Allometric equations for pioneer tree species and estimation of the aboveground biomass of a tropical secondary forest in East Kalimantan

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ABSTRACT To estimate the aboveground biomass of tropical secondary forests dominated by pioneer species, allometric equations to relate diameter at breast height with the dry mass of the aboveground organs of several pioneer species were developed. The aboveground biomass of secondary forests was estimated using four methods based on the allometric equations. Biomass estimated with an allometric equation for all species combined was equivalent to that estimated with species-specific allometric equations. However, the estimated biomass based on a general-purpose allometric equation was substantially higher than that using other allometric equations. The allometric equation for all species combined is suitable for estimating the biomass of a secondary forest from the view points of accuracy and labor.

Key words: biomass estimation, East Kalimantan, pioneer species, fallow forest

INTRODUCTION

The estimation of aboveground biomass is an essential tool for evaluating the productivity and nutrient cycling of forests. As well, the recent studies on global climate change have highlighted the role of forests as carbon sinks. Changes in the cover, utilization, and management of forests all affect the exchange of carbon between terrestrial ecosystems and the atmosphere (Bolin *et al.*, 2000). To assess the role of forests as carbon sinks and sources, an accurate means of estimating forest biomass must be developed.

Tropical forests are a particular concern because they are undergoing significant change, and there are few reliable biomass estimates for these forests (Brown, 1997). In addition, tropical forests have the greatest potential to serve as sinks for carbon dioxide if appropriately managed (Brown *et al.*, 1996). The biomass dynamics of secondary forests, such as fallow forests, are of special interest, because such forests are spreading rapidly as a result of forest degradation in the tropics. For these reasons, we need an efficient and accurate means of biomass estimation for secondary forests composed mainly of pioneer species. With biomass estimations the magnitude of the sources and sinks in these forests can be evaluated and the role of secondary tropical forests in the global carbon cycle will be better understood.

Aboveground biomass can be measured with two common methods. Weighing tree biomass in the field is the most accurate approach, but is destructive and laborious, and is thus generally limited to small areas. In contrast, a method using allometric relationships between tree dimensions and aboveground biomass is more cost-effective. Moreover, well-developed allometric equations can estimate forest biomass of other stands easily and non-destructively. Species-specific equations should be used, because trees of different species can differ greatly in tree architecture and wood density (Shukla and Ramakrishnan, 1986; Vester and Cleef, 1998; Castro-Diez *et al.*, 1998). However, it can be very difficult to develop species-specific equations for each species in most primary tropical rainforests because enormous numbers of tree species usually grow in these forests. Since secondary forests are often dominated by only small numbers of pioneer species, it is much easier to develop species-specific equations. Because the wood densities of pioneer species are usually low, allometric equations for these species may differ significantly from those for species with a higher wood density.

In the present study, the development of allometric equations for several tropical pioneer tree species in East Kalimantan, Indonesia is discussed. By means of these equations, the aboveground biomass of secondary forests dominated by pioneer species was estimated using four methods, and the accuracy of each method was evaluated.

METHODS

Study area

The study area was Sebulu, East Kalimantan, in the Indonesian part of Borneo (0° 16' S, 116° 59' E, about 130 m asl). For our study, we selected forests on a low, undulating plateau with some small rivers and shallow basins. This topography is common in the lowlands of East Kalimantan. The geology of the study area is characterized by Tertiary sedimentary rocks of various textures (Ohta *et al.*, 2000), and the soils are classified mainly as ultisols. From 1993 to 1997, the annual rainfall averaged about 1800 mm, and the mean temperature averaged approximately 28 °C. There used to be dipterocarp forests with aboveground biomass of 509 t/ha (Yamakura *et al.*, 1986a) in this area. Selected logging was carried out in the 1970s. These forests also experienced large-scale forest fires twice: once between 1982-83 (Malingreau *et al.*, 1985) and again in 1997-98 (Mori, 2000); most plants were lost in the first fire. After those fires, illegal logging and shifting cultivation spread widely throughout the burned area. The deforested lands subsequently became either secondary forests of pioneer species or alang-alang (*Imperata cylindrica* [L.] Beauv.) grasslands.

Field measurements and data analysis

Sixteen plots (10 m × 10 m) in fallow forests were established from June 1993 to October 1994. Each plot was dominated by no more than six species. The three most abundant species in most plots were a *Ficus* sp., *Geunsia pentandra* (Roxb.) Merr., and *Piper aduncum* L. (Hashimoto *et al.*, 2000). All individual trees with a girth at breast height (GBH) ≥ 10 cm were identified, and their GBH was converted to the diameter at breast height (DBH). Some upper story trees (GBH ≥ 10 cm) of each species with a range of sizes in each plot were selected, as follows:

- 1) If there were fewer than six trees of a species in the plot, 1 or 2 trees were sampled.
- 2) If there were 6 to 30 trees of a species in the plot, 3 trees were sampled.
- 3) If there were more than 30 trees of a species in the plot, about 10 % of the trees were sampled.

These sample trees were felled at ground level and separated into two parts: assimilative organs (leaves) and non-assimilative organs (stems and branches). Then the fresh weight of each part was determined. Samples from each part were weighed, and then oven-dried at 80 °C for 48 h and weighed again to calculate the ratio of fresh weight to dry weight. Trees with GBH < 10 cm and all herbaceous plants were also cut and weighed. Samples taken from each plant part were also oven-dried at 80 °C for 48 h and weighed to calculate the ratio of fresh weight to dry weight.

For each tree species, the allometric relationship between DBH and total dry weight of the aboveground organs (W_t), as well as between DBH and the dry weights of stems and branches (W_{sb}) and of leaves (W_l) were separately analyzed, through regressions of logarithmically transformed variates. These variates often satisfy an allometric equation of the following form:

$$\ln(W) = a \times \ln(\text{DBH}) + b \quad \text{Equation 1}$$

where W is either of W_t , W_{sb} or W_l , and a and b are coefficients.

Because none of the variates were independent of the others, a geometric mean regression line was used to describe the relationship between DBH and the variates (Ricker, 1984). For each tree species, the values of a and b in equation 1 were estimated using the actual weight values obtained by destructive sampling.

The biomass of the 16 sample plots was estimated using four methods:

Method 1: Allometric equations for the relationship between DBH and W_{sb} and between DBH and W_t for each species in each plot were developed. (For species with only two samples, equations that linked the two points on the DBH — W_{sb} and DBH — W_t graphs were developed. For those with only one sample, the ratios of DBH to W_{sb} and of DBH to W_t were used.) The aboveground biomass in each plot was estimated by inserting each DBH value into the allometric equations to generate a weight value, and summing the results. Actual measured weights for the trees we sampled were used directly rather than weights estimated by equation 1.

Method 2: Allometric equations for the relationship of DBH to W_t for the three dominant species and others, which include all samples except the three dominant species, were developed from the data for the whole plot. Then the aboveground biomass of each plot was estimated by inserting each DBH value into the resulting allometric equations to generate a weight value, and summing the results.

Method 3: An allometric equation for the relationship of DBH to W_t was developed from the data for all samples. The aboveground biomass of each plot was estimated by inserting each DBH value into the allometric equation to generate a weight value, then summing the results.

Method 4: The aboveground biomass of each plot was estimated by inserting each DBH value into the following allometric

equation:

$$\ln(W_i) = 2.530 \times \ln(\text{DBH}) - 2.134$$

Equation 2

This equation was developed by Brown (1997) to estimate the biomass of trees growing in the moist tropics.

In all the methods, the weights of small plants (except trees with GBH ≥ 10 cm) were added to the weight of upper story trees and the aboveground biomass of each plot was calculated.

ANCOVA was used to test for differences in the regression lines. Differences in the slopes of the allometric lines (a) were tested first. Because there was no significant difference in the value of a , interspecific differences in the sampled means of $\ln(W_i)$ were tested for after adjusting for a common mean of $\ln(\text{DBH})$ and a common slope of the allometric line (Sokal and Rohlf, 1997).

RESULTS AND DISCUSSION

We obtained 191 datasets for the relationships between DBH and W_{sb} , W_l , and W_t for the pioneer tree species (Appendices 1–4). From these datasets, we developed allometric equations for the three dominant species, other pioneer tree species, and all species combined (Table 1, Figure 1). Table 1 also includes regression lines for *Paraserianthes falcata* (L.) Nielsen in planted forests in the Philippines (Kawahara *et al.*, 1981) and for trees of DBH ≥ 4.5 cm growing in a natural dipterocarp forest (Yamakura *et al.*, 1986b) in Sebulu for comparison. Both the latter regressions were also performed using a geometric mean regression. The allometric lines for the three dominant pioneer species showed highly significant correlations between DBH and W_t ($r^2 \geq 0.91$).

Table 1. Estimates of the regression coefficient (a) and intercept (b) for the geometric mean regressions for the three most common species, all other species, and all species combined as follow.

$\ln(W_i) = a \times \ln(\text{DBH}) + b$, where W_i = total aboveground biomass

Entries within column "Adjusted means of $\ln(W_i)$ " not sharing common letters differ significantly at $P < 0.05$ level based on Gabriel's approximate method (Sokal & Rohlf, 1997), but "All species combined" and "Tropical trees in the moist tropics" are not included in this test.

	a	b	Number of samples	Range of DBH (cm)	Adjusted r^2	Adjusted means of $\ln(W_i)$
<i>Ficus</i> sp.	2.60	-2.59	26	3.5 – 9.1	0.95	1.55 ^a
<i>Geunsia pentandra</i>	2.62	-2.89	20	3.4 – 16.2	0.91	1.31 ^a
<i>Piper aduncum</i>	2.39	-2.42	37	3.2 – 8.3	0.92	1.38 ^a
Other species	2.40	-2.49	108	3.2 – 20.3	0.81	1.36 ^a
All species combined	2.44	-2.51	191	3.2 – 20.3	0.85	
<i>Paraserianthes falcata</i> (Kawahara <i>et al.</i> , 1981)	2.56	-2.95	20	4.1 – 36.1	0.98	1.25 ^a
Trees in natural dipterocarp forest (Yamakura <i>et al.</i> , 1986b)	2.62	-2.30	76	4.5 – 130.5	0.98	1.97 ^b
Tropical trees in the moist tropics (Brown, 1997)	2.53	-2.13	170	5 – 148	0.97	

Fig. 1. Geometric mean regression lines for the relationship between DBH and total aboveground biomass (W_t)

The differences among the allometric lines (DBH < 10 cm) of the three dominant species, other species, *Paraserianthes falcataria* and trees in a natural dipterocarp forest were tested with ANCOVA. While there was no difference among the slopes (a) of the allometric lines, there were significant differences among the adjusted means of $\ln(W_t)$ (Sokal and Rohlf, 1997) (Table 1). The adjusted mean of $\ln(W_t)$ of trees in a dipterocarp natural forest reported by Yamakura *et al.* (1986b) was significantly larger than the other values. This result implies that the tree architecture and wood density did not differ significantly among the pioneer species, but clearly differed between pioneer and climax species. Specific gravity of *Geunsia pentandra* is 0.43 (Seng, 1951), and specific density of *Piper aduncum* is 0.475 g/cm³ (López *et al.*, 2002). On the other hand, the specific gravities of the dominant species in the natural dipterocarp forest (Sukardjo *et al.*, 1990) are larger, 0.92 (*Dipterocarp crinitus* Dyer; No. 2 of basal area ranking in the study of Sukardjo *et al.*, 1990), 0.71 (*Hopea mengarawan* Miq.; No. 3), 0.99 (*Shorea laevis* Ridl.; No. 4) (Seng, 1951). These differences in specific gravity may cause the differences in adjusted means of allometric line. The allometric line of Brown (1997) was not included in our ANCOVA, because their data comprised several different study sites, including that of Yamakura *et al.* (1986b) and some unpublished data.

Using the allometric equations we derived and that of Brown (1997), the aboveground biomass for each of our 16 plots was calculated. Using the species-specific allometry (Method 1), it was estimated that the aboveground biomass ranged between 8 and 57 t/ha. Because all plants were not harvested, the true aboveground biomass could not be estimated. It is desirable to make allometric equations for not only each species, but also for each stand, to estimate accurate biomass, because the differences in stand density may affect allometric relations. In doing that, however, there is some possibility that the estimation error may increase since the sample number of each species would decrease to make each allometric equation. For instance, the ratios of DBH to W_b and of DBH to W_t were used for only an individual sample in Method 1. However, because the errors due to small sample size seemed negligible for most species, which had a considerable number of samples, the estimates by Method 1 are regarded as the most accurate ones. The values estimated by Methods 2 - 4 were

compared to those by Method 1. The differences between methods were expressed as the average of

$$|\text{Method 1} - \text{Method (2,3,4)}| / \text{Method 1}$$

of each plot. The aboveground biomass calculated using Methods 2 and 3 both differed by about 13 % from the values calculated using Method 1 (Fig. 2). There was no significant difference between the calculated values using Methods 2 and 3, because the differences in the allometric equations for the three dominant pioneers and for the other species were not significant. However, values calculated using Method 4 were about 54 % greater than those calculated using Method 1.

Fig. 2. Calculation of total aboveground biomass of a secondary forest with three estimation methods (Methods 2, 3, and 4) compared with the value for Method 1 (based on species-specific allometry)

In estimating the aboveground biomass of secondary forests dominated by pioneer species, it is possible that general-purpose allometric equations may lead to overestimates, however those equations may be very useful to estimate forest biomass on a global scale. In conclusion, allometric equations for all species combined are most suitable for estimating the total aboveground biomass of secondary forests dominated by pioneer species that have regenerated after shifting cultivation. These equations offer moderate accuracy, and produce estimates with far less labor than in approaches based on species-specific sampling.

This study showed the usefulness of the species-pooled allometric equation for the estimation of the above ground biomass of the study forests. Further clarification on the applicability of species-pooled equations to tropical secondary forests in other regions and with different pioneer species is still required.

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Appendix 1. Dry weight of the aboveground organs of *Ficus* sp.

Plot No.	GBH (cm)	Wl (kg)	Wsb (kg)	Total (kg)
1	19.1	0.93	8.40	9.32
1	17.0	0.57	4.88	5.44
1	11.5	0.24	2.04	2.28
2	11.2	0.17	1.95	2.11
2	12.7	0.26	2.55	2.82
2	14.3	0.30	3.57	3.87
3	11.8	0.23	2.55	2.78
3	17.5	0.51	6.63	7.14
3	22.0	0.96	10.79	11.76
4	12.2	0.31	3.02	3.33
4	12.7	0.24	1.83	2.07
6	12.3	0.32	2.68	3.00
6	11.8	0.17	1.68	1.85
7	19.1	1.41	7.12	8.53
7	14.8	0.76	4.68	5.44
7	11.0	0.33	2.12	2.45
8	28.1	3.48	18.70	22.18
9	15.3	0.40	4.00	4.39
9	19.3	0.74	7.04	7.79
9	10.9	0.09	2.03	2.12
10	13.5	0.17	2.98	3.15
10	17.4	0.32	5.83	6.15
10	27.2	0.73	12.51	13.25
15	11.0	0.07	1.78	1.85
15	28.6	3.47	25.32	28.79
16	11.6	0.19	1.38	1.57

1) GBH: Girth at breast height

2) Wl: Dry weight of leaves

3) Wsb: Dry weight of stems and branches

Appendix 2. Dry weight of the aboveground organs of *Geunsia pentandra*

Plot No.	GBH (cm)	Wl (kg)	Wsb (kg)	Total (kg)
2	10.7	0.15	1.39	1.53
2	17.3	0.56	3.36	3.92
2	23.2	1.45	8.12	9.58
3	50.8	4.85	65.58	70.43
3	17.4	0.02	2.47	2.50
4	16.2	0.10	3.08	3.19
4	36.5	1.91	30.74	32.65
6	24.5	1.85	11.62	13.47
6	18.2	0.68	3.84	4.53
6	10.9	0.02	1.33	1.35
7	22.7	1.04	7.30	8.34
7	17.4	0.40	3.92	4.32
8	36.1	12.25*	33.35	45.59
9	24.2	1.37	10.36	11.73
9	12.6	0.65	6.70	7.36
9	46.7	5.61	59.30	64.91
10	15.1	0.14	4.00	4.13
10	19.8	0.45	6.93	7.38
15	33.1	3.00	21.51	24.51
15	11.1	0.03	1.40	1.43

1) GBH: Girth at breast height

2) Wl: Dry weight of leaves

3) Wsb: Dry weight of stems and branches

* An obviously anomalous value, possibly caused by measurement error.

Appendix 3. Dry weight of the aboveground organs of *Piper aduncum*

Plot No.	GBH (cm)	Wl (kg)	Wsb (kg)	Total (kg)
3	11.5	0.15	2.19	2.34
3	16.0	0.31	5.28	5.58
4	13.1	0.11	2.46	2.57
4	10.2	0.04	1.41	1.45
6	14.0	0.26	3.09	3.35
6	15.5	0.17	2.77	2.94
6	10.1	0.21	1.60	1.82
7	10.1	0.14	0.94	1.08
7	14.0	0.24	2.87	3.12
7	12.6	0.18	2.22	2.40
8	12.0	0.19	2.21	2.40
8	17.5	0.51	6.68	7.19
8	10.9	0.22	1.84	2.05
8	19.7	0.29	5.88	6.17
8	15.4	0.20	3.45	3.66
9	18.1	0.29	6.46	6.75
9	21.4	0.55	8.24	8.79
9	13.5	0.08	3.76	3.83
9	10.5	0.05	1.37	1.43
10	13.4	0.09	2.25	2.34
10	19.0	0.24	7.00	7.24
10	21.1	0.31	6.61	6.91
12	10.3	0.11	1.21	1.32
13	10.1	0.09	1.25	1.34
13	13.5	0.20	2.43	2.64
13	15.3	0.19	3.09	3.28
14	15.4	0.39	4.35	4.74
14	18.6	0.61	6.95	7.55
14	13.3	0.28	3.63	3.91
14	17.0	0.47	5.13	5.60
15	26.1	0.25	10.79	11.04
15	23.5	0.33	8.82	9.15
15	18.3	0.07	4.28	4.34
15	21.0	0.31	8.04	8.36
15	12.2	0.11	1.78	1.89
16	10.4	0.09	1.83	1.92
16	16.4	0.34	4.16	4.50

1) GBH: Girth at breast height

2) Wl: Dry weight of leaves

3) Wsb: Dry weight of stems and branches

Appendix 4. Dry weight of the aboveground organs of other pioneer species

Species name	Plot No.	GBH (cm)	Wl (kg)	Wsb (kg)	Total (kg)	Species name	Plot No.	GBH (cm)	Wl (kg)	Wsb (kg)	Total (kg)
<i>Artocarpus</i> sp.	7	31.6	2.13	8.21	10.35	<i>Mallotus</i> sp.	14	13.2	0.18	3.48	3.65
<i>Blumea</i> sp.	3	10.5	0.02	0.66	0.68	<i>Mallotus</i> sp.	14	20.8	0.32	5.76	6.08
<i>Bridelia</i> sp.	7	23.1	2.14	11.36	13.50	<i>Melastoma malabathricum</i>	2	11.5	0.08	1.90	1.99
<i>Cratogeomys arborescens</i>	2	12.5	0.58	4.23	4.81	<i>Melastoma malabathricum</i>	2	10.9	0.24	3.37	3.61
<i>Dysoxylon</i> sp.	13	14.0	0.37	3.61	3.98	<i>Melastoma malabathricum</i>	2	13.3	0.30	4.28	4.58
<i>Dysoxylon</i> sp.	13	12.2	0.31	2.58	2.89	<i>Melastoma malabathricum</i>	6	12.2	0.17	2.58	2.75
<i>Euodia</i> sp.	7	23.3	2.99	9.90	12.89	<i>Melastoma malabathricum</i>	6	10.2	0.14	2.13	2.27
<i>Euodia</i> sp.	1	11.5	0.26	1.42	1.68	<i>Melastoma malabathricum</i>	7	13.6	0.33	4.58	4.91
<i>Euodia</i> sp.	1	18.8	0.75	4.14	4.90	<i>Melastoma malabathricum</i>	7	10.5	0.15	3.17	3.32
<i>Euodia</i> sp.	1	23.3	1.39	0.94	2.32	<i>Melastoma malabathricum</i>	13	12.7	0.27	3.76	4.03
<i>Euodia</i> sp.	2	11.5	0.44	1.04	1.49	<i>Melastoma malabathricum</i>	8	13.6	0.05	3.68	3.73
<i>Euodia</i> sp.	13	13.7	0.30	1.92	2.22	<i>Nauclea</i> sp.	7	16.0	4.92	18.95	23.87
<i>Euodia</i> sp.	13	14.2	0.36	1.68	2.03	<i>Nauclea</i> sp.	16	10.8	0.33	1.89	2.22
<i>Fordia</i> sp.	1	11.9	1.22	2.58	3.80	<i>Nauclea</i> sp.	16	17.0	0.50	4.72	5.21
<i>Fordia</i> sp.	8	11.0	0.43	1.87	2.31	<i>Nauclea</i> sp.	16	20.5	1.02	6.99	8.01
<i>Fordia</i> sp.	8	11.9	0.86	2.19	3.04	<i>Nauclea</i> sp.	16	26.8	1.96	17.46	19.41
<i>Fordia</i> sp.	8	13.3	0.94	3.17	4.11	<i>Poikilospermum</i> sp.	10	14.9	0.02	1.29	1.31
<i>Fordia</i> sp.	8	22.1	3.78	13.85	17.63	<i>Pterospermum javanicum</i>	15	36.8	4.81	39.20	44.01
<i>Fordia</i> sp.	8	15.3	1.46	6.04	7.51	<i>Trema orientalis</i>	13	13.9	0.20	1.86	2.05
<i>Fordia</i> sp.	9	13.0	1.17	3.94	5.12	<i>Trema orientalis</i>	13	13.5	0.18	1.65	1.83
<i>Helisia</i> sp.	4	10.6	0.14	1.84	1.98	<i>Trema orientalis</i>	13	10.6	0.06	1.07	1.13
<i>Leucosyke capitellata</i>	2	15.3	0.06	4.03	4.09	<i>Trema tomentosa</i>	5	11.7	0.14	1.10	1.24
<i>Leucosyke capitellata</i>	2	14.4	0.25	4.29	4.54	<i>Trema tomentosa</i>	5	14.6	0.34	2.24	2.58
<i>Leucosyke</i> sp.	14	10.8	0.37	2.40	2.77	<i>Trema tomentosa</i>	5	14.0	0.28	2.01	2.29
<i>Leucosyke</i> sp.	14	12.2	0.72	2.63	3.35	<i>Trema tomentosa</i>	5	13.7	0.26	2.10	2.36
<i>Macaranga gigantea</i>	3	26.8	0.53	8.25	8.78	<i>Trema tomentosa</i>	5	10.7	0.19	1.12	1.31
<i>Macaranga gigantea</i>	4	55.3	6.59	46.82	53.41	<i>Trema tomentosa</i>	5	10.0	0.19	0.97	1.16
<i>Macaranga gigantea</i>	4	48.6	3.09	39.59	42.68	<i>Trema tomentosa</i>	5	10.0	0.23	1.10	1.33
<i>Macaranga gigantea</i>	4	19.9	0.44	4.14	4.58	<i>Trema tomentosa</i>	5	11.2	0.16	1.08	1.24
<i>Macaranga</i> sp. 1	3	38.9	2.74	26.05	28.79	<i>Trema tomentosa</i>	11	11.5	0.13	0.73	0.86
<i>Macaranga</i> sp. 1	15	11.7	0.01	0.45	0.45	<i>Vernonia arborea</i>	1	32.6	2.15	15.15	17.29
<i>Macaranga</i> sp. 1	15	16.4	0.11	4.25	4.36	<i>Vernonia arborea</i>	1	21.7	0.66	4.09	4.75
<i>Macaranga</i> sp. 1	3	49.5	5.99	53.38	59.37	Sp. 1	2	12.2	0.36	2.65	3.02
<i>Macaranga</i> sp. 1	3	22.7	0.88	6.93	7.81	Sp. 1	2	11.2	0.27	1.92	2.19
<i>Macaranga</i> sp. 1	4	22.1	0.66	7.10	7.77	Sp. 1	10	21.0	0.01	11.11	11.12
<i>Macaranga</i> sp. 1	4	63.8	2.65	70.21	72.87	Sp. 1	10	14.0	0.15	3.71	3.86
<i>Macaranga</i> sp. 1	4	47.8	3.03	48.84	51.87	Sp. 1	10	16.0	0.14	5.99	6.13
<i>Macaranga</i> sp. 1	10	19.4	0.17	5.05	5.21	Sp. 2	3	14.8	0.08	4.07	4.14
<i>Macaranga</i> sp. 1	10	31.8	2.23	18.79	21.02	Sp. 2	3	10.9	0.04	2.32	2.36
<i>Macaranga</i> sp. 1	10	30.1	1.84	14.25	16.09	Sp. 3	7	29.5	1.72	14.32	16.04
<i>Macaranga</i> sp. 2	11	12.1	0.47	1.17	1.64	Sp. 3	7	36.6	3.38	22.34	25.71
<i>Macaranga</i> sp. 2	11	11.2	0.32	1.10	1.41	Sp. 4	8	15.4	0.65	4.24	4.89
<i>Macaranga</i> sp. 2	11	11.2	0.35	1.02	1.37	Sp. 4	8	13.3	0.69	3.62	4.31
<i>Macaranga</i> sp. 2	11	10.7	0.25	0.85	1.10	Sp. 5	8	12.6	0.14	2.42	2.56
<i>Macaranga</i> sp. 2	11	14.8	0.63	1.76	2.39	Sp. 5	8	10.0	0.09	1.52	1.60
<i>Macaranga</i> sp. 2	11	10.3	0.46	0.94	1.40	Sp. 6	8	11.4	0.31	1.66	1.97
<i>Macaranga</i> sp. 2	11	10.3	0.57	1.00	1.57	Sp. 6	8	16.0	0.61	4.12	4.74
<i>Macaranga</i> sp. 2	11	13.4	0.50	1.38	1.88	Sp. 7	4	19.6	0.20	4.90	5.10
<i>Macaranga</i> sp. 3	2	18.4	0.58	4.90	5.47	Sp. 8	8	11.0	0.74	1.90	2.64
<i>Macaranga</i> sp. 3	13	17.3	0.24	4.69	4.92	Sp. 9	16	11.9	0.44	2.44	2.88
<i>Macaranga</i> sp. 3	13	13.7	0.06	1.57	1.63	Sp. 10	16	23.2	0.39	5.09	5.49
<i>Macaranga</i> sp. 3	13	21.2	0.18	5.08	5.26	Sp. 11	16	16.9	0.31	3.74	4.05
<i>Macaranga</i> sp. 4	14	26.5	1.23	14.73	15.96						
<i>Macaranga</i> sp. 4	14	36.7	1.16	33.19	34.35						
<i>Macaranga</i> sp. 5	3	13.0	0.28	1.85	2.14						
<i>Macaranga</i> sp. ?	8	13.3	0.28	3.32	3.59						

1) GBH: Girth at breast height

2) Wl: Dry weight of leaves

3) Wsb: Dry weight of stems and branches