

## ESTIMATION OF DIAMETER AT BREAST HEIGHT FROM STUMP MEASUREMENTS FOR DEODAR, (*CEDRUS DEODARA*) OF AZAD KASHMIR

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### Summary

Diameters of deodar (*Cedrus deodara*) trees were measured at 1 (30.48 Cm) interval above ground level upto 7 feet (2.13 meters). Each set of diameters showed a strong linear correlation with diameter at breast height. Straight line regression equations were developed for each set of diameter separately using sets of diameter at different heights as independent variables and diameter breast height as dependent variable. DBH was estimated from these equations against diameter range from 6 to 60 inches for British units and 2 Cm to 136 Cm. for Metric Units at different heights of stem from ground level upto 7 feet (2.13 meter).

### Introduction

Volume tables for the important commercial coniferous species of Azad Kashmir are available (1). Like all other volume tables these provide cubical contents of standing trees against their diameter at breast height. In case of illicit removal of tree, for compounding of damage cases, stump diameter measurements are taken, assuming it equivalent to measurement of diameter breast height. This results in over-estimation of volume, price and compensation. Which sometimes can create problems in the absence of relationship between stump diameter and diameter at breast height (4.5 feet).

Stump diameter can be used for estimation of volume of cut trees (2, 3). But no such relationship exists for deodar (*Cedrus deodara*). Since deodar is one of the most valuable timber specie of Azad Kashmir, it has been considered necessary to develop a relationship between diameter at different stump heights and diameter breast height for estimation of volume and related price etc.

### Basic Data

Over-bark diameter of 496 deodar trees were measured at 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, feet height above ground level alongwith diameter breast height (4.5 feet of 1.37 meter) with steel callipers from Compartment 1 to 7 of Keran Division and 15, 18 and 19 of Sharda Division. Diameters classes covered in data, range from 6 inch to 61 inch. Summary of the number of trees, for which data was recorded in different diameter classes is provided in Table I.

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TABLE I  
Frequency of trees Measured in each Diameter Class.

Dia-class inches.	No. of trees.	Dia-class inches.	No. of trees.
6	4	34	11
7	11	35	5
8	11	36	8
9	9	37	7
10	10	38	15
11	11	39	6
12	9	40	10
13	10	41	9
14	11	42	6
15	9	43	6
16	11	44	8
17	9	45	8
18	10	46	8
19	10	47	7
20	10	48	11
21	6	49	6
22	11	50	8
23	8	51	6
24	9	52	11
25	12	53	10
26	7	54	6
27	6	55	9
28	11	56	8
29	11	57	9
30	12	58	5
31	8	59	11
32	10	60	8
33	9	61	3
Total:—		496	

### Method

Diameters of deodar trees measured at particular heights from one set. Seven different stump heights were taken, thus there were seven sets of diameter. A strong linear correlation



was observed, when each set of diameter was separately correlated with sets of diameter at breast height. Simple linear regression equations were derived by the least square method for each set of diameter taking DBH as dependent (Y) and diameter at 1, 2, . . . . 7 feet above ground level as independent variable ( $X_i$ , where  $i$  varies from 1 to 7). Relevant statistics of relationship are provided in Appendix I. The regression equations with their respective correlation coefficients are given in Table 2.

TABLE 2

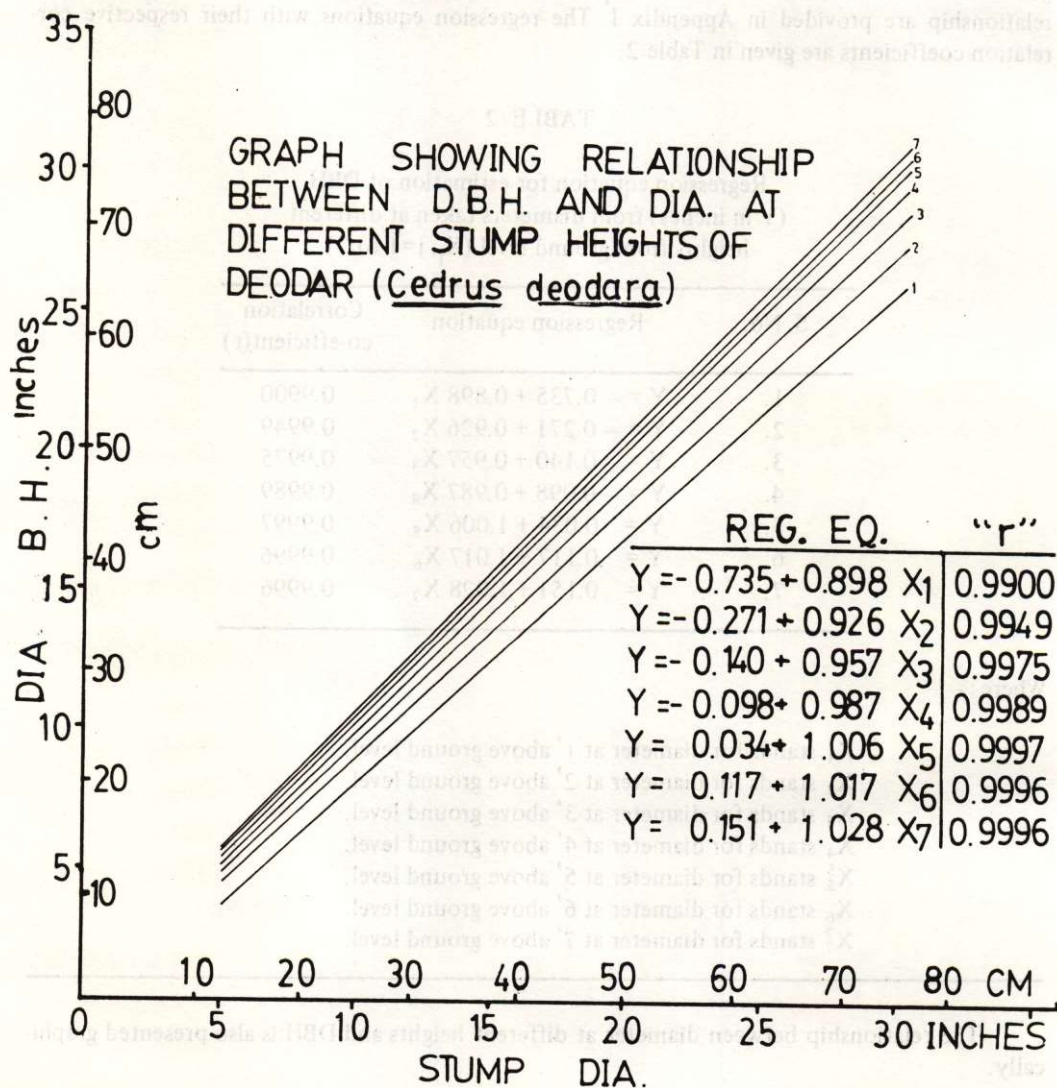
Regression equation for estimation of DBH  
(Y in inches) from diameters taken at different  
heights from ground level ( $X_i$ ,  $i=1$  to 7)

S. No.	Regression equation	Correlation co-efficient(r)
1.	$Y = -0.735 + 0.898 X_1$	0.9900
2.	$Y = -0.271 + 0.926 X_2$	0.9949
3.	$Y = -0.140 + 0.957 X_3$	0.9975
4.	$Y = -0.098 + 0.987 X_4$	0.9989
5.	$Y = 0.034 + 1.006 X_5$	0.9997
6.	$Y = 0.117 + 1.017 X_6$	0.9996
7.	$Y = 0.151 + 1.028 X_7$	0.9996

Where:—

- $X_1$  stands for diameter at 1' above ground level.
- $X_2$  stands for diameter at 2' above ground level.
- $X_3$  stands for diameter at 3' above ground level.
- $X_4$  stands for diameter at 4' above ground level.
- $X_5$  stands for diameter at 5' above ground level.
- $X_6$  stands for diameter at 6' above ground level.
- $X_7$  stands for diameter at 7' above ground level.

The relationship between diameter at different heights and DBH is also presented graphically.





The regression equations converted to Metric units are shown in Table 3.

TABLE 3

Regression equation in Metric unit ( $X_2$  in cms)

1.	$Y = -1.867 + 0.898 X_1$
2.	$Y = -0.688 + 0.926 X_2$
3.	$Y = -0.357 + 0.957 X_3$
4.	$Y = -0.250 + 0.987 X_4$
5.	$Y = 0.088 + 1.006 X_5$
6.	$Y = 0.296 + 1.017 X_6$
7.	$Y = 0.384 + 1.028 X_7$

Diameter breast height was estimated from each equation. The estimates are given in Appendices II and III for British and Metric units respectively.

### Consulting the Appendices

Knowing the diameter over-bark of a stump and its height from ground level, the DBH can be obtained from the appropriate Appendix by consulting the row for stump diameter and column for stump height.

### Acknowledgement

Help rendered by Messrs. Fatehullah and Manzoor Ahmed Foresters and Mr. Saleem Forest Guard is acknowledged with thanks.

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## APPENDIX I

## RELEVANT BASIC STATISTICS FOR THE RELATIONSHIP BETWEEN DIA. AT BREAST HEIGHT AND DIA. AT DIFFERENT STUMP HEIGHTS OF DEODAR

DIFFERENT STATISTICAL FUNCTIONS	STUMP HEIGHT (FEET)						
	1	2	3	4	5	6	7
1. Number of observations.	496	496	496	496	496	496	496
2. Sum of independent variable ( $X_i$ )	18142.50	17344.90	16717.50	16194.80	15830.80	15619.80	15441.30
3. Sum of dependent variable $Y_i$	15951.40	15951.40	15951.40	15951.40	15951.40	15951.40	15951.40
4. Sum of $X_i$ square	813373.17	748853.59	697403.33	655171.40	626933.84	610596.40	597290.75
5. Sum of $X_i$ square	636336.12	636336.12	636336.12	636336.12	636336.12	636336.12	636336.12
6. Sum of cross products of ( $X_i Y_i$ )	717454.99	689176.01	665422.32	645130.96	631503.00	622622.95	616455.63
7. Mean of $X_i$	36.5776	34.9696	33.7046	32.6508	31.9169	31.4915	31.1317
8. Mean of $Y_i$	32.1601	32.1601	32.1601	32.1601	32.1601	32.1601	32.1601
9. Standard deviation of sample $X_i$ $Y_i$	17.3940 15.7850	16.9557 15.7850	16.4499 15.7850	15.9797 15.7850	15.6775 15.7850	15.4851 15.7850	15.3463 15.7850
10. Standard dev. of population $X_i$ $Y_i$	17.3765 15.7691	16.9386 15.7748	16.4333 15.7741	15.9635 15.7747	15.6617 15.7660	15.4701 15.7351	15.3309 15.7691
11. Linear Eq. constant (a)	-0.7349	-0.2708	-0.1405	-0.0984	0.0345	0.1166	0.1512
12. Co-efficient of linear equation (b)	0.8985	0.9266	0.9575	0.9871	1.0064	1.0167	1.0282
13. Correlation Co-efficient (r)	0.9900	0.9949	0.9975	0.9989	0.9997	0.9996	0.9996

## APPENDIX II

DIAMETER BREAST HEIGHT ESTIMATED FROM DIAMETER  
STUMP HEIGHT IN BRITISH UNIT

DIA (INCHES)	STUMP HEIGHT IN FEET						
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>
DIAMETER BREAST HEIGHT (INCHES)							
0.5	0.3	0.2	0.3	0.4	0.5	0.6	0.7
1.0	0.2	0.6	0.8	0.9	1.0	1.1	1.2
1.5	0.6	1.1	1.3	1.4	1.5	1.6	1.7
2.0	1.1	1.6	1.8	1.9	2.0	2.1	2.2
2.5	1.5	2.0	2.2	2.4	2.5	2.7	2.7
3.0	2.0	2.5	2.7	2.9	3.0	3.2	3.2
3.5	2.4	3.0	3.2	3.3	3.5	3.8	3.7
4.0	2.8	3.4	3.7	3.8	4.0	4.2	4.3
4.5	3.3	3.9	4.2	4.3	4.5	4.7	4.8
5.0	3.7	4.3	4.6	4.8	5.1	5.2	5.3
5.5	4.2	4.8	5.1	5.3	5.6	5.7	5.8
6.0	4.6	5.3	5.6	5.8	6.1	6.2	6.3
6.5	5.1	5.7	6.2	6.4	6.6	6.7	6.8
7.0	5.5	6.2	6.5	6.8	7.1	7.2	7.3
7.5	6.0	6.7	7.0	7.3	7.6	7.7	7.9
8.0	6.4	7.1	7.5	7.8	8.1	8.2	8.4
8.5	6.9	7.6	8.0	8.3	8.6	8.7	8.9
9.0	7.3	8.1	8.5	8.8	9.1	9.3	9.4
9.5	7.8	8.5	8.9	9.3	9.6	9.8	9.9
10.0	8.2	9.0	9.4	9.8	10.1	10.3	10.4
10.5	8.7	9.4	9.9	10.3	10.6	10.8	10.9
11.0	9.1	9.9	10.4	10.7	11.1	11.3	11.5
11.5	9.6	10.4	10.9	11.2	11.6	11.8	12.0
12.0	10.0	10.8	11.3	11.7	12.1	12.3	12.5
12.5	10.5	11.3	11.8	12.2	12.6	12.8	13.0
13.0	10.9	11.8	12.3	12.7	13.1	13.3	13.5
13.5	11.4	12.2	12.8	13.2	13.6	13.8	14.0
14.0	11.8	12.7	13.2	13.7	14.1	14.3	14.5
14.5	12.3	13.1	13.7	14.2	14.6	14.8	15.0
15.0	12.7	13.6	14.2	14.7	15.1	15.4	15.6
15.5	13.2	14.1	14.7	15.2	15.6	15.9	16.1
16.0	13.6	14.5	15.2	15.7	16.1	16.4	16.6



## APPENDIX II (Contd.)

DIA (INCHES)	STUMP HEIGHT IN FEET						
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>
16.5	14.1	15.0	15.6	16.2	16.6	16.9	17.1
17.0	14.5	15.5	16.1	16.7	17.1	17.4	17.6
17.5	15.0	15.9	16.6	17.2	17.6	17.9	18.1
18.0	15.4	16.4	17.1	17.7	18.1	18.4	18.7
18.5	15.9	16.9	17.6	18.2	18.6	18.9	19.2
19.0	16.3	17.3	18.0	18.6	19.1	19.4	19.7
19.5	16.8	17.8	18.5	19.6	19.6	19.9	20.2
20.0	17.2	18.2	19.0	19.6	20.1	20.4	20.7
20.5	17.7	18.7	19.5	20.1	20.6	20.9	21.2
21.0	18.1	19.2	19.9	20.6	21.2	21.5	21.7
21.5	18.6	19.6	20.4	21.1	21.7	22.0	22.2
22.0	19.0	20.1	20.9	21.6	22.2	22.5	22.8
22.5	19.5	20.6	21.4	22.1	22.7	23.0	23.3
23.0	19.9	21.0	21.9	22.6	23.2	23.5	23.8
23.5	20.4	21.5	22.3	23.1	23.7	24.0	24.3
24.0	20.8	22.0	22.8	23.6	24.2	24.5	24.8
24.5	21.3	22.4	23.3	24.1	24.7	25.0	25.3
25.0	21.7	22.9	23.9	24.6	25.2	25.5	25.8
25.5	22.2	23.3	24.3	25.1	25.7	26.0	26.4
26.0	22.6	23.8	24.7	25.6	26.2	26.5	26.9
26.5	23.1	24.3	25.2	26.0	26.7	27.1	27.4
27.0	23.5	24.7	25.7	26.5	27.0	27.6	27.9
27.5	24.0	25.2	26.2	27.0	27.7	28.1	28.4
28.0	24.4	25.7	26.6	27.6	28.2	28.6	28.9
28.5	24.9	26.1	27.1	28.0	28.7	29.1	29.4
29.0	25.3	26.6	27.6	28.5	29.2	29.6	30.0
29.5	25.8	27.0	28.1	29.0	29.7	30.1	30.5
30.0	26.2	27.5	28.6	29.5	30.2	30.6	31.0
30.5	26.7	28.0	29.0	30.0	30.7	31.1	31.5
31.0	27.1	28.4	29.5	30.5	31.2	31.6	32.0
31.5	27.6	29.9	30.0	31.0	31.7	32.1	32.5
32.0	28.0	29.4	30.5	31.5	32.2	32.6	33.1
32.5	28.5	29.8	31.0	32.0	32.7	33.2	33.6
33.0	28.9	30.3	31.4	32.5	33.2	33.7	34.1
33.5	29.4	30.7	31.9	33.0	33.7	34.2	34.6
34.0	29.8	31.2	32.4	33.5	34.2	34.7	35.1
34.5	30.3	31.7	32.9	34.9	34.7	35.2	35.6
35.0	30.7	32.1	33.3	34.4	35.2	35.7	36.1
35.5	31.2	32.6	33.8	34.9	35.7	36.2	36.6
36.0	31.6	23.1	34.3	35.4	36.2	36.7	37.1

## APPENDIX II (Contd.)

DIA (INCHES)	STUMP HEIGHT IN FEET						
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>
36.5	32.1	38.5	34.8	35.9	36.7	37.2	37.7
37.0	32.5	34.0	35.3	36.4	37.2	37.7	38.2
37.5	32.9	34.4	35.7	36.9	37.7	38.2	38.7
38.0	33.4	34.9	36.2	37.4	38.3	38.8	39.2
38.5	33.8	35.4	36.7	37.9	38.8	39.2	39.7
39.0	34.3	35.8	37.2	38.4	39.3	39.8	40.2
39.5	34.7	36.3	37.7	38.9	39.8	40.3	40.7
40.0	35.2	36.8	38.1	39.4	40.3	40.8	41.3
40.5	35.6	37.2	38.6	39.9	40.8	41.3	41.8
41.0	36.1	37.7	39.1	40.4	41.3	41.8	42.3
41.5	36.5	38.1	39.6	40.9	41.8	42.3	42.8
42.0	37.0	38.6	40.0	41.3	42.3	42.8	43.3
42.5	37.4	39.1	40.5	41.8	42.8	43.3	43.8
43.0	37.9	39.5	41.0	42.3	43.3	43.8	44.3
43.5	38.3	40.0	41.5	42.8	43.8	44.3	44.9
44.0	38.8	40.5	42.0	43.3	44.3	44.9	45.4
44.5	39.2	40.9	42.4	43.8	44.8	45.4	45.9
45.0	39.7	41.4	42.9	44.3	45.3	45.9	46.4
45.5	40.1	41.9	43.4	44.8	45.8	46.4	46.9
46.0	40.6	42.8	43.9	45.3	46.3	46.9	47.4
46.5	41.0	42.8	44.4	45.8	46.8	47.4	47.9
47.0	41.5	43.2	44.8	46.3	47.3	47.9	48.5
47.5	41.9	43.7	45.3	46.8	47.8	48.4	49.0
48.0	42.4	44.2	45.8	47.3	48.3	48.9	49.5
48.5	42.8	44.6	46.3	47.8	48.8	49.4	50.0
49.0	43.3	45.1	46.7	48.3	49.3	49.9	50.5
49.5	43.7	45.6	47.2	48.7	49.8	50.4	51.0
50.0	44.2	46.0	47.7	49.2	50.3	51.0	51.5
50.5	44.6	46.5	48.2	49.7	50.8	51.5	52.1
51.0	45.0	46.9	48.7	50.2	51.3	52.0	52.6
51.5	45.5	47.4	49.1	50.7	51.8	52.5	53.1
52.0	46.0	47.4	49.6	51.2	52.3	53.0	53.6
52.5	46.5	48.3	50.1	51.7	52.8	53.5	54.1
53.0	46.9	48.8	50.6	52.2	53.3	54.0	54.6
53.5	47.3	49.3	51.0	52.7	53.9	54.5	55.1
54.0	47.7	49.7	51.5	53.2	54.3	55.0	55.7
54.5	48.2	50.2	52.0	53.7	54.9	55.5	56.2
55.0	48.6	50.6	52.5	54.2	55.4	56.0	56.7
55.5	49.1	50.1	52.0	54.7	55.9	56.6	57.2
56.0	49.5	51.6	53.4	55.2	56.4	57.1	57.7
56.5	50.0	52.0	53.9	55.7	56.9	57.6	58.2



## APPENDIX II (Contd.)

DIA (INCHES)	STUMP HEIGHT IN FEET						
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>
57.0	50.4	52.5	54.4	56.2	57.4	58.1	58.7
57.5	50.9	53.0	54.9	56.7	57.9	58.6	59.3
58.0	51.3	53.4	55.4	57.1	58.4	59.2	59.8
58.5	51.8	53.9	55.8	57.6	58.9	59.6	60.3
59.0	52.2	54.4	56.3	58.1	59.4	60.1	60.8
59.5	52.7	54.8	56.8	58.6	59.9	60.6	61.3
60.0	53.1	55.3	57.3	59.1	60.4	61.1	61.8

## APPENDIX III

DIAMETER BREAST HEIGHT ESTIMATED FROM DIAMETER  
STUMP HEIGHT IN METRIC UNITS

## HEIGHT IN METRIC UNITS

DIA (CMS)	STUMP HEIGHT IN CENTEMETER						
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>
	30	61	92	122	152	183	213

## DIAMETER BREAST HEIGHT (CENTEMETERS)

2	—	1.2	1.5	1.7	2.1	2.3	2.4
4	1.7	3.0	3.5	3.7	4.1	4.4	4.5
6	3.5	4.9	5.4	5.7	6.1	6.4	6.5
8	5.3	6.7	7.3	7.6	8.1	8.4	8.6
10	7.1	8.6	9.2	9.6	10.1	10.5	10.7
12	8.9	10.4	11.1	11.6	12.2	12.6	12.7
14	10.7	12.3	13.0	13.6	14.2	14.5	14.8
16	12.5	14.1	14.9	15.5	16.2	16.6	16.8
18	14.3	16.0	16.9	17.5	18.2	18.6	18.8
20	16.1	17.8	18.8	19.5	20.2	20.6	20.9
22	17.9	19.7	20.7	21.5	22.2	22.7	23.0
24	19.7	21.5	22.6	23.4	24.2	24.7	25.0
26	21.5	23.4	24.5	25.4	26.2	26.7	27.1
28	23.3	25.2	26.4	27.4	28.2	28.8	29.2
30	25.1	27.1	28.3	29.4	30.3	30.8	31.2
32	26.9	28.9	30.3	31.3	32.3	32.8	33.3
34	28.7	30.8	32.2	33.3	34.3	34.9	35.3
36	30.5	32.6	34.1	35.3	36.3	36.9	37.4
38	32.3	34.5	36.0	37.2	38.3	38.9	39.4
40	34.1	36.3	37.9	39.2	40.3	41.0	41.5
42	35.8	38.2	39.8	41.2	42.3	43.0	43.6
44	37.6	40.0	42.7	43.2	44.3	45.0	45.6
46	39.4	41.9	43.7	45.1	46.1	47.1	47.7
48	41.2	43.8	45.6	47.1	48.4	49.1	49.7
50	43.0	45.6	47.5	49.1	50.4	51.1	51.8
52	44.8	47.5	49.4	51.1	52.4	53.2	53.8
54	46.6	49.3	51.3	53.0	54.4	55.2	55.9
56	48.4	51.2	53.2	55.0	56.4	57.2	57.9
58	50.2	53.0	55.1	57.0	58.4	59.3	60.0
60	52.0	54.9	57.1	59.0	60.4	61.3	62.1
62	53.8	56.7	59.0	60.9	62.5	63.3	64.1



## APPENDIX III (Contd.)

DIA (CMS)	STUMP HEIGHT IN CENTEMETER						
	X <sub>1</sub> 30	X <sub>2</sub> 61	X <sub>3</sub> 92	X <sub>4</sub> 122	X <sub>5</sub> 152	X <sub>6</sub> 183	X <sub>7</sub> 213
64	55.6	58.6	60.9	62.9	64.5	65.4	66.2
66	57.4	60.4	63.8	64.9	66.5	67.4	68.2
68	59.2	62.3	64.7	66.9	68.5	69.4	70.3
70	61.0	64.1	66.6	68.8	70.5	71.5	72.3
72	62.8	66.0	68.5	70.8	72.5	73.5	74.4
74	64.6	67.8	70.5	72.8	74.5	75.5	76.4
76	66.4	69.7	72.4	74.8	76.5	77.6	78.5
78	68.2	71.5	74.3	76.7	78.5	79.6	80.6
80	70.0	73.4	76.2	78.7	80.6	81.6	82.6
82	71.8	75.2	78.1	80.7	82.6	83.7	84.7
84	73.6	77.1	80.0	82.6	84.6	85.7	86.7
86	75.4	78.9	81.9	84.6	86.6	87.7	88.8
88	77.1	80.8	83.8	86.6	88.6	89.8	90.8
90	78.9	82.6	85.8	88.6	90.6	91.8	92.9
92	80.7	84.5	87.7	90.5	92.6	93.9	95.0
94	82.5	86.3	89.6	92.5	94.6	95.9	97.0
96	84.3	88.2	91.5	94.5	96.7	97.9	99.1
98	86.1	90.1	93.4	96.5	98.7	100.0	101.1
100	87.9	91.9	95.3	98.4	100.7	102.0	103.0
102	89.7	93.8	97.2	100.4	102.7	104.0	105.2
104	91.5	95.6	99.2	102.4	104.7	106.1	107.3
106	93.3	97.5	101.1	104.4	106.7	108.1	109.3
108	95.1	99.3	103.0	106.3	108.7	110.1	111.4
110	96.9	101.2	104.9	108.3	110.7	112.2	113.5
112	98.7	103.0	106.8	110.3	112.8	114.2	115.5
114	100.5	104.9	108.7	112.3	114.8	116.2	117.6
116	102.3	106.7	110.6	114.2	116.8	118.3	119.6
118	104.1	108.6	112.6	116.2	118.8	120.3	121.7
120	105.9	110.4	114.5	118.2	120.8	122.3	123.7
122	107.7	112.3	116.4	120.2	122.8	124.4	125.8
124	109.5	114.1	118.3	122.1	124.8	126.4	127.8
126	111.3	115.0	120.2	124.1	126.8	128.4	129.9
128	113.1	117.8	122.1	126.1	128.8	130.5	132.0
130	114.9	119.7	124.0	128.1	130.9	132.5	134.0
132	116.7	121.5	126.0	130.0	132.9	134.5	136.1
134	118.5	123.4	127.9	132.0	134.9	136.6	138.1
136	120.3	125.2	129.8	134.0	136.9	138.6	140.2