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Biomass of Understorey Plants between 1.5 and 5.0m in a Logged-over Forest

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RINGKASAN

Biomassa komponen pokok tingkat bawah Hutan Dipterokarp Pamah antara ketinggian 1.5 dan 5.0m telah ditentukan dengan tuaian 47 pokok dari sebuah petak berukuran 0.01 ha. Jumlah biomassa atas tanah ialah 2.78 tonnes/ha, yang terdiri dari 81% batang, 7.5% dahan dan 11.5% daun. Indeks perluasan daun (leaf area index) pada stratum ini ialah 0.36. Individu biomassa pokok dan komponennya telah dihubungkan dengan lilitan gelangan dan regressi bererti didapati dengan batang, komponen kayu dan berat keseluruhan. Dengan menggunakan persamaan regressi ini, anggaran biomassa lain boleh diperolehi dan anggaran yang terdapat pada petak luas 0.2 ha adalah hampir dengan anggaran yang terdapat secara tuaian. Ini menunjukkan kesesuaian kaedah persamaan regressi untuk penganggaran biomassa, khususnya di mana tebangan tidak dibenarkan.

SUMMARY

The biomass of various components of understorey plants of a Lowland Dipterocarp Forest, between 1.5 and 5.0 m in height, was determined by harvesting 47 plants from a 0.01 ha plot. The total above ground biomass was equivalent to 2.78 tonnes/ha, and this was made up of 81 percent stem, 7.5 percent branch and 11.5 percent leaf. The leaf area index (LAI) of the stratum was 0.36. Individual biomass of plant components and of the total plant was related to their collar girth. Using these regression equations, estimates based on measurements of collar girth in a 0.2 ha plot was found to be very close to that obtained by harvesting. This suggests that regression equations could be suitable for estimating biomass especially where no felling is allowed.

INTRODUCTION

Nutrient cycling is probably one of the most important processes occurring in the tropical rain-forest. In order to quantify it and to estimate the rates of turnover, it is essential to obtain information on the biomass of the various components of the system, such as the plants and litter layer, as well as to determine the concentration of various nutrients in these components.

A major study on the total above-ground biomass in a primary rain-forest in Malaysia was undertaken between 1971 and 1973 by Kato, Tadaki and Ogawa (1978) in Pasoh Forest Reserve. In that study, the biomass of all the plants, from the ground layer to the tallest trees was determined by complete harvesting and found to be 475 tonnes/ha.

This study is part of an effort to obtain biomass information in a logged-over forest so that comparisons may be made with that obtained for Pasoh Forest Reserve. This paper reports on the biomass for the stratum 1.5–5.0 m, obtained by sampling all the trees within a 0.01 ha plot.

MATERIALS AND METHODS

Site

The study was conducted in compartment six of the Air Hitam Forest Reserve, which is located approximately 5 km west of the Universiti

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Pertanian Malaysia Campus at Serdang, Selangor. The area is a lowland Dipterocarp Forest of the Kedondong sub-type. It is gently undulating with altitudes below 150 m, and experiences an annual rainfall of over 2000 mm. The area was selectively logged more than twenty years ago and has been silviculturally treated in the 1960's.

Study Plot

A plot measuring 20 m by 100 m was established on a north-facing slope of a low spur on the southern section of the compartment. The plot was subdivided into twenty $10m^2$ subplots. All the plants between 1.5 and 5.0 m in height, except palms and creepers or climbers, were labelled and their collar girth (at ground level) measured. From this enumeration, the mean density for the subplot was determined and the subplot with a density nearest the mean density was selected for destructive sampling for biomass determination.

Destructive sampling

Each tree was identified as far as possible before being cut. After felling, the girth was remeasured and the total height was also determined. The branches were removed from the main stem and the leaves were separated from the branches and twigs. These three components were then weighed separately. Representative samples of all components were collected and taken to the laboratory for determination of their fresh-weight to oven-dry weight factor. Each sample tree was treated separately.

Data analysis

Biomass was calculated using two methods, *viz:–*

a) determining the mean weight of a plant or the plant component from the sample subplot and multiplying by the mean density.

and b) establishing regression equations of weight on girth using the weight and girth data from the destructive sampling and using these equations on the girth data for all the plants in the

i) 0.01 ha sample sub plot and multiplying by 100, and

ii) 0.2 ha study plot and multiplying by 5.

RESULTS AND DISCUSSION

Although the stratum studied is structurally a relatively minor component of the forest, it is important in that it contains many useful plants, such as fruit trees and ornamentals as well as the saplings of many commercially important timber trees, such as *Shorea, Dyera, Canarium* and others. Further, the turnover of organic matter of this stratum is often more rapid than that of the higher strata and so it plays an important role in nutrient cycling and maintaining soil fertility.

Study Plot

Climbers and palms such as *Eugeissona* sp. and *Oncospermum* sp. and various rattans were excluded from this study as these plants have unusual forms and could not be divided into the three major above-ground components of stem, branch and leaf. Further, their heights could not be easily and accurately determined and, also some such as *Eugeissona* do not have stems. A total of 292 such plants were found in the study plot, this being equivalent to a density of 1460 (plants/ha).

The mean density of plants (other than climbers and palms) between 1.5 and 5.0 m in height in the Air Hitam Forest Reserve was found

Table 1
Characteristics of 0.2 ha Study Plot

Characteristic		No/Mean	Range (based on 20 0.01 ha plots)
Plant between 1.5 and 5.0 m in height	Density (No/ha)	4720	1700 – 10700
	Girth (cm)	7.3	1.6 – 30.1
Palms			
Rattan	(density)	290	
Bertam	(density)	330	
Other palms	(density)	140	
Woody climbers	(density)	700	

to be 4720 (trees/ha) (Table 1). However, the plants in this stratum are very unevenly distributed, as the range of densities obtained vary from 1700 to 10700 (trees/ha). This may be partly accounted for by the presence of gaps of different sizes in the canopy as a result of the selective logging as well as the silvicultural treatment following it. Despite this high variability, the mean density obtained compares well with the value of 6535 for a similar stratum in the Amazonian rainforest (Fittkau and Klinge. 1973).

The collar girth of the plant is also very variable, ranging from 1.6 cm to 30 cm, the mean being 7.3 cm (Table 1). The distribution of plants over the different girth size classes is skewed, with over 80 percent of the plants having girths below 10.0 cm, and 93 percent of them with girths below 14.0 cm, as many of the plants with girths above 12.0 cm have previously been cut or slashed, so that their current overall height is still below 5.0 m and so are included in the stratum in this study.

Subplot

Of the twenty sub-plots of 0.01 ha, only one had a density of 4700 trees/ha, and it was chosen as the plot for destructive sampling.

Of the 47 trees sampled, 24 came from the five families, Myrtaceae (7), Rhizophoraceae (5), Euphorbiaceae (5), Myristicaceae (4) and Sterculiaceae (3). These families are mostly main canopy and understorey families. A notable feature is the absence of dipterocarps in this stratum although within the study plot there are a few dipterocarp trees with DBH of over 30 cm.

The size of the trees sampled in this subplot ranged from 2.8 cm to 14.3 cm (Table 2) and is thus smaller than that found for the whole study plot. However, the mean girth is very close to the overall mean girth and thus it can be assumed that the mean sized tree in the sample sub-plot is sufficiently representative of the mean sized tree of the whole study plot.

The mean above-ground biomass of a plant in the stratum in the plot is 590 g. The biomass of individual plants, however, varies quite considerably from 84 g to 3.7 kg, a factor of over 44, compared with a factor of approximately 5 for their girth size variation.

Of the total above-ground biomass, an average of 81.1 percent consist of stems, 11.4 percent of leaves and 7.5 percent of branches. Among these components, leaf shows the lowest range, while the stem biomass ranges from 30 g. to 3000 g. The branch fraction too shows a great variation with 10 trees having no branches at all. These trees are from the families Sterculiaceae, Burseraceae and Myrtaceae some of which have seedlings and saplings that do not form branches.

Table 2
Characteristics of destructive sample plot and trees sampled

Characteristics		No. or Mean	Range
No. of plants between 1.5 and 5.0 m		47	
Girth of plants (cm)		7.2	2.8 – 14.3
Dry weight (g) :	Leaf	67.6 (11.4*)	12.5 – 371.5
	Branch	44.1 (7.5)	0 – 367.6
	Stem	478.3 (81.1)	30 – 3404.2
	Total	590.1 (100)	83.5 – 3.477
Leaf Area (m^2/plant)		0.774	0.212 – 3.477

*Values in brackets indicate value as percentage of total

Regressions

Individual biomass of the sample trees is related to their respective girths using the widely used allometric growth equation, $Y \doteq ab^x$ (Kira and Shidei, 1967; Whittaker and Woodwell, 1968). Values of biomass and girth were log-transformed so as to linearise the data to facilitate determination of the constants (Baskerville, 1971). The equation is then in the form

$$\log Y = a + b \log X$$

where Y = biomass of standing crop

X = a measured parameter of the crop, often girth or diameter

and a and b are constants.

Regression equations were determined for leaf, branch, stem and branch and the total biomass (*Figures 1–4*). All the equations were found to be significant ($P<0.05$). The branch component had the lowest correlation coefficient ($r = 0.39$, $P<0.05$) and this was due in part to the presence of 10 plants without any branch.

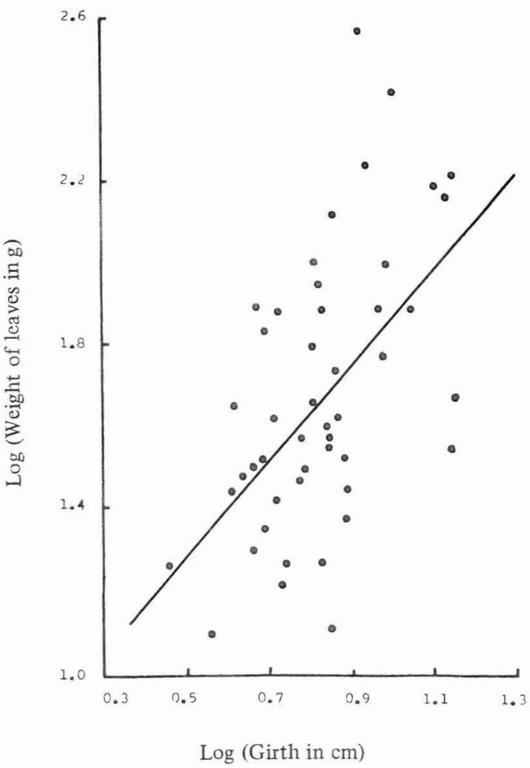

Fig. 1. Relationship between total oven dry weight of leaves (log W_1, weight in g) and girth (log G, girth in cm). The equation of the line is Log W_1 = 0.70 + 1.18 (log G) (r = 0.55, P<0.05).

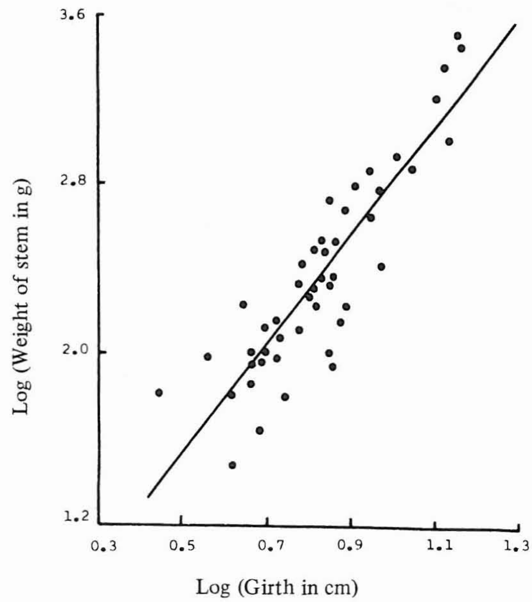

Fig. 2. Relationship between total oven dry weight of stem (log W_s, weight in g) and girth (log G, girth in cm). The equation of the line is Log W_s = 0.23 + 2.59 (log G) (r = 0.89, P<0.01).

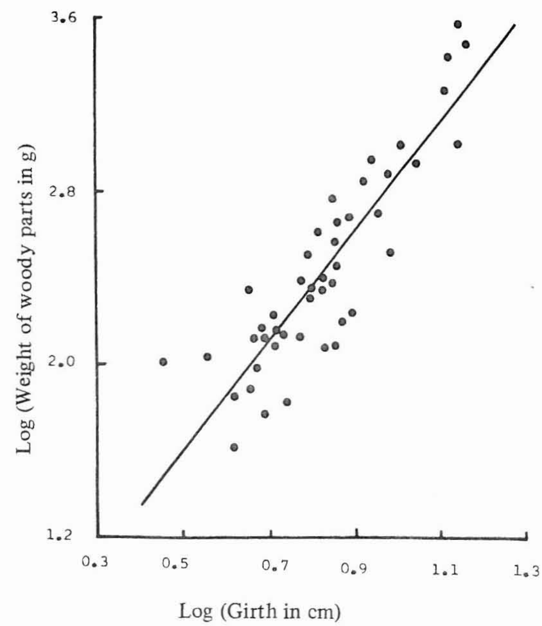

Fig. 3. Relationship between total oven dry weight of woody tissues (log W_w, weight in g) and girth (log G, girth in cm). The equation of the line is Log W_w = 0.36 + 2.51 (log G) (r = 0.87, P<0.01).

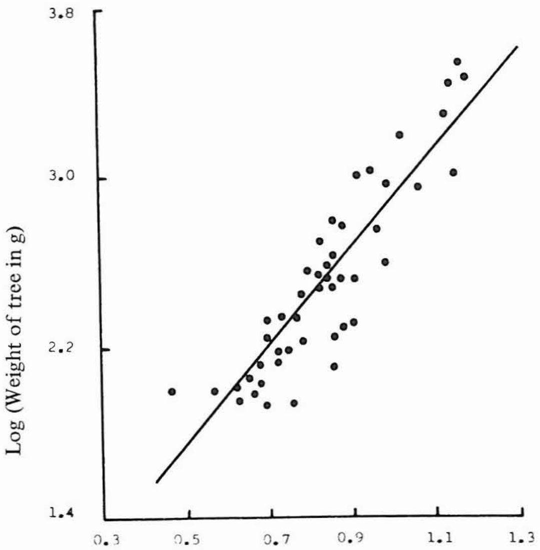

Fig. 4. Relationship between total oven dry weight of whole tree (log W, weight in g) and girth (log G, girth in cm). The equation of the line is Log W = 0.59 + 2.33 (log G) (r = 0.87, P<0.01).

The leaf component too had a low correlation coefficient ($r = 0.55$, $P<0.05$) with the points being fairly widely scattered on both sides of the regression line. The stem, stem and branch, and the total biomass on the other hand are better correlated with girth (with r generally >0.85 and $P<0.01$). This indicates that girth is a good estimator of the biomass of the stem as well as the whole tree.

Good relationships between girth and total biomass have also been found by others (Art and Marks, 1971). Generally better relationships are obtained between girth and biomsss of the total tree and stem than between girth and the biomass of leaf or branch. This is partly because the biomass of the stem and the whole tree increase continuously whereas the biomass of the branch and leaf tend to level off as these two components suffer considerable loss through leaf and branch fall.

Estimates

Using the above regression equations, the biomass of the individual plants in the stratum, and their components, in the whole study plot can be estimated. By adding the total weights and the weights of the components the total above-ground biomass can be obtained.

Summation was done at two levels, viz: the subplot level, using the estimated weights of the 47 trees in the sample subplot, and the study-plot level using the estimated weights of all the 944 trees. This was done to provide comparisons between the actual biomass (obtained by harvesting) and the predicted biomass (Table 3) as well as the biomass estimated from a larger sample. Deviations from the actual value are expressed as a percentage of the biomass obtained from the destructive sampling.

It should be noted that the biomass of the whole tree obtained from one regression equation does not necessarily equal the sum of the biomass of the leaves, branches and stems obtained from separate equations. This is to be expected as the products of separate equations are not cumulative because data transformation is involved.

While estimates of biomass of leaf and branch are not improved much by using a larger plot, estimates for the whole tree, woody and the stem fractions are considerably improved when the estimates are based on a larger sample (Table 3). This concurs with the finding of Dice (1970) that with larger samples, the error of the estimates falls, resulting in greater accuracy.

The biomass and leaf area obtained for the stratum is comparable to the data obtained for other dipterocarp forest undergrowth in Southeast Asia (Table 4). The plants in the Amazonian Forest are characterised by their high proportion of leaf while those from the Air Hitam Forest and Thailand have a relatively lower proportion of leaf. This difference, however, could not be verified because of insufficient information on the ecology of the areas.

CONCLUSION

The density of plants between 1.5 and 5.0 m in height was 4720 trees per ha. The biomass of leaves, branches and stems determined by harvesting 47 trees in this stratum are 0.32 tonnes, 0.21 and 2.25 t per ha., respectively. The leaf area index of this stratum totalled 0.36. The biomass of the whole plant and the woody components correlated ($P<0.05$) less significantly. Biomass girths, whereas the biomass of leaves and branches correlated ($P<0.05$) less significantly. Biomass estimated from regression equations generally underestimated the actual biomass, but on a scale of 0.2 ha, the differences relative to the actual values fall to below 10%. This relatively low difference suggests that the method might be suitable especially where felling is not allowed or

Table 3
Comparison of biomass obtained by harvesting and by using regression equations on the girth data from the sample plot (0.01 ha) and the whole study plot (0.2 ha), (Values are in t/ha)

Component	a) Harvest of 0.01 ha plot	b) Regression estimate from 0.01 ha plot	% Difference*	c) Regression Estimate from 0.2 ha plot	% Difference**
Leaf	0.32	0.25	–21.8	0.25	–21.8
Branch	0.21	0.09	–57.1	0.10	–52.3
Stem	2.25	1.81	–19.5	2.19	– 2.6
Woody Components	2.46	2.03	–21.8	2.43	– 1.2
Total	2.78	2.30	–17.2	2.67	– 3.9

* % Difference $= \frac{(a - b)}{a} \times 10$

** % Difference $= \frac{(a - c)}{a} \times 100$

Table 4
Comparison of biomass of various plant components of understorey plants and leaf area from various regions (t/ha)

Area	Leaf	Branch	Stem	Total Leaf Area (m²)	
Amazon[1] (1.5 – 5.0 m)	3.2	1.1	2.9	7.2	NA
Amazon[2] (1.7 – 3.0 m)	2.2	0.7	1.8	4.7	NA
Thail[3] and undergrowth	0.62		1.80	2.4	1.5
Pasoh[4] (1.3 – 5.0 m)	0.40	NA	NA	NA	0.60
This study	0.32	0.21	2.21	2.72	0.36

[1] Fittkau and Klinge (1973)
[2] Klinge and Rodrigues (1973) – data is fresh weight
[3] Ogawa *et al.* (1965)
[4] Kato *et al.* (1978)

possible due to the high costs; or where felling is not recommended when studies on biomass build-up and nutrient cycling are being carried out.

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