LOCAL VOLUME TABLES FOR *CEDRUS DEODARA* OF GILGIT-BALTISTAN

Anwar Ali[1], Muhammad Iftikhar[2], Sajjad Ahmad[3], Ayaz Khan[4] and Sultan Muhammad[5]

ABSTRACT

The accuracy of growing stock estimates depends on the availability of local volume tables to infer volume of trees from forest inventory data. The current study was undertaken to prepare local volume tables for *Cedrus deodara* of Gilgit-Baltistan (GB). Data was collected from 52 sample trees which were measured for the study in natural dry temperate forests of Gilgit-Baltistan. Diameter at Breast Height (DBH) and total height of the sample tree were measured before felling. After felling, the bole was cut into 2m logs with end log of variable length. The over bark mid diameter of the log and its length were measured for determining volume of logs. Total volume of a tree was determined by adding volumes of all logs. Different regression models were tested for deterring best relationship between DBH and height and DBH and Volume. On the basis of the best fit models, volume tables were prepared in 2cm dbh classes. These tables yielded volume estimates closer to the actual values obtained field measurement.

INTRODUCTION

The use of volume tables to the management of coniferous forests of North West Pakistan dates back to 1920's when Kulu averages worked out by Sir Gerald Trevor were applied in almost all working plans of these forests. Later on, Standard and Local Volume Tables were prepared for coniferous forests of different areas of Pakistan. However, no volume table was prepared for the natural forests of Gilgit-Baltistan. Volume Tables prepared for other areas were applied for estimation of growing stock in the forests of Gilgit-Baltistan.

Gilgit-Baltistan is situated in the extreme north of Pakistan, bordering China and Afghanistan in the north (35˚-37') and India in the east (72˚-75'), covering an area of 72,496 square kilometers. Gilgit-Baltistan hosts valuable forest ecosystems. The total forest area of Gilgit-Baltistan is 337,491 ha. Major forest tree species of GB include *Cedrus deodara* (Deodar), *Pinus wallichiana* (Kail), *Abies pindrow* (Fir), *Picea smithiana* (Spruce), *Pinus gerardiana*

1 Forest Mensuration Officer, Pakistan Forest Institute, Peshawar
2 Sub-divisional Forest Officer, GB Forest Department
3 Range Forest Officer, GB Forest Department
4 Senior Research Officer, Pakistan Forest Institute, Peshawar
5 Lecturer, Institute of Agriculture Sciences and Forestry, University of Swat

(Chilghoza) and *Quercus ilex* (Oak). Accurate estimates of growing stock in the forests are not possible without local volume tables of the tree species.

Cedrus deodara locally called as deodar or Himalayan cedar is a magnificent coniferous evergreen tree, 45-60 m tall with a diameter of 0.8 to 1.1 m (Sheikh, 1993). It has high cultural value in the Indian Subcontinent. It is the national tree of Pakistan and is held in high esteem not only for its vigour, beauty and age but also for the fragrance and remarkable qualities of its wood. Deodar wood is the strongest among the Himalayan conifers and comparable to teak in properties.

The volume tables were prepared using different allomteric equations based on regression models. These tables give over bark and under bark estimates of small wood, timber and total volume of given tree species both in metric as well as British units. As the forests of Gilgit-Baltistan are under tremendous pressure due to increasing demand for timber and fuelwood, the use of current volume tables to forest working plans will help in minimizing the over-exploitation of the forests.

MATERIAL AND METHODS

Basic data for preparation of the current volume tables was collected during a study primarily designed for development of 'Local Biomass and Carbon Tables for Major Tree Species of Gilgit-Bbaltistan' during April-September, 2015. As the biomass study involved destructive sampling and felling of sample trees, the sample size was kept low. However, additional trees were measured for preparation of dia-height functions and volume estimation by taking data from standing sample trees by climbing them. Where the trees could not be climbed, the measurements were taken with Spiegel Relaskop. In total 52 trees were measured for volume estimation of deodar out of which 32 were felled for measurement whereas 20 trees were measured in standing position. For determination of dia-height function 59 trees were measured in different deodar stands in the area. DBH of the sample trees ranged from 8 cm to 123 cm whereas height ranged from 4.5-44 m. Sample trees were arranged in diameter classes of 5 cm from 6 to 125 cm. For determination of height functions, additional trees were measured to cover any variation in height due to site quality, slope and aspect. In each diameter class, 2-3 sample trees were randomly selected and measured. Efforts were made to select trees of normal form and shape to closely represent the forest stands of the area. Trees with broken top, forked stem, excessive or less branching or any other abnormality were avoided. The detail of sample trees measured is given in table 1.

Table 1. Detail of sample trees used in the preparation of volume table

Function	Range of dbh (cm)	Range of heights (m)	Number of sample trees
Tree Height	8-152	4.5-44	59
Total Volume	8-123	4.5-42	52

Diameter at Breast Height (DBH) and total height of the sample tree were measured before felling. After felling, the bole was cut into 2 m logs with end log of variable length. The over bark mid diameter of the log and its length were measured for determining volume of logs using Huber's formula. Big branches upto 20 cm diameter at thin end were included in timber measurement whereas small branches upto 5 cm diameter at thin end were included in small wood. Volume upto 5 cm overbark diameter at the thin end of the stem including branches was taken as total volume of the tree, whereas volume upto 20 cm diameter over bark at the thin end of the stem including branches was taken as timber volume of the tree. The volume from 20 cm down to 5 cm over bark of the stem and branches was accounted as volume of small wood of the tree. Total volume of a tree was determined by adding volumes of all logs upto 5 cm at the thin end.

The method employed for development of the current volume tables consists of two stages. In the first stage an analytical relationship was developed between DBH and height and in the second stage allometric equations were developed for estimation of timber and total volume using various regression models. The following regression models were used for estimating height, timber volume and total volume for each species.

i. Models for Height Estimation

$H= a+bD$ ....(1)

$H= a+bD+cD^2$ ....(2)

$H= a+b\ln(D)$ ....(3)

ii. Models for Timber Volume Estimation

$TM= a+bD+cD^2$ ....(4)

$TM= a+b(D^2H)+c(D^2H)^2$ ....(5)

$TM=aD^b$ ....(6)

$TM= a(D^2H)^b$ ....(7)

iii. Models for Total Volume Estimation

$TV= a+bD+cD^2$ ....(8)

$TV= a+b(D^2H)+c(D^2H)^2$ ....(9)

$TV=aD^b$ ....(10)

$TV= a(D^2H)^b$ ....(11)

Where

D = Diameter over bark at Breast Height in cm
H = Total height of tree in m
TM =Timber Volume in m^3
TV =Total Volume in m^3
ln = Natural Logarithm
a = regression constant
b, c = regression coefficients

All the above mentioned models were tested for the species and the model which showed best performance on the following criteria was finally selected.

i. Minimum sum of square of the residual error
ii. Minimum standard error of the estimate
iii. Maximum value of R^2

RESULTS AND DISCUSSIONS

Height Estimation

Out of the three models for height estimation, Model No.3 gave best performance on the given criteria and also yielded reasonable height estimates for large size trees in which height growth is almost stopped (Figure 1). Based on this model, the following regression equation was developed.

$$H= - 34.394+15.355\ln(D)$$

The equations alongwith indices of best fit for the selected models are given in the Table No.2.

Table 2. Regression Models alongwith indices of best fit

Estimate	Regression Model	Allometric equation	N	SEE (%)	SS of Residuals	R^2
Height	H=a+lnD	H=15.355ln(D) - 34.394	59	5.52	1733.47	0.743
Timber Volume	$TV=a+b(D^2H)+c(D^2H)^2$	$TV=4E\text{-}12(D^2H)^2 + 2E\text{-}05(D^2H) + 0.0478$	49	16.31	22.19	0.984
Total Volume	$V= a(D^2H)^b$	$TV = 4E\text{-}05(D^2H)^{0.9733}$	52	16.37	16.14	0.989

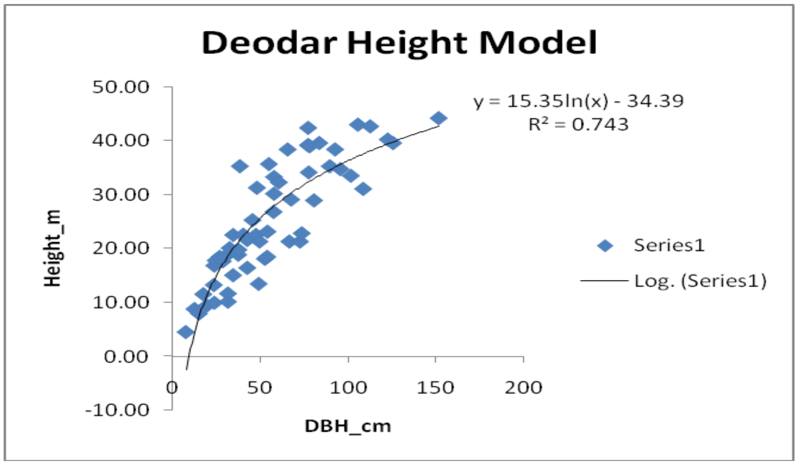

Fig.1 Dia-Height Function for deodar

Timber Volume Estimation

Model No. 5 showed best performance on the given criteria and also yielded timber estimates nearer to actual values of timber volume for given sample trees. The indices of best fit are given in table 2. The graphical representations of the model is shown in figures. Based on this model, the following regression equation was developed for estimation under bark timber volume.

$$TV=+\ 0.0478+\ 2E\text{-}05(D^2H)\ 4E\text{-}12(D^2H)^2$$

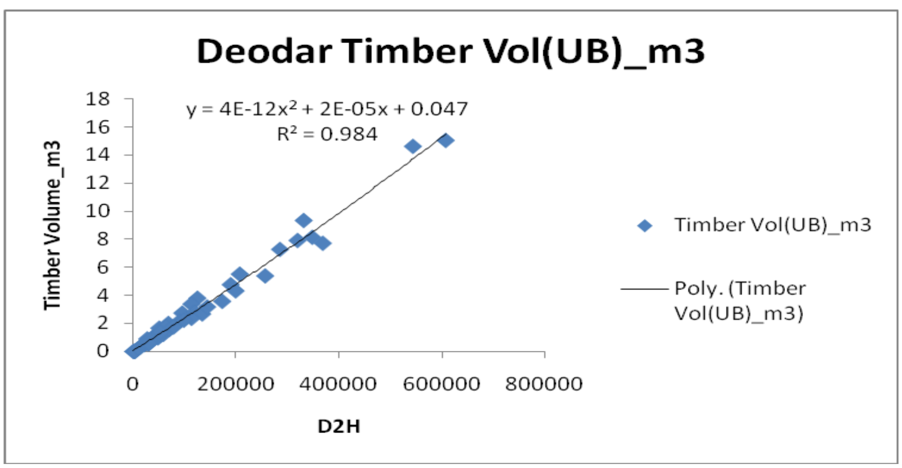

Fig.2. Deodar Timber Volume Model

Total Volume Estimation

Out of four models tested for estimation of total volume, Model No. 11 showed best performance on the given criteria and yielded total volume estimates closer to actual values. The indices of best fit are given in table 2. The graphical representations of the model is shown in figures. Based on this model, the following regression equation was developed for estimation of total volume.

$$TV = 4E\text{-}05(D^2H)^{0.9733}$$

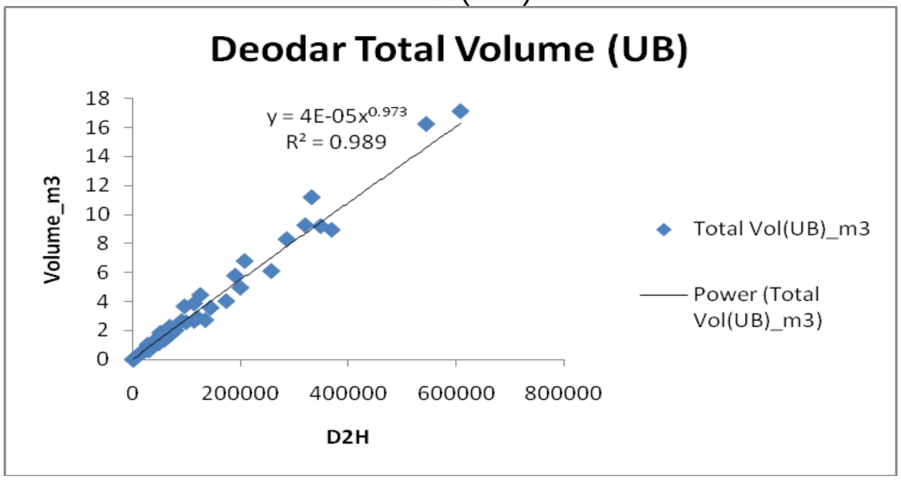

Fig 3. Deodar Total Volume Model

The total volume yielded by the above regression model was also compared with the estimates produced by the existing volume table for Upper Indus Kohistan which is adjacent to the study area and has similar climatic conditions. The result is given in table No.3. It is evident from the data that the current volume tables gave estimates of total volume closer to the actual values obtained from field measurement. The current volume table over estimated by 2.3% compared to 20.1% underestimation by the volume table of Indus Kohistan. Thus it is advisable to use the current volume tables for estimating growing stock in the study area.

Table 3. comparison of total volume with actual and existing volume table

Total Trees Measured	Actual volume (m^3)	Estimate by Current Volume Table (m^3)	Estimate by Volume Table (Indus Kohistan) (m^3)
52	169	173	135

Use of Volume Tables

Volume Tables were prepared on the basis of selected regression models both in metric as well as British units. The Volume Tables given in the appendix I and II were prepared by 2 cm diameter class interval in metric units and the tables from 6 to 10 were prepared by 1 inch diameter class intervals in British units. Diameter classes show mid values for the range of diameters. For example 50 cm DBH class include trees with DBH 49.1 to 51.0 cm in metric units. On the other hand, 20 DBH class includes trees ranging from 19.6 to 20.5 inches in British units. These tables provide under bark estimates of timber and total volume. The small wood volume estimates can be obtained by subtracting timber from the total volume of the tree. In order to obtain over bark estimates, multiply the volume table figures by 1.18.

CONCLUSION

Cedrus deodara growing in dry temperate forests of Gilgit-Baltistan show different growth pattern from the species found in other forest areas of Pakistan. It is, therefore, necessary to prepare local volume tables for the species. Results showed good relationship between volume as dependent variable and DBH and height as independent variables. The R^2 was found to be 0.98 and Relative Standard Error of Estimate was found as 16.37% which indicated good fit of the model. The total volume yielded by the given regression equation was also compared with the estimates produced by the existing volume table for Upper Indus Kohistan which is adjacent to the study area and has similar climatic conditions. It was found that the current volume tables gave estimates of total volume closer to the actual values obtained from field measurement. The current volume table over estimated by 2.3% compared to 20.1% underestimation by the volume table of Indus Kohistan. Thus it is advisable to use the current volume tables for estimating growing stock in the study area.

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APPENDIX-I

Local Volume Table (UB) of *Cedrus deodara* (Deodar) in Metric Units

DBH_cm	Height_m	Timber Volume_m3	Total Volume_m3	DBH_cm	Height_m	Timber Volume_m3	Total Volume_m3
12	5.00	-	0.024	82	33.27	4.722	6.440
14	6.13	-	0.040	84	33.64	5.021	6.823
16	8.18	-	0.068	86	34.00	5.330	7.217
18	9.99	-	0.104	88	34.36	5.652	7.624
20	11.61	0.063	0.148	90	34.70	5.985	8.043
22	13.07	0.076	0.200	92	35.04	6.331	8.474
24	14.41	0.214	0.261	94	35.37	6.689	8.917
26	15.63	0.260	0.330	96	35.69	7.059	9.373
28	16.77	0.311	0.408	98	36.01	7.443	9.841
30	17.83	0.370	0.496	100	36.32	7.839	10.321
32	18.82	0.435	0.592	102	36.62	8.249	10.814
34	19.75	0.507	0.699	104	36.92	8.672	11.320
36	20.63	0.585	0.815	106	37.21	9.110	11.838
38	21.46	0.671	0.941	108	37.50	9.561	12.369
40	22.25	0.765	1.076	110	37.78	10.027	12.912
42	23.00	0.866	1.222	112	38.06	10.508	13.469
44	23.71	0.974	1.379	114	38.33	11.003	14.038
46	24.39	1.091	1.545	116	38.60	11.514	14.619
48	25.05	1.215	1.723	118	38.86	12.041	15.214
50	25.68	1.348	1.911	120	39.12	12.583	15.822
52	26.28	1.489	2.109	122	39.37	13.142	16.442
54	26.86	1.639	2.319	124	39.62	13.717	17.076
56	27.42	1.797	2.539	126	39.87	14.309	17.722
58	27.95	1.964	2.771	128	40.11	14.918	18.382
60	28.47	2.140	3.013	130	40.35	15.545	19.055
62	28.98	2.325	3.267	132	40.58	16.190	19.740
64	29.47	2.520	3.532	134	40.81	16.852	20.439
66	29.94	2.724	3.809	136	41.04	17.534	21.151
68	30.40	2.938	4.097	138	41.26	18.235	21.877
70	30.84	3.162	4.396	140	41.48	18.954	22.615
72	31.27	3.395	4.708	142	41.70	19.694	23.367
74	31.69	3.640	5.031	144	41.92	20.454	24.133
76	32.10	3.894	5.365	146	42.13	21.234	24.911
78	32.50	4.159	5.712	148	42.34	22.035	25.703
80	32.89	4.435	6.070	150	42.54	22.858	26.509

APPENDIX-II

Local Volume Table (UB) of *Cedrus deodara* (Deodar) in British Units

DBH_inch	Height_ft	Timber Volume_cft	Total Volume_cft	DBH_inch	Height_ft	Timber Volume_cft	Total Volume_cft
5	15	-	0.9	33	110	176.3	239.7
6	24	-	2.0	34	112	190.3	257.4
7	32	-	3.5	35	113	204.8	275.8
8	39	-	5.5	36	115	220.1	294.9
9	45	6.7	8.0	37	116	236.1	314.7
10	50	8.7	10.9	38	117	252.8	335.3
11	55	10.9	14.3	39	119	270.2	356.5
12	59	13.6	18.3	40	120	288.4	378.4
13	63	16.6	22.8	41	121	307.3	401.0
14	67	20.0	27.8	42	122	327.1	424.4
15	71	23.9	33.4	43	124	347.6	448.5
16	74	28.1	39.6	44	125	369.0	473.3
17	77	32.8	46.4	45	126	391.3	498.8
18	80	37.9	53.7	46	127	414.4	525.1
19	82	43.5	61.7	47	128	438.4	552.0
20	85	49.6	70.2	48	129	463.3	579.8
21	87	56.1	79.4	49	130	489.2	608.2
22	90	63.1	89.2	50	131	516.0	637.5
23	92	70.6	99.6	51	132	543.8	667.4
24	94	78.7	110.7	52	133	572.7	698.1
25	96	87.2	122.4	53	134	602.5	729.6
26	98	96.3	134.7	54	135	633.5	761.8
27	100	106.0	147.7	55	136	665.5	794.7
28	102	116.2	161.4	56	137	698.7	828.4
29	104	127.0	175.7	57	138	733.0	862.9
30	105	138.4	190.7	58	139	768.5	898.2
31	107	150.4	206.3	59	140	805.2	934.2
32	109	163.1	222.7	60	140	843.1	970.9