FIELD DOCUMENT NO. 2

ASSISTANCE TO THE FORESTRY SECTOR

OF

B A N G L A D E S H

VOLUME FUNCTIONS FOR PLANTATION SPECIES AND ELEMENTS FOR GROWTH MODELS FOR TEAK

BY

F. COX

MENSURATION CONSULTANT

Food and Agriculture Organization of the United Nations
FAO/UNDP Project BGD/79/017
Assistance to the Forestry Sector
July 1984

FIELD DOCUMENT NO. 2

ASSISTANCE TO THE FORESTRY SECTOR

OF

BANGLADESH

Volume Functions for Plantation Species and Elements for Growth Models for Teak

by

F. Cox
Mensuration Consultant

Food and Agriculture Organization of the United Nations
FAO/UNDP Project BGD/79/017
Assistance to the Forestry Sector
July 1984

ABSTRACT

During the period January/December 1983 an inventory of the forest plantations of the Chittagong District was carried out.

In order to test the existing volume functions that could be used to estimate stocking, some trees were felled and measured during that same period.

This report deals with the testing of existing volume functions and the construction of new equations when it was judged necessary. The resulting volume functions were then used to process the inventory data obtaining stand parameters for each inventory plot. This information was finally used to construct a preliminary set of yield tables for teak.

In a next stage these yield functions will have to be validated in order to establish the degree of confidence with which they can be used.

BANGLADESH

Assistance to the Forestry Sector

BGD/79/017

Mensuration Consultant

Terms of Reference

Under the general direction of the Project Coordinator and in close consultation with the Senior Forest Inventory Officer and counterpart staff, the Consultant will:

1. Review and evaluate the existing volume tables for teak and decide how and how much additional information should eventually be collected.

2. Based on data to be provided by the Project, decide on the required number of volume tables to be constructed for other planted species and the amount of information to be collected.

3. Describe in detail the methodology to be used for both 1 and 2 above and prepare the E.D.P. Instructions.

4. From existing data in the Forest Department and the F.R.I. and from preliminary inventory data obtained so far by the Project, prepare growth/yield models for teak and the other planted species considered under 2 above.

5. Train counterpart personnel in all activities mentioned.

6. Prepare a draft technical report to be submitted before his departure.

7. Carry out such other technical duties as may be required to fulfil the objectives of his consultancy.

Duty Station	:	Chittagong and Dhaka, Bangladesh
E. O. D.	:	As soon as possible
Duration	:	Two months
Language	:	English

Time Schedule

16 - 20 February	Santiago - Rome. Briefing
21 - 22 "	Rome - Dhaka - Chittagong
23 - 27 "	Documentation on the project
28 - 29 "	Field trips : Chittagong Forest Division
1 - 2 March	Data processing system analysis
3 - 4 "	Field trip : Cox's Bazar Forest Division
5 - 9 "	Programming
10 - 16 "	Dhaka : Data entry - Data validation - Programs correction - Compilation and testing
17 - 18 "	Chittagong : System revision and improvement
19 - 29 "	Dhaka : Data processing - 1st part
30 - 31 "	Chittagong : Data analysis
1 - 2 April	" : Data analysis
3 - 8 "	" : Writing report
9 - 12 "	Data processing last part
13 - 15 "	Dhaka - Santiago

TABLE OF CONTENTS

1. INTRODUCTION

One of the main objectives of Project BGD/79/017 "Assistance to the Forestry Sector", is to make an evaluation of the mixed hardwood/teak plantations in the Chittagong District and Chittagong Hill Tracts.

According to Forest Department sources more than 100,000 hectares have been established to-date, of which approximately 70% is estimated to be teak, either in pure stands or in mixture with other hardwood species.

In order to convert the data obtained from field sampling into reliable estimatos as regards the potential production capacity of these plantations, it was necessary to check and adapt the existing volume equations for the species concerned and to determine some basic elements for the constructions of growth models for teak.

The document describes the most relevant findings while Appendix 1 presents an overview of the results in tabulated form. A description of the processing system is presented in Appendix 2.

2. ANALYSIS OF EXISTING VOLUME FUNCTIONS

2.1 VOLUME FUNCTIONS AVAILABLE

The first volume functions for Bangladesh were developed by "Forestal, Forestry and Engineering International Ltd." to process forest inventories carried out between 1958 and 1963 in the Chittagong Hill Tracts and the Sundarbans forests. These functions were collected and published by B. Kingston (1979).

E.W. Hindley (1982) presented volume functions for 15 Bangladesh species developed by the Commonwealth Forestry Institute at Oxford University using information collected by the Forest Research Institute at Chittagong between 1977 and 1978.

The main features of these volume equations are briefly summarized in Table 1 (Appendix 1). The table only shows those species which occur in plantations.

Choudhury J.H. and Davidson J. (1984) presented a revised and more explicit version of same volume functions for species Gamar (Gmelina arborea Roxb.), Chapalish (Artocarpus chapalasha Roxb.), Dhakijam (Syzygium grande Wt. Wald) and Teligarjan (Dipterocarpus turbinatus Gaertn. F.)

Functions based on one independent variable were not considered since they are not adequate for plantation inventories.

2.2 TESTING MATERIAL

177 sample trees of species Gamar, Dhakijam and Garjan were felled and measured by Project BGD/79/017 to test the existing volume functions. This number should be adequate also to develop new equations if required.

The statistical description of the sample the data is in Table 2 (Appendix 1).

The method used to collect information is described in Working Paper No.6. Procedures and standards adopted to compute tree volumes are described in Appendix 2.

TEST OF EQUATIONS

All existing volume equations of the three above mentioned species were tested against the sample tree data. The testing program is described in Appendix 2 and the results are shown in Table 3 (Appendix 1).

All tested volume equations proved to be biased. However, it should be pointed out that this bias does not imply a bad adjusting method or a faulty procedure of data collection. It simply means that, with regard to a specific population, such as the one represented by the test sample and tree model adopted, the existing equations are not applicable.

Results for species Gamar showed that bias was small enough to allow the use of the existing equations, provided that proper adjusting factors were developed.

On the other hand the magnitude of bias for species Dhakijam and Garjan made use of adjusting factors inconvenient and construction of new volume functions was decided.

2.4 TEST OF DIFFERENCE BETWEEN SPECIES AND LOCALITIES

Before adjusting the volume functions, the feasibility of pooling information for groups of species was tested. Convenience of adjusting different volume equations for a same species in different localities was also tested.

To test the possibility of pooling information from different species in common equations a covariance analysis was performed.

The conclusion was that pooling of information was not possible for any of the species tested. However, to test the need of segregating information according to localities, a different test was applied since the covariance analysis showed certain inconsistency while dealing with the variation between intercepts. This inconsistency was probably due to the fact that theoretical assumptions were far from being met. Table 4 (Appendix 1) shows the results obtained using a test of differences between volume equations for same species in different localities based on conditional variables (Alder D. 1980).

Similarity of volume equations between all localities for a same species was observed with only one exception: equations for volume up to 20cm diameter limit for Dhakijam showed differences in slope that were significant at a 5% level. However, since this difference did not affect both types of volume, it was decided to disregard it.

It was then decided to fit independent volume functions for each species pooling different localities in a common slope and different intercept was fitted, according to the results obtained in the covariance analysis.

2.5 FITTING NEW VOLUME EQUATIONS

A first attempt was made to produce regression models based on a stepwise free selection of terms from within a wide variety of functions of diameter, total height and combination of both. These models had to be rejected, due to the fact that most of them included terms in which diameter or height were raised to high exponents making their use dangerous and creating irregularities between volume equations for different diameter limits.

New equations were adjusted using two different models:

Model 1: $V = b_o + b_1 D^2 + b_2 H + b_3 D^2 H$

Model 2: $V/D^2H = b_o + b_1/H + b_2/D^2 + b_3/(D^2H)$

D = reference diameter, cm

H = total height, m

V = volume inside bark up to either 10cm or 20cm diameter limit.

Only statistically significant coefficients were included in equations. The final volume functions, shown in Table 5 (Appendix 1), along with the adjusted original volume functions for Gamar, were now ready for testing.

2.6 TEST OF NEW VOLUME FUNCTIONS

The new volume equations were tested by replicating them over source data. The results are shown in Table 6 (Appendix 1).

No bias was present in the new equations except in some models that showed a significant cuadratic term of estimated values in function of residuals over them. This might produce biased estimations when extrapolations are made and, in certain cases, at the limits of the range of actual values.

As result of this test, following volume equation were selected :

i. For species Gamar : the original Oxford equations, adjusted for bias, showed the least mean square error, no significant bias and the highest proportion of accurate estimates.

According to Oxford models, total volume inside bark for Gamar is estimated by means of following equation :

$$Vt = 0.00020994\ D^{1.63502} H^{0.78485} * (.74986 + 0.0031724D - 0.00002432D^2)$$

Conversion function for volume up to diameter limit 10 cm including adjusting function for bias gives following estimator :

$$V10 = 0.01 + 1.13\ V_t\ (.99337 - 2.77683e^{-.14116D})$$

Similar estimator is obtained for volume up to 20 cm diameter limit :

$$V20 = 0.05 + 0.9344\ V_t\ (1-e^{-.2048D})\ 186.5.$$

ii. For species Dhakijam, simple combined variables models proved to be the best among tested equations :

$$V10 = 0.032944 + 0.000025764\ D^2H$$

$$V20 = 0.079765 + 0.000023617\ D^2H$$

iii. For species Garjan following models were selected :

$$V10 = 0.043442 + 0.000028969\ D^2H$$

$$V20 = 0.059623 - 0.00030587D^2 + 0.000035782\ D^2H$$

For other species such as Teak and Chapalish, the Oxford volume functions were adopted. Volume tables and form factor tables derived from new and Oxford functions are shown in Tables 7.1 to 7.22. (Appendix 1).

In order to make the volume functions operational they were included in a subroutine called VOLTRE which will be used to process inventory data.

3. SOME ELEMENTS OF GROWTH MODELS

Due to a lack of information, very little has been done in the past regarding yield and growth models.

The plantation inventory carried out in 1983 constitutes the first reliable source of information and will now be used to produce some elements of growth models.

The construction of highly flexible growth models, as required for modern decision taking in management, sets information needs that are far from being achieved by the plantation inventory. In this respect information from permanent plots is irreplaceable.

However, there are several, useful yield functions that can be constructed with these inventory data. They can give approximate answers to primary questions raised from the side of plantation management.

3.1 SOURCE DATA

At the time this consultancy began, the inventory data were still not processed in the way needed for yield studies.

Once tree volume functions were developed, the inventory data could be processed and stand parameters at plot basis were obtained. The method used as well as an exact description of stand parameters can be found in Appendix 2.

3.2 YIELD FUNCTIONS

The method used to develop yield function is described in 2.4 (Appendix 2).

Yield tables for teak are shown in Tables 8.1 to 8.6. They are derived from the set of yield functions presented below.

The symbols adopted to represent the variables involved are as follows :

H = Mean height of the 100 largest diameter trees per hectare

A = Age in years

S = Site index corresponding to mean height (H) at age 50

G = Basal area, m^2/ha, including all trees 4cm d.b.h. and above

DM = Diameter of the tree of mean basal area (mean square diameter) including all trees 4cm and larger

N = Number of trees per hectare 4cm d.b.h. and above

V = Volume in m^3/ha i.b. of bole and crown log up to a diameter limit of 10cm.

i. Mean height function.

$$H = S^{(0.83482 + 7.8605/A)} \, e^{(0.70863 - 34.2352/A)} \quad (1)$$

This equation is derived from Slavicky's Site Index functions (Slavicky J.S., 1978) by means of multiple regression analysis. The coefficient of correlation is nearly 1. It can not yet be interpreted in the usual way since the dependent variable H is not a random variable.

ii. Basal area functions.

Two basal area functions were constructed. The first equation uses only mean height as independent variable while the second includes number of trees per hectare as a second independent variable :

$$G = 0.80 + 0.15171 \, H^{1.5643} \quad (2)$$

$$G = 0.45 + 0.00088387 \, H^{2.4789} \, N^{(0.78113 - 0.13024 \log_e H)} \quad (3)$$

Both models were replicated against the source data resulting in the following statistics :

		Model (2)	Model (3)
Mean square error in percent		36.2%	28.5%
Percent of observations that deviate less than p% from the true value :	p = 10%	20.1%	26.1%
	20%	40.2%	45.2%
	30%	58.8%	70.9%

Model (2) can be used to estimate average trends of stand density while model (3) is more useful to estimate stand density of individual stands in such cases where a probable error of estimate of around 30% is acceptable.

iii. Volume functions.

A simple combined variable equation was selected as volume model :

$$V = - 3.17465 + 0.32131HG \quad (4)$$

The correlation coefficient of this model is 0.987 and the error of estimate is 11%. These statistical properties make it a very useful estimating function, for inventory purposes among others.

If a still higher accuracy is desired, the following model, which includes mean diameter as an additional independent variable, could be used :

$$V = -44.808 + 0.29897 HG + 16.54 \log_e DM \qquad (5)$$

From these functions, the yield tables presented in Tables 8.1 to 8.6 (Appendix 1) were derived.

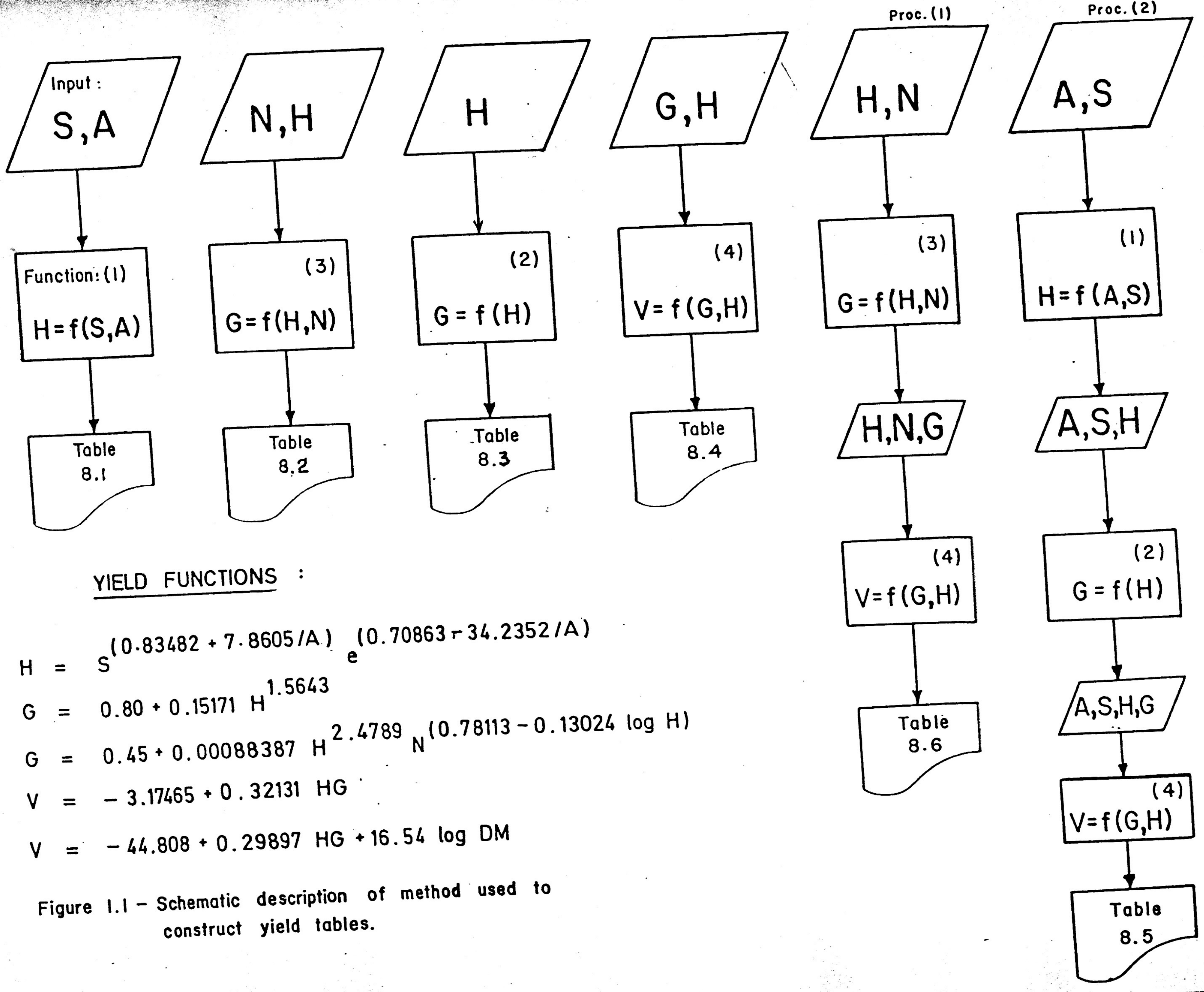
The way used to derive each table is shown in Figure 1.1 on page 9.

Estimations made by means of Table 8.6, or by means of the corresponding procedure used for its construction, will be associated with a probable error of 35%. By using table 8.5, or the corresponding procedure followed for its construction, the probable estimating error is 37%. No bias is to be expected.

These indications can be summarized in the following table which shows the different ways of estimating stand volume in Teak plantations and the associated probable errors :

Independent variables	Function or procedure	Probable error %
A,S	Proc. (2)	37%
A,S,N or H,N	Proc. (1)	35%
G,H	Func. (4)	11%
G,H,DM	Func. (5)	9%

It can be seen that by including the number of trees per hectare as an additional predictor to site and age in the yield models, only a 2% increase in accuracy is obtained. This is due to the fact that stand density in almost all the stands is not a result of scheduled management interventions, but rather a result of uncontroled human, animal or natural effects. Under these circumstances a very weak relationship exists between basal area or volume and number of trees per hectare, for stands having the same age and same site index.



YIELD FUNCTIONS :

$$H = S^{(0.83482 + 7.8605/A)} \, e^{(0.70863 - 34.2352/A)}$$

$$G = 0.80 + 0.15171 \, H^{1.5643}$$

$$G = 0.45 + 0.00088387 \, H^{2.4789} \, N^{(0.78113 - 0.13024 \log H)}$$

$$V = -3.17465 + 0.32131 \, HG$$

$$V = -44.808 + 0.29897 \, HG + 16.54 \log DM$$

Figure 1.1 – Schematic description of method used to construct yield tables.

4. SUMMARY AND RECOMMENDATIONS

Before processing the data of the plantation inventory collected in 1983 it was considered advisable to test the already available volume functions.

Regarding the tree model adopted and provided that the sample of trees used is representative of the population of the plantations inventoried, all volume functions available gave biased estimations.

Since bias for species Gamar was of a low magnitude, use of original functions, corrected for bias, was considered as a valid alternative. They were to be tested together with the new adjusted functions for the three species.

After testing all the new and corrected functions those who showed better statistical performance were selected. For Gamar, the corrected function proved to be the most accurate among the three alternatives tested. For Dhakijam and Garjan, simpler models proved to be in general more reliable than the more complex ones.

The selected volume equations are considered adequate to process the data of the plantation inventory. They can not be considered however as " general volume functions " since the sample on which they are based is too limited for this purpose. To construct " general volume functions " at least 70 to 100 sample trees, uniformly distributed over all diameter classes, have to be measured for each species at each geographic location.

The yield models constructed for Teak are to be regarded as preliminary, until they are validated with reliable information consisting of growth figures observed in Teak stands. Permanent plots provide the best base to carry out this validation. Replication of yield functions over inventory data is also a good way to test the sensibility of the models.

The consultant is of the opinion that present conditions are not suitable yet to start with massive permanent plot experiments or with a continuous plantation inventory with permanent plots, which can provide appropriate data for the construction of more flexible yield models.

Even so, it is convenient to start at least with a comprehensive study of site conditions based on stem analysis and soil observations. As a result of these studies site index functions as well as functions relating productivity of stands to environmental factors can be obtained.

BIBLIOGRAPHY

Alder, D. Forest volume estimation and yield prediction.
1980 Vol. 2 - Yield Prediction. FAO Forestry Paper 22/2, Rome, 193p.

Chaturvedi, A.N. General volume tables and height-diameter
1973 relationships for teak (Tectona grandis). Indian Forest Records, Vol. 12, N.8. P. 1-8.

Choudhury, J.H. and Davidson, J. Stand volume tables for four
1984 tree species grown in plantations in Bangladesh. Bangladesh Forest Research Institute. Inventory Division, Bull. N. 2, 144p.

Hindley, E.W. Mapping - Forest Inventory - Growth Studies.
1982 UNDP/FAO Project BGD/79/017, Working Paper No. 1, 180p.

Islam, SK.S. Islam, MD.N. and Latif, MD.A. Provisional Commercial
1978 Volume Table for Teak (Tectona grandis, Linn. F). 12p.

Kingston, B. A Collation of tree and Bamboo volume tables of
1979 Bangladesh. UNDP/FAO Project BGD/72/005, Field Document No. 5, 173p.

Slavicky, J.S. Forest Inventory and Aerial Photogrammetry. UNDP/
1978 FAO Project BGD/72/005, Field Document No. 5, 173p.

Snedecor, W.G. Metodos estadisticos aplicados a la investigacion
1964 agricola y biologica. Mexico D.F., Cia. Edit. Continental, 626p.

Appendix 1

TABLES

1. VOLUME FUNCTIONS FOR PLANTATION SPECIES IN BANGLADESH.
2. STATISTICAL DESCRIPTION OF SAMPLE TREE DATA.
3. TEST OF EXISTING VOLUME FUNCTIONS.
4. TEST OF DIFFERENCES BETWEEN VOLUME FUNCTIONS USING CONDITIONAL VARIABLES. RESULTS.
5. NEW VOLUME FUNCTIONS.
6. REPLICATION OF NEW VOLUME FUNCTIONS OVER SAMPLE TREE DATA. RESULTS.
7. VOLUME TABLES FOR PLANTATION SPECIES.
8. YIELD TABLES FOR TEAK.

Table 1:

VOLUME FUNCTIONS FOR PLANTATION SPECIES IN BANGLADESH

Species	Forest type	Year	Type of volume[1]	Diameter limit	Stump height	Sample size	Source	Function
Gamar	Plantation	1978	$(BO + CR)_{o.b.}$	tip[2]	0.3 m	486	Choudhury & Davidson (1984)	$\log_e V = 1.63502 \log_e D + 0.784847 \log_e H - 8.468708$
Chapalish	Plantation	1978	$(BO + CR)_{o.b.}$	tip[2]	0.3 m	427	Choudhury & Davidson (1984)	$\log_e V = 1.82851 \log_e D + 0.735381 \log_e H - 8.94495$
Chapalish Gamar Dhakijam	Plantation	1963	$BO_{i.b.}$	8" or crown point	0.6 m	45	Kingston (1979)	$V = 0.2602 + 0.00001851\, D^2H$
Civit	High forest	1963	BO i.b.	8" or crown	0.6 m	111	Kingston (1979)	$D^2H < 1200 : V = 0.01059 + 0.000028866\, D^2H$ $D^2H \geq 1200 : V = 0.0979 + 0.000024987\, D^2H$
Dhakijam	Plantation	1978	$(BO + CR)_{o.b.}$	tip[2]	0.3 m	314	Choudhury & Davidson (1984)	$V = 0.00019297\, D^2 + 0.000029437 + 0.0002489\, DH + 0.0000243726\, D^2H$
Garjan	High forest	1963	$BO_{i.b.}$	8" or crown	0.6 m	94	Kingston (1979)	$D^2H \leq 980 : V = 0.10947 + 0.000031346\, D^2H$ $D^2H > 980 : V = 0.4576 + 0.000025368\, D^2H$

Species	Forest type	Year	Type of volume (1)	Diameter limit	Stump height	Sample size	Source	Function
Garjan	Plantation	1963	$(BO + CR)_{o.b.}$	tip (2)	0.3 m	436	Choudhury & Davidson, (1984)	$V = 0.0006455 + 0.00039088\ D^2 + 0.00014783\ DH + 0.00002407\ D^2H$
Teak	Plantation	1970	$BO_{i.b.}$	20 cm	-	2012	Chaturvedi A.N., 1973	$V = 0.0645 + 0.2322\ D^2H$
Teak	Plantation	1970	$BO_{i.b.} + (CR + BR)_{o.b.}$	5 cm	-	2012	Chaturvedi, A.N., 1973	$V = 0.1217 + 0.2257\ D^2H$
Teak	Plantation	1977	$(BO + CR)_{o.b.}$	10 cm	Variable	616	Islam et al. (1978)	$V = 0.0000465\ D^{1.58} \times H^{1.603}$
Teak	Plantation	1977	$(BO + CR)_{o.b.}$	tip (1)	0.3 m	605	Hindley, (1982)	$\log_e V = -9.48076 + 1.62116 \log_e D + 1.16483 \log_e H$

(1) BO : bole volume; CR : crown log volume; BR : branch volume.

(2) Conversion functions have been developed to estimate volume inside and outside bark up to diameter limits of 5,10,15 and 20 cm.

Table 2:

STATISTICAL DESCRIPTION OF SAMPLE TREE DATA

	Ref. diam. (cm.)	Total height (m.)	Bole length (m.)	Bole volume 20 cm.	Bole vol. 10 cm. + crown vol.	Bark volume %	Bole form factor
Species : Gamar							
Sample size : 51							
MEAN	27.69	15.32	9.00	0.29	0.40	17.51	0.57
COEFFICIENT OF VARIATION	0.67	0.47	0.64	2.00	1.48	0.60	0.25
SMALLEST VALUE	12.50	7.80	3.10	0.00	0.02	10.20	0.38
LARGEST VALUE	52.20	22.80	15.70	1.08	1.34	31.60	0.72
Species : Dhakijam							
Sample size : 51							
MEAN	27.59	18.45	9.48	0.34	0.49	17.21	0.60
COEFFICIENT OF VARIATION	0.71	0.55	0.65	2.04	1.53	0.43	0.21
SMALLEST VALUE	11.00	9.40	3.40	0.00	0.02	12.20	0.48
LARGEST VALUE	50.50	32.80	17.50	1.30	1.42	29.20	0.76
Species : Garjan							
Sample size : 75							
MEAN	37.78	22.83	13.99	1.06	1.29	17.26	0.52
COEFFICIENT OF VARIATION	0.62	0.36	0.41	1.61	1.46	0.33	0.17
SMALLEST VALUE	13.50	9.70	5.30	0.00	0.05	9.60	0.35
LARGEST VALUE	80.00	42.70	24.80	5.23	5.40	30.10	0.69

Table 3:

TEST OF EXISTING VOLUME FUNCTIONS

Function(1)	n	Mean values (m^3) Actual (A)	Mean values (m^3) Estim. (E)	M.S.E. %	$A-E = b_o + b_1E$: b_o	b_1	t_{b1}	F-value for quadratic component	for paired diff.	Proportion of estimations deviating less than P % from actual value: P = 5%	10%	20%
Gamar (3)	36	0.40	0.61	58.8	-0.43	0.36	3.9**	2.9	-10.5**	11.1	11.1	25.0
Gamar (1), converted to vol.i.b., 10 cm	51	0.40	0.36	22.4	-0.01	0.13	3.1**	0.0	3.5**	19.6	43.1	82.4
Gamar (1), converted to vol.i.b., 20 cm	36	0.40	0.35	26.4	0.05	0.02	0.3	1.0	3.9 **	2.8	11.1	44.4
Dhakijam (3)	36	0.48	0.70	54.6	-0.41	0.27	2.8**	7.8**	-8.7 **	5.6	11.1	11.2
Dhakijam (5), conv. to vol.i.b., 10 cm	51	0.49	0.58	33.9	0.03	-0.20	-5.8**	4.1*	-4.5**	11.8	29.4	58.8
Dhakijam (5), conv. to vol.i.b., 20 cm	36	0.48	0.60	47.7	0.07	-0.32	-5.7**	10.7**	-3.7**	8.4	22.2	36.1
Garjan (6)	60	1.32	1.89	50.5	-0.62	0.03	0.7	3.6	-12.3**	5.0	6.7	21.7
Garjan (7), converted to vol.i.b., 10 cm	75	1.29	1.61	37.2	-0.11	-0.13	-6.0**	0.0	-7.7**	5.3	10.7	20.0
Garjan (7), converted to vol.i.b., 20 cm	60	1.32	1.77	50.3	-0.07	-0.21	-6.9**	0.7	-6.9**	8.3	11.7	25.0

(1) For identification of function see Table 1.1

* Significant at 5% level.

** Significant at 1% level.

Table 4:

TEST OF DIFFERENCES BETWEEN VOLUME FUNCTIONS USING CONDITIONAL VARIABLES. RESULTS

Species	Diameter limit, cm	b_o	b_1	t_{b_1}	b_2	b_3	t_{b_3}
Gamar	10	.015814	.01170	.32	$.26166*10^{-4}$	$.42798*10^{-7}$	0.02
	20	-.082148	.020709	.52	$.26002*10^{-4}$	$-.25239*10^{-5}$	-1.09
Dhakijam	10	.033845	-.0018254	-.04	$.26723*10^{-4}$	$-.17933*10^{-5}$	-0.81
	20	-.10433	.046530	.94	$.26440*10^{-4}$	$-.53087*10^{-5}$	-2.427*
Garjan	10	-.018058	-.024397	-.24	$.29031*10^{-4}$	$-.12388*10^{-5}$	-.65
	20	-.099244	-.078329	-.69	$.25674*10^{-4}$	$.57042*10^{-6}$	.27

Basic model : $V = b_o + b_1 I_c + b_2 D^2H + b_3 I_c D^2H$

I_c value is 0 for trees from locality 1 and 1 from locality 2.

Table 5:
NEW VOLUME FUNCTIONS

Function Nr.	Species	Type*	Function
1.	Gamar	(BO + CR) 10	$V = 0.01559 + 0.01229\, I_c + 0.000026181\, D^2H$ $I_c = 0$ for locality 1, $= 1$ for locality 2
2.	Gamar	(BO + CR) 10	$V/D^2H = 0.000016905 + 0.0077369/D^2 + 0.00014973/H - 0.090675/D^2H$
3.	Gamar	BO 20	$V = 0.09394 + 0.00011840\, D^2 + 0.000019393\, D^2H$
4.	Gamar	BO 20	$V/D^2H = 0.000044557 - .011529/D^2 - 0.000030661/H + 0.083417/D^2H$
5.	Dhakijam	(BO + CR) 10	$V = 0.03294 + 0.000025764\, D^2H$
6.	Dhakijam	(BO + CR) 10	$V/D^2H = 0.000023282 + 0.00012268/H - 0.017784/D^2H$
7.	Dhakijam	BO 20	$V = 0.079764 + 0.000023617\, D^2H$
8.	Dhakijam	BO 20	$V/D^2H = 0.000046088 - 0.015122/D^2 - 0.00039057/H + 0.141365/D^2H$
9.	Garjan	(BO + CR) 10	$V = 0.043442 + 0.000028969\, D^2H$
10.	Garjan	(BO + CR) 10	$V/D^2H = 0.000026553 - 0.0035327/D^2 + 0.000059612/H + 0.030901/D^2H$
11.	Garjan	BO 20	$V = -0.05962 - 0.00030587\, D^2 + 0.000035782\, D^2H$
12.	Garjan	BO 20	$V/D^2H = 0.000032294 - 0.015183/D^2 - 0.00010251/H + 0.10988/D^2H$

(BO + CR) 10 : Volume inside bark of bole and crown, up to a diameter limit of 10 cm.

BO 20 : Bole volume inside bark up to a diameter limit of 20 cm.