TREE VOLUME TABLES FOR TEAK (TECTONA GRANDIS) IN BANGLADESH

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1. INTRODUCTION

Tectona grandis (Teak) is exotic in Bangladesh. The species was introduced in 1872 near Kaptai in the Chittagong Hill Tracts and has since been planted extensively in the Hill Tracts, Sylhet, Chittagong and Cox's Bazar Forest Divisions from where it is now cut commercially from the oldest plantations.

With the changeover to the metric system of measurement, metric volume tables are now required. The tables given here have been re-computed from a set of data for 605 felled sample trees originally making up part of a sample of 635 trees that were measured by Islam, Islam and Latif (unpublished work, 1978) to compute commercial volume tables (4 in top diameter, stump height 1.7 ft) in imperial units which have been used successfully by the Forest Department over the last couple of years.

To cover the changeover period from imperial, to metric, both kinds of tables have been included in this publication in regression form. Imperial regressions with girth as an entry point also have been provided.

2. COLLECTION OF DATA

Data from felled sample trees were collected from the 1874-1879 plantations at Kaptai under Chittagong Hill Tracts (South) Forest Division. Representative sample trees were accepted on the basis of a subjective sampling method according to a frequency table of 2 inch (5.0 cm) diameter and 5 feet (1.5 m) height classes, while attempting to reach an average of 28 trees in each cell. Measurements of all trees were taken carefully in order to avoid measurement error as far as was practicable. Stump height, diameter at breast height, bole log length, crown log length, two end diameters and bark thickness of each log, branch length and diameter and total tree height were among the variables measured.

These data were sent to the Unit of Tropical Silviculture, Oxford Forestry Institute, Oxford, England for computer compilation and fitting of regressions.

3. COMPILATION OF DATA

Total stem volumes were computed by sectional method, summing the volume for each log.

In addition to the primary variables of Volume (V), Diameter at breast height (D) and total Height (H), various functions and ratios of these variables (D^2, $1/D$, $1/D^2$, Log (V), Log (D), DH, D^2H, V/D^2H, $1/DH$, $1/D^2H$, H/D^2, H/D, and Log (H) were derived to provide additional variables for testing in regression analyses.

4. COMPUTATION OF VOLUME FUNCTION

Fifteen regression models were tried for best fit using the different variables as follows:

1. $V = a + bD$
2. $V = a + bD + cD^2$
3. $V = a + bD^2$
4. $V = a + bD^2H$
5. $V = a + bD^2 + cH + dD^2H$
6. $V = a + bD^2 + cDH + dD^2H$
7. $\ln(V) = a + b \ln(D)$
8. $\ln(V) = a + b \ln(D) + c \ln(H)$
9. $V/D^2 = a + b/D^2 + c/D$
10. $V/D^2 = a + b/D$
11. $V/D^2H = a + b/D^2H$
12. $V/D^2H = a + b/D^2 + cH/D^2 + dH$
13. $V/D^2H = a + b/D^2H + c/H + d/D^2$
14. $V/D^2 = a + b/D^2 + cH/D + dH$
15. $V/D^2H = a + b/D^2H + c/H + d/D$

Where V, D and H are as described above, a is the regression constant and b, c and d are regression coefficients. The logarithmic functions are to the base e (natural logarithms).

The regression models of best fit were chosen by reference to various parameters describing the regressions, including lowest furnival index, high multiple correlation coefficient and low standard deviation.

The best models were:

for <u>One-Way Tables</u> : Model No. 7

and for <u>Two-Way Tables</u> : Model No. 8

5. STAND TABLE

Sample trees used in developing the total volume overbark functions had diameter and height class distributions as shown in Table 1. Since all the computer-generated volume tables have a similar format, in some tables few to many values shown will be well outside the range of the original data boundaries.

Extrapolation in the tables much outside the range of height and diameter indicated by the stand table should only be done with caution.

6. CONFIDENCE LIMITS

Confidence limits at the 95 percent level have been provided for the two-way total volume overbark tables only; these limits do not apply to individual trees but to all trees of the particular diameter and height. These volume tables should not be used to determine volumes of individual trees in a stand. The mean height and diameter of the stand should be calculated first, then these means found in the table in order to read off the mean tree volume, which would be then multiplied by the number of stems per hectare to arrive at volume per hectare. Methods for using such tables were set out by Choudhury and Davidson (1984).

7. THE VOLUME FUNCTIONS

7.1 Metric Units

Total volume overbark

The best one-way function was the logrithmic one (Model 7):

$\ln(V) = 2.12337 \ln(D) - 7.567916$

where D is dbh in cm

H is total height in m and

V is total volume overbark in m^3

using lorarithms to the base e.

Also logrithmic was the best two-way function (Model 8):

$\ln(V) = 1.62116 \ln(D) + 1.16483 \ln(H) - 9.48076$

where V, D and H are as described above.

Table 1

TECTONA GRANDIS - STAND TABLE - NUMBER OF TREES BY DIAMETER AND HEIGHT CLASSES*

Diameter	HEIGHT CLASSES 24.0	38.0	52.0	66.0	80.0	94.0	108.0	122.0	136.0	150.0	164.0	178.0	GT* 185.0	Total
6.0	0	5	22	14	0	0	0	0	0	0	0	0	0	41
10.0	2	1	9	24	25	0	0	0	0	0	0	0	0	61
14.0	0	0	4	19	26	12	3	1	0	0	0	0	0	65
18.0	0	0	0	5	10	30	16	4	0	1	0	0	0	66
22.0	0	0	1	4	11	25	23	10	3	1	0	0	0	78
26.0	0	0	1	2	2	13	22	23	4	2	0	0	0	69
30.0	0	0	0	1	2	4	13	14	10	0	1	0	0	45
34.0	0	0	0	1	0	4	15	12	7	3	1	0	0	43
38.0	0	0	0	0	1	6	20	20	11	5	0	0	0	63
42.0	0	1	0	0	0	3	9	22	5	1	1	0	0	42
46.0	0	0	0	0	0	2	1	5	5	2	0	0	0	15
50.0	0	0	0	0	0	0	0	8	3	1	0	0	0	12
54.0	0	0	0	0	0	0	0	2	1	0	0	0	0	3
58.0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
62.0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
GT64.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2	7	37	70	77	99	123	122	49	16	3	0	0	605

* Diameter and Height classes are in inches and feet respectively since this was the way in which these data were originally collected.

7.2 Imperial Units

Total volume overbark

The same respective models were used as for the metric tables.

For a one-way table:

$\ln(V) = 2.12337 \ln(D) - 2.0244$ and for a two-way table:

$\ln(V) = 1.62116 \ln(D) + 1.16483 \ln(H) - 5.78932$

where V, D and H are as previously described, but in imperial units of ft^3, inches and feet respectively, and logarithms are again to the base e.

8. CONVERSION FACTORS

Conversion factors (F) were computed to be applied to total volume overbark for deriving total volume underbark and merchantable volume to various top-end diameter limits. Tables of conveaion factors have been included. All factors are predicted from diameter at breast height (D).

8.1 Metric Conversion Factors

Underbark/overbark

This factor is derived by quatratic function -

$F = D/(3.01537 + 1.08688D - 0.0003429 D^2)$

5 cm top diameter limit

A constant factor of 1.00 should be used.

10 cm top diameter limit

This factor is derived by an exponential function -

$F = 0.9979585 (1 - e^{- 0.0687285D}, 0.310291$

15 cm top diameter limit

$F = 0.997621 - 256.13564D^{- 2.260389}$

20 cm top diameter limit

$F = 0.97739 - 3.72804 e^{- 0.08793882D}$

Branch wood volume

$F = 0.001087D - 0.0092912$

Computed metric factors for a range of diameters are set out in Table 2.

8.2 Imperial Conversion Factors

Underbark/overbark

$F = D/(1.187155 + 1.08688D - 0.000871589D^2)$

Two inch top diameter limit

Use a constant factor of 1.00

Table 2 - TEAK (TECTONA GRANDIS) METRIC CONVERSION FACTORS (Note: This table also can be used for imperial conversions (cm/2.54 = in) or for girth in either units (C/3.1416 = D) by substitution in the left hand (DBH) column.

DBH(CM.)	BASE	5 CM.	10 CM.	15 CM.	20 CM.	BRANCH
10	0.722	1.000	0.803			0.082
13	0.761	1.000	0.846			0.085
16	0.787	1.000	0.880	0.513		0.088
19	0.807	1.000	0.906	0.668		0.091
22	0.822	1.000	0.924	0.761		0.093
25	0.834	1.000	0.939	0.820	0.564	0.095
28	0.844	1.000	0.950	0.860	0.660	0.021
31	0.852	1.000	0.960	0.889	0.733	0.024
34	0.859	1.000	0.967	0.909	0.790	0.026
37	0.865	1.000	0.973	0.925	0.833	0.031
40	0.871	1.000	0.978	0.936	0.867	0.034
43	0.875	1.000	0.982	0.946	0.892	0.037
46	0.880	1.000	0.985	0.953	0.912	0.041
49	0.884	1.000	0.987	0.959	0.927	0.044
52	0.887	1.000	0.989	0.964	0.939	0.047
55	0.891	1.000	0.991	0.968	0.948	0.050
58	0.894	1.000	0.992	0.971	0.955	0.054
61	0.897	1.000	0.993	0.974	0.960	0.057
64	0.899	1.000	0.994	0.976	0.964	0.060
67	0.902	1.000	0.995	0.979	0.967	0.064
70	0.904	1.000	0.995	0.980	0.969	0.067
73	0.906	1.000	0.996	0.982	0.971	0.070
76	0.909	1.000	0.996	0.983	0.973	0.073
79	0.911	1.000	0.997	0.984	0.974	0.077
82	0.913	1.000	0.997	0.985	0.975	0.080
85	0.915	1.000	0.997	0.986	0.975	0.083
88	0.917	1.000	0.997	0.987	0.976	0.086
92	0.919	1.000	0.997	0.988	0.976	0.091
95	0.921	1.000	0.998	0.988	0.977	0.094
98	0.922	1.000	0.998	0.989	0.977	0.097
101	0.924	1.000	0.998	0.990	0.977	0.100
104	0.926	1.000	0.998	0.991	0.977	0.104
107	0.927	1.000	0.998	0.991	0.977	0.107
110	0.928	1.000	0.998	0.991	0.977	0.110
113	0.930	1.000	0.998	0.992	0.977	0.114
116	0.932	1.000	0.998	0.992	0.977	0.117
119	0.933	1.000	0.998	0.992	0.977	0.120
122	0.935	1.000	0.998	0.993	0.977	0.123
125	0.936	1.000	0.998	0.993	0.977	0.127
128	0.938	1.000	0.998	0.993	0.977	0.130
131	0.939	1.000	0.998	0.993	0.977	0.133
134	0.940	1.000	0.998	0.994	0.977	0.136
137	0.942	1.000	0.998	0.994	0.977	0.140
140	0.943	1.000	0.998	0.994	0.977	0.143
143	0.944	1.000	0.998	0.994	0.977	0.146

Four inch top diameter limit

$$F = 0.9979585\ (1 - e^{-0.1745705D})^{0.310291}$$

Six inch top diameter limit

$$F = 0.997621 - 31.145D^{-2.260389}$$

Eight inch top diameter limit

$$F = 0.97739 - 3.72804\ e^{-0.2233646D}$$

Branch wood volume

$$F = 0.002761D - 0.0092912$$

9. VERIFICATION OF THE TABLES

Provisional, unpublished, commercial, imperial volume tables for teak, prepared by the BFRI (Islam, Islam and Latif, 1978), have been used successfully for the past two years by the Forest Department.

These tables were justified for use in the Sylhet, Chittagong, Cox's Bazar and Chittagong Hill Tracts by obtaining small samples of 10, 14, 13 and 10 trees respectively from those areas, felled for the purpose, and true volume determined by Smallian formula. It was determined by t-test in each case that the two samples (check trees and volume table trees) could have been drawn from the same population, thus enabling wide use of the tables in Bangladesh.

The present tables were computed using 30 less trees (605 as against 635 previously) but do not differ statistically to those mentioned above. These present tables were used recently by FAO/UNDP Project BGD/79/017 in its inventory of plantations in the Cox's Bazar, Chittagong and Chittagong Hill Tracts regions (Cox, 1984).

10. TABLES BASED ON GIRTH

Since there is a preference for girth-entry tables in the field, these have been provided also. Equations based on girth are as follows:

Metric Units

One-way: $\ln(V) = 2.12337\ \ln(G) - 9.9986$

Two-way: $\ln(V) = 1.62116\ \ln(G) + 1.16483\ \ln(H) - 11.33651$

Imperial Units

One-way: $\ln(V) = 2.12337\ \ln(G) - 4.4550878$

Two-way: $\ln(V) = 1.62116\ \ln(G) + 1.16483\ \ln(H) - 7.6451114$

where G is girth at breast height overbark in cm or ins respectively, other symbols as before.

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