UGANDA FOREST DEPARTMENT TECHNICAL NOTE

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REGIONAL FOREST OFFICER
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A PRELIMINARY YIELD TABLE FOR CUPRESSUS LUSITANICA GROWN IN PLANTATIONS IN UGANDA.



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REFERENCE

Bruce and Schumacher - Forest Mensuration pp. 395 - 397

LUSITANICA GROWN IN PLANTATIONS IN UGANDA.

Introduction

As short a time as five years ago it was still considered that rotations of 35-40 years were required for growing softwood plantations. The reasons for this assumption are vague but it has been stated for many years that the aim is to produce final crops with a mean diameter overbark of 45 cm (18 inches) and it was expected that growing periods of this length of time were necessary.

2. The major user of exotic softwoods, and in particular Cypress, is the building construction industry where it is used almost entirely for shuttering concrete works. Further limited market research has also indicated that the sizes in greatest demand are boards of 15 cm wide and 2.5 cm in thickness. The demand for larger sizes is limited and even the demand for hardwood timbers greater than 30 cm wide is a market restricted to finer furniture timbers. With this data in mind an economic appraisal of Pinus patula plantations was made and it was found that economic rotations of 20 - 25 years were required and that these would provide a plentiful supply of final crop trees from which the sizes of boards in greatest demand could be cut.

3. The growth and yields of Cypress are very similar to those obtained from Pinus patula and it is expected that the economic rotation will be very similar as price structures as yet show little variation although costs of establishment are slightly greater in Cypress plantations.

4. With an increasing demand for homegrown exotic softwoods from the established sawmills forward planning of supplies now bears a high priority hence the nature of this yield table is a preliminary yield table.

Origin of the Data

5. A system of permanent sample plots in softwood plantations has been in existence in Uganda for many years. These plots are assessed at frequent intervals and the data is compiled and processed by computor at the C.F.I., Oxford. Growth measurement data has been obtained from sample plots, in 7 softwood plantations many of which had been assessed several times.

6. Dominant height was calculated from the 100 trees of largest diameter per hectare and mean height from 250 trees per hectare selected at random.

7. Volume was calculated as silvolume in all sample plots from the following formula:

$$Vs = \frac{D^2H}{100} \times 0.2 \quad \text{or} \quad Vs = B.A. \times H \times 0.3667$$

Where D is in inches and H is in feet and 0.3667 being the form factor under bark.

8. Silvolume is adequately described in T.N. No. 74 of 1959 and T.N. No. 89 of 1961.

Volume

9. Silvolume was converted to a "true" volume over bark in the following manner. The volume of each entry in a two way volume table produced at the C.F.I. for Cypress grown in Uganda was obtained from the following formula:

Volume= Basal Area x Height x Form factor

In each case the form factor was recalculated and the results plotted graphically as a function of diameter and height, see appendix 1. It was then possible to convert the volume of both the main crop and the thinnings by obtaining the appropriate form factor from the graph by the use of the diameter of the mean basal area tree and the mean height of each plot and recalculating the volume as follows:

$$\text{Volume o.b./ac.} = \frac{\text{Silvolume / ac.}}{0.3667} \times \text{Form factor}$$

Total Volume Production

10. Regression analysis of total volume production per acre on dominant height was calculated by several models and the equation of best fit was found to be :

$$\text{Volume} = -1078.42 + 63.19\,H - 0.09702\,H^2 + 0.006867\,H^3$$

Where Volume is in $ft.^3$ o.b./ac.
and H is dominant height in feet.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Variance Ratio F	Coeff. of Linear Correl. R	Determination Coeff. R2	Standard Deviation
Regression	3	1.03539 (09)	3.45130 (08)	1114.90	0.95809	0.91794	556.383
Residual	299	9.25592 (07)	309562				
Total	302	1.12795 (09)					

The figures in brackets ( ) also denote the number of places the decimal point has to be moved.

11. The data was subsequently converted to m^3/ha (o.b.) and a graphical plot of the data is produced in appendix 2.

Dominant Height

12. This is obtained as the mean of the heights of the 100 largest diameter trees per hectare and in the case of sample plots this is the mean of the 4 largest trees per plot. From an analysis of the regression of Dominant Height on Age the following equation was produced:

$$\text{Height} = -3.26287 + 7.14468\ \text{Age} - 0.170935\ \text{Age}^2$$

Where Height is in feet and Age in years.

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	Variance Ratio F	Coeff. of Linear Correl. R	Determination Coeff. R2	Standard Deviation
Regression	2	56285.4	28142.7	403.55	0.85383	0.72902	8.35090
Residual	300	20921.2	69.7375				
Total	302	77206.6					

13. This equation produced odd results from the age of 15 years onwards when the data was used with the volume production curve due to a too rapid culmination of height growth beyond this point. To overcome this problem a separate regression analysis of the data for plots of 15 years and over was carried out with a weighted regression:

$$\frac{\text{Age}^2}{\text{Height}} = 2.37689 + 0.039308\ \text{Age}^2$$

Where Height is in feet and Age in years.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	Variance Ratio F	Coeff.of Linear Correl. R	Determination Coeff. R2	Standard Deviation
Regression	1	2373.0	2373.0	347.34	0.85214	0.72614	2.6139
Residual	131	895.0	6.832				
Total	132	3268.0					

14. Both curves are presented graphically in appendix 3 but in metric units.

Mean Height

15. Mean height is calculated from the heights of 250 trees per hectare (10 per sample plot) selected at random. Regression analysis of the mean height data produced a weighted equation as the best fit to the data as follows:

$$\frac{Age^2}{Height} = 0.893662 + 0.0124297\ Age^2$$

Where the height is measured in feet.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Variance Ratio F	Coeff.of Linear Correl. R	Determination Coeff. R2	Standard Deviation
Regression	1	299.6	299.6	973.22	0.91587	0.83882	0.5549
Residual	187	57.57	0.3079				
Total	188	327.2					

16. The curve is presented graphically in appendix 4 in metric units.

Relationship between Dominant and Mean Heights

17. The relationship between Dominant and Mean height was investigated by subjecting the data to regression analysis. The following equation was found to be the best fit to the data:

Log Mean Ht. = - 0.546987 + 1.11982 Log Dominant Height

Where the height values are in feet.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Variance Ratio F	Coeff. of Linear Correl. R	Determination Coeff. R2	Standard Deviation
Regression	1	25.55	25.55	11452.64	0.99193	0.98393	0.0472
Residual	187	0.4172	0.002231				
Total	188	25.97					

18. The data has been produced in metric units as an alignment chart in appendix 5.

Site Index Curves

19. Employing the regression equations quoted in paras 12 and 13 a series of site index curves were reproduced at 2 metre intervals based on an age of 10 years. The regression equation of the coefficient of variation of the residual heights from the regression curve on age was calculated and the following weighted equation found to be the most suitable:

$$\frac{\text{Age}^2}{\text{Coefficient of Variation}} = -0.00946623 + 0.0137438\ \text{Age}^2$$

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Variance Ratio F	Coeff. of Linear Correl. R	Determination Coeff. R2	Standard Deviation
Regression	1	59.15	59.15	555.44	0.98590	0.97200	0.3263
Residual	16	1,704	0.1065				
Total	17	60.86					

20. The coefficient of variation were than used to produce Height Correction Factors (H.C.F.) :

$$\text{H.C.F.} = \frac{\text{Ht at S.I.Value} - \text{Regr.Ht. at x yrs.} - \text{Regr.Ht at age 10 yrs.}}{\text{Regr. Ht. at age 10 yrs x Coeff. of Var. at 10 years x Coeff. of Var. at x years.}}$$

These height correction factors were then used to correct harmonised site index curves as follows:

$$\text{Ht.at S.I.Value} = \frac{\text{Regr.Ht.} \pm \text{H.C.F. x Coeff.of Var. at x yrs.}}{100}$$

21. The resultant curves are reproduced in metric units in appendix 6.

The Yield Tables

i) Total Volume Production

22. Applying the dominant heights of the Site Index classes the total volume production was obtained converted to metric units using the regression equation in para 10.

ii) Increment

23. Both C.A.I. and M.A.I. were calculated for each S.I. class and the results plotted graphically. It was found that the C.A.I. curves were very uneven, these were smoothed out by eye and the Total Volume Production figures and the M.A.I. figures corrected.

iii) Thinning Yield

24. Because thinning methods have changed during the past 20 years and also because in many instances thinnings were not carried out at the correct specified time or had to be repeated the following year for various reasons it was found impossible to obtain a regression equation that would produce satisfactory yield data. With this lack of adequate information and because the management of Cypress plantations is very similar to the management of Pine plantations reference was made to the Pinus patula yield table in T.N. 167/70. Thinning yields from this source were quoted as a percentage of the total volume production and the following results were obtained:

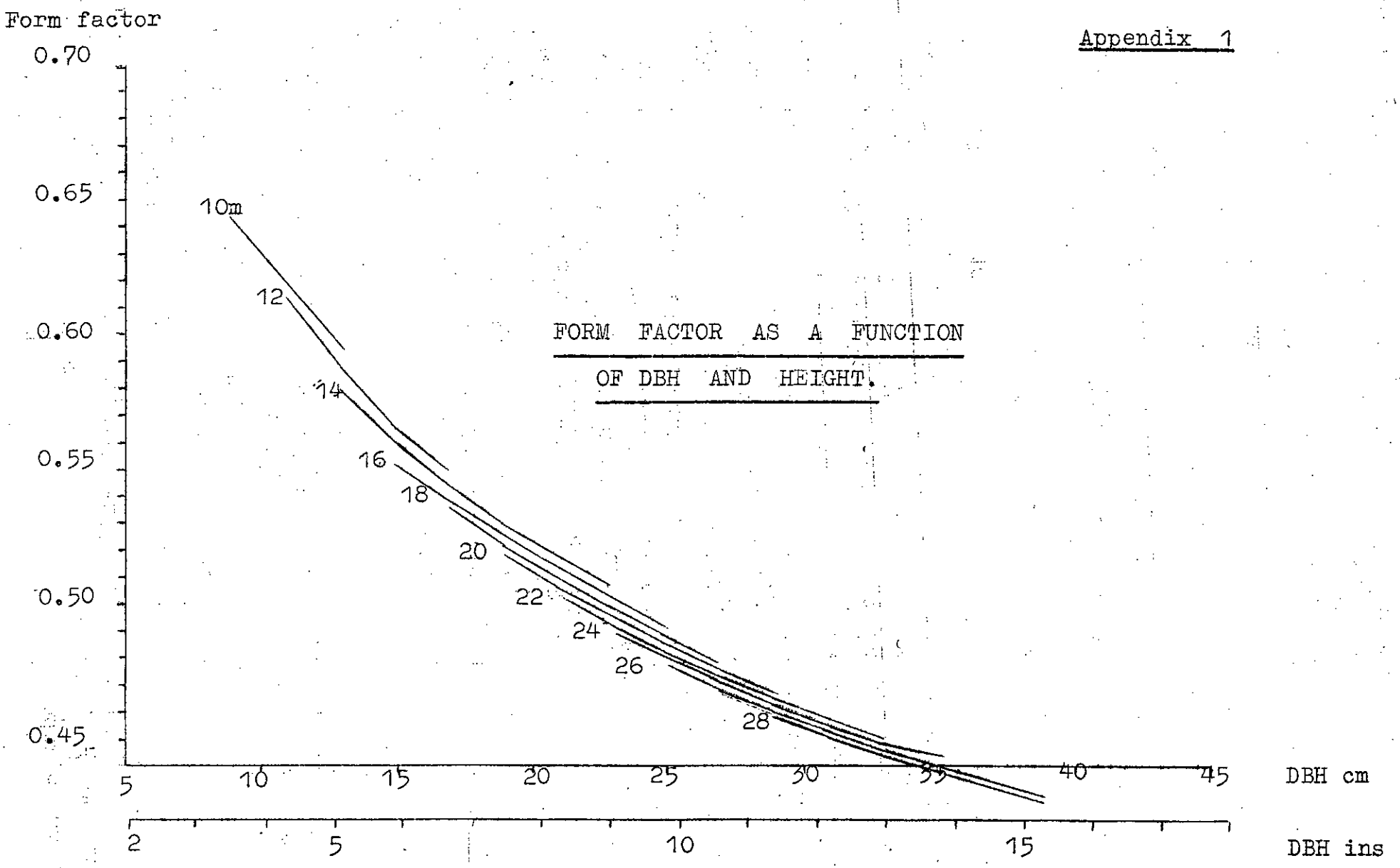
Age	Thinning yield % of Total Volume Production by S.I.					
	50	60	70	80	90	100
8			21	21	21	21
9	21	10				
15			33	33	33	33
16	33	33				
20			28	28	28	28
22	27	28				

25. The following percentage factors were then applied to the Yield Tables

Age	%
7	21
14	33
20	28

26. Extreme caution must be observed in the use of the thinning yields.

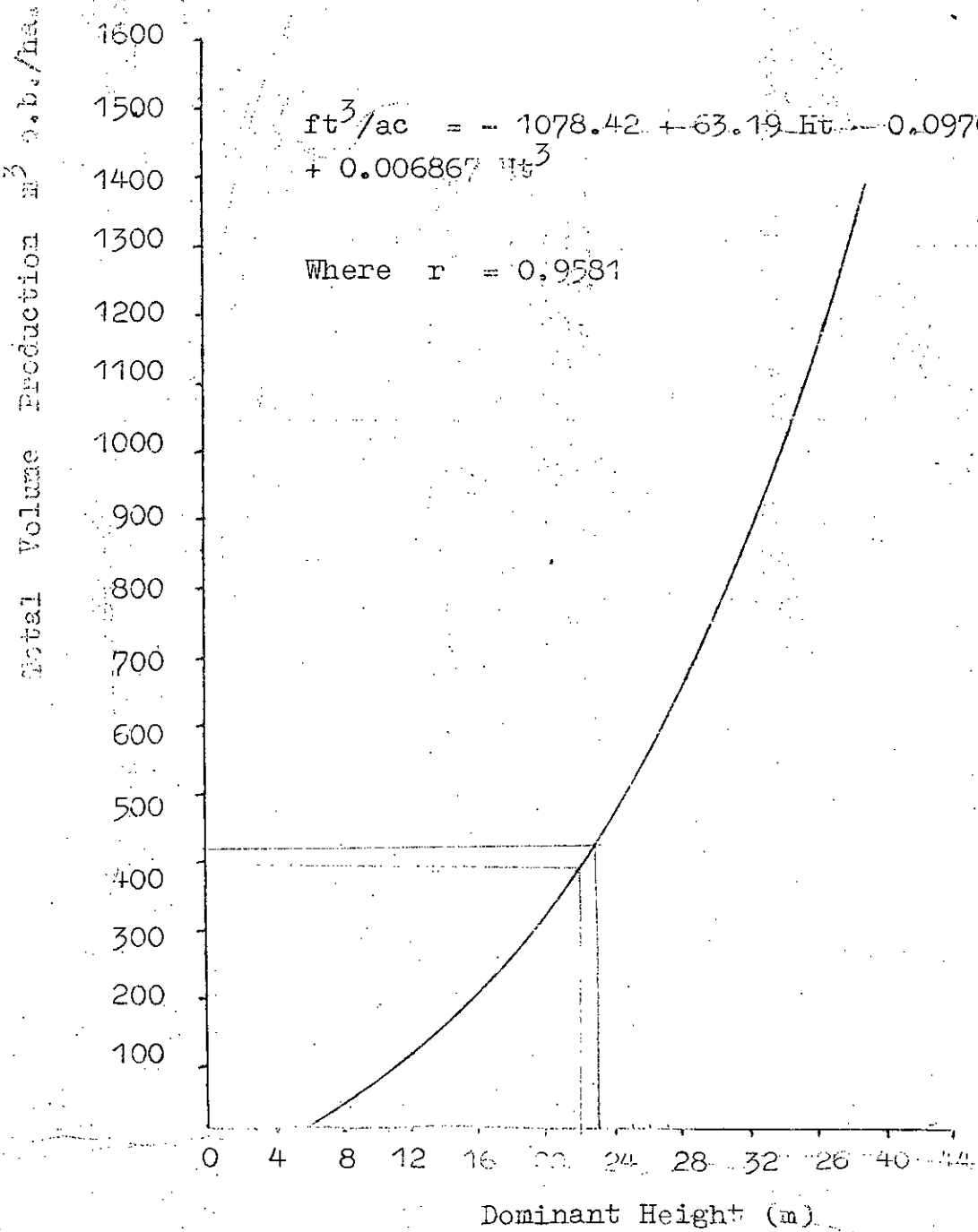
Appendix 1



FORM FACTOR AS A FUNCTION OF DBH AND HEIGHT.

TOTAL VOLUME PRODUCTION ON DOMINANT HEIGHT

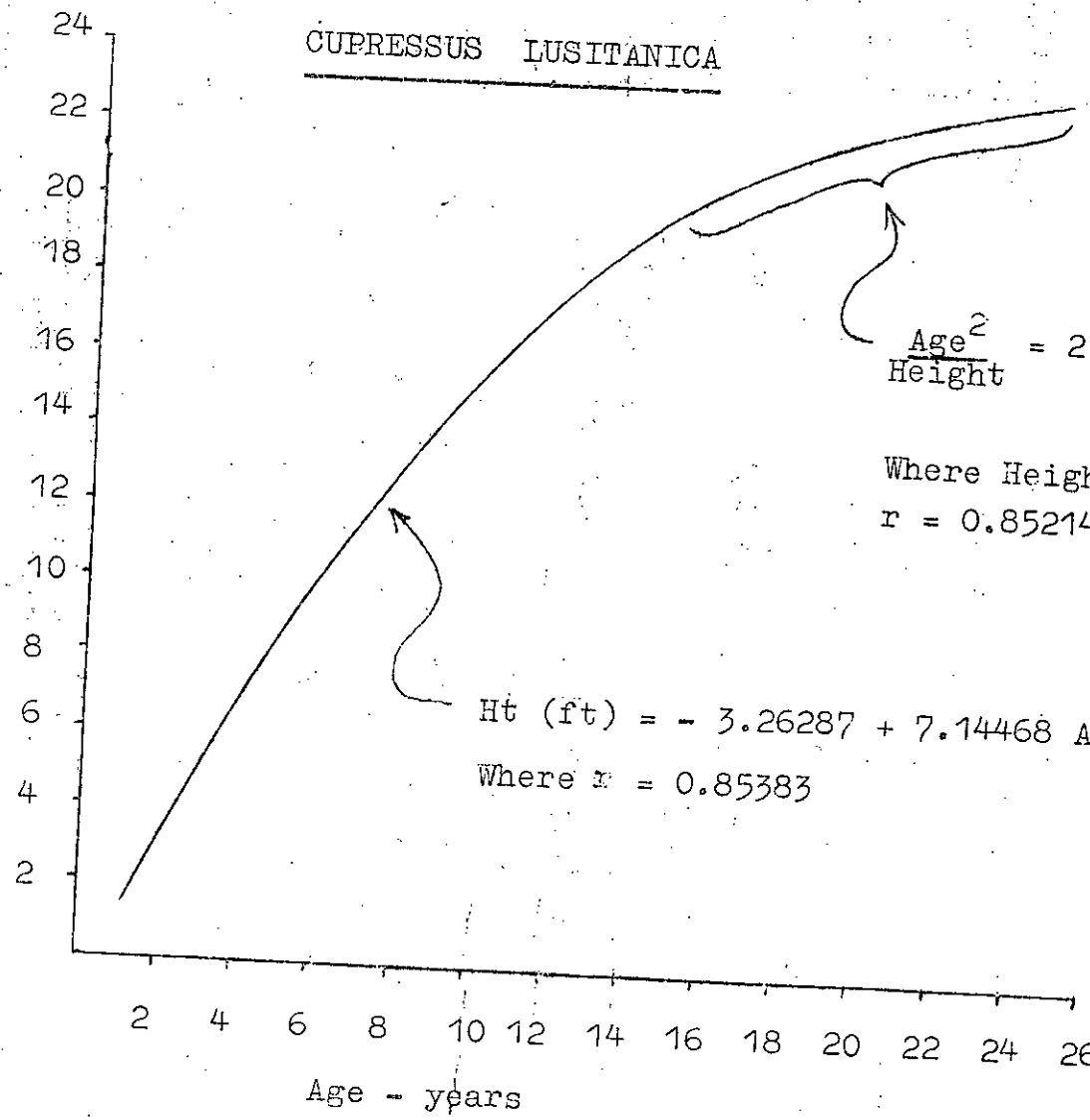
CUPRESSUS LUSITANICA.



Appendix 3

DOMINANT HEIGHT ON AGE

CUPRESSUS LUSITANICA



$$\frac{\text{Age}^2}{\text{Height}} = 2.37689 + 0.039308\ \text{Age}^2$$

Where Height is in feet

$r = 0.85214$

$$\text{Ht (ft)} = -3.26287 + 7.14468\ \text{Age} - 0.170935\ \text{Age}^2$$

Where $r = 0.85383$

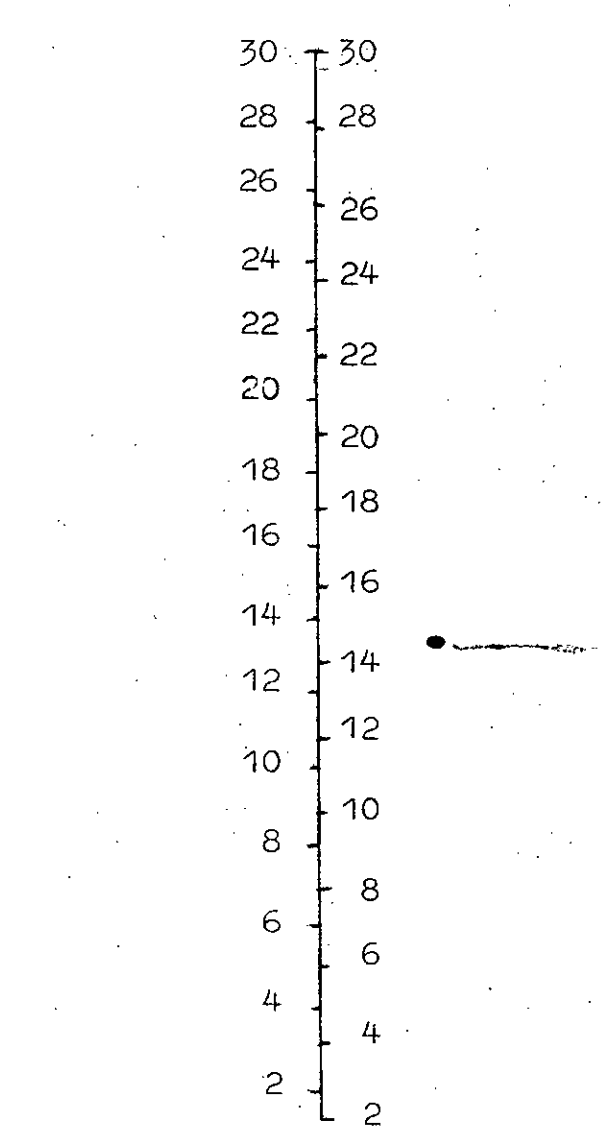
CUPRESSUS LUSITANICA

ALIGNMENT CHART

$$\text{Log } y = -0.546987 + 1.11982 \text{ Log } x$$

Values in feet

$R^2 = 0.98556$



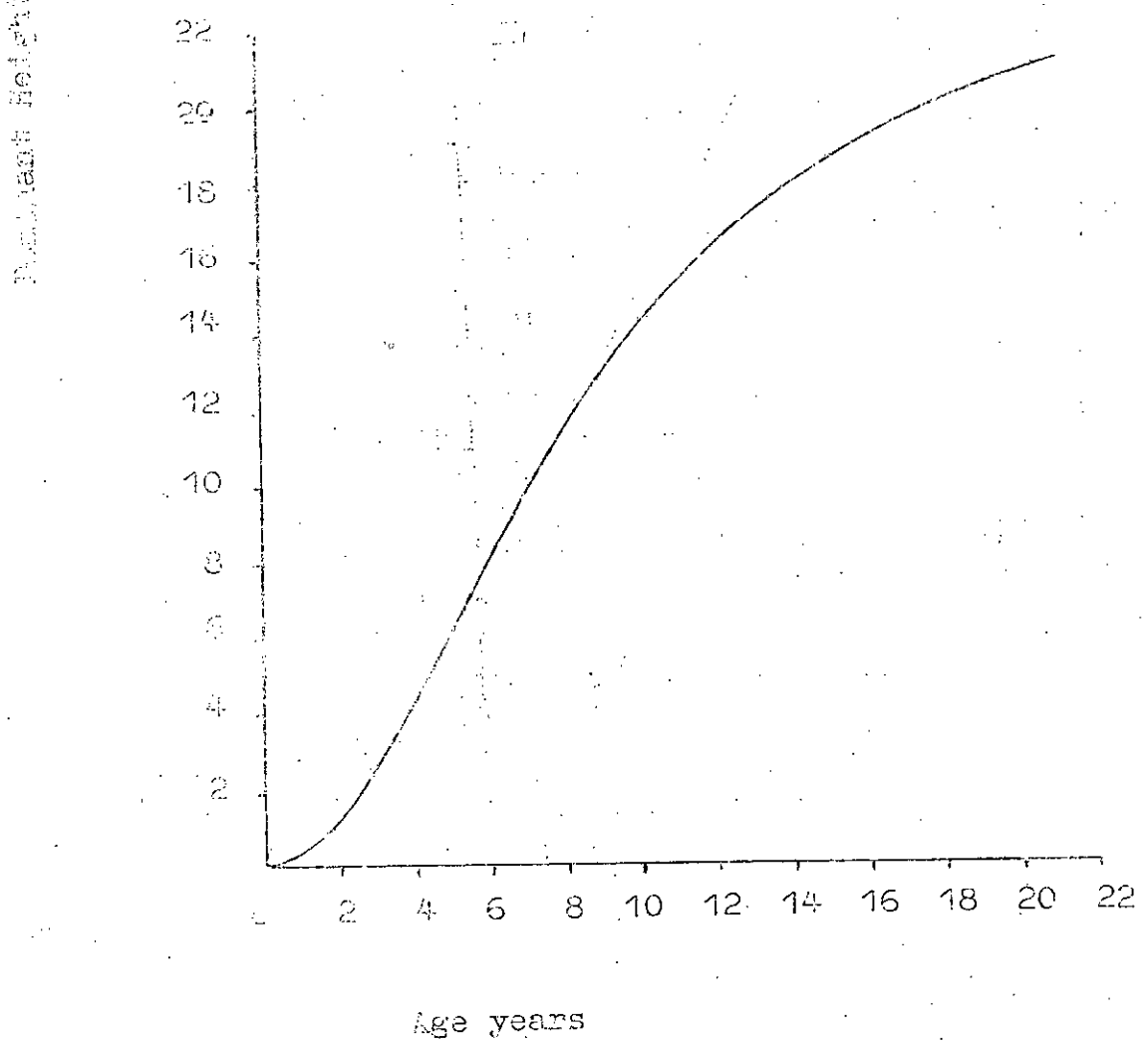
MEAN HEIGHT ON AGE

CUPRESSUS LUSITANICA

$$\frac{Age^2}{Height} = 0.893662 + 0.0124297\ Age^2$$

Where Height is in feet

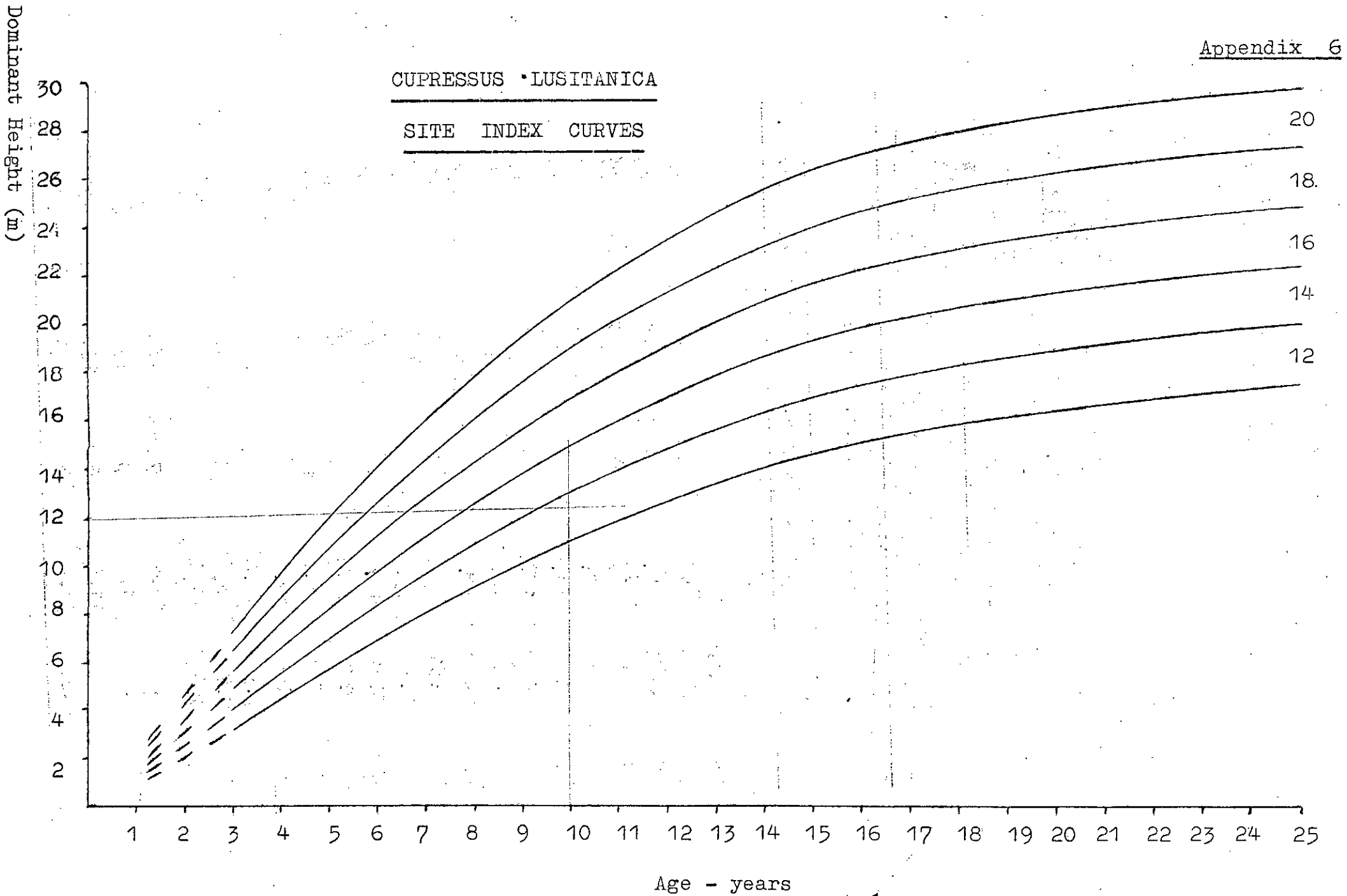
r = 0.91587



Appendix 6

CUPRESSUS LUSITANICA

SITE INDEX CURVES



SITE INDEX 12

Age	$\bar{h}$ dom.	M.A.I.	C.A.I.	Main Crop	Thin Vol.	Total Vol.
Years	m	m3/ha.	m3/ha.	m3/ha.	m3/ha	m3/ha.
3	3.60					
4	5.00					
5	6.34	3.6		18		18
6	7.63	6.5	21	39		39
7	8.84	8.4	20	47	12	59
8	9.97	9.9	20	67		79
9	11.06	11.0	20	87		99
10	12.00	11.8	19	106		118
11	12.93	12.4	18	124		136
12	13.78	12.8	17	141		153
13	14.51	13.0	16	158		169
14	15.18	13.1	15	111	61	184
15	15.84	13.2	14	125		198
16	16.29	13.1	12	137		210
17	16.71	13.0	11	148		221
18	17.08	12.8	10	158		231
19	17.38	12.6	9	167		240
20	17.72	12.4	8	106	69	248
21	17.96	12.1	7	113		255
22	18.19	11.9	7	120		262
23	18.42	11.7	7	127		269
24	18.60	11.5	6	133		275
25	18.81	11.2	5	138		280

Note - C.A.I. smoothed curve to give a smooth Total Volume Curve.

SITE INDEX 14

Age	$\bar{h}$ dom.	M.A.I.	C.A.I.	Main Crop	Thin Vol.	Total Vol.
Years	m	m3/ha	m3/ha	m3/ha	m3/ha	m3/ha
4	6.05	3.3	2	13		13
5	7.60	[illegible].6	2[illegible]	38		38
6	9.07	10.5	2[illegible]	63	18	63
7	10.44	12.6	25	70		88
8	11.72	14.1	25	95		113
9	12.93	15.3	25	120		138
10	14.00	16.2	24	144		162
11	15.02	16.9	24	168		186
12	15.94	17.4	23	191		209
13	16.75	17.8	22	213		231
14	17.48	17.9	20	150	83	251
15	18.20	17.9	18	168		269
16	18.69	17.8	16	184		285
17	19.14	17.6	14	198		299
18	19.52	17.3	12	210		311
19	19.85	16.9	11	221		322
20	20.17	16.6	10	138	93	332
21	20.43	16.2	9	147		341
22	20.68	15.9	8	155		349
23	20.89	15.5	7	162		356
24	21.08	15.1	7	169		363
25	21.27	14.8	6	175		369

Note - C.A.I. smoothed curve to give a smooth Total Volume Curve.

Age	$\bar{h}$ dom	M.A.I.	C.A.I.	Main Crop	Thin Vol.	Total Vol.
Years	m	m3/ha	m3/ha	m3/ha	m3/ha	m3/ha
3	5.24	3.3		1		1
4	7.10	3.5	29	30		30
5	8.86	11.8	29	59		59
6	10.51	14.8	30	89		89
7	12.04	16.9	29	93	25	118
8	13.47	18.5	30	123		148
9	14.79	19.8	30	153		178
10	16.00	20.7	29	182		207
11	17.11	21.5	29	211		236
12	18.10	22.0	28	239		264
13	18.99	22.3	26	265		290
14	19.77	22.4	24	185	104	314
15	20.66	22.4	22	207		336
16	21.10	22.3	20	227		356
17	21.56	21.9	17	244		373
18	21.97	21.6	15	259		388
19	22.32	21.2	13	272		401
20	22.63	20.6	11	168	115	412
21	22.90	20.1	10	178		422
22	23.15	19.6	9	187		431
23	23.36	19.1	8	195		439
24	23.55	18.6	7	202		446
25	23.73	18.1	7	209		453

Note - C.A.I. smoothed curve to give a smooth Total Volume Curve.

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SITE INDEX 18

Age	$\bar{h}$ dom	M.A.I.	C.A.I.	Main Crop	Thin Vol.	Total Vol.
Year	m	m3/ha	m3/ha	m3/ha	m3/ha	m3/ha
3	6.07	4.7		14		14
4	8.16	11.8	33	47		47
5	10.12	16.2	34	81		81
6	11.95	19.3	35	116		116
7	13.65	21.7	36	120	32	152
8	15.21	23.5	36	156		188
9	16.66	24.9	36	192		224
10	18.00	26.1	37	229		261
11	19.20	26.9	35	264		296
12	20.27	27.5	34	298		330
13	21.24	27.8	32	330		362
14	22.07	28.0	30	231	129	392
15	22.92	28.0	28	259		420
16	23.50	27.7	23	282		443
17	23.99	27.2	20	302		463
18	24.41	26.7	17	319		480
19	24.79	26.1	15	334		495
20	25.08	25.4	13	205	142	508
21	25.37	24.8	12	217		520
22	25.64	24.1	10	227		530
23	25.83	23.4	9	236		539
24	26.03	22.8	8	244		547
25	26.19	22.2	7	251		554

Note - C.A.I. smoothed curve to give a smooth Total Volume Curve.

SITE INDEX 20

Age	$\bar{h}$ dom	M.A.I.	C.A.I.	Main Crop	Thin Vol.	Total Vol.
Year	m	m3/ha	m3/ha	m3/ha	m3/ha	m3/ha
3	6.88	8.7		26		26
4	9.21	16.3	39	65		65
5	11.38	21.0	40	105		105
6	13.39	24.3	41	146		146
7	15.25	26.8	42	149	39	188
8	16.96	28.9	43	192		231
9	18.53	30.6	44	236		275
10	20.00	32.0	45	281		320
11	21.29	33.0	43	324		363
12	22.43	33.7	41	365		404
13	23.48	34.2	40	405		444
14	24.36	34.4	38	284	159	482
15	25.27	34.5	35	319		517
16	25.91	34.1	29	348		546
17	26.42	33.5	23	371		569
18	26.85	32.7	20	391		589
19	27.26	31.9	18	409		607
20	27.54	31.2	16	251	174	623
21	27.84	30.3	14	265		637
22	28.11	29.5	12	277		649
23	28.30	28.7	10	287		659
24	28.50	27.8	9	296		668
25	28.65	27.0	8	304		676

Note - C,A.I. smoothed curve to give a smoothed Total Volume Curve.