A VOLUME TABLE FOR PLANTED *ACACIA MANGIUM* IN PENINSULAR MALAYSIA

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WAN RAZALI WAN MOHD., KHALI AZIZ HAMZAH & CHEW, T. K. 1989. A volume table for planted *Acacia mangium* in Peninsular Malaysia. Eight unweighted (including two logarithmic transformed) and seven weighted forms of volume equations were fitted by the least squares method to volume data of a 5-y-old *Acacia mangium* plantation. Furnival's index criterion was used to select the best fit equations, for overbark and underbark volumes. The logarithmic equation, adjusted for bias, was chosen as the most appropriate model for the species. The final equations, used to construct the overbark (Vo) and underbark (Vi) volume tables are:

$$Vo = 0.0003150 \times D^{1.54738} \times H^{0.80931}, \quad Vi = 0.0002707 \times D^{1.51310} \times H^{0.84789}$$

where Vo and Vi are merchantable tree volumes (m^3) up to 10 *cm* diameter overbark, D the breast height diameter (*cm*), and H the total log length (*m*). The equations were found to estimate a merchantable tree volume and hence the aggregate standing volume satisfactorily under the given study conditions. As usual, a test of applicability of these equations is needed if they are to be applied elsewhere.

Key words: *Acacia mangium* - volume equation - least squares regression - Furnival's index - volume correction factor

Introduction

The Compensatory Forest Plantation Programme (CFPP) envisaged to establish about 188,000 *ha* of forest plantations in Peninsular Malaysia within 15 *y*, starting from 1981 and ending 1995 (Johari 1988). The CFPP was expected to cost about MR$517 (US$207) million. The Asian Development Bank (ADB) has financed US$24.5 million to establish about 40,000 *ha* of forest plantations in Peninsular Malaysia for the period from 1985 to 1987. By the end of 1988 only 30,613 *ha* had been planted. The remainder of the area to be planted under the ADB project was implemented in 1988. Similarly, the World Bank has planned to finance the establishment of about 150,000 *ha* of forest plantation in Sabah by the year 2000. By the end of 1988 about 40,000 *ha* had been planted. The main species planted under the ADB project is *Acacia mangium.* With this emphasis, it is important that full research and development support be given to ensure its success.

However, the shift to plantation forestry in both Peninsular Malaysia and Sabah has taken place rather quickly and many fundamental management issues are only beginning to be given urgent attention. One of the most important issues is to be able to estimate the current yield of a tree or a stand in order to be used, for example, in the preparation of a forest management plan. Hence, volume tables were prepared for planted *A. mangium* plantations.

Materials and methods

Sample plots

Data were collected from Plot 9 in Compartment 40 Rantau Panjang Forest Reserve in Selangor, Peninsular Malaysia. *A. mangium* trees were planted in November 1981 at a planting space of 3 × 3 *m.* The area of the sample plot (Plot 9) is about 3 *ha* and the soil belongs to Bungor series of Typic paleudults taxonomy. Although the stand was approximately five years old, the distribution of diameters and heights of sample trees were wide enough to construct this volume table.

Measurement of sample trees

Felled trees

These were thinnings from the above plantation. The thinning was carried out in January 1987 with the objective of establishing a seed production area for *A. mangium.* Prior to felling, the base diameter (0.3 *m* above ground level) and the diameter at breast height (DBH - 1.3 *m* above ground level) of each selected tree as measured. The following measurements were also taken after felling:

- total height in *m,* merchantable height in *m* (up to 10 *cm* diameter overbark of the main stem), diameter overbark at 3 *m* intervals along the stem length and at its mid-point (1.5 *m* intervals), and bark thickness (*cm*) at each point of diameter measurement.

All diameters were measured using a diameter tape and bark thickness using a bark-gauge. A total of 336 felled trees were measured.

Standing trees

For the standing trees, sample points were established using a "10 Point Sampling Design" (Wan Razali *et al.* 1983) in which the first sample point was randomly located in the entire stand and the other nine sample points were systematically located. Once the sample point was located at each point, the method of variable plot cruising (Dilworth & Bell 1969) using wide angle Spiegel Relaskop was employed to sight in (at 1.3 *m* from the ground level using basal area factor of 1.0) the sample trees. A total of 187 such standing trees were then marked for measurements. Except for the base diameter and diameter at breast height which were measured using a diameter tape, all other measurements of standing trees were carried out using a wide angle Spiegel Relaskop. The same parameters (as in felled trees) except the bark thickness were measured on each standing tree. Diameters were also measured at every 20% of tree's merchantable height.

Volume calculation

The volumes of each section of felled and standing trees were calculated using either Smalian's or Newton's formula. For felled trees both overbark and underbark volumes were calculated while for standing trees only overbark volumes were calculated.

Smalian's formula

This formula was used for log sections with two diameter measurements. The volumes of standing tree samples were calculated using this formula.

i. Volume overbark

$$V1 = 0.00003927\ (D_l^2 + D_s^2) \times L$$

• Newton's formula

The formula was used for log sections with three diameter measurements. The volumes of felled tree samples were calculated using this formula.

i. Volume overbark

$$V2 = 0.00001309\ (D_l^2 + 4D_m^2 + D_s^2) \times L$$

ii. Volume underbark

$$V3 = 0.00001309\ [(D_l - 2Bt_l)^2 + 4(D_m - 2Bt_m)^2 + (D_s - 2Bt_s)^2] \times L$$

where V1 and V2 are the volume overbark, V3 is the volume underbark, L is the length of the log section, D_l is the diameter at the large end of the log section, D_m

is the diameter at the mid-point of the log section, D_s is the diameter at the small end of the log section, Bt_l is the bark thickness at the large end of the log section, Bt_m is the bark thickness at the mid-point of the log section and Bt_s is the bark thickness at the small end of the log section.

For both felled and standing trees, the volumes of individual sections were then added to give the total tree volume up to 10 *cm* diameter.

Constructing volume equations

The method of least squares was used for the construction of volume equations. The data were fitted to both unweighted and weighted volume equations. For the overbark volume equations, data from both felled and standing trees were used. However, only data from felled trees were used for underbark volume equations.

Unweighted equations

Eight unweighted volume equations were used in the study.

$$V = b_0 + b_1 D \quad (1)$$
$$V = b_0 + b_1 D + b_2 D^2 \quad (2)$$
$$V = b_0 + b_1 D^2 \quad (3)$$
$$V = b_0 + b_1 D^2 H \quad (4)$$
$$V = b_0 + b_1 D^2 + b_2 H + b_3 D^2 H \quad (5)$$
$$V = b_0 + b_1 D^2 + b_2 DH + b_3 D^2 H \quad (6)$$
$$\text{Log}_e V = b_0 + b_1 \log_e D \quad (7)$$
$$\text{Log}_e V = b_0 + b_1 \log_e D + \log_e H \quad (8)$$

where D is the DBH (*cm*), H is the total log length (*m*) from the ground to 10 *cm* overbark and V is the merchantable volume (m^3).

Weighted equations

One of the assumptions of a regression analysis is that of homogeneity of variance. Wright (1964) and Cunia (1964) discussed the need to weigh volume equations in most circumstances in order to equalise the variance in volume along the regression line or surface. The variance of the residuals from arithmetic volume equations tends to vary with tree size and has been found, in some cases, to be proportional to $(D^2)^2$ or $(D^2H)^2$. Thus the appropriate weight to use is $(D^2)^{-2}$ or $(D^2H)^{-2}$ in order to stabilise the variance of the residuals.

The question of weights as such can often be simplified in the regression analysis by multiplying both sides of a volume equation by the square root of that weight. It follows from this that the factors to be used in this case are $1/D^2$ and $1/D^2H$.

In this study, seven weighted volume equations were used.

$$V/D^2 = b_0 + b_1(1/D^2) + b_2(1/D) \quad (9)$$
[Equation 2 divided by D^2]

$$V/D^2 = b_0 + b_1(1/D^2) \quad (10)$$
[Equation 3 divided by D^2]

$$V/D^2H = b_0 + b_1(1/D^2H) \quad (11)$$
[Equation 4 divided by D^2H]

$$V/D^2 = b_0 + b_1(1/D^2) + b_2(H/D^2) + b_3(H) \quad (12)$$
[Equation 5 divided by D^2]

$$V/D^2H = b_0 + b_1(1/D^2H) + b_2(1/H) + b_3(1/D^2) \quad (13)$$
[Equation 5 divided by D^2H]

$$V/D^2 = b_0 + b_1(1/D^2) + b_2(H/D) + b_3(H) \quad (14)$$
[Equation 6 divided by D^2]

$$V/D^2H = b_0 + b_1(1/D^2H) + b_2(1/H) + b_3(1/D) \quad (15)$$
[Equation 6 divided by D^2H]

(V, D, and H in equations (9) to (15) are as defined before).

With the inclusion of transformations of the dependent variable and weighted regressions into the analysis, problems arise when selecting the most suitable equation. Regression in which the same dependent variable (volume in this case) has been subjected to different weightings cannot be compared directly for selecting the most suitable equation using coefficient of determination, R^2. The regression may be biased by different weightings of the dependent variables. To overcome this problem, Furnival (1961) suggested an index for comparing these equations. The Furnival Index (FI) is expressed as follows:

$$FI = [f'(V)]^{-1}s$$

where FI is the Furnival Index, $[f'(V)]^{-1}$ is the geometric mean of the derivative of the dependent variable with respect to volume, and s is the residual standard error from the fitted regression.

Regression analysis was carried out using a commercial statistical package on a micro computer system. Further analysis was done to calculate the Furnival Index (FI). The equation with the smallest FI indicates the best fit regression.

Results and discussion

The DBH and total height of the sample trees ranged from 10.50 to 27.50 *cm* and 13.10 to 30.30 *m* respectively. The merchantable height ranged from 2.6 to 18.0 *m*. Table 1 shows the summary of results calculated from various parameters measured. From the Relaskop readings of the standing trees, it was found that the area under study has an average basal area of 18.7 $m^2\ ha^{-1}$ and an average volume (overbark) of 120.8 $m^3\ ha^{-1}$. The number of trees in the stand left after thinning was approximately 610 trees ha^{-1}.

Table 1. Summary of parameters measured and calculated (*Acacia mangium*)

Parameters	Standing trees				Felled trees				Felled & standing trees			
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
Number of tree measured		187				336				523		
DBH (*cm*)	19.5	3.01	10.8	26.8	18.3	3.41	10.5	27.5	18.7	3.32	10.5	27.5
Merchantable height (*m*) (up to 10 *cm* diameter)	9.0	2.06	2.7	17.6	10.7	2.91	2.6	18.0	10.1	2.73	2.6	18.0
Total tree height (*m*)	19.7	2.39	13.8	28.9	20.2	2.29	13.1	30.3	20.0	2.34	13.1	30.3
Merchantable volume (m^3)* (overbark)	0.198	0.073	0.030	0.385	0.199	0.083	0.025	0.410	0.198	0.079	0.025	0.410
Merchantable volume (m^3) * (under bark)			-		0.172	0.073	0.021	0.382			-	

* Based on Smalian's or Newton's formula and volume was up to 10 *cm* diameter overbark

Tables 2 and 3 show the results of the analysis carried out. In all the equations, Vo and Vi are respectively the merchantable volumes (m^3) overbark and underbark up to 10 *cm* diameter, D the DBH (*cm*), and H the total log length (*m*). The equation with the smallest FI value was chosen as having the best fit to the data. These are as follows:

Volume equation (overbark)

$$\text{Log}_e\text{Vo} = -8.06868 + 1.54738\text{Log}_e\text{D} + 0.80931\text{Log}_e\text{H}$$

and

Volume equation (underbark)

$$\text{Log}_e\text{Vi} = -8.22118 + 1.51310\text{Log}_e\text{D} + 0.84789\text{Log}_e\text{H}.$$

Calculation of a tree volume using a logarithmic equation is affected by a systematic error which is introduced when taking the antilogarithm of the volume. The error however can be approximately corrected by multiplying the volume equation by a factor as follows (H. A. Meyer internal communication):

$$f = e^{(s^2/2)}$$

where f is the tree volume correction factor, s^2 is the logarithmic equation error variance, and e = 2.718282.

Table 2. Unweighted and weighted overbark volume equations for *Acacia mangium*

Volume equation	Standard error (S.E.)	R^2	Geometric mean (G.M.)	Furnival Index (FI)
A. Unweighted				
$Vo = -0.1960 + 0.02104D$	0.0375	0.7771	1.0	0.0375
$Vo = -0.26653 + 0.02895D - 0.00021D^2$	0.0374	0.7785	1.0	0.0374
$Vo = -0.00460 + 0.00056D^2$	0.0389	0.7590	1.0	0.0389
$Vo = 0.04225 + 0.00004D^2H$	0.0243	0.9061	1.0	0.0443
$Vo = -0.04680 + 0.00027D^2 + 0.00961H + 0.00001D^2H$	0.0224	0.9595	1.0	0.0224
$Vo = -0.0323 + 0.00024D^2 + 0.00084DH - 0.000001D^2H$	0.0223	0.9214	1.0	0.0223
$Log_eVo = -8.8157 + 2.43369 \log_e D$	0.2245	0.8970	0.1791	0.0402
$Log_eVo = -8.06868 + 1.54738 \log_e D + 0.80931 \log_e H$	0.1082	0.9547	0.1791	0.0193 *
B. Weighted				
$Vo/D^2 = 7.676 \times 10^{-5} - 1.7861 \times 10^{-4} (1/D^2) + 1.864 \times 10^{-5} (1/D)$	1.144×10^{-4}	0.1388	340.358	0.0389
$Vo/D^2 = 6.307 \times 10^{-4} - 2.871 \times 10^{-5} (1/D^2)$	1.168×10^{-4}	0.1009	340.358	0.0398
$Vo/D^2H = 4.80 \times 10^{-5} + 1.837 \times 10^{-5} (1/D^2H)$	8.3×10^{-6}	0.4234	3294.468	0.0273
$Vo/D^2 = 2.0651 \times 10^{-4} - 2.887 \times 10^{-5} (1/D^2) + 7.70 \times 10^{-6} (H/D^2) + 2.0 \times 10^{-8}(H)$	6.67×10^{-5}	0.7075	340.358	0.0227
$Vo/D^2H = 2.256 \times 10^{-5} - 2.229 \times 10^{-5} (1/D^2H) + 1.8 \times 10^{-7} (1/H) + 6.77 \times 10^{-6} (1/D^2)$	7.5×10^{-6}	0.5346	3294.468	0.0247
$Vo/D^2 = 1.6565 \times 10^{-4} - 1.568 \times 10^{-5} (1/D^2) + 6.9 \times 10^{-7} (H/D) + 1.0 \times 10^{-9} (H)$	6.74×10^{-5}	0.7018	340.358	0.0229
$Vo/D^2H = 7.79 \times 10^{-6} - 1.323 \times 10^{-5} (1/D^2H) + 1.4 \times 10^{-7} (1/H) + 6.7 \times 10^{-7} (1/D)$	7.6×10^{-6}	0.5240	3294.468	0.0250

* The best fit volume equation

Consequently, the tree volume correction factor (f) of the logarithmic equation for overbark and underbark volume equations are 1.00587 (s^2 = 0.0117) and 1.00682 (s^2 = 0.0136) respectively.

The final volume equations (Vo and Vi) of *A. mangium* are:

$$Vo = 0.0003150 \times D^{1.54738} \times H^{0.80931}$$

and

$$Vi = 0.0002707 \times D^{1.51310} \times H^{0.84789}$$

Volume tables based on these equations are shown in Tables 4 and 5.

Table 3. Unweighted and weighted underbark volume equations for *Acacia mangium*

Volume equation	Standard error (S.E.)	R^2	Geometric mean (G.M.)	Furnival Index (FI)
A. Unweighted				
$Vi = -0.17883 + 0.01917D$	0.0336	0.7912	1.0	0.0336
$Vi = -0.28430 + 0.03126D - 0.00033D^2$	0.0333	0.7954	1.0	0.0333
$Vi = -0.00765 + 0.0052D^2$	0.0354	0.7675	1.0	0.0354
$Vi = 0.3368 + 0.00004D^2H$	0.0229	0.9027	1.0	0.0229
$Vi = -0.03088 + 0.00018D^2 + 0.00734H + 0.00002D^2H$	0.0216	0.9143	1.0	0.0216
$Vi = -0.01980 + 0.00016D^2 + 0.00065DH - 0.0000001D^2H$	0.0215	0.9151	1.0	0.0215
$Log_eVi = -9.24781 + 2.54940 Log_eD$	0.2343	0.8194	0.15213	0.0356
$Log_eVi = -8.22118 + 1.51310 Log_eD + 0.84789 Log_eH$	0.1166	0.9554	0.15213	0.0177 *
B. Weighted				
$Vi/D^2 = -1.4957 \times 10^{-4} - 2.3119 \times 10^{-4}(1/D^2) - 2.487 \times 10^{-5} (1/D)$	9.54×10^{-5}	0.2810	322.789	0.0308
$Vi/D^2 = 5.996 \times 10^{-4} - 3.405 \times 10^{-5}(1/D^2)$	1.005×10^{-4}	0.1995	322.789	0.0324
$Vi/D^2H = 4.115 \times 10^{-5} + 1.462 \times 10^{-5}(1/D^2H)$	7.1×10^{-6}	0.4246	3284.599	0.0233
$Vi/D^2 = 1.5572 \times 10^{-4} - 2.214 \times 10^{-5}(1/D^2) + 6.01 \times 10^{-6} (H/D^2) + 2.0 \times 10^{-9}(H)$	5.93×10^{-5}	0.7230	322.789	0.0191
$Vi/D^2H = 1.912 \times 10^{-5} - 2.12 \times 10^{-5} (1/D^2H) + 1.8 \times 10^{-7} (1/H) + 5.4 \times 10^{-6} (1/D^2)$	6.4×10^{-6}	0.5398	3284.599	0.0210
$Vi/D^2 = 1.3276 \times 10^{-4} - 1.419 \times 10^{-5}(1/D^2) + 5.9 \times 10^{-7}(H/D) + 1.0 \times 10^{-9}(H)$	5.91×10^{-5}	0.7247	322.789	0.0191
$Vi/D^2H = 4.56 \times 10^{-6} - 1.57 \times 10^{-5} (1/D^2H) + 1.5 \times 10^{-7} (1/H) + 5.8 \times 10^{-7}(1/D)$	6.4×10^{-6}	0.5414	3284.599	0.0210

* The best fit volume equation

Accuracy and application

One way to assess the accuracy of a volume table is by comparing the "true" volume (calculated volume in this case) with the predicted volume (volume derived from the equation). We found that the average predicted merchantable tree volume (0.192 m^3 - overbark) approximated the true overbark volume, 0.198 m^3. Similarly, the average predicted merchantable tree volume (0.164

Table 4. The merchantable volume overbark (m^3) of *Acacia mangium*

Diameter class (cm)	Height class (m)																		
	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
10	0.019	0.027	0.034	0.041	0.047	0.054	0.060	0.066	0.072	0.077	0.083	0.089	0.094	0.099	0.105	0.110	0.115	0.120	0.126
11	0.023	0.031	0.040	0.047	0.055	0.062	0.069	0.076	0.083	0.090	0.096	0.103	0.109	0.115	0.121	0.128	0.134	0.140	0.145
12	0.026	0.036	0.045	0.054	0.063	0.071	0.079	0.087	0.095	0.103	0.110	0.117	0.125	0.132	0.139	0.146	0.153	0.160	0.166
13	0.029	0.041	0.051	0.061	0.071	0.081	0.090	0.099	0.107	0.116	0.125	0.133	0.141	0.149	0.157	0.165	0.173	0.181	0.188
14	0.033	0.045	0.057	0.069	0.080	0.090	0.101	0.111	0.121	0.130	0.140	0.149	0.158	0.167	0.176	0.185	0.194	0.203	0.211
15	0.036	0.051	0.064	0.077	0.089	0.100	0.112	0.123	0.134	0.145	0.155	0.166	0.176	0.186	0.196	0.206	0.216	0.225	0.235
16	0.040	0.056	0.071	0.085	0.098	0.111	0.124	0.136	0.148	0.160	0.172	0.183	0.195	0.206	0.217	0.228	0.239	0.249	0.260
17	0.044	0.061	0.078	0.093	0.108	0.122	0.136	0.149	0.163	0.176	0.189	0.201	0.214	0.226	0.238	0.250	0.262	0.274	0.285
18	0.048	0.067	0.085	0.101	0.118	0.133	0.148	0.163	0.178	0.192	0.206	0.220	0.234	0.247	0.260	0.273	0.286	0.299	0.312
19	0.053	0.073	0.092	0.110	0.128	0.145	0.161	0.178	0.193	0.209	0.224	0.239	0.254	0.268	0.283	0.297	0.311	0.325	0.339
20	0.057	0.079	0.100	0.119	0.138	0.157	0.175	0.192	0.209	0.226	0.243	0.259	0.275	0.291	0.306	0.322	0.337	0.352	0.367
21	0.061	0.085	0.108	0.129	0.149	0.169	0.188	0.207	0.226	0.244	0.262	0.279	0.296	0.313	0.330	0.347	0.363	0.380	0.396
22	0.066	0.092	0.116	0.138	0.160	0.182	0.203	0.223	0.243	0.262	0.281	0.300	0.319	0.337	0.355	0.373	0.390	0.408	0.425
23	0.071	0.098	0.124	0.148	0.172	0.195	0.217	0.239	0.260	0.281	0.301	0.321	0.341	0.361	0.380	0.399	0.418	0.437	0.455
24	0.075	0.105	0.132	0.158	0.184	0.208	0.232	0.255	0.278	0.300	0.322	0.343	0.364	0.385	0.406	0.426	0.447	0.467	0.486
25	0.080	0.112	0.141	0.169	0.196	0.222	0.247	0.272	0.296	0.319	0.343	0.366	0.388	0.411	0.433	0.454	0.476	0.497	0.518
26	0.085	0.119	0.150	0.179	0.208	0.235	0.262	0.288	0.314	0.339	0.364	0.388	0.413	0.436	0.460	0.483	0.506	0.528	0.551
27	0.091	0.126	0.159	0.190	0.220	0.250	0.278	0.306	0.333	0.360	0.386	0.412	0.437	0.462	0.487	0.512	0.536	0.560	0.584
28	0.096	0.133	0.168	0.201	0.233	0.264	0.294	0.324	0.352	0.381	0.408	0.436	0.463	0.489	0.515	0.541	0.567	0.592	0.617
29	0.101	0.140	0.177	0.212	0.246	0.279	0.311	0.342	0.372	0.402	0.431	0.460	0.488	0.516	0.544	0.571	0.599	0.625	0.652
30	0.107	0.148	0.187	0.224	0.259	0.294	0.327	0.360	0.392	0.423	0.454	0.485	0.515	0.544	0.573	0.602	0.631	0.659	0.687
31	0.112	0.156	0.196	0.235	0.273	0.309	0.344	0.379	0.412	0.446	0.478	0.510	0.542	0.573	0.603	0.634	0.664	0.693	0.723
32	0.118	0.164	0.206	0.247	0.287	0.325	0.362	0.398	0.433	0.468	0.502	0.536	0.569	0.601	0.634	0.666	0.697	0.728	0.759
33	0.124	0.171	0.216	0.259	0.300	0.340	0.379	0.417	0.454	0.491	0.527	0.562	0.597	0.631	0.665	0.698	0.731	0.764	0.796
34	0.129	0.180	0.227	0.272	0.315	0.357	0.397	0.437	0.476	0.514	0.551	0.588	0.625	0.661	0.696	0.731	0.766	0.800	0.834
35	0.135	0.188	0.237	0.284	0.329	0.373	0.415	0.457	0.498	0.538	0.577	0.615	0.653	0.691	0.728	0.765	0.801	0.837	0.872
36	0.141	0.196	0.248	0.297	0.344	0.389	0.434	0.477	0.520	0.562	0.602	0.643	0.683	0.722	0.760	0.799	0.836	0.874	0.911
37	0.147	0.205	0.258	0.309	0.359	0.406	0.453	0.498	0.542	0.586	0.629	0.671	0.712	0.753	0.793	0.833	0.873	0.912	0.950
38	0.154	0.213	0.269	0.323	0.374	0.423	0.472	0.519	0.565	0.611	0.655	0.699	0.742	0.785	0.827	0.868	0.909	0.950	0.990
39	0.160	0.222	0.280	0.336	0.389	0.441	0.491	0.540	0.588	0.636	0.682	0.728	0.773	0.817	0.861	0.904	0.947	0.989	1.031
40	0.166	0.231	0.291	0.349	0.405	0.458	0.511	0.562	0.612	0.661	0.709	0.757	0.803	0.850	0.895	0.940	0.985	1.029	1.072

Volume equation: $Vo = 0.0003150 \times D^{1.54758} \times H^{0.80951}$

Figures within lines indicate the range of data collected

Table 5. Merchantable volume underbark (m^3) of *Acacia mangium*

Diameter class (cm)	Height class (m) 2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
10	0.016	0.022	0.029	0.035	0.040	0.046	0.051	0.057	0.062	0.067	0.073	0.078	0.083	0.088	0.093	0.097	0.102	0.107	0.112
11	0.018	0.026	0.033	0.040	0.047	0.053	0.059	0.066	0.072	0.078	0.084	0.090	0.096	0.101	0.107	0.113	0.118	0.124	0.129
12	0.021	0.030	0.038	0.046	0.053	0.061	0.068	0.075	0.082	0.089	0.096	0.102	0.109	0.116	0.122	0.128	0.135	0.141	0.147
13	0.024	0.033	0.043	0.051	0.060	0.068	0.077	0.085	0.092	0.100	0.108	0.115	0.123	0.130	0.138	0.145	0.152	0.159	0.166
14	0.026	0.037	0.048	0.057	0.067	0.076	0.086	0.095	0.103	0.112	0.121	0.129	0.138	0.146	0.154	0.162	0.170	0.178	0.186
15	0.029	0.041	0.053	0.064	0.074	0.085	0.095	0.105	0.115	0.124	0.134	0.143	0.153	0.162	0.171	0.180	0.189	0.198	0.207
16	0.032	0.046	0.058	0.070	0.082	0.094	0.105	0.116	0.127	0.137	0.148	0.158	0.168	0.179	0.189	0.199	0.208	0.218	0.228
17	0.035	0.050	0.064	0.077	0.090	0.103	0.115	0.127	0.139	0.150	0.162	0.173	0.185	0.196	0.207	0.219	0.228	0.239	0.250
18	0.039	0.055	0.070	0.084	0.098	0.112	0.125	0.138	0.151	0.164	0.177	0.189	0.201	0.213	0.225	0.237	0.249	0.261	0.272
19	0.042	0.059	0.075	0.091	0.106	0.121	0.136	0.150	0.164	0.178	0.192	0.205	0.218	0.232	0.245	0.257	0.270	0.283	0.295
20	0.045	0.064	0.082	0.099	0.115	0.131	0.147	0.162	0.177	0.192	0.207	0.222	0.236	0.250	0.264	0.278	0.292	0.306	0.319
21	0.049	0.069	0.088	0.106	0.124	0.141	0.158	0.175	0.191	0.207	0.223	0.239	0.254	0.269	0.285	0.300	0.314	0.329	0.344
22	0.052	0.074	0.094	0.114	0.133	0.151	0.170	0.187	0.205	0.222	0.239	0.256	0.273	0.289	0.305	0.321	0.337	0.353	0.369
23	0.056	0.079	0.101	0.122	0.142	0.162	0.181	0.200	0.219	0.238	0.256	0.274	0.292	0.309	0.327	0.344	0.361	0.378	0.395
24	0.060	0.084	0.108	0.130	0.152	0.173	0.193	0.214	0.234	0.253	0.273	0.292	0.311	0.330	0.348	0.367	0.385	0.403	0.421
25	0.064	0.090	0.114	0.138	0.161	0.184	0.206	0.227	0.249	0.270	0.290	0.311	0.331	0.351	0.370	0.390	0.409	0.429	0.448
26	0.067	0.095	0.121	0.147	0.171	0.195	0.218	0.241	0.264	0.286	0.308	0.330	0.351	0.372	0.393	0.414	0.434	0.455	0.475
27	0.071	0.101	0.128	0.155	0.181	0.206	0.231	0.256	0.279	0.303	0.326	0.349	0.372	0.394	0.416	0.438	0.460	0.481	0.503
28	0.075	0.106	0.136	0.164	0.191	0.218	0.244	0.270	0.295	0.320	0.345	0.369	0.393	0.416	0.440	0.463	0.486	0.509	0.531
29	0.079	0.112	0.143	0.172	0.201	0.230	0.257	0.284	0.311	0.337	0.363	0.388	0.414	0.438	0.463	0.488	0.512	0.536	0.560
30	0.084	0.118	0.151	0.182	0.213	0.242	0.271	0.300	0.328	0.355	0.382	0.409	0.436	0.462	0.488	0.514	0.539	0.565	0.590
31	0.088	0.124	0.158	0.191	0.223	0.254	0.285	0.315	0.344	0.373	0.402	0.430	0.458	0.486	0.513	0.540	0.567	0.593	0.620
32	0.092	0.130	0.166	0.201	0.234	0.267	0.299	0.330	0.361	0.392	0.422	0.451	0.481	0.510	0.538	0.567	0.595	0.623	0.650
33	0.097	0.136	0.174	0.210	0.245	0.280	0.313	0.346	0.379	0.410	0.442	0.473	0.503	0.534	0.564	0.594	0.623	0.652	0.681
34	0.101	0.143	0.182	0.220	0.257	0.293	0.328	0.362	0.396	0.429	0.462	0.495	0.527	0.558	0.590	0.621	0.652	0.682	0.713
35	0.106	0.149	0.190	0.230	0.268	0.306	0.342	0.378	0.414	0.449	0.483	0.517	0.550	0.584	0.616	0.649	0.681	0.713	0.745
36	0.110	0.156	0.199	0.240	0.280	0.319	0.357	0.395	0.432	0.468	0.504	0.539	0.574	0.609	0.643	0.677	0.711	0.744	0.777
37	0.115	0.162	0.207	0.250	0.292	0.333	0.372	0.412	0.450	0.488	0.525	0.562	0.599	0.635	0.670	0.706	0.741	0.776	0.810
38	0.120	0.169	0.215	0.260	0.304	0.346	0.388	0.429	0.469	0.508	0.547	0.585	0.623	0.661	0.698	0.735	0.771	0.808	0.843
39	0.125	0.176	0.224	0.271	0.316	0.360	0.403	0.446	0..487	0.528	0.569	0.609	0.648	0.687	0.726	0.764	0.802	0.840	0.877
40	0.129	0.182	0.233	0.281	0.328	0.374	0.419	0.463	0.506	0.549	0.591	0.633	0.674	0.714	0.754	0.794	0.834	0.873	0.911

Volume equation: $Vi = 0.0002707 \times D^{1.51310} \times H^{0.84789}$

Figures within lines indicate the range of data collected

m^3 - underbark) derived from the equation is quite close to the true volume, 0.172 m^3. The differences between the true and predicted volumes, 0.006 m^3 for overbark and 0.008 m^3 for underbark, are too small to be of practical importance.

The use of the volume table is indeed simple. One needs to measure the DBH (either overbark or underbark) and total log length of a tree to the nearest 1 *cm* and 1 *m* respectively. Then the merchantable tree volume (either overbark or underbark) is obtained directly from the table. However, if one measures the DBH and the total log length of a tree, for example, to the nearest 0.1 *cm* and 0.1 *m* respectively, then the merchantable tree volume may be obtained by interpolation in the table, or by substituting those values (DBH and total log length) into the volume equation.

Conclusion

Although the data were collected from a specific region and plantation, the volume models constructed can be expected to give a satisfactory estimate for the aggregate standing volume of planted *A. mangium* stands in Peninsular Malaysia. But as with all volume equations, a test of applicability is always necessary if used outside the range of data and/or under other conditions.

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