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ABOVE-GROUND BIOMASS ESTIMATION OF A SECONDARY FOREST IN SARAWAK

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CHAI, F.Y.C. 1997. Above-ground biomass estimation of a secondary forest in Sarawak. An above-ground biomass study of trees, shrubs, ferns, grasses and lianas in a 10- to 14-y-old secondary forest at Semengok, Kuching was carried out in 1981 as part of a study of nutrient cycling in shifting cultivation land. This was done by destructive sampling in a 20 x 10 m plot of representative vegetation sited on a midslope of 15 degrees. Ninety-four per cent of the above-ground oven-dry weight biomass totalling 32.0 t ha^{-1} were made up of trees and shrubs of diameters 5 cm and above. The tree and shrub stratum averaged 8.1 m in height and 6.2 cm diameter at breast height and was dominated by *Trichospermum kurzii, Macaranga* spp., *Dillenia suffruticosa* and *Vitex pubescens.* The undergrowth was dominated by a sedge, *Cyperus cyperinus,* while the liana component was mainly *Embelia effusa.* The above-ground biomass of trees and shrubs was 58.3% stem wood, 12.9% stem bark, 15.3% branches, 6.5% twigs and 6.9% leaves. Regressions of shoot total height and shoot component dry weights on dbh and or dbh^2h were significant.

Key words: Secondary forest - above-ground biomass - shifting cultivation regression

CHAI, F.Y.C. 1997. Anggaran biojisim atas tanah hutan sekunder di Sarawak. Kajian biojisim atas tanah pokok, pokok renik, paku-pakis, rumput dan liana di hutan sekunder berumur 10 - 14 tahun di Semengok, Kuching dijalankan pada tahun 1981 sebagai sebahagian daripada kajian kitaran nutrien di tanah pertanian pindah. Kajian pensampelan menghancur dijalankan di plot berukuran 20 x 10 m bagi pertumbuhan yang terletak di cerun tengah 15 darjah. Sembilan puluh empat peratus biojisim berat keringan ketuhar atas tanah berjumlah 32.0 t ha^{-1} terdiri daripada pokok dan pokok renik berdiameter 5 cm dan ke atas. Pokok dan stratum pokok renik secara purata ialah 8.1 m tinggi dan 6.2 cm diameter aras dada dan dikuasai oleh *Trichospermum kurzii, Macaranga* spp., *Dillenia suffruticosa* dan *Vitex pubescens.* Tumbuhan bawah dikuasai oleh rumput, *Cyperus cyperinus,* manakala komponen liana sebahagian besarnya ialah *Embelia effusa.* Biojisim atas tanah pokok dan pokok renik ialah 58.3% kayu batang, 12.9% kulit batang, 15.3% dahan, 6.5% ranting dan 6.9% daun. Regresi jumlah ketinggian pucuk dan berat kering komponen pucuk ke atas dbh dan dbh^2h adalah ketara.

Introduction

This work was part of a major study on nutrient cycling in shifting cultivation by the Royal Institute of Holland in one of five agro-ecological regions in Southeast Asia. The main object of this study was to relate the biomass figures obtained to the nutrient cycling process on land undergoing shifting agriculture. Biomass in this study refers to phytomass, specifically the standing crops of trees, shrubs, herbs, etc. or the primary producers. Secondary forest is a forest which has developed by natural secondary succession on land abandoned after shifting agriculture. A secondary forest in Sarawak is characterised by the presence of herbaceous weeds, shrubs, small rapid growing, short-lived trees and larger, light demanding and rapid-growing trees such as of *Macaranga, Mallotus* and *Trema* species. This study sought to discover some indirect means of estimating the biomass of some major secondary forest tree and shrub species in Sarawak. In this study, biomass estimation was by the harvest or destructive sampling method in a 20 × 10 m plot in a 10- to 14-y-old secondary forest, followed by development of regressions of tree shoot dimensions on diameter and height.

Methods

Study area

The biomass plot of 20 × 10 m was located within the Agricultural Experimental Reserve at Semengok, about 20 km from Kuching, the capital city of Sarawak, Malaysia (Figure 1). A 0.32-ha secondary forest within the Reserve was subjectively selected due to its easy accessibility. An enumeration (50%) of the vegetation within this area was then done by counting trees and shrubs occurring in the <5, 5-10, 10-15, 15-20 and > 20 cm diameter (at breast height) classes. The biomass plot was then located within the 0.32-ha area so as to have representative vegetation of the larger area. The biomass plot was a 10- to 14-y-old secondary forest on midslope with a gradient of 10-20 degrees and an easterly aspect. The soil within the biomass plot was Red-Yellow Podsolic (clayey ultisol) belonging to Semengok Series. Elevation of the site was about 42 m above sea level. The mean annual temperature of the area was 26 °C and the mean annual total rainfall about 3900 mm.

The vegetation in the study area consisted mainly of trees and shrubs less than 10 cm dbh and was dominated by *Trichospermum kurzii* (Tiliaceae), *Gochidion lutescens* and *Macaranga* species (Euphorbiaceae), *Pithecellobium jiringa* (Leguminosae), *Dillenia suffruticosa* (Dilleniaceae), and *Vitex pubescens* (Verbenacea). The undergrowth was dominated by a sedge, *Cyperus cyperinus* (Cyperaceae) and the canopy by a liana, *Embellia effusa* (Myrsinaceae). The trees and shrubs averaged 8.1 m in height and 6.2 cm diameter at breast height (1.3 m above ground level) for all individuals.

Biomass estimation

The fresh weights of ferns, grasses and lianas were determined by direct weighing of their total harvest while those of shrubs, trees and their components were determined by weighing from their samples harvested from the plot. Altogether, 61 trees and shrubs, excluding 2 dead ones, were felled from the biomass plot. The oven-dry weights were constant weights obtained after drying at 105 °C. Ferns, grasses, liana branches and liana foliage were weighed directly or by representative samples. Liana stem dry weights were determined from 20 cm long stem samples taken from each 2 m long liana stem section.

The dry weights of stems of trees and shrubs were determined from weights of 10 cm long samples of each 1 m long stem section. Stem bark thickness was measured from the 10 cm long stem samples. The dry weights of branches, twigs (< 1 cm diameter over bark) and leaves were determined from dry weights of representative samples.

Allometry of shoot component weights on d [stem diameter (dbh, diameter at breast height for trees)] or d_0 (diameter at ground level for shrubs) and on dbh^2h (where h is the total height of trees and shrubs) was calculated by simple linear regression. Logarithmic regression was not examined.

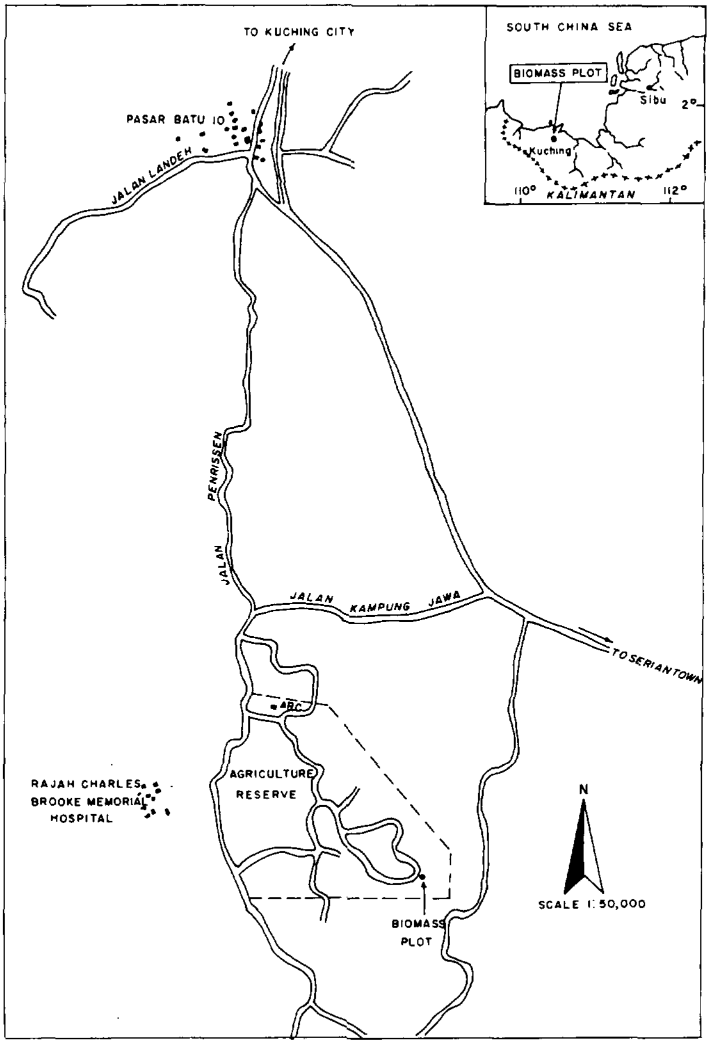

Figure 1. Location of biomass plot

Results

Trees and shrubs

The species composition and diameter distribution of trees and shrubs in the plot are shown in Table 1. The dominant trees were *Trichospermum kurzii* (30% in density), *Pithecellobium jiringa* (10%), *Macaranga javanica* (8%) and *Gochidion lutescens* (7%), while the important shrubs were *Vitex pubescens* (8%), *Ficus brunneo-aurata* (8%) and *Dillenia suffruticosa* (7%). The biggest tree harvested was that of *Vernonia arborea* (12.8 m high and 16.9 cm dbh) while the smallest was a tree of *Campnosperma auriculatum* (3.5 m high and 3.1 cm dbh). In terms of basal area distribution, the most common tree species, *Trichospermum kurzii* (1056 cm^2), accounted for almost half the total basal area (2289 cm^2) in the plot, followed by *Pithecellobium jiringa* (246 cm^2) and *Vernonia arborea* (224 cm^2).

The oven-dry weights of the vegetation in the plot are shown in Table 2 which indicates that trees and shrubs accounted for 94 % (30.1 t ha^{-1}) of the biomass of all vegetation (32.0 t ha^{-1}) in the plot. Table 3 shows that one third of the total above-ground biomass was distributed in one species, *T. kurzii* (10.2 t ha^{-1}), and three quarters of it was accounted for by *T. kurzii* and four other species, viz. *V. arborea* (4.8 t ha^{-1}) *P. jiringa* (3. 4 t ha^{-1}), *V. pubescens* (2. 7 t ha^{-1}) and *M. javanica* (1 .4 t ha^{-1}).

The distribution of dry weight biomass among the plant shoot components by species is shown in Table 4. On average, 58 % of the shoot total component biomass was concentrated in stem wood, 13 % in stem bark, 15 % in branch wood, 6 % in twig wood and bark and 7 % in the foliage.

Table 1. Species composition and frequency distribution of tree and shrub by dbh class in a 10 x 20 m plot

Species/vegetation form	Number in dbh (cm) class				Percentage
	2.5-5	5-10	10-20	Total	
Trichospermum kurzii (T)	2	12	4	18	29.5
Pithecellobium jiringa (T)	2	2	2	6	9.8
Vitex pubescens (S)	2	3		5	8.2
Macaranga javanica (T)	4	1		5	8.2
Ficus brunneo-aurata (S)	5			5	8.2
Gochidion lutescens (T)	2	2		4	6.6
Dillenia suffruticosa (S)	1	3		4	6.6
Euphorbiaceae sp. (T)	3			3	4.9
Evodia alba (T)	2			2	3.3
Nauclea subdita (T)		2		2	3.3
Adinandra dumosa (T)	1			1	1.6
Macaranga beccariana (T)		1		1	1.6
Campnosperma auriculatum (T)	1			1	1.6
Vernonia arborea (T)			1	1	1.6
Cratoxylum formosum (S)	1			1	1.6
Fagraea racemosa (T)		1		1	1.6
Meliaceae sp. (T)	1			1	1.6
Total	27	27	7	61	
Percentage	44.3	44.3	11.5		

Note: T = tree; S = shrub; dbh = diameter at breast height.

Table 2. Biomass of each species group

Species group	Oven-dry weight (kg 200 m^{-2})	Oven-dry weight (kg ha^{-1})	Percentage of total
Trees and shrubs	602.3	30 113	94.1
Lianas	13.9	694	2.2
Ferns and grasses	23.7	1 186	3.7
Total	639.9	31 993	100.0

Table 3. Biomasss of tree and shrub species

Species	Oven-dry weight kg 200 m^{-2}	Oven-dry weight kg ha^{-1}	Percentage of total	Cumulative percentage
Trichospermum kurzii	200.4	10 200	33.3	33.3
Vernonia arborea	96.5	4 825	16.0	49.3
Pithecellobium jiringa	68.9	3 444	11.4	60.7
Vitex pubescens	54.6	2 728	9.1	69.8
Macaranga javanica	28.3	1 413	4.7	74.5
Nauclea subdita	27.3	1 362	4.5	79.0
Cratoxylum formosum	23.9	1 194	4.0	83.0
Dillenia suffruticosa	23.3	1 164	3.9	86.9
Gochidion lutescens	21.8	1 090	3.6	90.5
Evodia alba	15.7	785	2.6	93.1
Ficus brunneo-aurata	10.8	538	1.8	94.9
Fagraea racemosa	10.3	515	1.7	96.6
Macaranga beccariana	8.1	405	1.3	97.9
Adinandra dumosa	5.9	297	1.0	98.9
Euphorbiaceae sp.	5.0	249	0.8	99.7
Campnosperma auriculatum	1.0	48	0.2	99.9
Meliaceae sp.	0.7	37	0.1	100.0
Total	602.3	30 113		

Ferns, grasses and lianas

There were three species of grasses and four species of ferns in the biomass plot. A sedge, *Cyperus cyperinus,* dominated the undergrowth forming 63 % of the total biomass of the herb layer. A fern, *Nephrolepis dicksonoides,* and a grass, *Coelorachis glandulosa,* accounted for 20 and 12 % respectively of the herbaceous biomass (Table 5). The dominant climber or liana was *Embelia effusa* making up 62 % of the liana biomass with *Uncaria cordata* (13 %), *Dalbergia* species (8%) and *Gynochthodes sublanceolata* (6%) also important (Table 6).

Table 4. Plant components of above-ground biomass by species/species group

Species	Stem wood	Stem bark	Branch wood + bark	Twig wood + bark	Leaf	Flower
T. kurzii	62.4	22.8	7.6	3.2	4.0	
V. arborea	63.9	8.0	18.8	2.7	6.7	
P. jiringa	45.1	8.6	29.5	7.8	7.0	
V. pubescens	61.4	7.0	15.7	7.9	8.0	
M. javanica	43.8	6.8	25.0	19.0	5.5	
N. subdita	67.6	11.8	5.7	7.3	7.5	
C. formosum	61.8	2.6	12.8	14.5	8.3	
D. suffruticosa	30.6	3.3	39.7	14.7	11.7	
G. lutescens	54.7	9.8	18.1	5.7	11.4	0.4
E. alba	62.5	10.1	11.5	5.1	10.9	
F. brunneo-aurata	59.2	7.5	14.8	12.6	5.6	0.3
F. racemosa	56.7	12.4	8.2	9.8	11.0	1.9
M. beccariana	66.8	14.8	2.8	1.1	11.7	2.9
A. dumosa	39.5	6.4	5.3	18.7	30.0	
Euphorbiaceae sp.	53.2	5.3	17.3	10.9	13.2	
C. auriculatum	49.9	10.8		0.9	38.4	
Meliaceae sp.	62.7	9.1	9.0	12.1	7.1	
Overall average percentage	58.3	12.9	15.3	6.5	6.9	0.1
Cumulative percentage	58.3	71.2	86.5	93.0	99.9	100.0

Table 5. Composition of stem and leaf biomass for fern and grass species

	Stem		Leaf		Total	Percentage
Species	kg	%	kg	%	kg	
Cyperus cyperinus (G)			15.03		15.03	63.4
Nephrolepis dicksoniodes (F)	3.18	68.3	1.48	31.7	4.66	19.7
Coelorhachis glandulosa (G)			2.92		2.92	12.3
Curculigo villosa Wall. (G)			0.36		0.36	1.5
Lygodium cf. *borneense* (F)			0.33		0.33	1.4
Gleichenia linearis (F)			0.27		0.27	1.1
Lygodium circinnatum (F)			0.15		0.15	0.6
Total	3.18		20.54		23.72	
Percentage		13.4		86.6		

Note: G = grass; F = fern.

Regressions

Regressions of shoot height and shoot components weight on dbh and on dbh^2h were statistically significant ($p<0.05$, Tables 7 and 8). For the most abundant species, *Trichospermum kurzii*, and also for all species combined, the regressions of various shoot component and total shoot weights on dbh or dbh^2h were all significant. As much as 63 to 99 % (R^2, the coefficient of determination) of the variation in the shoot component weights was accounted for by dbh or dbh^2h, the independent variable in these regressions.

Table 6. Composition of biomass for liana species

Species	Stem (%)	Branch & twig (%)	Leaf (%)	Total dry weight (kg)	Percent -age	Cumu- lative %
Embelia effusa	64.6	29.4	6.0	8.63	62.2	62.2
Uncaria cordata	57.8	18.6	23.6	1.77	12.7	74.9
Dalbergia sp.	52.7	39.0	8.3	1.16	8.4	83.3
Gynochthodes sublanceolata	81.8	9.6	8.6	0.83	6.0	89.3
Rubus mollucanus	33.9	50.2	15.8	0.60	4.3	93.6
Flagellaria sp.	81.7		18.3	0.36	2.6	96.2
Flagellaria indica	35.7	36.9	27.4	0.22	1.6	97.8
Similax odoratissima	49.2	19.4	31.4	0.14	1.0	98.8
Jasminum sp.	68.2	24.9	6.9	0.09	0.7	99.5
Diploclisia glaucescens	32.3	56.6	11.2	0.06	0.5	100.0
Total				13.86		
Percentage	62.1	27.9	10.0			

Table 7. Regressions of shoot dimensions on diameter in a secondary forest after shifting cultivation

Species	*T. kurzii*	*P. jiringa*	*V. pubescens*	*M. javanica*	*F. brunneo-aurata*	All species
n	18	6	5	5	5	17
Total height (m)						
a	5.99	3.30			2.58	3.74
b	0.57	0.48			0.88	0.59
R^2	0.83	0.94			0.81	0.68
Stem dry weight (kg)						
a	- 13.58	- 3.49	- 4.81		- 0.82	- 18.68
b	2.78	1.49	1.65		0.67	4.48
R^2	0.63	0.97	0.91		0.81	0.82
Stem wood dry weight (kg)						
a	- 11.00	- 3.01	- 4.32	- 2.67	- 0.74	- 16.55
b	2.16	1.29	1.48	1.19	0.60	3.95
R^2	0.63	0.97	0.91	0.78	0.84	0.80
Branch wood and bark dry weight (kg)						
a	- 2.98	- 2.16	- 1.26			- 5.07
b	0.45	0.84	0.40			1.17
R^2	0.79	0.89	0.84			0.80
Total dry weight (kg)						
a	-16.85	- 6.13	- 7.14	- 7.50	- 1.39	- 24.80
b	3.37	2.66	2.43	3.04	1.06	6.14
R^2	0.67	0.99	0.89	0.99	0.91	0.80

Note: Regressions are in the allometry $y = a + bx$, where x is the diameter at breast height (dbh in cm), y the dependent variable indicated, a and b coefficients and R^2 the coefficient of determination for each regression.

Table 8. Regressions of shoot dimensions on dbh^{2}h in a secondary forest after shifting cultivation

Species	*T. kurzii*	*P. jiringa*	*V. pubescens*	*M. javanica*	*F. brunneo-aurata*	All species
n	18	6	5	5	5	17
Stem dry weight (kg)						
a	- 1.22	0.52	1.00		0.16	0.29
b	125.55	138.82	118.06		168.03	186.08
R^2	0.77	0.99	0.92		0.93	0.96
Stem wood dry weight (kg)						
a	- 1.42	0.44	0.89		0.14	0.15
b	97.33	119.46	106.04		149.20	164.98
R^2	0.76	0.99	0.93		0.95	0.95
Branch wood and bark dry weight (kg)						
a	- 0.60	0.18	0.18			0.04
b	16.28	75.90	28.03			47.65
R^2	0.81	0.86	0.82			0.92
Total dry weight (kg)						
a	- 1.75	1.28	1.46	- 1.81	0.99	1.24
b	149.83	240.79	172.68	542.19	256.59	255.16
R^2	0.80	0.96	0.89	0.90	0.98	0.94

Note: Regressions are in the allometry y =a+bx, where x is dbh^{2}h (dbh= diameter at breast height in cm and h is height in m), y the dependent variable indicated, a and b coefficients and R^2 the coefficient of determination for each regression.

Discussion

The exact age of the biomass plot was not known. However, by comparing the stand structure in the biomass plot with figures on diameters and heights for known aged secondary forests in other parts of Sarawak (Lee, personal communication), the true age of the biomass plot was nearer to 10 years than 14. A few other biomass studies of secondary forest in Sarawak have been conducted since the Semengok study was completed in 1981. Ewel *et al.* (1983) reported that a 4.5- and 9.5-y-old site on Red-Yellow Podsolic soils (sandy ultisol) in Sabal Forest Reserve supported 10.9 and 34.4 t ha^{-1} respectively. They reported that a 4.5-y fallow on alluvial soil, also at Sabal, produced 46.6 t ha^{-1} of biomass. Lim and Basri (1985) estimated the biomass for a 3.5-y-old secondary forest over sandy loam at Oya Road Plantation Reserve to be 6.2 t ha^{-1}. Halenda (1989) estimated the overstorey biomass for a 7- to 10-y site also on Red-Yellow Podsolic soil (clayey ultisol) at Niah Forest Reserve to be 84.1 t ha^{-1}. Riswan and Kenworthy (1985) calculated that the stem (10 cm dbh and above) biomass of a 1.5-y-old secondary forest in Samarinda, East Kalimantan to average 37 t ha^{-1} while that of a 35-y-old forest to be not less than 113 t ha^{-1}.

The biomass appears to vary depending on the site conditions, namely soils, the floristics (species composition), overstorey structure (as indicated by mean height and dbh) and nutrient impoverishment. For instance, the similarly species rich (27 species in a 0.04 ha) site at Niah as the Semongok site (17 species in a 0.02 ha), but with an overstorey averaging 10.4 m in height and 8.5 cm in dbh carries almost three time more biomass (97.0 versus 32.0 t ha^{-1}). The richer alluvial site carries four times more biomass than a site on nutrient-poor Red-Yellow Podsolic soil at Sabal. Kellman (1970) reported different biomass figures for various plots of the same age at Mindanao, Philippines. For example, the fresh weight biomass for an area with 26 plant species was 27 t ha^{-1} compared with 83 t ha^{-1} for another area with 46 plant species, both at 7 y of age.

In the secondary forest in Semengok, tree and shrub biomass greatly overshadowed that of other plants, a fact also noted by Ewel *et al.* (1983) and Halenda (1989). The study in Semengok indicates that 60 % of total biomass was concentrated in stem wood. Ewel *et al.* (1983) reported for the 9.5-y-old plot that three quarters of the biomass was in the tree stems while Halenda (1989) stated that stemwood accounted for 65 % of the overstorey growth (86% of the total mean above-ground) biomass. About 13 % of the biomass at Semengok was in the barks of trees and shrubs while Halenda (1989) stated that the overstorey biomass had 10.4 % stem bark.

The correlations between shoot component and shoot total biomass with dbh were high in this study. High correlations were also observed in secondary forests in Niah (Halenda 1989) and in other forest types, e.g. in mixed deciduous woodland (Bunce 1968) and oak-pine forest (Whittaker & Woodwell 1968). Many biomass investigators had in the past investigated the use of dbh^2h in formulating the best regression relationship for predicting biomass. In this study, it was observed that the prediction of biomass by dbh^2h instead of dbh was only slightly improved. Halenda (1989) noted that the use of dbh alone gave equally good results. Madgwick and Satoo (1975) noted no improvement in using dbh^2h over dbh in predicting biomass. In this study, the mixed or all species regressions appeared to be able to predict biomass as well as individual species regressions. The fact that dbh is more easily measured than height means that regressions on dbh are easier to obtain and can be more widely used for similar plant communities of secondary vegetation. However, Whittaker and Woodwell (1968) stated that the regression on diameter from one community cannot be applied to another of different height-diameter relations and growth rate.

Conclusion

The above-ground biomass of the secondary vegetation of the study area was composed mainly of trees and shrubs. More than half of the biomass was concentrated in stem wood. Significant simple linear regressions existed in relating shoot weight parameters to both dbh and dbh^2h. Five tree and shrub species, namely *Trichospermum kurzii, Vernonia arborea, Pithecellobium jiringa, Vitex pubescens* and *Macaranga javanica,* contributed to the major portion of the woody stratum total biomass.

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