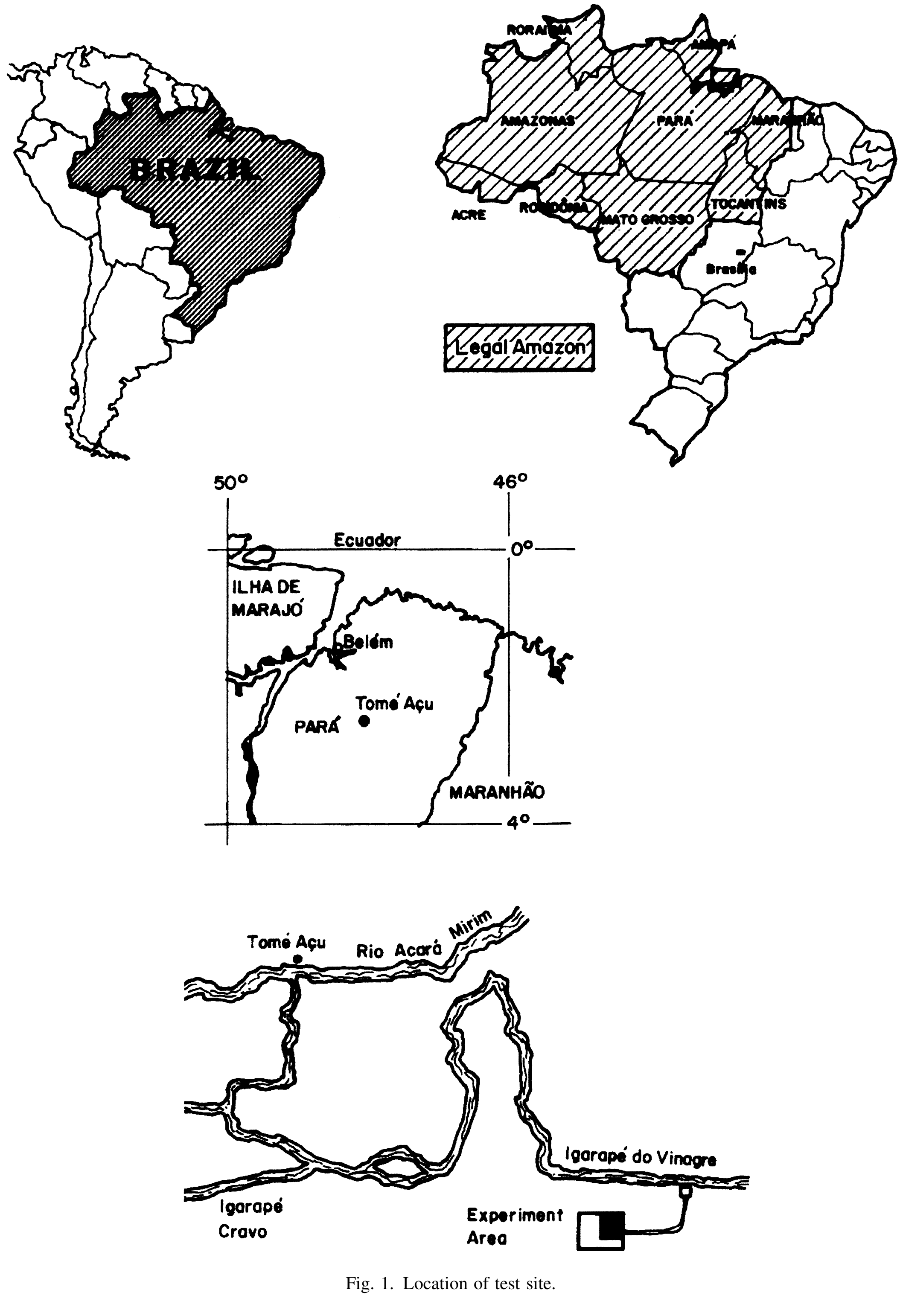

Fig. 1. Location of test site.

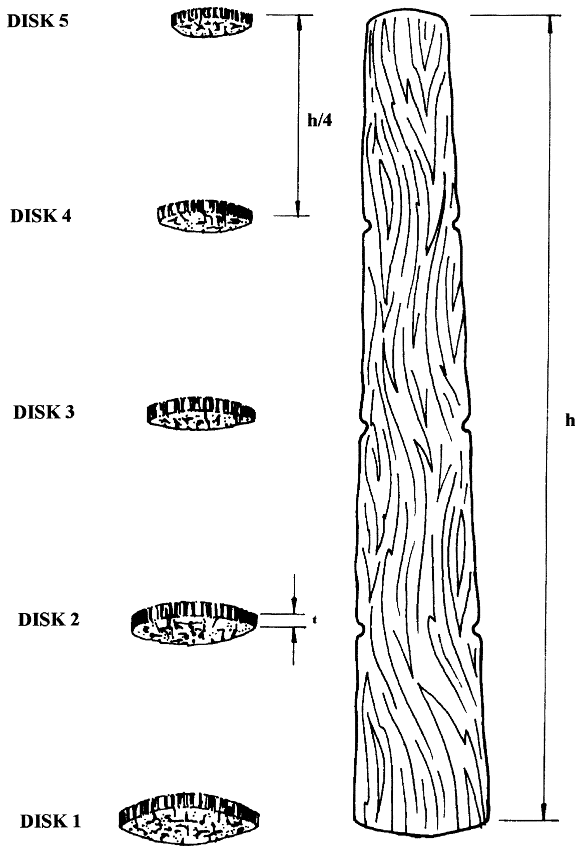

Fig. 2. Schematic of partition procedure for mass determination of trunks, where t is the disk thickness and h the height of the trunk.

near Araracuara, Departamento Caquetá, Colombia, and was based on 54 samples.

The complete data set of the samples for the three experiments mentioned in this work is given in Table 2. The frequency distribution (N) of the size of the individuals is shown using 10 cm bin ranging from 10 to 120 cm with the modified bin range of the extremes.

3. Results and discussion

The fresh biomass of 127 trees in the area was determined using the direct method, as previously described. The resulting data were divided into two parts, the first corresponding to data of 73 trees whose trunks and crowns were completely weighed in scales and the second part, including 54 trees, whose trunks had their mass determined by the procedure described above.

For the 73 trees, the biomass was 6996 kg for trunks and 3520 kg for crowns. For the 54 individuals, the weights of the trunks and crowns were 86 022 kg and 73 047 kg, respectively. The total aboveground biomass of the 127 trees was 169 585 kg. Table 3 summarizes the results.

The predictor parameters for the 127 trees obtained from the inventories were inserted in the fourteen equations in order to compare with the field measurements. The biomass results and the relative errors are presented in Tables 4 and 5, respectively. The overall biomass, predicted by equations designed by FW_7 and FW_8 were within $\pm 0.6\%$ of the field value, while for FW_1, FW_9, FW_{10} and FW_{13} the predicted biomass was within $\pm 10\%$. Overall errors for the other equations were very large, expecially for FW_4 and FW_6. The errors are also presented by 5-cm DBH intervals. In the size categories for which there was a large number of tree ($10 \leq DBH \leq 14$ cm and $15 \leq DBH \leq 19$ cm), the best model was FW_7.

The data obtained by direct weighing in the area were extrapolated to an adjacent 1-ha area, where buring was performed, and for which inventory data were also available. By direct extrapolation, the biomass content would have been estimated to be 848 t ha^{-1} for the category DBH$\geq$10 cm, a value which is not common for regions in the Amazon forest. However, applying FW_7 to the forest inventory data, the corresponding biomass for the same category was estimated to be only 275 t ha^{-1}. With FW_8 the estimate would be 597 t ha^{-1}.

The discrepancy between the results obtained with FW_7 (275 t ha^{-1}) and FW_8 (597 t ha^{-1}) in the adjacent 1-ha area, where fire was set, was probably due to the fact that bole lengths could only be estimated during the performance of the inventory, whereas in the 0.2-ha area, bole lengths were measured accurately. Trunk heights enter FW_7 with the power of 1.747, so a bias of 20% in biomass trunk estimation, when conducting the inventory, would result in an error of 38%. FW_8 does not contain trunk height and, therefore, is more suitable when bole lengths are unreliable.

In the literature, values found for vertical biomass in other regions in the Amazon vary from 290 to 900 t ha^{-1} (Klinge and Rodrigues, 1973; Brown et al., 1992; Brown et al., 1995). The average total

Table 1
Equations and regression coefficients. FW is the fresh weight (kg), D the diameter at breast height (cm), H the total tree height (m), ρ the average wood density (g cm^{-3}), M the average moisture content in terms of mass of moisture per unit mass of fresh biomass, α, β, γ and ψ the regression coefficients, and R^2 the coefficient of determination

Equations	Coefficients				
	α	β	γ	Ψ	R^2
FW_1 [a]$=\alpha D^{\beta}$ (1)	4.06	1.76	—	—	0.874
FW_2 [a]$=\alpha+\beta D+\gamma D^2$ (2)	400.32	39.99	0.97	—	0.875
FW_3 [a]$=\alpha+\beta D+\gamma(D^2)H$ (3)	318.09	38.12	0.03	—	0.90
FW_4 [a]$\alpha+\beta D+\gamma(D^2)+\Psi(D^2)H$ (4)	350.69	55.50	2.25	0.09	0.92
FW_5 [a]$=\alpha+\beta D^2+\gamma(D^2)H$ (5)	175.83	0.79	0.07	—	0.88
FW_6 [a]$=\alpha+\beta D+\gamma H$ (6)	533.26	130.22	51.00	—	0.82
FW_7 [a]$=\alpha(D^{\beta})H^{\gamma}$ (7)	0.026	1.529	1.747	—	0.92
FW_8 [b]$=(\alpha D^{\beta})/(1-M)$ (8)	0.465	2.202	—	—	0.90
FW_9 [b]$=(\alpha D^2)/(1-M)$ (9)	1.120	—	—	—	0.94
FW_{10} [b]$=\{\exp[\alpha+\beta\ln(D^2)]\}/(1-M)$ (10)	−1.966	1.242	—	—	0.97
$FW_{11}=\{\exp[\alpha+\beta\ln(H\rho D^2)]\}/(1-M)$ (11)	−2.904	0.993	—	—	0.99
FW_{12} [b]$=\{\exp[\alpha+\beta\ln(\rho D^2)]\}/(1-M)$ (12)	−0.906	1.177	—	—	0.99
$FW_{13}=\{\exp[\alpha+\beta\ln(HD^2)]\}/(1-M)$ (13)	−3.843	1.035	—	—	0.97
FW_{14} [b]$=\{\exp[\alpha+\beta\ln(D^2)+\gamma\ln(\rho)]\}/(1-M)$ (14)	−1.020	1.185	1.071	—	0.99

[a] Higuchi and Carvalho, 1994.
[b] Overman et al., 1994.

Table 2
Distribution of the frequencies of the individuals in the three experiments

DBH (cm)	Frequency (N)		
	Colombia (Overman et al., 1994)	Manaus (Higuchi and Carvalho, 1994)	Tomé Açu (Araújo, 1995)
5–10	1	158	—
10–20	11	105	89
20–30	8	31	15
30–40	8	21	7
40–50	7	10	6
50–60	5	4	5
60–70	4	3	3
70–80	4	2	0
80–90	3	0	1
90–100	3	0	0
100–110	0	0	0
110–120	0	1	0
138	0	0	1
Total	54	335	127

Table 3
Mass of trunks and crowns for the 127 individuals found in the 0.2 ha test area

DBH Interval (cm)	Number of individuals	Trunk mass (kg)	Crown mass (kg)	Total mass (kg)
10<20	73	6996	3520	10516
DBH≥10	54	86022	73047	159069
Total	127	—	—	1695855

Table 4
Biomass obtained by direct determination and by applying the fourteen models. FW is the fresh weight (kg). Weight is per plot (total weight in 0.2 ha)

DBH (cm)	N	Real Mass (kg)	FW_1 (kg)	FW_2 (kg)	FW_3 (kg)	FW_4 (kg)	FW_5 (kg)	FW_6 (kg)	FW_7 (kg)	FW_8 (kg)	FW_9 (kg)	FW_{10} (kg)	FW_{11} (kg)	FW_{12} (kg)	FW_{13} (kg)	FW_{14} (kg)
10–14	62	6653	18197	60693	49691	88518	24817	165223	6341	10260	15058	6176	9288	12874	5016	11954
15–19	27	9568	16313	37008	30606	66238	21315	99897	8947	10974	14861	7387	12562	14627	7094	13668
20–24	6	4105	5733	10622	8832	21720	7698	26912	3569	4321	5555	3126	5223	5988	3026	5618
25–29	9	12045	12478	20039	16929	46076	17812	47409	8952	10254	12646	7862	13189	14662	7815	13802
30–34	4	6627	6539	9972	8597	24477	9932	22933	5240	5631	6812	4433	7680	8167	4600	7700
35–39	3	10919	6671	9282	8080	24815	10625	19584	5573	6206	7248	5133	8484	9244	5169	8739
40–44	4	11169	11508	14990	14129	45787	21376	30146	12788	11427	12953	9854	18273	17408	11358	16497
45–49	2	4722	7537	9256	8972	30600	14890	17039	8806	8004	8799	7204	12976	12478	8185	11854
50–54	2	9168	8475	10175	8876	31431	14603	17298	6783	9269	10054	8501	12002	14597	7543	13882
55–59	3	15680	15286	17776	17548	63073	31741	29243	17815	17511	18595	16542	27941	28021	17889	26691
60–64	1	6720	5548	6367	6256	22833	11540	10097	6226	6492	6828	6216	10138	10464	6513	9976
65–69	2	23212	13013	14601	16053	58887	31474	22334	19430	15850	16367	15570	28871	25902	18828	24728
86	1	18939	10298	11002	13012	49992	27985	13892	16488	14075	13788	14880	26112	23931	17461	22941
138	1	30060	23646	24339	33554	134688	80474	20985	43686	39822	35460	48099	76995	72747	53895	70269
Total		169585	161179	256121	241134	709136	326282	542991	170644	170096	85024	160984	269735	271111	174391	258319

Table 5
Partial and total errors involved in the application of each of the fourteen models.

DBH (cm)	Error(%) FW_1	FW_2	FW_3	FW_4	FW_5	FW_6	FW_7	FW_8	FW_9	FW_{10}	FW_{11}	FW_{12}	FW_{13}	FW_{14}
10–14	173.5	812.3	646.9	1230.5	273.0	2383.4	−4.7	54.2	126.3	−7.2	39.6	93.5	−24.6	79.7
15–19	70.5	286.8	219.9	592.3	122.8	944.1	−6.5	14.7	55.3	−22.8	31.3	52.9	−25.9	42.9
20–24	39.7	158.8	115.2	429.1	87.5	555.6	−13.1	5.3	35.3	−23.8	27.2	45.9	−26.3	36.9
25–29	3.6	66.4	40.5	282.5	47.9	293.6	−25.7	−14.9	5.0	−34.7	9.5	21.7	−35.1	14.6
30–34	−1.3	50.5	29.7	269.4	49.9	246.1	−20.9	−15.0	2.8	−33.1	15.9	23.2	−30.6	16.2
35–39	−38.9	−15.0	−26.0	127.3	−2.7	79.4	−49.0	−43.2	−33.6	−53.0	−22.3	−15.3	−52.7	−20.0
40–44	3.0	34.2	26.5	309.9	91.4	169.9	1435	2.3	16.0	−11.8	63.6	55.9	1.7	47.7
45–49	59.6	96.0	90.0	548.0	215.3	260.8	86.5	69.5	86.3	52.6	174.8	164.3	73.3	151.0
50–54	−7.6	11.0	−3.2	242.8	59.3	88.7	−26.0	1.1	9.7	−7.3	30.9	59.2	−17.7	51.4
55–59	−2.5	13.4	11.9	302.3	102.4	86.5	13.6	11.7	18.6	5.57	8.2	78.7	14.1	70.2
60–64	−17.4	−5.3	−6.9	239.8	71.7	50.3	−7.4	−3.4	1.6	−7.5	50.9	55.7	−3.1	48.5
65–69	−43.9	−37.1	−30.8	153.7	35.6	−3.8	−16.3	−31.7	−29.5	−32.9	24.4	11.6	−18.9	6.5
86	−45.6	−41.9	−31.3	164.0	47.8	−26.6	−12.9	−25.7	−27.2	−21.4	37.9	26.4	−7.8	21.1
138	−21.3	−19.0	11.6	348.1	167.7	−30.2	45.3	32.5	18.0	60.0	156.1	142.0	79.3	133.8
Total	−5.0	51.0	42.2	318.2	92.4	220.2	0.6	0.3	9.1	−5.1	59.1	59.9	2.8	52.3

biomass of the Amazon forest is estimated to be 327 t ha^{-1} (Fearnside, 1994).

The relative importance of the estimate of the biomass of the largest tree in the test area is marked. This individual by itself represents 17.8% of the total fresh biomass. FW_7 yields an error of −45.3% for this particular tree, while for FW_8 the error is −32.5%. If this individual is taken out of the 127 trees of the inventory, then FW_7 would give an error of −9.0%, while FW_8 would give an error −6.6%. FW_1 would then become the best equation for the area, with an error of −1.43%. The equations that would give an error within ±10% would be FW_1, FW_7, FW_8 and FW_9. This demonstrates the instability of the predictions and indicates the need for relatively large data sets in order to better determine regression parameters and applying the predictive models.

4. Conclusion

A comparison with field results and the results of fourteen biomass equations applied to forest inventory in a 0.2-ha test site located in the town of Tomé Açu, state of Pará, yielded the following equations as the most appropriate to express the biomass content of trees with DBH≥10 cm for the test site:

$$FW_7 = \alpha D^{\beta} H^{\gamma},$$

where α=0.026, β=1.529 and γ=1.47 (Higuchi and Carvalho, 1994) and

$$FW_8 = \alpha D^{\beta}/(1 - M),$$

where α and β are 0.465 and 2.202, respectively, and M the biomass moisture content, defined in terms of mass of moisture per unit mass of fresh biomass (Overman et al., 1994). The aboveground fresh biomass weight predicted by the above equations were within ±0.6% of the weight determined in the field.

Acknowledgements

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Appendix

Results of forest inventory

Here, we present in Table 6, the results of the forest inventory conducted in the test area, where DBH is the diameter at the breast height (cm), H_{trunk} and H_{crown} the lengths of the corresponding trunks (m) and crowns (m), respectively, and m_{trunk}, m_{crown} and m_{total}

Table 6
Biomass for each individual in the test area

Brazilian common name	Botanical name	Family name	DBH (cm)	H_{trunk} (cm)	H_{crown} (cm)	m_{trunk} (kg)	m_{crown} (kg)	m_{total} (kg)
Sorva	*Couma macrocarpa* Barb.	Apocynaceae	10	5	2	41	6	47
Arataciú	*Sagotia racemosa* Baill.	Euphorbiaceae	10	5	2	40	12	52
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	10	10	5	68	21	89
Caneleira	*Ryania augustifolia* Mart.	Piperaceae	10	6	7	50	20	70
Arataciú	*Sagotia racemosa* Baill.	Euphorbiaceae	10	10	2	43	11	54
Faveira	*Vatairea paraensis* Ducke.	Fabaceae	10	9	3	33	5	38
Guajará Popoca	*Chrysophyllum* sp.	Sapotaceae	13	9	8	108	36	144
Cumaru	*Dipterix odorata* (Aubl.) Willd.	Fabaceae	12	11	5	126	23	149
Canela Jacamim	*Piper arthante* Aubl.	Piperaceae	10	6	5	40	29	69
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	11	14	2	66	12	79
Arataciú	*Sagotia racemosa* Baill.	Euphorbiaceae	10	8	5	54	13	67
Guajará patinho	*Chrysophyllum* sp.	Sapotaceae	11	5	6	58	32	90
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	13	7	6	86	33	119
Canela Jacamim	*Piper arthante* Aubl.	Piperaceae	11	11	3	70	8	78
Caneleira	*Ryania augustifolia* Mart.	Piperaceae	10	6	8	51	32	84
Taquari	*Mabea taquary* Aubl.	Euphorbiaceae	13	12	2	118	9	127

Table 6 (*Continued*)

Brazilian common name	Botanical name	Family name	DBH (cm)	H_{trunk} (cm)	H_{crown} (cm)	m_{trunk} (kg)	m_{crown} (kg)	m_{total} (kg)
Guajará Popoca	*Chrysophyllum* sp.	Sapotaceae	12	4	6	56	32	88
Caneleira	*Ryania augustifolia* Mart.	Piperaceae	13	7	9	97	65	162
Arataciú	*Sagotia racemosa* Baill.	Euphorbiaceae	12	9	4	60	25	85
Ingá	*Inga marginata* Willd.	Mimosaceae	11	6	7	65	20	85
Arataciú	*Sagotia racemosa* Baill.	Euphorbiaceae	11	7	3	42	17	60
Paranari	*Parinarium rodolphi* Huber.	Rosaceae	12	12	4	135	18	154
Arataciú	*Sagotia racemosa Baill.*	Euphorbiaceae	12	10	2	60	21	81
Louro Branco	*Ocotea guianensis* Huber.	Lauraceae	10	10	5	70	22	91
Canela Jacamim	*Piper arthante* Aubl.	Piperaceae	10	4	2	11	15	26
Canela Jacamim	*Piper arthante* Aubl.	Piperaceae	11	5	5	65	45	110
Guajará	*Chrysophyllum sericeum* A.DC.	Sapotaceae	13	10	6	96	30	125
Caneleira	*Ryania augustifolia* Mart.	Piperaceae	12	8	4	93	25	118
Canaã	*Canaresco comumis* L.	Cannaceae	11	4	2	46	29	75
Guajará Vermelho	*Chrysophyllum* sp.	Sapotaceae	10	9	4	52	34	86
Guajará Popoca	*Chrysophyllum* sp.	Sapotaceae	10	5	6	28	12	40
Macucu	*Licania hetermorpha* Benth.	Rosaceae	10	11	4	102	34	136
Bacurirana	*Rheedia macrophylla* Mart.	Guttiferae	10	12	3	63	9	71
Canela	*Cinamomum zeylanicum* L.	Lauraceae	11	11	2	15	8	23
Mangue	*Rhizophora mangle* L.	Rhizophoraceae	10	4	2	46	29	75
Seringa	*Hevea brasiliensis* Aubl.	Euphorbiaceae	11	6	2	39	5	44
Araracanga	*Aspidosperma desmanthum* DC.	Apocynaceae	10	5	2	24	7	30
Mangue	*Rhizophora mangle* L.	Rhizophoraceae	10	4	2	20	10	29
Louro Branco	*Ocotea guianensis* Huber.	Lauraceae	10	8	4	58	11	69
Morron	Eschweilera sp.	Lecythidaceae	11	6	4	80	56	136
Matá-matá Branco	*Eschweilera mata-mata Huber.*	Lecythidaceae	12	7	5	88	33	121
Guajará	*Chrysophyllum sericeum* A.DC.	Sapotaceae	12	12	8	117	29	146
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	11	7	7	65	28	93
Canela Jacamim	*Piper arthante* Aubl.	Piperaceae	13	5	4	51	11	62
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	11	8	4	86	33	119
Taquari	*Mabea taquary* Aubl.	Euphorbiaceae	13	10	3	98	29	127
Cariperana	*Parinarium barbatum* Ducke.	Rosaceae	15	12	4	163	51	214
Embaúba	*Cecropia paraensis* Huber.	Moraceae	14	16	3	85	14	98
Taquari	*Mabea taquary* Aubl.	Euphorbiaceae	15	17	3	188	21	209
Bacurirana	*Rheedia macrophylla* Mart.	Guttiferae	19	18	4	180	43	223
Louro Branco	*Ocotea guianensis* Huber.	Lauraceae	11	9	8	57	32	89
Ingá	*Inga marginata* Willd.	Mimosaceae	11	2	14	19	118	137
Caneleira	*Ryania augustifolia* Mart.	Piperaceae	16	9	11	169	195	364
Ingá	*Inga marginata* Willd.	Mimosaceae	19	7	5	176	33	209
Matá-matá	*Eschweilera mata-mata* Huber.	Lecythidaceae	13	11	2	108	46	154
Caneleira	*Ryania augustifolia* Mart.	Piperaceae	12	9	2	59	41	100
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	17	11	9	186	102	288
Matá-matá	*Eschweilera mata-mata* Huber.	Lecythidaceae	13	9	9	95	109	204
Guajará	*Chrysophyllum sericeum* A.DC.	Sapotaceae	16	12	8	167	66	233
Guajará	*Chrysophyllum sericeum* A.DC.	Sapotaceae	12	10	9	12	45	57
Caneleira	*Ryania augustifolia* Mart.	Piperaceae	14	7	13	106	162	268
Tento	*Ormosia excelsa* Benth.	Fabaceae	10	11	3	43	17	60
Louro Branco	*Ocotea guianensis* Huber.	Lauraceae	10	7	8	47	36	82
Matá-matá	*Eschweilera mata-mata* Huber.	Lecythidaceae	11	11	3	99	35	134
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	15	11	5	141	82	222
Caneleira	*Ryania augustifolia* Mart.	Piperaceae	14	12	6	90	120	210
Guajará	*Chrysophyllum sericeum* A.DC.	Sapotaceae	18	14	9	240	169	409
Achuá	*Saccoglotis guianensis* Benth.	Humiriaceae	16	14	9	296	109	405
Guajará	*Chrysophyllum* sp.	Sapotaceae	16	15	4	205	63	268

Table 6 (*Continued*)

Brazilian common name	Botanical name	Family name	DBH (cm)	H_{trunk} (cm)	H_{crown} (cm)	m_{trunk} (kg)	m_{crown} (kg)	m_{total} (kg)
Breu	Protium heptaphyllum (Aubl.) March.	Burseraceae	18	12	7	202	137	339
Macucu	*Licania heteromorpha* Benth.	Rosaceae	18	12	9	337	204	540
Guajará Vermelho	*Chrysophyllum* sp.	Sapotaceae	19	13	8	361	225	585
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	18	8	8	189	205	394
Louro Branco	*Ocotea guianensis* Huber.	Lauraceae	18	15	5	291	52	342
Caramuxi	*Micropholis paraensis* Hub.	Sapotaceae	16	11	5	300	171	471
Guajará Vermelho	*Chrysophyllum* sp.	Sapotaceae	17	12	6	273	173	446
Guajará Cutiti	*Chrysophyllum* sp.	Sapotaceae	16	13	4	221	100	321
Embaúba	*Cecropia paraensis* Huber.	Moraceae	21	15	4	301	84	385
Ingá	*Inga marginata* willd.	Mimosaceae	18	9	8	248	208	455
Caneleira	*Ryania augustifolia* Mart.	Piperaceae	18	7	4	198	41	238
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	26	12	6	641	518	1159
Jaboteira	*Fevillea uncipetala* Kuhlm.	Curcubitaceae	18	12	6	261	163	424
Angelim	*Dinizia excelsa* Ducke.	Mimosaceae	28	13	6	592	324	916
Jaboteira	*Fevillea uncipetala* Kuhlm.	Curcubitaceae	14	6	6	74	72	146
Guajarana	Chrysophyllum sp.	Sapotaceae	19	14	8	367	176	544
Cupuí	*Theobrama subincanum* Mart.	Sterculiaceae	15	12	7	199	58	257
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	24	13	6	477	373	850
Guajará Popoca	*Chrysophyllum* sp.	Sapotaceae	21	16	7	413	139	551
Ingá	*Inga marginata* Willd.	Mimosaceae	28	15	5	778	573	1351
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	19	14	4	227	142	369
Urucurana	*Sloanea dentata* L.	Tiliaceae	23	18	4	636	234	871
Urucurana	*Sloanea dentata* L.	Tiliaceae	16	15	4	251	62	313
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	14	12	5	152	96	248
Ingá Chato	*Inga fagifolia* (L.) Willd.	Mimosaceae	26	9	10	1534	843	2377
Canela Jacamim	*Piper arthante* Aubl.	Piperaceae	12	10	3	78	28	106
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	30	14	9	726	382	1108
Mará-matá	*Eschweilera mata-mata* Huber.	Lecythidaceae	14	11	5	138	63	201
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	18	12	5	160	99	259
Breu	*Protium heptaphyllum* (Aubl.) March.	Burseraceae	35	14	6	939	1230	2169
Louro Tamaquaré	···	Lauraceae	67	18	20	5068	3449	8517
Morron	*Eschweilera* Sp.	Lecythidaceae	28	16	8	1111	868	1980
Guajará	*Chrysophyllum* sp.	Sapotaceae	37	11	19	1241	1934	3175
Amapá	*Parahancornia amapa* (Hub.) Ducke.	Apocynaceae	31	14	10	783	521	1304
Louro Faia	*Euplassa Pinata* L.	Lauraceae	60	20	14	3466	2287	5754
Guajará Perdeneira	*Chrysophyllum* sp.	Sapotaceae	44	24	12	3683	1389	5072
Jaboteira	*Fevillea uncipetala* Kuhlm.	Curcubitaceae	53	12	11	1242	1252	2494
Guajará Bolacha	*Chrysophyllum* sp.	Sapotaceae	51	15	15	1841	1796	3636
Caneleira	*Ryania augustifolia* Mart.	Piperaceae	21	13	11	312	247	559
Guajará Perdeneira	*Chrysophyllum* sp.	Sapotaceae	29	15	14	1169	903	2072
Cariperana	*Parinarium barbatum* Ducke.	Rosaceae	24	9	10	348	432	780
Guajará Popoca	Chrysophyllum sp.	Sapotaceae	49	18	18	2673	1103	3776
Guajará Peludo	*Chrysophyllum excelsum* A.DC.	Sapotaceae	25	16	11	482	198	680
Breu Amarua	*Thalia geniculata* L.	Marantaceae	41	18	14	2438	1083	3521
Matá-matá	Eschweilera mata-mata Huber.	Lecythidaceae	27	11	14	570	643	1213
Macucu	*Licania heteromorpha* Benth.	Rosaceae	30	13	16	664	1286	1950
Mururé	*Brosimopsis acutifolia* (Hub.) Ducke.	Moraceae	56	24	14	4432	1701	6133
Timborana	*Enterolobium schomburgkii* L.	Mimosaceae	138	25	24	13834	16225	30060
Guajará Peludo	*Chrysophyllum excelsum* A.DC.	Sapotaceae	48	20	9	2446	835	3281
Ucuubarana	*Tryanthera sagotiana* (Benth.) Warb.	Myristicaceae	28	23	0	886	58	944
Mangaba	*Hancornia speciosa* Gom.	Apocynaceae	59	22	11	3532	1168	4700
Louro Mulato	*Ocotea neesiana* Nees.	Lauraceae	40	12	16	1466	1148	2613
Castanhola	*Terminalia catappa* L.	···	58	16	15	3609	3224	6833

Table 6 (*Continued*)

Brazilian common name	Botanical name	Family name	DBH (cm)	H_{trunk} (cm)	H_{crown} (cm)	m_{trunk} (kg)	m_{crown} (kg)	m_{total} (kg)
Parajuba	*Manilkara amazonica* Huber.	Sapotaceae	36	21	8	2121	869	2991
Matá-matá	*Eschweilera mata-mata* Huber.	Lecythidaceae	30	14	10	696	415	1111
Guajarana	*Chrysophyllum* sp.	Sapotaceae	41	21	8	2481	927	3408
Angelim Pedra	*Hymenolobium petraeum* Ducke.	Fabaceae	66	17	24	6445	8250	14695
Samaúma	*Ceiba pentandra* (L.) Gaerth.	Bombacaceae	86	21	22	6507	12432	18939
Total						93021	76571	169586

the masses of the corresponding trunks (kg), crowns (kg) and total, trunk plus crown (kg).

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