Biomass and Productivity of 4.5 Year-Old *Acacia mangium* in Sarawak

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Key words: *Acacia mangium;* plantation; biomass; productivity; allometric regression.

ABSTRAK

Acacia mangium adalah salah satu spesies utama untuk penanaman dalam ladang hutan dan penghutanan semula di Malaysia. Ia telah dipilih kerana berupaya membesar dengan cepat dan juga mengatasi rumpai. Satu dirian Acacia mangium yang berumur 4.5 tahun di Sarawak didapati mempunyai kepadatan 1084 batang pokok/ha dan mempunyai ketinggian melebihi 20 m. Ukuran garis pusat paras dada (gpd) julat antara 4.3 cm hingga 24.2 cm dan purata gpd ialah 14.3 cm. Regresi biojisim dahan dan ranting, batang dan keseluruhan pokok (atas tanah) ke atas garis pusat menghasilkan persamaan dengan pekali korelasi, r, yang melebihi 0.95. Biojisim dirian yang dianggarkan adalah 82.1 t/ha. Pertambahan min tahunan sebanyak 18.3 t/ha adalah berbandingan dengan nilai daripada tanaman seperti Encalyptus nitens dan getah. Kebanyakan pokok sampel mempunyai teras kayu yang tercacat warna dan bahagian dalam yang lembut dan bersifat pulpa. Oleh demikian kajian tambahan adalah disyorkan.

ABSTRACT

Acacia mangium, one of the main species used for forest plantations as well as reforestation in Malaysia, has been selected on account of its rapid growth and ability to overcome competition from weeds. A 4.5 year-old plantation stand in Sarawak had a density of 1084 trees/ha and a top height of over 20 m. The dbh of the trees ranged from 4.3 cm to 24.2 cm and averaged 14.3 cm. Regression of branch, stem and total above-ground biomass on dbh produced equations with correlation coefficients, r, of over 0.95. The biomass of the stand was estimated at 82.1 tonnes/ha. The mean annual increment of 18.2 t/ha is comparable to those of intensively managed crops such as *Eucalyptus nitens* and rubber. Several sample trees had stained heartwood and soft pulpy cores and further studies are recommended.

INTRODUCTION

The rapid rate of logging and deforestation in Malaysia have resulted in the degradation of forests and soils, as well as the forecast shortage of timber. In Peninsular Malaysia where logging has been intensive and silvicultural treatment and recovery relatively slow, the shortage of general utility timber is expected to be felt in the 1990's. To offset this, the Compensatory Planta-

tion Programme (CPP) has been initiated and over 180,000 ha of land has been allocated for it. In Sabah and Sarawak, intensive logging and deforestation through shifting agriculture have produced vast areas of poor secondary forest, most of which do not support much woody biomass. Reforestation has been initiated in both these States: plantations have been established in Sabah for the production of wood for pulp and paper while in Sarawak, the main objective is the

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rehabilitation of waste lands.

In all these attempts to establish plantations and to reforest areas, *Acacia mangium, Paraserianthes falcataria* (also known as *Albizia falcata*) and *Gmelina arborea* have consistently been chosen as the main species (Chai and Kendawang, 1984; Yong, 1984 and Liew, 1984). *A. mangium* has been selected because of its high growth rate as first reported by Tham (1976) and subsequently supported by others (Tan and Jones, 1982; Lim and Basri, 1985). Lim (1985) determined the biomass of open-grown. *A. mangium* and extra-polated the growth rates obtained to plantation conditions and estimated a mean annual increment (MAI) in biomass in excess of 18 tonnes/ha.

This study follows that by Lim and Basri (1985) who compared biomass accumulation by a naturally regenerating area and an *A. mangium* stand. In that study, the above-ground (AG) biomass of the *Acacia mangium* stand was determined using a modified Smalian formula. In this study, however, the biomass of the same stand was determined through destructive sampling of 11 trees. The build-up of organic matter was then estimated using diameter at breast height (dbh) data from the study plots with the biomass regressions obtained from the sample trees.

MATERIALS AND METHODS

Site

The study was conducted in the Oya Road Forest Plantation located near Sibu in Sarawak. Detailed description of the site and the *A. mangium* plots (AMP) are in Lim and Basri (1985). Although 6 plots were enumerated in the earlier study in 1982, only 5 were remeasured in 1983. The data presented is based on these 5 plots.

Methods

The dbh of trees in the plots were measured in August 1982 and August 1983. In 1983, 11 trees with dbh ranging from 7 cm to 25 cm were randomly selected outside the study plots for destructive sampling. Each tree was cut at ground level and the branches removed. The stem was then measured and cut into 10 equal lengths. Where forking occurred, the longest and straightest was considered the main stem. Each log was then weighed and a 5 cm thick sample disc cut from the base of each log section and weighed for oven-dry weight determination. The leaves were separated from the branches and the total fresh weights of the branches and leaves determined. Fruits and flowers were found only on one tree and were treated as part of the branch component. At least 2 grab-samples of approximately 1 to 2 kg each of leaves and branches and twigs were collected into sample bags and weighed for oven-dry weight determination. All fresh weights in the field were recorded with spring balances (Salter 25 kg ± 0.1 kg or 10 kg ± 0.05 kg) and samples for oven-dry weight determination with a triple beam balance (Ohaus, 1600 ± 0.1 g).

Samples were oven-dried at 80°C for at least 2 days till constant weight was achieved and weighed on an electronic top-pan balance accurate to 0.01 g. The equivalent oven-dry weight of the tree components were calculated using the formula,

$$\text{Dry wt of Component} = \text{Fresh wt of Component} \times \text{Average \% dry wt of sample}$$

The dry weights of the components and the whole three were then related to their respective dbh using the allometric equation,

$$\text{Log(weight)} = a + b \, \text{Log(dbh)}$$

where weight is in kg

dbh is in cm

and a and b are constants

The equations were applied to the individual dbh data from the study plots and biomass estimates of the various components as well as the whole tree for each plot determined. Assuming that the dbh-weight regressions remained the same through 1982 and 1983, the equations were then used on the dbh data from 1982 to obtain biomass estimates for 1982 and the current annual increment (CAI) in biomass calculated.

RESULTS AND DISCUSSION

Study Plots

A total of 122 trees was found in the five study plots of 15 m × 15 m each, giving an overall density of 1084 trees per ha (Table 1). No mortality was recorded in the year of study. However, a number of trees were observed to be affected by "pink disease" caused by *Corticium salmonicolor*.

As the trees were planted in January 1979, the trees averaged four and a half years at the time of sampling. The dbh of the trees in 1983 ranged from 4.3 cm to 24.2 cm, a difference of over five-fold. The mean dbh in 1982 was 12.2 cm while that in 1983 was 14.3 cm, an increase of approximately 17%. Individual increments, however, ranged from a low 0.6 cm to 4.8 cm. The mean annual increment (MAI) of dbh of 3.5 cm in 1982 and 3.2 cm in 1983 compare favourably with the MAI dbh of 3.7 cm for *Paraserianthes falcataria*, 2.9 cm for *Eucalyptus*

deglupta and 3.5 cm for *Gmelina arborea* observed over a period of 5 years (Tan and Jones, 1982).

Tree heights also vary quite considerably as shown by the heights of the 11 sample trees which ranged from 8.5 m to 21.5 m. The top heights of the trees increased by over 5 m in the year. Again this compares well with the MAI of dominant height of between 3.7 and 5.0 m reported for *P. falcataria*, *E. deglupta* and *G. arborea* (Tan and Jones, 1982).

Sample Trees

The dbh of the sample trees range from 5.9 cm to 24.8 cm and except for the smallest trees, generally covers the range of dbh sizes found in the study plots (Table 2). Generally, trees in different size-classes (of 3.2 cm dbh or 10 cm girth interval) are represented. However, the class distribution of the sample does not reflect that in the stand so that although the mean dbh of the sample trees approximates to that of the study

TABLE 1

Summary of characteristics of trees in 1982 and 1983 and of sample trees

Characteristic	Sample Plots		Sample Trees
	1982	1983	
Total No. of trees	122	122	11
Size classes (Dbh in cm)			
<7.99	6	2	2
8.00 − 11.14	26	23	1
11.15 − 14.31	56	39	4
14.32 − 17.49	28	38	1
17.50 − 20.68	4	17	1
>20.69	0	3	2
Diameter at breast height (cm)			
Mean	12.19	14.26	14.23
Minimum	3.72	4.30	5.79
Maximum	19.42	24.19	24.99
Height (m)			
Top/mean	15.0	20.5	17.2
Min.	—	—	8.5
Max.	—	—	21.5
Basal Area (sq. m.)	1.545	2.083	0.202

plots, the mean weight of the sample trees cannot be assumed to be representative of the plots.

The above-ground biomass of the sample trees ranged from 5.5 kg to 271.6 kg — a fifty-fold difference in comparison to the five-fold difference in dbh. A greater difference is found in the branch biomass which ranges from 0.4 kg to 105.9 kg. This high difference and variability probably results from intense crown competition between adjacent trees causing extreme suppression of some smaller trees. The percentage contribution of the various components to the total weight of the tree also varies considerably; leaf contributes between 1.9 to 10.6%; branch between 8.0 to 39% and stem between 55.6 to 87.9%. In contrast, stems of open-grown *A. mangium* account for less than 47% of the total biomass while leaf contributes between 13.8 and 22.7% and branches between 34.1 and 49.5% (Lim, 1985).

Regressions

The high variance in dbh as well as the biomass make it difficult if not impossible to estimate the total biomass reliably using the mean values. Nevertheless, the biomass of the components and of the whole tree when correlated to the dbh on a log-log basis, gives regressions with correlation coefficients, r, generally over 0.85 and in most cases over 0.95 (Table 3).

To check the accuracy of the equations as well as the method used in the earlier study (Lim and Basri, 1985) the dbh data of the 11 sample trees were used with a) the regressions obtained, b) the Smalian Equation using top-height and c) the Smalian Equation using actual height (Table 4). The estimates from the log regression and the Smalian equation using actual height differed from the actual biomass by less than 3.0% whereas the Smalian equation using top-height over-estimated by approximately 8.0%.

TABLE 2

Mean and range of biomass and proportions of various components of sample trees

Character	Biomass (kg)		Proportion (%)	
	Mean	Range	Mean	Range
Leaves	4.20	0.58 – 15.39	4.7	1.9 – 10.6
Branch	24.13	0.44 – 105.90	19.8	8.0 – 39.0
Stem	58.64	5.04 – 150.93	73.5	55.6 – 87.9
Wood	82.72	4.91 – 256.17	93.3	76.3 – 98.1
Total	86.91	5.49 – 271.56	100.0	

TABLE 3

Statistics of regressions of biomass of whole tree and components on dbh. The regression is in the form,
Log (biomass) = b log (dbh) + a

Component	a	b	r	p
Leaf	– 2.2622	1.6885	0.859	<0.001
Branch	– 4.4955	3.3914	0.959	<0.001
Stem	– 2.2634	2.3945	0.972	<0.001
Wood	– 2.5143	2.6171	0.981	<0.001
Whole tree	– 2.3270	2.5201	0.984	<0.001

While other methods are available for estimating the biomass of a stand making use of dbh data of the sample trees, (such as the use of the mean biomass) they are considered less accurate because of the difference in the size-class distribution of the sample and that of the stand.

Biomass

The regressions were applied to the dbh of individual trees in all the study plots, and estimates of the various components obtained for both 1982 and 1983 (Table 5). The total biomass for 1983 was 82.1 tonnes/ha and that for 1982 was 57.7 t/ha. The latter value compares well with the estimate (of 54.1 t/ha) obtained in the earlier study (Lim and Basri, 1985) using the Smalian equation with top-height.

From the estimated biomass in 1982 and 1983, the MAI biomass in 1982 and 1983 are 16.5 and 18.2 t/ha respectively and the CAI for the period is 24.4 t/ha. This suggests that the

trees are still in the growing phase of development. Taking the MAI values and projecting them backwards, and assuming a Sigmoid or S-shaped growth curve, then it seems the increment of the stand is beginning to level off — evidence perhaps of the canopy being closed and the stand in need of thinning.

The high productivity of the *A. mangium* in the study plots is probably due to regular application of fertiliser to the cocoa planted in between them (Lim and Basri, 1985) and confirms the reported inherent capacity of the species for rapid growth and its ability to overcome competition from other plants.

As direct comparisons of biomass from different aged stands are not justified, comparisons are made on the basis of productivity, namely the MAI biomass over the total age of the stand (Table 6). Several estimates have been made of above-ground biomass and production rates of tropical species (UNESCO/UNEP/FAO,

TABLE 4

Comparison of total biomass of the 11 sample trees with biomass predicted by using (a) log regression, (b) Smalian equation using actual height and (c) Smalian equation using top-height of 20.5 m

	Actual	Log regression	Smalian equation	
			Actual height	Top-height
Total biomass (kg)	959.0	972.2	982.7	1035.6
Difference		13.2	23.7	76.6
% difference		1.4	2.5	8.0

TABLE 5

Biomass of trees in 1982 and 1983 and estimate of current annual increment (CAI)

Component	1982 (t/ha)	1983 (t/ha)	CAI (t/ha/year)
Leaf	3.16	3.76	0.60
Branch	10.45	16.97	6.52
Stem	41.70	58.24	16.54
Wood	53.76	77.90	23.94
Whole tree	57.71	82.12	24.41

TABLE 6

Comparison of biomass and biomass increment for various tropical and sub-tropical species

Species	Age (years)	Biomass (t/ha)	MAI Biomass (t/ha/year)	Reference
1. *Acacia mangium* (plantation)	4.5	82.07	18.23	This study
2. *A. mangium* (plantation)	3.5	54.4	15.5	Lim *et al.*, 1985
3. *A. mangium* (open-grown)	3.5	64.1	18.3	Lim, 1985
4. *Albizia falcata* (plantation)	5	75.6	15.1	Kawahara *et al.*, 1981
5. *Eucalyptus nitens* (plantation)	4	79.2	19.8	Madgwick *et al.*, 1981
6. *Hevea brasiliensis* (plantation)	6.75	138.0	20.4	Templetion, 1968
7. *Shorea robusta* (plantation)	5	15.5	3.1	De Angelis *et al.*, 1981
8. *Tectona grandis* (plantation)	5	49.6	9.9	De Angelis *et al.*, 1981

1978; De Angelis, Gardner and Shugart, 1981) and values of productivity range from 3 to 35.5 tonnes/ha/year. Some of the higher values are periodic annual increments and so are not directly comparable to MAI values. Of the species used for CPP, data on biomass and productivity are available for *Paraserianthes falcataria* (Kawahara, Kanazawa and Sakurai, 1981) and *Acacia mangium* (Lim, 1985), as well as other species of *Eucalyptus* such as *E. nitens* (Madgwick, Beets and Gallagher, 1981). The MAI value of 18.2 t/ha/year obtained in this study could be greater if the productivity of the cocoa is included. Even so, it is relatively high compared to several other species and matches more intensively managed tree species such as *Eucalyptus nitens* which are planted at very high densities of over 6000 trees/ha (Madgwick, *et al.*, 1981) and rubber, *H. brasiliensis* (Templeton, 1968) which is intensively managed.

A significant proportion of the trees in the study area was observed to be forked or had twin leader-shoots. In view of this and of the potential use of the trees as a source of wood chips and possibly as fuel biomass, the use of branches especially those with large diameters should seriously be considered.

Most of the sample trees had a light-reddish brown (Munsell colour chart) heartwood bordered by a much darker brown zone and several trees had pulpy cores especially in the lower stem. The presence of a similar dark brown zone between the heartwood and sapwood has also been reported in *Acacia mangium* in Sabah (Liew, 1984). These could result from fungal infection and warrant further study.

CONCLUSION

The high variability in the dbd, height and biomass of the trees of the same species, origin, age and growing conditions suggest that the variability may be genetic in nature. If so, there is potential for further improvement in production through selection and this should be researched on as soon as possible.

The results of this study confirm the high productivity reported for *A. mangium* and justifies the selection of the species for reforestation and land rehabilitation projects since canopy closure can be achieved within 2 to 3 years. However, caution needs to be exercised as the occurrence of diseases such as *Corticium salmonicolor*, the presence of pulpy cores and the staining of the sapwood-heartwood zone may adversely affect the productivity and end-use potential of the wood. Studies on various aspects of pests and diseases as well as utilisation potential of the species is recommended.

ACKNOWLEDGEMENTS

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