COMMERCIAL VOLUME TABLE FOR TEAK (*Tectona grandis* Linn. f.) IN BANGLADESH BY REGRESSION TECHNIQUE

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ABSTRACT

Usefulness of volume table for teak (*Tectona grandis*) can hardly be overemphasized. The paper deals with the preparation of a commercial volume table of teak based on data collected during 1977 from 1874, 1875, 1876, 1878 and 1879 plantations at Kaptai in the Chittagong Hill Tracts (South) Forest Division in Bangladesh. Thirteen mathematical models of tree volume on diameter at breast height (D B H) and volume on D B H and total height were compared. The best relationships judged principally by Furnival's Index were used to compute volume tables.

সারসংক্ষেপ

সেগুন বাগানের ভলিয়ুম টেবিলের প্রয়োজনীয়তা অনস্বীকার্য্য। এ প্রবন্ধ সেগুন বাগানের বাণিজ্যিক ভলিয়ুম টেবিল প্রস্তুত করনের উপর রচিত। এতে পার্ব্বত্য চট্টগ্রাম (দক্ষিণ) বন বিভাগের কাপ্তাইয়ে ১৮৭৪, ১৮৭৫, ১৮৭৬, ১৮৭৮ ও ১৮৭৯ সালের সেগুন বাগান থেকে ১৯৭৭ সালের সংগৃহীত উপাত্তসমূহ ব্যবহার করা হয়েছে। ভলিয়ুমের সাথে বুক সমান ব্যাস এবং বুক সমান ব্যাস ও মোট উচ্চতা সম্পর্ক যুক্ত ১৩টি গাণিতিক মডেল তুলনা করা হয়েছে। এ সকল মডেল থেকে সর্বনিম্ন "ফার্নিভাল ইনডেক্স" এর আলোকে বাছাইকৃত সঠিক সম্পর্কযুক্ত মডেল ব্যবহার করে ভলিয়ুম টেবিল প্রস্তুত করা হয়েছে।

INTRODUCTION

Teak is a large deciduous tree mostly with tall fluted boles. It grows on moderate slopes with well drained deep alluvium soil. The species was first introduced in Bangladesh at Kaptai in the Chittagong Hill Tracts in 1872. At present, it is being successfully grown in Sylhet, Chittagong and the Chittagong Hill Tracts.

Studies on tree biometry in respect of volume table for teak have probably not been done in Bangladesh. But an acceptable volume table of this valuable forest species is essential for timber inventory works of the Forest Department as well as for various research activities in forestry.

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BASIC DATA

Data from felled sample trees were originally collected from 1874, 1875, 1876, 1878 and 1979 plantations at Kaptai in Chittagong Hill Tracts (South) Forest Division. Representative sample trees (Table 1) were considered on the basis of one kind of subjective sampling method according to a frequency table of two inches diameter classes taking an average of 28 trees per class. Data on measurement of all sample trees were taken carefully to avoid measurement error as far as practicable. The stump height, diameter at breast height (DBH) bole log length, crown log length, branch log length, two end diameters, bark thickness of every log and top height of each sample tree were measured for calculating the total volume outside bark, merchantable height and total height. The measurement procedures are mentioned under Definitions and Standards.

DEFINITIONS AND STANDARDS

Diameter at breast height over bark : Diameter at breast height outside bark was measured in inches by a caliper.

Diameter of logs : Diameter at two ends of a log was measured outside the bark in inches. Logs up to a minimum four inches top diameter were considered.

Stump height : Stump height of each felled tree was measured in feet.

Total height : Total height was measured in feet. Forked (below breast height) trees were included in the sample considering each fork a separate tree.

Log length : Each unlogged sample tree was divided into as many 10′ long sections as possible. In cases where the last section was found to be less than 5′, it was included as an extension of the previous log. In case of a logged tree, the actual length of each log was taken.

Standard timber volume : The total volume of all bole and crown logs with a minimum of 4′′ average top diameter outside bark has been defined as standard timber volume. The volume for all logs were calculated in cubic feet by employing Smalian formula.

Standard smallwood volume : The total volume of all branch logs with the same minimum average top diameter outside bark has been assumed as standard smallwood volume. The volume for each branch log was calculated in cubic feet by the Smalian formula.

Total volume over bark : The aggregate of all standard timber volume and smallwood volume of a sample tree has been considered as total volume over bark.

Quarter girth volume : Quarter girth volume was obtained by multiplying conversion constant (0.785) with table volume.

PROPOSED TECHNIQUES FOR VOLUME TABLE COMPUTATION

One-way volume table : One-way volume table is based on a single independent variable for DBH under the assumption of definitive height-diameter relationship for the species under consideration (i. e., tree of a given diameter class tends to be of similar height and form). For

quick timber inventory as well as increased convenience and efficiency, it is necessary to develop this one-way volume table of reasonable measure of precision which directly gives volume corresponding to different diameter classes (Malik 1970).

A few relationships of volume-diameter (Malik 1970) with 635 sample trees have been established by the computer. The best model (Appendix–I) was selected on the basis of square of multiple correlation coefficient, mean square error, Furnival index, F–test and Student's t-test. The best selected model has also been justified through graphical interpretation.

Two-way volume table: Two way volume table is based on DBH and total height as independent variables. Although it is time-consuming and expensive to measure height of trees particularly in the case of extensive forest population (Malik 1970) this kind of table usually gives predicted volume close to true value because of the addition of one important independent height variable.

Table 1. Height-diameter data of teak

DBH (inch)	Height (feet)																
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	Total
7		2	8	16	31	9											82
12	1	1		10	10	32	22	7	3			1					87
17			1	1	3	7	10	22	25	10	4			1			84
22			1		4	6	8	16	26	20	11	5	3	2			102
27					1	2	2	2	8	20	17	11	2	1	1		67
32			1			1	1	1	6	17	14	8	6		1		56
37					3	3	2	3	9	19	17	16	7	5	1		85
42								4	4	7	17	9	1	2	1	1	46
47											8	3	6	1			17
52											4	2		1			7
57												1					1
62										1							1
Total :	1	3	11	27	52	67	54	55	81	94	92	56	25	12	4	1	635

Various relations of height-diameter (Malik 1970.) and volume-height (Myers 1963; Burey, Wright and Matos 1972) with 616 sample trees were examined in the computer. The best relations in both the cases were selected on the basis of the same statistics as in volume-diameter relation (Appendix–I). The bestselected height-diameter relation is justified by graphical interpretation. Next, the statistically best selected volume-diameter-height relationship was carefully verified with true natural curve in the light of the best selected height-diameter relation. Moreover, the multi-collinearity among the explanatory variables of diameter and height was checked.

The two volume tables (Appendix II and Appendix III) with appropriate areas, species, models adopted, multiple correlation coefficient and standard error of the estimate have been prepared.

VERIFICATION AND JUSTIFICATION OF TABLES

The percentage amount of variation explained by the model as well as the average square of the difference of true volume and predicted volume have been found satisfactory. The two volume tables have been tested in areas of Sylhet, Chittagong, Chittagong Hill Tracts and Cox's Bazar. Samples of 10, 14, 10 and 13 trees were taken in these four places respectively. The true volume was calculated by Smalian formula. It has been examined through t-test that the two samples (true volume and etsimated volume) in each place have come from the same population resulting insignificant difference between the two samples. Thus, the two volume tables have been justified in each of the above places. This method of verification for volume tables was also used in Iraq by Clonaru and Getan (1976).

PROCEDURE FOR USING THE TABLES

The tables have been prepared by 1″ diameter classes and 10′ height classes. The diameter and the height shown in the volume tables are the overbark diameter measured at breast height and the total height measured from ground level to the tip respectively. Thus, an average tree of 5″. D.B.H. and 30′ height means 4.6″ to 5.5″ D.B.H. and 25.1′ to 35′ height respectively. But these tables should not be used to estimate volume of individual trees in a stand. Rather they give average volume of a stand having average DBH and average height. Thus, total volume of a stand may be estimated by multiplying the number of stems with average table volume. Trees having characteristics similar to sample trees will give better precision in volume estimation.

ACKNOWLEDGEMENT

The author extends his thanks to all the officers and Fieldmen of Forest Inventory and Forest Economics & Statistics Division, Bangladesh Forest Research Institute, Chittagong for their co-operation in collecting and organizing data. Thanks are also due to Mr. M. Musa, Senior Scientific Officer and Mr. M. Murshed, Scientific Officer, Atomic Energy Commission, Dhaka for their help in computing volume equations.

REFERENCES

Burley, J. Wright. H. L. and Matos, E. 1972. A volume tables for *Pinus caribea* var. Caribaea. The Commonwealth Forestry Review. Vol. 51(2), No. 148 : 137–143

Clonaru and Getan, F. O. 1976. *Pinus brutia Ten.* Form factor and volume tables for use in Iraq. Forest Research Centre, Baghdad, Iraq, 22 pp

Myers, C. A. 1963. Taper and related tables for Southwestern Ponderosa Pine. Rocky Mountain Forest and Range Experiment Stations, Forest Collins, Colorado, U. S. A. 24 pp

Malik, M. A. 1970. Local volume tables of the coniferous species of Northern West Pakistan. Pakistan Forest Institute, Peshawar. 42 pp

Appendix I. **Height-diameter, volume-diameter and volume-diameter-height equations for** *Tectona grandis* Linn. f. data

Sl. No.	Equations	R^2	M. S. E.	F. I.
1.	$H=a_o+a_1D+a_2D^2$	0.62	237.34	16.95
2.	$Log_eH=a_o+a_1Log_eD$	0.61	0.04	18.25
3.	$Log_eH=a_o+a_1\frac{1}{D}$	0.64	0.03	17.55
4.	$Log_eH=a_o+a_1Log_eD+a_2(Log_eD)^2$	0.65	0.03	17.16
5.	$\frac{D^2}{H}=a_o+a_1D+a_2D^2$	0.83	32.98	2605.99
6.	$Log_eVOB_E=a_o+a_1Log_eD$ (BEST FIT)	0.88	0.23	40.79
7.	$VOB_E=a_o+a_1D^2$	0.49	17940.92	133.94
8.	$VOB_E=a_o+a_1D+a_2D^2$	0.61	13663.98	116.89
9.	$VOB_E=a_o+a_1D^2+a_2D^4$	0.69	10897.46	104.39
10.	$\frac{VOB_E}{D^2}=a_o+a_1\frac{1}{D^2}$	0.03	0.03	79.80
11.	$\frac{VOB_E}{D^2}=a_o+a_1\frac{1}{D^2}+a_2D^2$	0.04	0.03	79.85
12.	$VOB_E=a_o+a_1D^2H$	0.69	11104.46	105.38
13.	$VOB_E=a_o+a_1D^2+a_2H+a_3D^2H$	0.70	10613.86	103.02
14.	$Log_eVOB_E=a_o+a_1Log_eD+a_2Log_eH$(BEST FIT)	0.92	0.16	33.36
15.	$Log_eVOB_E=a_o+a_1Log_eD+a_2Log_eH+a_3Log_eDUP$	0.95	0.09	25.18
16.	$\frac{VOB_E}{D^2H}=a_o+a_1\frac{1}{D^2H}$	0.0004	0.000003	84.09
17.	$\frac{VOB_E}{D^2}=a_o+a_1\frac{1}{D^2}+a_2\frac{H}{D^2}+a_3H$	0.15	0.04	84.38
18.	$\frac{VOB_E}{D^2H}=a_o+a_1\frac{1}{H}+a_2\frac{1}{D^2}+a_3\frac{1}{D^2H}$	0.01	0.000003	83.91

Note : *H=Total height, D=Diameter at breast height, VOB_E=Volume over bark excluding stump and DUP=upper stem diameter*

Appendix II. One-way volume table (in cubic feet)

Species : Teak (*Tectona grandis* Linn. f.)

Place : (i) Sylhet, (ii) Chittagong Hill Tracts, (iii) Chittagong and (iv) Cox's Bazar

Total volume over bark=stem volume over bark+small-wood volume over bark.

Total volume=volume upto 4 inch top diameter, stump height=1.7 ft

D. B. H. over bark (inch)	Estimated volume over bark (cft)	D. B. H. over bark (inch)	Estimated volume over bark (cft)	D. B. H. over bark (inch)	Estimated volume over bark (cft)	D. B. H. over bark (inch)	Estimated volume over bark (cft)
4	1.94	21	82.50	38	315.77	55	728.99
5	3.21	22	91.66	39	334.86	56	759.33
6	4.84	23	101.36	40	354.60	57	790.36
7	6.87	24	111.61	41	374.98	58	822.09
8	9.29	25	122.41	42	396.00	59	854.51
9	12.13	26	133.77	43	417.66	60	887.64
10	15.39	27	145.70	44	439.96	61	912.47
11	19.10	28	158.20	45	462.91	62	956.01
12	23.25	29	171.27	46	486.52	63	991.26
13	27.87	30	184.93	47	510.78	64	1027.22
14	32.96	31	199.17	48	535.71	65	1063.90
15	38.53	32	214.01	49	561.30	66	1101.30
16	44.59	33	229.44	50	587.55	67	1139.43
17	51.14	34	245.48	51	614.48	68	1178.28
18	58.21	35	262.12	52	642.09	69	1217.85
19	65.78	36	279.30	53	470.37	70	1258.16
20	73.88	37	297.25	54	699.34	71	1499.20

Derived from : $VOB_E = 0.084D^{2.263}$

Standard error of estimate : 0.479

Correlation coefficient : 0.9374

Appendix III. Two-way volume table (in cubic feet)

Species : Teak (*Tectona grandis* Linn. f.).

Place : (i) Sylhet, (ii) Chittagong Hill Tracts, (iii) Chittagong, (iv) Cox's Bazar.

Total volume over bark=stem volume over bark+small wood volume over bark.

Total volume=volume upto 4 inches top diameter

Cubic feet over bark *Stump height* : 1.7 ft

D. B. H. o. b. (inch)	Total height (feet)								
	20	30	40	50	60	70	80	90	100
4	0.51	0.97	1.54	2.20	2.94	3.77	4.67	5.64	6.68
5	0.72	1.38	2.19	3.13	2.19	5.63	6.64	8.03	9.50
6	0.96	1.84	2.92	4.17	5.59	7.16	8.86	10.70	12.67
7	1.23	2.35	3.72	5.32	7.13	9.13	11.31	13.66	16.17
8	1.51	2.90	4.60	6.57	8.80	11.27	13.96	16.86	19.97
9	1.82	3.46	5.54	7.92	10.61	13.58	16.82	20.31	24.05
10	2.15	4.12	6.54	9.35	12.53	16.04	19.87	23.99	28.41
11	2.50	4.79	7.60	10.87	14.56	18.64	23.09	27.89	33.03
12	2.87	5.50	8.72	12.47	16.71	21.39	26.50	32.00	37.89
13	3.26	6.24	9.90	14.16	18.96	24.28	30.07	36.32	43.00
14	3.66	7.02	11.13	15.91	21.32	27.29	33.81	40.83	48.34
15	4.09	7.83	12.41	17.75	23.77	30.43	37.70	45.33	53.91
16	4.52	8.67	13.74	19.65	26.32	33.70	41.75	50.42	59.70
17	4.98	9.54	15.12	21.63	28.97	37.09	45.94	55.49	65.70
18	5.45	10.44	16.55	23.67	31.71	40.60	50.28	60.73	71.91
19	5.94	11.37	18.03	25.78	34.54	44.22	54.77	66.15	78.32
20	6.44	12.33	19.55	27.96	37.45	47.95	59.39	71.73	84.93

Appendix III (Cont'd)

D. B. H. o. b. (inch)	Total height (feet)								
	20	30	40	50	60	70	80	90	100
21	6.95	13.32	21.12	30.20	40.45	51.79	64.15	77.48	91.74
22	7.48	14.33	22.73	32.50	43.54	55.74	69.05	83.39	88.74
23	8.03	15.37	24.38	34.87	46.70	59.80	74.07	89.46	105.92
24	8.58	16.44	26.08	37.29	49.95	63.96	79.22	95.68	113.29
25	9.16	17.54	27.82	39.78	53.28	68.22	84.50	102.06	120.84
26	9.74	18.66	29.59	42.32	56.69	72.58	89.90	108.58	128.56
27	10.34	19.81	31.41	44.92	60.17	77.04	95.42	115.25	136.46
28	10.95	20.98	33.27	47.58	63.73	81.59	101.07	122.07	144.53
29	11.58	22.18	35.17	50.29	67.36	86.25	106.83	129.03	152.77
30	12.21	23.40	37.10	53.09	71.07	90.99	112.71	136.13	161.18
31	12.86	24.64	39.08	55.88	74.85	95.83	118.70	143.37	169.75
32	13.53	25.91	41.09	58.75	78.70	100.76	124.81	150.74	178.48
33	14.20	27.20	43.13	61.68	32.62	105.78	131.03	158.25	187.37
34	14.88	28.51	45.22	64.66	86.61	110.89	137.35	165.90	196.42
35	15.58	19.85	47.34	67.69	90.67	116.08	143.79	173.67	205.63
36	16.29	31.21	49.49	70.77	94.80	121.37	150.34	181.58	214.99
37	17.01	32.59	51.68	37.90	98.99	126.74	156.99	189.61	224.50
38	17.74	33.99	53.90	77.08	103.25	132.19	163.74	197.77	234.16
39	18.49	35.41	56.16	80.31	107.58	137.73	170.60	206.06	243.97
40	19.24	36.86	58.45	83.59	111.97	143.35	177.57	214.47	253.93
41	20.01	38.32	60.78	86.92	116.42	149.05	184.63	223.00	264.03
42	20.78	39.81	63.14	90.29	120.94	154.84	191.80	231.65	274.28

Appendix III (Cont'd)

D. B. H. o. b. (inch)	Total height (feet)								
	20	30	40	50	60	70	80	90	100
43	21.57	41.32	65.53	93.71	125.52	160.70	199.06	240.43	284.66
44	22.37	42.85	67.95	97.18	130.16	166.65	206.42	249.32	295.19
45	23.18	44.40	70.41	100.69	134.87	172.67	213.89	258.33	305.86
46	24.00	45.97	72.90	104.25	139.63	178.77	221.44	267.46	316.67
47	24.83	47.55	75.42	107.85	144.46	184.95	229.10	276.71	327.62
48	25.67	49.16	77.97	111.50	149.34	191.21	236.85	186.07	338.70
49	46.52	50.79	80.55	115.19	154.29	197.54	244.69	295.54	349.92
50	27.38	52.44	83.16	118.93	159.29	203.95	252.63	305.12	361.26
51	28.25	54.11	85.81	122.71	164.39	210.43	260.66	314.82	372.75
52	29.13	55.79	88.48	126.53	169.48	216.99	268.78	324.63	384.36
53	30.02	57.50	91.18	130.39	174.66	223.62	276.99	334.55	396.10
54	30.92	59.22	93.92	134.30	179.89	230.32	285.29	344.58	407.98
55	31.83	60.96	96.68	138.25	185.18	237.98	293.63	354.71	419.98
56	32.74	62.72	99.47	142.25	190.53	243.93	302.16	360.96	432.11
57	33.67	64.50	102.29	146.28	195.93	250.86	310.73	375.31	444.36
58	34.61	66.30	105.14	150.36	201.39	257.85	319.39	385.76	456.74
59	35.56	68.11	108.02	154.47	206.91	264.91	328.13	396.32	469.24
60	36.52	69.95	110.93	158.63	212.48	272.02	336.97	406.99	481.87

Appendix III (Cont'd)

D. B.H. o. b. (inch)	Total height (feet)						
	110	120	130	140	150	160	170
4	7.78	8.05	10.17	11.45	12.79	14.19	15.64
5	11.07	12.73	14.47	16.30	18.20	20.19	22.25
6	14.17	16.98	19.30	21.74	24.28	26.92	29.67
7	18.84	21.66	24.62	27.73	30.97	34.35	37.85
8	23.26	26.75	30.41	34.24	38.25	42.42	46.75
9	28.12	32.22	36.63	41.25	46.07	51.09	56.31
10	33.10	38.05	43.26	48.72	54.42	60.35	66.51
11	38.48	44.24	50.20	56.64	63.26	70.15	77.31
12	44.15	50.76	57.70	64.98	72.58	80.49	88.71
13	50.10	57.60	65.48	73.74	82.37	91.35	100.67
14	56.32	64.75	73.62	82.90	92.60	100.69	113.17
15	62.81	72.21	82.10	92.45	103.26	114.52	126.21
16	69.55	79.96	90.91	102.38	114.35	126.81	139.76
17	76.54	88.00	100.05	112.67	125.85	139.56	153.81
18	83.78	96.32	109.51	123.32	137.74	152.75	168.34
19	91.25	104.91	119.27	134.32	150.02	166.37	183.36
20	98.95	113.76	129.34	145.65	162.69	180.42	198.83
21	106.88	122.88	139.70	157.33	175.73	194.88	214.77
22	115.04	132.25	150.36	169.33	189.13	209.74	231.15
23	123.41	141.88	161.30	181.65	202.89	225.00	247.97
24	131.99	151.74	172.52	194.28	217.00	240.65	265.21
25	140.78	161.85	184.01	207.22	231.46	256.69	282.88
26	149.78	172.20	195.78	220.47	246.26	273.10	300.97

Appendix III (Cont'd)

D. B. H. o. b. (inch)	Total height (feet)						
	110	120	130	140	150	160	170
27	158.99	182.78	207.81	234.02	261.39	289.88	21946
28	168.39	193.59	220.10	247.86	276.85	307.02	338.35
29	177.99	204.63	232.64	261.99	292.63	324.52	357.64
30	187.78	215.89	245.45	276.41	308.73	342.38	377.32
31	197.77	225.37	258.50	291.10	325.15	360.59	397.39
32	207.94	239.07	271.79	306.09	341.87	379.14	417.83
33	218.30	250.98	285.34	321.33	358.90	398.02	438.65
34	228.85	263.10	299.12	336.85	376.24	417.25	459.83
35	239.57	275.43	313.14	352.63	393.87	436.80	481.38
36	250.47	287.96	327.39	368.68	411.80	456.68	503.29
37	261.56	300.70	341.87	384.99	430.02	476.89	525.56
38	272.81	313.65	356.58	401.56	448.52	497.41	548.18
39	284.24	326.79	371.52	418.39	467.31	518.25	571.14
40	295.84	340.12	386.69	435.46	486.30	539.40	584.45
41	307.61	353.65	402.07	452.79	505.74	560.86	618.10
42	319.55	367.38	417.67	470.36	525.36	582.63	642.09
43	331.65	381.29	433.50	488.18	545.26	604.70	666.41
44	343.92	394.40	449.53	506.23	565.43	627.06	691.06
45	356.35	409.60	465.78	524.53	585.87	649.73	716.04
46	368.05	424.17	482.24	543.07	606.58	672.69	741.34
47	381.70	438.83	498.91	561.84	627.54	695.94	766.97
48	394.61	453.67	515.78	580.84	648.77	719.48	792.91
49	407.68	468.60	532.86	600.08	670.25	743.31	819.17

D. B. H. o. b. (inch)	Total height (feet) 110	120	130	140	150	160	170
50	420.90	483.90	550.14	619.54	691.99	767.41	845.74
51	434.28	499.28	567.63	639.23	713.98	791.80	872.62
52	447.81	514.83	585.31	659.15	736.23	816.47	899.80
53	461.49	530.56	603.20	679.20	758.72	841.42	927.30
54	475.32	546.47	621.28	699.65	781.46	866.64	955.09
55	489.30	562.54	639.55	720.23	804.45	892.13	983.19
56	503.43	578.79	658.02	741.03	827.68	917.90	1011.58
57	517.71	595.20	676.68	762.04	851.16	943.93	1040.27
58	532.13	611.78	695.54	783.27	874.87	970.23	1069.25
59	546.70	628.53	714.58	804.72	898.82	996.79	1098.52
60	561.42	645.45	733.81	826.37	923.01	1023.61	1028.08
61	576.27	662.52	753.23	848.24	947.43	1050.70	1157.93
62	591.27	679.77	772.83	870.31	972.00	1078.04	1188.07
63	606.41	697.17	792.61	892.59	996.98	1105.64	1218.49
64	621.68	714.73	812.58	915.08	1022.38	1133.50	1249.19
65	637.10	732.46	832.74	937.78	1047.44	1161.61	1280.16

Derived from VOB_E : $0.000465\ D^{1.580}\ H^{1.603}$
Standard error of estimate : 0.389
Correlation coefficient : 0.9596