TREE VOLUME TABLES FOR *ACACIA MANGIUM* IN THE PLANTATIONS OF BANGLADESH

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ABSTRACT

Acacia mangium Willd. (mangium) is a promising fast growing multipurpose tree species of the family *Leguminosae.* The species has been successfully introduced to Bangladesh and is being planted since 1983. An attempt was made to prepare the volume tables for the species. Diameter at breast height (D)-volume and D-height-volume relationships were determined to estimate the total volumes overbark and underbark. It was observed that the logarithmic function to the *base e* gives a good fit model for the same.

সারসংক্ষেপ

ম্যানজিয়াম লিগুমিনাসী পরিবারের বহুবিধ ব্যবহারোপযোগী একটি প্রজাতির গাছ। বিদেশ হইতে আনিয়া এই প্রজাতির গাছ বাংলাদেশে সাফল্যের সাথে লাগান হইতেছে। এই প্রজাতির গাছের ভল্যুম পরিমাপ করার জন্য ভল্যুম টেবিল তৈয়ার করার একটি প্রচেষ্টা নেওয়া হয়। বুক উচ্চতায় গাছের ব্যাস এবং বুক উচ্চতায় গাছের ব্যাস ও মোট উচ্চতার সহিত ভল্যুমের সম্পর্ক নির্ণয় করিয়া প্রয়োজনীয় টেবিল তৈয়ার করা হয়।

INTRODUCTION

Acacia mangium Willd. (mangium) is a promising fast growing multipurpose tree species of the family *Leguminosae.* It is indigenous to Northern Australia, Papua New Guinea and Eastern Indonesia. The species was first tried in Bangladesh in 1979 and the initial growth rate was satisfactory. Subsequently, a provenance trial was established in 1983 and suitable provenances for Bangladesh were selected (Zashimuddin *et. al.* 1983). Since then the species is being planted by the Forest Department.

The species can be used as fuelwood, sawn timber, poles and as a raw material for pulpwood, plywood and particle board. One of the advantages of this species is that it can thrieve well in poor and dry soils and gives higher yield in comparison to local species.

The trees of the initial plantations are by now 6-9 years old. The plantations raised for fuelwood are ready for harvesting. But, there is no table to estimate the volume of the trees. Therefore, an attempt was made to prepare volume tables for the species in Bangladesh.

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MATERIALS AND METHODS

Collections of data : Data were collected from the felled trees. Diameters at breast height (dbh) were measured first. Then the trees were felled leaving 7-10 cm stump and the total heights were measured. The trees were marked at one metre intervals from one metre above ground level to a top end diameter of approximately 3.0 cm overbark and diameters overbark were taken. The barks were then removed from each point of diameter measurement and underbark diameter measurements were taken. The dbh-height class distribution of the sample trees are given in Table 1.

Table 1 Distribution of the sample trees with respect to their diameter at breast height in centimetre and total height class in metres.

Dbh (cm)	Height class in metres								
	5	7	9	11	13	15	17	19	Total
5 - 10	7	10	13	6	3				39
10 - 15		1	3	19	15	4			42
15 - 20				9	24	11		1	45
20 - 25						4	2		6
Total	7	11	16	34	42	19	2	1	132

Compilation of data : The volumes of all the sections except the top and bottom portions were computed by using the mean cross-sectional area of the two ends of each section (Smallian formula). The bottom section was assumed cylindrical. The top most section was assumed a cone and volume was computed as one third of the cylindrical volume of the portion. The top end diameter measurement for each tree was considered as the base diameter of the cone. The volume of the cone was ignored for estimation of underbark tree volume. The individual tree volume was then estimated by summing up the volume of each section of a tree. Regression equations were used to relate these individual tree volumes (V) and were related to dbh (D) and total height (H) using various functions and transformations as required in the models.

Computation of volume function : Multiple regression analyses were done to select the best suited equations. The following 10 models were tried to select the equation of best fit with different variables as follows :

1. $V = b0 + b1\ D$
2. $V = b0 + b1\ D + b2\ D^2$
3. $V = b0 + b1\ D^2$
4. $V = b0 + b1\ D^2H$
5. $V = b0 + b1\ D^2 + b2\ H + b3\ D^2H$
6. $V = b0 + b1\ D^2 + b2\ DH + b3\ D^2H$
7. $\log(V) = b0 + b1 \log(D)$
8. $\log(V) = b0 + b1 \log(D) + b2 \log(H)$
9. $V/D^2 = b0 + b1\ HD^2 + b2/H + b3/D^2$
10. $V/D^2 = b0 + b1/D^2 + b2/H + b3/D$

Where V. D and H are described as above, b_0 is the regresstion constant and b1, b2 and b3 are regression coefficients. The logarithmic functions are to the base e.

The equations of the best fit were chosen based on the highest multiple coefficient of determination, F-ratio, lowest residual mean square and low Furnival index. Models were selected for estimation of the total volume overbark and total volume underbark to a top end diameter of approximately 3.0 cm overbark. The selected equations were also transformed for estimation of volume from the girth at breast height (G).

Validation of the selected models : The best suited regression equations were tested with a set of independent data on 33 trees collected and compiled in the same procedure. The actual volumes of these trees were collectively compared with the corresponding volume predicted by the selected models. The independent tests for validation were the absolute deviation percent, paired t-test, chi-square test and 45 degree line test (Islam *et. al.* 1992).

RESULTS AND DISCUSSIONS

The equations for the total volume overbark (Vob) and the total volume underbark to a top end diameter of approximately 3.0 cm overbark (Vub) were selected after the validation of the selected models. The mean sum of squares, multiple coefficient of determination, F-ratio and Furnival index as selection statistics and the error mean sum of squares (MSE), percent absolute deviation percent (%AD), t-value, slope made by the actual volumes with estimated volumes as validation statistics are given in Table 2 and the selected models are given below.

$$\log(V1ob) = -8.209 + 2.2178^* \log(D)$$

$$\log(V1ob) = -10.7488 + 2.2178^* \log(G)$$

$$\log(V2ob) = -9.1426 + 1.7612^* \log(D) + 0.83335^* \log(H)$$

$$\log(V2ob) = -11.1587 + 1.7612^* \log(G) + 0.83335^* \log(H)$$

$$\log(V1ub) = -9.00226 + 2.3246^* \log(D)$$

$$\log(V1ub) = -11.6633 + 2.3246^* \log(G)$$

$$\log(V2ub) = -10.2221 + 1.74054^* \log(D) + 1.07596^* \log(H)$$

$$\log(V2ub) = -21.2145 + 1.74054^* \log(G) + 1.07596^* \log(H)$$

Where :
- H = total height in meters,
- D = diameter at breast height in centimeter,
- G = girth at breast height in centimeter,
- Vob = total volume overbark in cubic meters
- Vub = total underbark volume upto a diameter of 3.0 cm in cubic meters.
- 1 = one way (dbh - volume) equation,
- 2 = two way (dbh - height - volume) equation.

Validation of the selected models : The selected models satisfied all the validation criteria. The most vivid ones are the slopes and percent total deviations. They are nearly 45 degree and less than 5% respectively. This nature was considered sufficient to mark the importance of minor discrepancies in the horizontal bands of deviations. From the results of the validation of the models, it can be concluded that the selected models can safely be used for estimation of the volumes of mangium tree in the plantations of Bangladesh. After the validation test, volume tables were prepared for ready use and are presented in Table 3, 4 and 5.

Confidence limit : These volume tables should not be used to estimate volumes of individual trees in a stand. These tables may be used for the mean tree of a stand which may be multiplied by the number of stem to get the total volume of the stand (Davidson and Choudhury, 1984). Estimation of volumes for trees much out side the height and dbh ranges shown in the stand table should only be done with caution.

Table 2. **Selection and validation statistics of best suited regression equations for estimating volumes of mangium in Bangladesh.**

	Selection statistics MSE	R^2	F-ratio	F. I	Validation statistics Absolute deviations (%)	t-value	slope (degre)	Chi-square	MSE
V1ob	0.0152	0.980	6905.8	0.0062	2.4	0.96	45.04	0.044	0.00007
V2ob	0.0091	0.989	5810.5	0.0048	0.7	0.37	44.35	0.021	0.00004
V1ub	0.0299	0.969	4282.9	0.0056	2.5	1.17	45.09	0.047	0.00013
V2ub	0.0219	0.977	2947.3	0.0048	1.2	1.13	44.71	0.011	0.00003

Table 3. **One-way predicted volumes (ob and ub) in cubic meters for mangium trees in plantations in Bangladesh.**

Dbh (cm)	Gbh (cm)	Vob (m^3)	Vub (m^3)
2	6.3	0.001	0.001
3	9.4	0.003	0.002
4	12.6	0.006	0.003
5	15.7	0.010	0.005
6	18.8	0.014	0.008
7	22.0	0.020	0.011
8	25.1	0.027	0.015
9	28.3	0.036	0.020
10	31.4	0.045	0.026
11	34.6	0.056	0.032
12	37.7	0.067	0.040
13	40.8	0.080	0.048
14	44.0	0.095	0.057
15	47.1	0.110	0.067
16	50.3	0.127	0.078
17	53.4	0.146	0.089
18	56.5	0.166	0.102
19	59.7	0.187	0.116
20	62.8	0.209	0.130
21	66.0	0.233	0.146
22	69.1	0.258	0.163
23	72.3	0.285	0.180
24	75.4	0.313	0.199
25	78.5	0.343	0.219

Table 4. Two-way predicted total overbark volumes for mangium trees in plantations in Bangladesh.

DBH (cm)	GBH (cm)	HEIGHT IN METERS — total overbark volume in cubic meters									
		2	4	6	8	10	12	14	16	18	20
2	6.3	0.001	00.1	0.002	0.002	0.002	0.003	0.003			
3	9.4	0.001	0.002	0.003	0.004	0.005	0.006	0.007			
4	12.6	0.002	0.004	0.005	0.007	0.008	0.010	0.011			
5	15.7	0.003	0.006	0.008	0.010	0.012	0.014	0.016			
6	18.8	0.004	0.008	0.011	0.014	0.017	0.020	0.023	0.025		
7	22.0	0.006	0.010	0.015	0.019	0.022	0.026	0.030	0.033		
8	25.1	0.007	0.013	0.019	0.024	0.028	0.033	0.038	0.042		
9	28.3	0.009	0.016	0.023	0.029	0.035	0.041	0.046	0.052		
10	31.4	0.011	0.020	0.027	0.035	0.042	0.049	0.056	0.062		
11	34.6	0.013	0.023	0.033	0.041	0.050	0.058	0.066	0.074	0.081	
12	37.7	0.015	0.027	0.038	0.048	0.058	0.068	0.077	0.086	0.095	
13	40.8	0.017	0.031	0.044	0.055	0.067	0.078	0.088	0.099	0.109	
14	44.0	0.020	0.035	0.050	0.063	0.076	0.089	0.101	0.113	0.124	
15	47.1	0.022	0.040	0.056	0.071	0.086	0.100	0.114	0.127	0.140	
16	50.3		0.045	0.063	0.080	0.096	0.112	0.127	0.142	0.157	0.172
17	53.4		0.050	0.070	0.089	0.107	0.125	0.142	0.158	0.175	0.191
18	56.5		0.055	0.077	0.098	0.118	0.138	0.157	0.175	0.193	0.211
19	59.7		0.061	0.085	0.108	0.130	0.152	0.172	0.193	0.213	0.232
20	62.8		0.066	0.093	0.118	0.143	0.166	0.189	2.211	0.233	0.254
21	66.0			0.102	0.129	0.155	0.181	0.206	0.230	0.254	0.277
22	69.1			0.110	0.140	0.169	0.196	0.223	0.250	0.275	0.301
23	72.3			0.119	0.151	0.182	0.212	0.241	0.270	0.298	0.325
24	75.4			0.128	0.163	0.197	0.229	0.260	0.291	0.321	0.350
25	78.5			0.138	0.175	0.211	0.246	0.280	0.313	0.345	0.376

Table 5. **Two-way predicted underbark volumes for mangium trees in plantations in Bangladesh.**

DBH (cm)	GBH (cm)	HEIGHT IN METERS underbark volume in cubic meters									
		2	4	6	8	10	12	14	16	18	20
2	6.3	0.000	0.001	0.001	0.001	0.001	0.002	0.002			
3	9.4	0.001	0.001	0.002	0.002	0.003	0.004	0.004			
4	12.6	0.001	0.002	0.003	0.004	0.005	0.006	0.007			
5	15.7	0.001	0.003	0.004	0.006	0.007	0.009	0.010			
6	18.8	0.002	0.004	0.006	0.008	0.010	0.012	0.014	0.016		
7	22.0	0.002	0.005	0.007	0.010	0.013	0.016	0.018	0.021		
8	25.1	0.003	0.006	0.009	0.013	0.016	0.020	0.023	0.027		
9	28.3	0.004	0.007	0.011	0.016	0.020	0.024	0.028	0.033		
10	31.4	0.004	0.009	0.014	0.019	0.024	0.029	0.034	0.040		
11	34.6	0.005	0.010	0.016	0.022	0.028	0.034	0.040	0.047	0.053	
12	37.7	0.006	0.012	0.019	0.026	0.033	0.040	0.047	0.054	0.062	
13	40.8	0.007	0.014	0.022	0.030	0.038	0.046	0.054	0.062	0.071	
14	44.0	0.008	0.016	0.025	0.034	0.043	0.052	0.061	0.071	0.081	
15	47.1	0.009	0.018	0.028	0.038	0.048	0.059	0.069	0.080	0.091	
16	50.3		0.020	0.031	0.042	0.054	0.066	0.078	0.090	0.102	0.114
17	53.4		0.022	0.035	0.047	0.060	0.073	0.086	0.100	0.113	0.127
18	56.5		0.025	0.038	0.052	0.066	0.081	0.095	0.110	0.125	0.140
19	59.7		0.027	0.042	0.057	0.073	0.089	0.105	0.121	0.137	0.154
20	62.8		0.030	0.046	0.063	0.080	0.097	0.114	2.132	0.150	0.168
21	66.0			0.050	0.068	0.087	0.105	0.124	0.144	0.163	0.183
22	69.1			0.054	0.074	0.094	0.114	0.135	0.156	0.177	0.198
23	72.3			0.059	0.080	0.102	0.124	0.146	0.168	0.191	0.214
24	75.4			0.063	0.086	0.109	0.133	0.157	0.181	0.206	0.231
25	78.5			0.068	0.092	0.117	0.143	0.169	0.195	0.221	0.248

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