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PLANTATION-GROWN *PINUS PATULA*
FROM THE VIPHYA PLATEAU, MALAWI

by

P.G. Adlard
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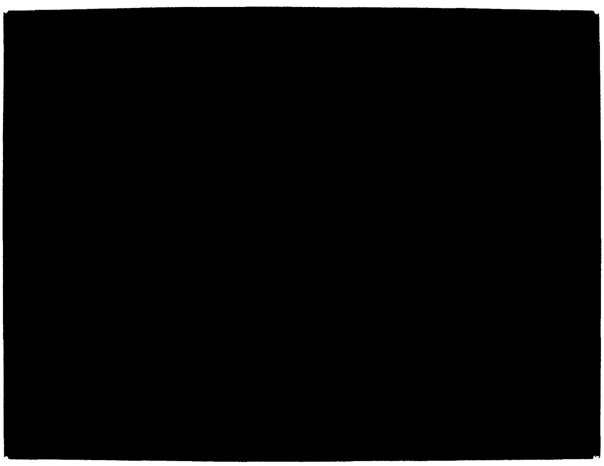
1979

DEPARTMENT OF FORESTRY
COMMONWEALTH FORESTRY INSTITUTE
UNIVERSITY OF OXFORD



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SUMMARY

Wood density was analysed on sections cut from a random sample of 78 trees of *Pinus patula* Schiede and Deppe aged between 4 and 18 years selected throughout the site range planted for pulpwood production on the Viphya plateau, Malawi. The sampled trees were stratified by age and altitude. Mean tree density was determined by analysis of separate growth rings along two radii on discs cut six levels up the stem of each tree. The correlation between mean tree density and topographic position, slope and exposure, as indicators of site differences, were investigated.

Topographic position, age and tree size accounted for 79% and 71% of the variation in wood density in two older strata but otherwise were not significant. The mean tree density for the whole plantation area based on samples from near the base of each tree, ignoring within-tree variation due to sampling height was estimated to be 0.454 ± 0.0153 g/cm^3. The pattern of mean tree density in relation to tree age is illustrated and suggests that the juvenile core of lighter wood persists till 6-8 years of age.

1 INTRODUCTION

1.1 An inventory of the plantation of *Pinus patula* Schiede and Deppe and *Pinus elliottii* Engelm. was carried out between April and June 1974 by a team from the Commonwealth Forestry Institute, Oxford under the auspices of FAO (Adlard *et al.*, 1974). The object of the inventory was to estimate the standing volume of timber and to predict potential yield of pulpwood from existing plantations as well as from those area of the Viphya expected to be afforested in the future.

1.2 The inventory provided essential information for decisions on the capacity of, and date for starting, a proposed pulp mill in the area. As the results were given in terms of total wood volume increment, assumptions had to be made on wood density to interpret the figures in terms of dry matter production - a more relevant parameter for prediction of raw material input required to a pulp mill. Wood samples were therefore collected during the inventory to provide material on which wood density studies could be carried out, to ascertain how wood density varied between stands established on the range of sites occurring in the area and to determine mean values of density for estimating dry matter production from the plantations.

1.3 Previous studies have shown that large between-tree variation in wood density occurred in *Pinus patula* stands but that between-site differences were small. For example, Plumptre (*see* Wormald, 1975, pp. 117-127) found that site differences accounted for less than 10%

of the total variation in wood density in timber samples from four sites differing in altitude and climate. In the only detailed study of which we are aware on the wood properties of Pinus patula from Malawi less than 4% of the total variation in wood density is attributed to sites within the same climatic region and 12% to individual trees (Burley, 1973). The largest source of variation was due to differences between rings within trees. In the same study the overall mean density for 22 year-old trees in Dedza (in central Malawi, 300 km south of the Viphya plateau) was estimated to be 0.451 g/cc corresponding closely to our estimate of 0.454g/cc.

1.4 Pinus patula is planted on a wide range of sites on the Viphya Plateau and its eastern escarpment slopes. These range in altitude from 1350m to 1800m and in mean annual rainfall from 900 mm to 1500 mm. The topography, especially on the escarpment, is highly dissected and consequently marked differences in precipitation, soil depth and moisture retention, and exposure to wind occur within short distances. It was necessary to investigate whether this degree of site variation, known to have a strong influence on variation in the productivity of wood volume, is also associated with differences in wood density.

2 METHODS

2.1 Selection of sample trees

78 trees were selected for wood density assessments at 62 sample points. These were a subsample of c. 3500 sample points assessed in the growing-stock inventory.

2.2 Assessment of site factors

Details of the sampling design are given in Adlard et al.(1974). The two-stage sampling procedure took altitude, an integrator of macro-climatic factors, as the basis for the primary stratification of the inventory area (Table 1). Local site factors (edaphic and microclimatic) were crudely assessed by indices of topographic position, slope and exposure. These were used to classify samples after the collection of data by 'post-stratification'.

The effect of site on density has been investigated in this report using topographic position scored on a scale of 1 to 5 as an independent variable in regression analyses with mean tree density as the dependent variable. Exposure scores were also used but proved to be less efficient at explaining variation than topographic position.

2.3 Selection of wood samples

At each of the 62 sample points selected for collection of volume data five trees were felled. These were representative of the range of tree diameters in the stand. Discs were cut from the largest of the felled trees at each sample point at six levels on the stem, at stump and at 5, 15, 25, 45 and 75 percent of the total tree height. In addition, at four sample points in older stands (compartments 98, 99, 158 and 181 at Chikangawa all within stratum 2) discs were cut at the same levels from all 5 felled trees at each sample point. Thus of the 78 trees sampled for density assessment 62 represent 'sites' and provide

TABLE 1

Stratification of Pinus patula stands

Stratum No.	Age years	Altitude m	Area ha	No. of trees sampled
1	10-22	1350-1500	1148	9
2	10-21	1500-1675	1418	39*
4	9	not differentiated	1129	12
5	8	1350-1500	957	2
6	8	1500-1675	1055	2
7	8	1675-1800	1788	2
8	7	1350-1500	1682	2
9	7	1500-1675	2480	2
10	7	1675-1800	871	2
11	6	1350-1675	2240	2
12	6	1675-1800	3096	3
13	5	not differentiated	2469	1

* from 23 secondary sample points: at 4 sample points 5 trees were sampled from the diameter range of the crop; elsewhere only a dominant or co-dominant tree was sampled, one at each sample point.

material for investigating the relation of density variation with site while 16 additional trees provide data for the study of variation between tree dominance classes within a site. Sections (2 x 7 cm) were cut from each disc from two randomly selected radii using a small band saw. The 12 wood samples from each tree were sent to Oxford for density assessment.

A large proportion of the samples were from the first two strata of the inventory design covering a wide range of age classes.

The older plantations, aged 10 or more years in 1974 are concentrated in three relatively small areas of the Viphya at Chikangawa (mainly over 1500m), Lusangazi and Luwawa (mainly below 1500m). The area planted annually before 1965 was too small to justify the separation of these stands into strata containing a narrower range of age-classes for inventory purposes. However for collection of wood samples the older trees provide more information and the range of ages has been sampled uniformly.

2.4 Measurement of wood density

Measurements of ring density along each radius were made using 5mm strips machined from the sample material. The strips were extracted in a 2:1 solution of benzene and alcohol for 24 hours, conditioned to 12% mc and X-rayed in accordance with the procedure established by

Hughes and Sardinha (1975). The resulting film was scanned with a Joyce Loebl microdensitometer fitted with a non-linear wedge and adjusted to give point measurements of density at intervals of 200 μm. These measurements were grouped into sequences corresponding to each period of annual growth and analysed using programs X-RAYDENS and SHEATH which first convert the data into measurements of gravimetric density (g/cc) and then, by considering values for each radius at all levels, calculate the mean density, volume and dry matter yield for each year of growth (the 'sheath' values in Appendix II). Summation of these data for successive sheaths provides mean values for the whole tree in each year of its growth (the 'tree values' in Appendix I and II). The mean tree density in each case was weighted by sheath volume.

3 RESULTS

3.1 A summary of the weighted mean tree densities for the 78 trees studied, together with selected tree and site parameters, is given as Appendix I. Each tree is identified by its compartment number and the number of the sample point around which the tree was felled. For each of the four groups of five trees felled near single sample points in stratum 2 the site parameters, topographic position, exposure and slope, and the density of the stand are the same. Stand density is quantified by the spacing percent index (the ratio of mean growing space to stand dominant height expressed as a percentage). Some explanatory notes are given at the foot of the table in Appendix I (sample tree and site data).

3.2 Principal components

Analysis of the data of Appendix I by orthogonalized regression gives some indication of the patterns of variation and inter-correlations in the data. The first three components accounted for 76% of the total variation; the first component (Table 2) was associated with tree size variables and the second predominantly with site variables, but the low proportion of total variation accounted for shows that important sources of variation have not been adequately quantified. Obviously genotype, which has been ignored, is a source of much unexplained, and in this study, unquantifiable variation.

The crude description of 'site' by a simple scoring of topographic position, exposure and slope cannot be expected to account for those factors of the site affecting growth (physical and chemical soil properties, rooting depth, soil and atmospheric moisture regimes) except in very general terms. Grouping low, medium and high altitude strata tends to group plots with high, medium and low rainfall respectively, but no account is taken of temperature, which bears an inverse relation to altitude. Only when more precise climatic parameters are quantified for the Viphya plateau, where there is great variability over short distances, will more precision be obtained in accounting for site effects on growth rates and wood density. It will also be noticed that the majority of the sample points at which selected trees were taken are on topographic positions 2 and 3, reflecting the predominance of these sites in the plantation area.

TABLE 2

Principal component analysis - tree mean data

		% Variation accounted for
Principal component	1:	46
" "	1 & 2	65
" "	1, 2 & 3	76

Variable:	Component 1	Component 2	Component 3
	Scaled eigenvectors		
Stratum	-0.873	0.136	-0.095
Date of 1st ring	-0.991	0.247	-0.074
Topographic position	0.152	1.000	-0.051
Exposure	0.096	0.962	-0.438
Slope	-0.017	0.507	1.000
Total tree height	1.000	0.108	0.095
Diameter bh	0.955	-0.011	-0.220
Spacing index	-0.586	-0.643	-0.111
Wood density	0.609	-0.426	0.262
Wood volume	0.920	-0.100	-0.217

Bearing in mind that the data under consideration were obtained as part of a standard growing stock inventory and not from a research study, and that one object of the inventory was to obtain an overall estimate of mean wood density over relatively large area the site variables selected do discriminate between trees to a useful degree. Figure 1 shows a plot of sample tree numbers on principal components 1 (x-axis) and 2 (y-axis). Large trees tend to appear on the right and trees on valley and lower slopes to the top of the diagram. Strata 1 and 2 overlap but trees growing on ridges in stratum 2 (43 and 47) are clearly discriminated from those growing on protected sites (44 and 46). This method of data presentation will aid interpretation of the regression analyses in the next section.

3.3 Regression analyses

As implied above close correlations between wood density and tree and site variables cannot be expected in this study. However, a number of linear and non-linear regressions were tested using wood density as the dependent variable. Non-linear regressions of density as a function of tree size, spacing index and age were of low significance.

The only linear multiple regression of interest was that relating density to age, volume and topographic position. The coefficients are given in Table 3.

TABLE 3

Coefficients for multiple linear regression

Wood density in relation to topographic position, age and tree size

Stratum	r^2	DENSITY = a a	+ b x (TOPOG) b	+ c x (AGE) c	+ d x (VOLUME) d
1	0.79	-746.5	-43.64	18.94	280.2
2	0.43	1493.0	6.40	-16.47	-88.74
4	0.71	422.0	25.38	0	-383.4

Attempts to relate density to strata, topography and exposure for growth rings of common physiological age for various groups of strata all proved non-significant. The conclusion drawn from these analyses is that for the objects of this study no significant improvement in the precision of mean tree densities can be expected by taking growth rate (from volume and age) or site (topographic position) into account.

3.4 Within-tree and between-tree variation

A measure of the variation pattern in the sample material is given in the analysis of variance of density of 2 radii, on 6 rings, 6 levels and 60 trees (table 4). The difficulties of analysing anorthogonal data have been side-stepped by selecting 6 rings of common physiological age in 60 trees covering all strata.

In order to compare density between strata of different ages more information on between-tree variation is obtained from an analysis of the data from the 5%-bole level only - where the maximum number of rings occurs. We distinguish between 'mean tree density' and '5% density' in the discussion below. The former is the weighted mean density of a variable number of rings on 2 radii and 6 bole levels; the latter is the weighted mean of a variable number of rings on 2 radii at the 5% bole level only. These means are compared for strata 1 and 2 and all strata combined in table 5. Mean tree density is the arithmetic mean of the weighted means for each tree given in Appendix I. 5% means are derived from analyses not given here. Use of the 5% mean is justified firstly by the assumption that whole tree stems will be pulped and that only the random between-tree variation is of interest in reaching a measure of mean wood density in this context and secondly by the evidence provided by Paterson (1967) and Plumptre (pers. comm.) which shows that mean tree density can be reliably predicted from measurements taken at the 5% level in *Pinus patula*.

TABLE 4

Analysis of variance of density of 6 rings, 2 radii, 6 levels on bole and 60 trees

Mixed model: Trees and radii, random; Rings and levels, fixed.

Item	Source	d.f.	Mean square	F	Tested against item	% Variance (from component analysis)
1	Trees	59	0.06339	36.0	4	19.7
2	Between levels	5	0.1165	14.1	3	3.0
3	Trees x levels	295	0.008272	4.5	4	11.1
4	Radii-in-levels and-trees	360	0.001840	1.0	8	2.4
5	Between rings	5	0.6790	106.6	6	19.6
6	Trees x radii	295	0.06367	5.6	8	9.4
7	Levels x radii	15	0.03089	16.23	8	3.5
8	Residual	2085	0.001902			31.3
	TOTAL	3119				

TABLE 5

Mean tree density and 5% density : all sites

Stratum	5% density	Standard error	Coefficient of variation %	Mean tree density
1	0.482	0.0129	2.68	0.454
2	0.455	0.0172	3.79	0.466
4-12	-	-	-	0.423
All *P. patula*	0.454	0.0153	3.36	0.445

3.5 Mean tree density variation with age

A tree-by-tree summary of successive growth layers or sheaths, from the pith outwards giving volumes, dry matter and density for each sheath as well as cumulative values, is reproduced as Appendix II . The pattern of density variation with age of formation of the growth ring is important in defining the juvenile core and for showing the effect of increasing rotation age on mean tree density. The mean densities for all sample trees within different strata are shown in figures 2-5. In strata 1 and 2 the average values include trees of different ages. Therefore, in order to illustrate the relation between density and age, values for the oldest tree within both stratum 1 and 2 are also plotted in figures 2 and 3.

There is some uncertainty over the age of the oldest tree (TN2) in stratum 1. The best 'guess' indicated assumes 'loss' of three rings at the centre and inaccuracy in the actual planting date for the compartment from which the tree was selected. In the early plantings on the Viphya frequent replacement of failed plants occurred so that establishment may have extended two or three years after the date of the original planting operation. The pattern of density in relation to age is similar in the data of all strata investigated. However, low density occurs in the the first 2-3 years, rising rapidly to years 6-8 thereafter increasing more slowly. The higher density of the first sheath studied is a result of this sheath being restricted to within a short distance from the base of the tree. The reduction in density at age 10 in stratum 1 may be associated with a heavy first thinning that would have occurred at around that time. A similar but less marked decline occurs with TN10 at age 11. Evidently the effects of a thinning will depend on the nature and severity of the release from competition experienced by the individual tree but information is lacking to pursue these conjectures further. It should be noted that no thinnings have occurred in strata 4-10.

3.6 Variation in density between tree classes

It has already been pointed out that dominant trees have been selected as trees for the extraction of wood samples at all randomly selected sample points. In order to show whether this would cause any bias in the estimates of mean tree density, trees covering the range of tree classes were selected at four sample points in the older stands of stratum 2 (see Appendix I); the compartments were C158C, C98A, C99A and C181B including sample tree numbers 12 to 26 and 31 to 35.

The mean tree densities for these 20 trees by diameter class and compartment and an analysis of this variance are shown in Table 6A and 6B.

TABLE 6A

Mean tree density g/cc within-site variation between tree classes

Sample point: Age (year) :	C158E/10 19	C98A/16 17	C99A/8 17	C181B/12 15	Means
Tree classes*					
1	0.490	0.535	0.487	0.466	0.494
2	0.428	0.484	0.437	0.484	0.458
3	0.496	0.543	0.456	0.471	0.492
4	0.528	0.446	0.518	0.530	0.505
5	0.400	0.443	0.486	0.520	0.462
Means	0.468	0.490	0.477	0.494	0.482

* Tree class 1 was selected from the top 20% of the diameter range;
Tree class 2 was selected from trees within 60-80% of diameter range etc.

TABLE 6B

Analysis of between-tree variation within sites

Analysis of variance:	df	SS	MS	F
Between sample points	3	7008.3	2336.10	1.37 NS
Between tree classes	4	2137.2	534.30	<1 NS
Residual	12	20385.3	1698.78	
Total SS	19	29530.8		

The between-tree-class variation is of no significance in this small sample and suggests that it can safely be ignored for estimation of mean density over a range of sites and that there is no evidence of bias as a result of selecting trees from the top 20% of the diameter range of the stand at the remaining sample points. The annual cumulative mean densities for five trees from one sample point are illustrated in figure 6.

4 CONCLUSIONS

Analysis of the data has shown that the 5%-density can be estimated with reasonable precision for the total plantation area, and only a small improvement in the precision of the estimate of mean tree density may be obtained by considering the effect of site factors for trees at a rotation age of about 15 years. It is recommended that further studies are carried out in order to quantify 'site' more adequately. Detailed measures of topographic position, exposure, aspect, nature of slope, soil depth and texture should be made at the relocatable sample points around which the sample trees were felled. Estimates of sample tree growing space and history of thinning round the sample trees could be obtained from compartment records and stump analyses. These data would enable further analyses to be carried out that could lead to indications of the effect of silvicultural management on individual tree density. Within-tree density variation can also be analysed and related to local site and treatment effects if such additional field observations become available.

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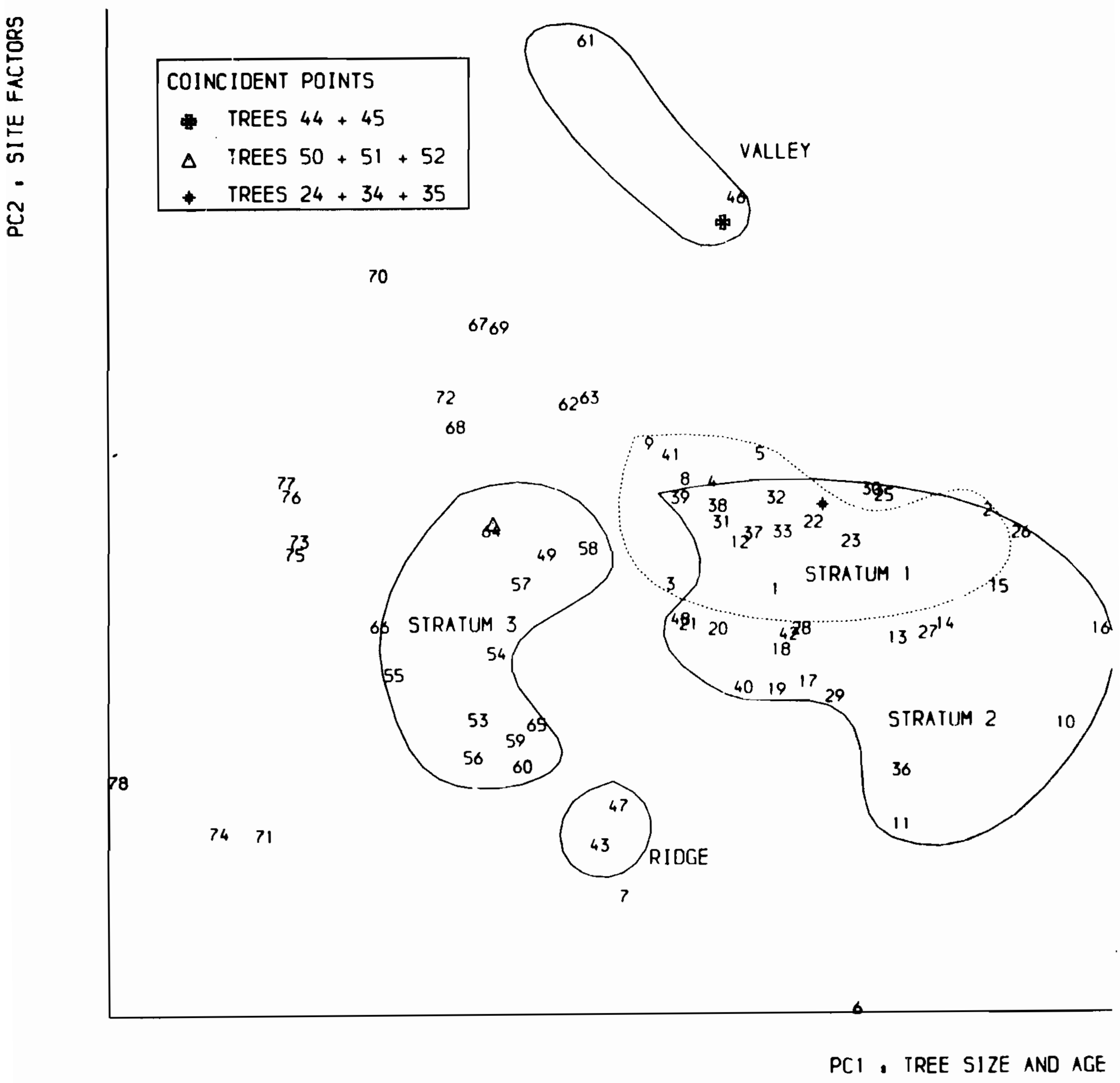

Figure 1.

Plot of sample trees on the first two principal components of variation.
PC = principal component.
Numbers refer to sample trees (See Appendix I).

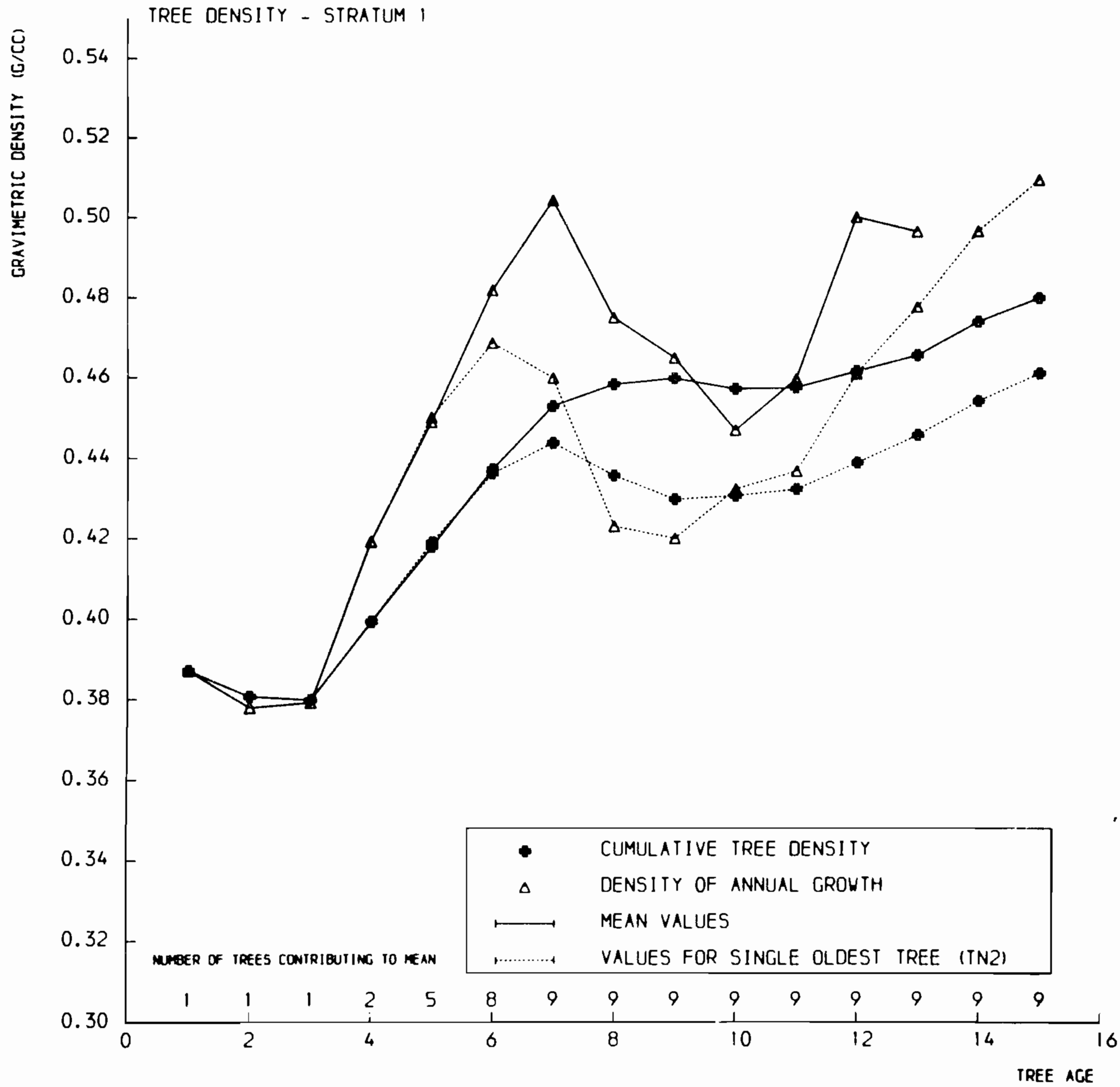

Figure 2.

Mean density of annual growth and cumulative density for successive years for all sample trees in Stratum 1.

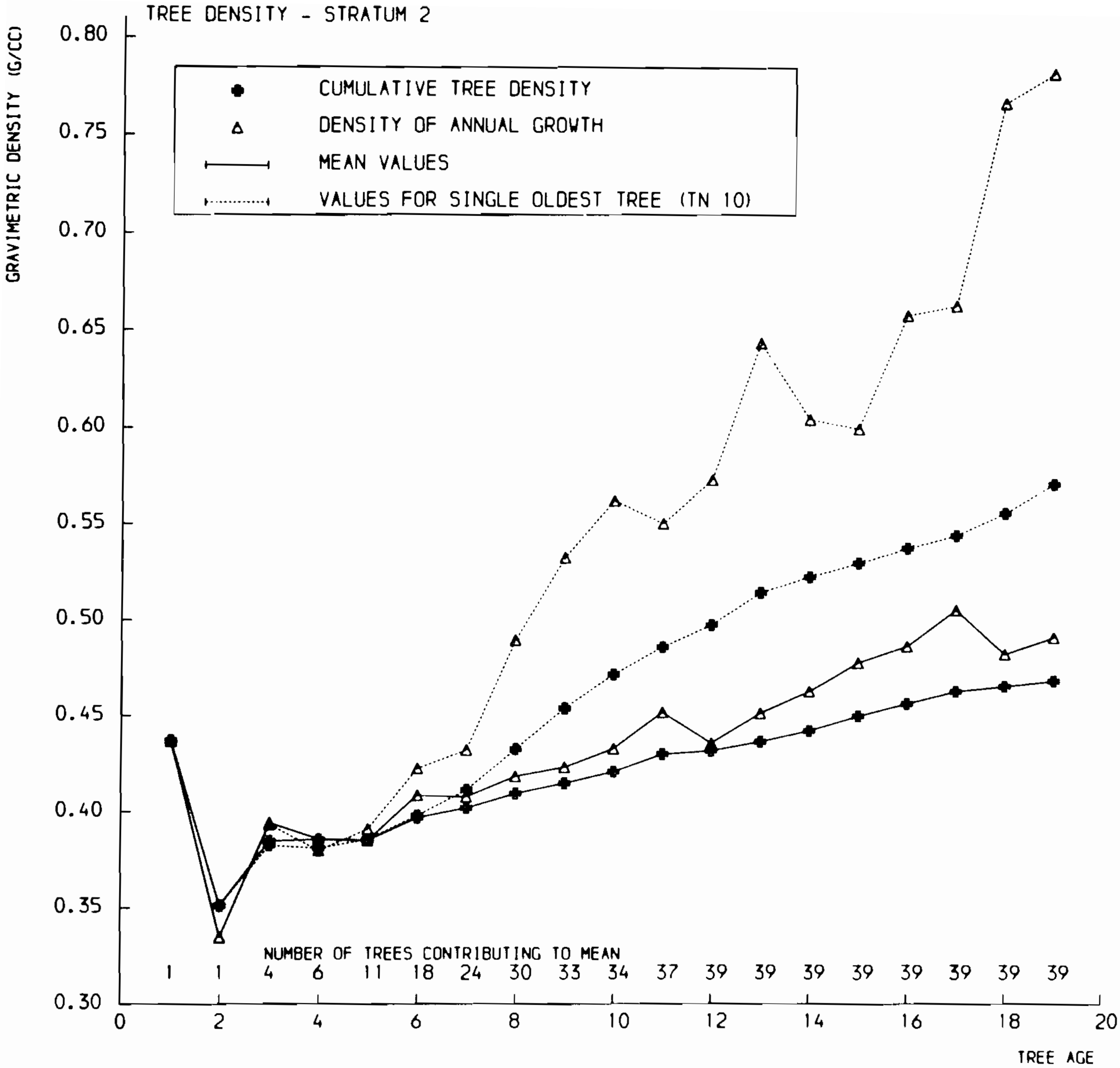

Figure 3.

Mean density of annual growth and cumulative density for successive years for all sample trees in Stratum 2.

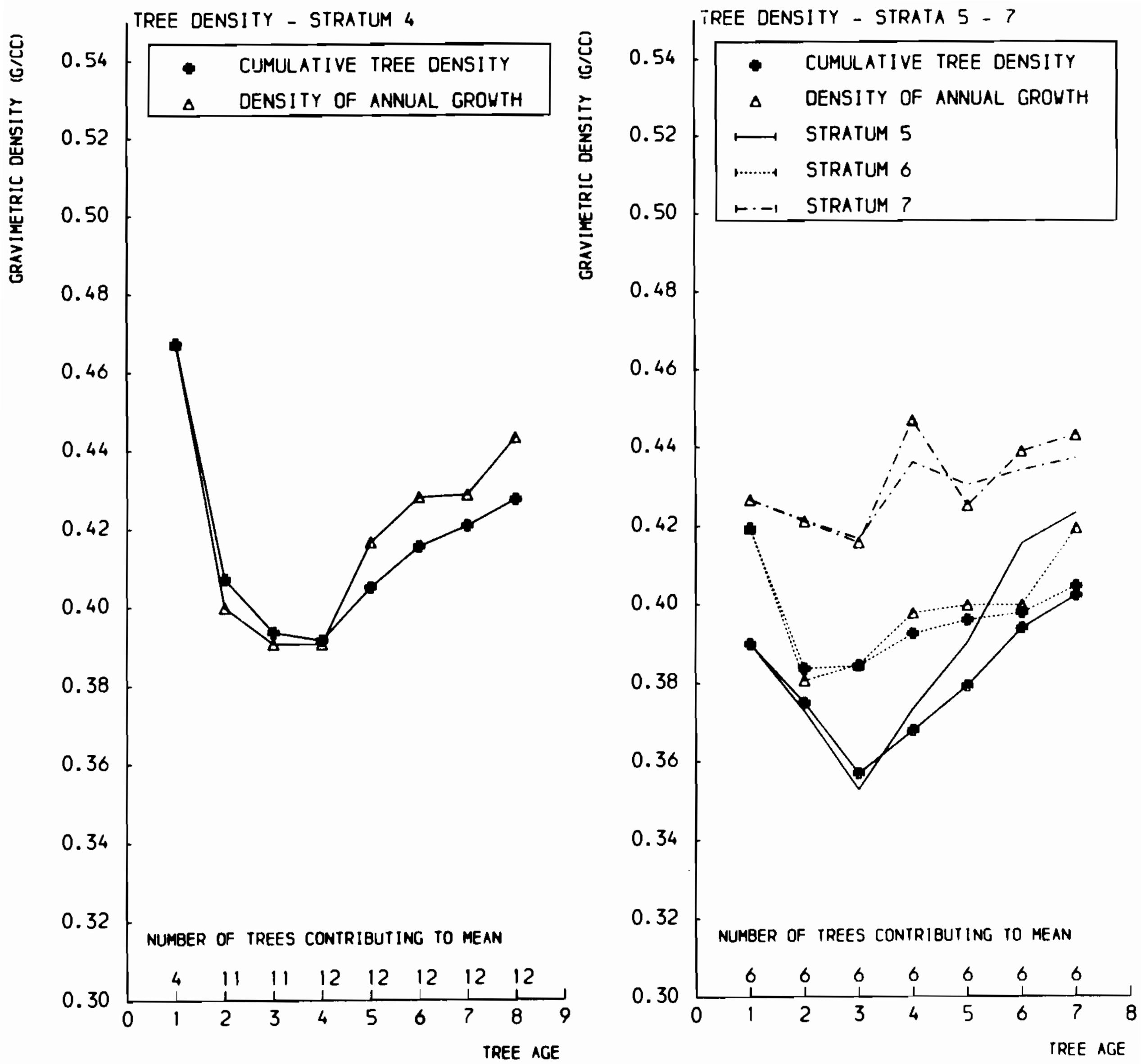

Figure 4.

Mean density of annual growth and cumulative density for successive years for all sample trees in Stratum 4 and Strata 5 - 7.

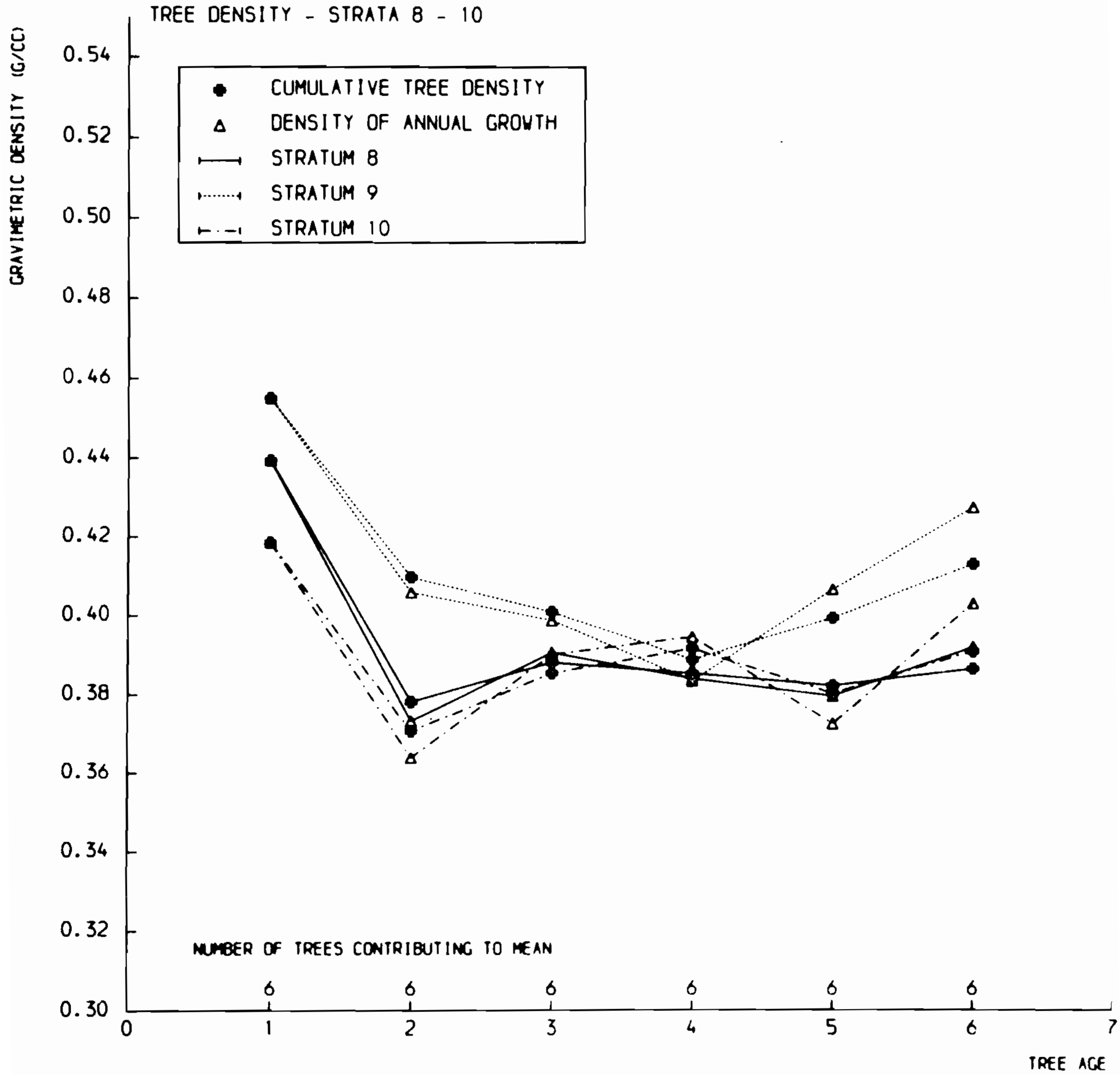

Figure 5.

Mean density of annual growth and cumulative density for successive years for all sample trees in Strata 8 - 10.

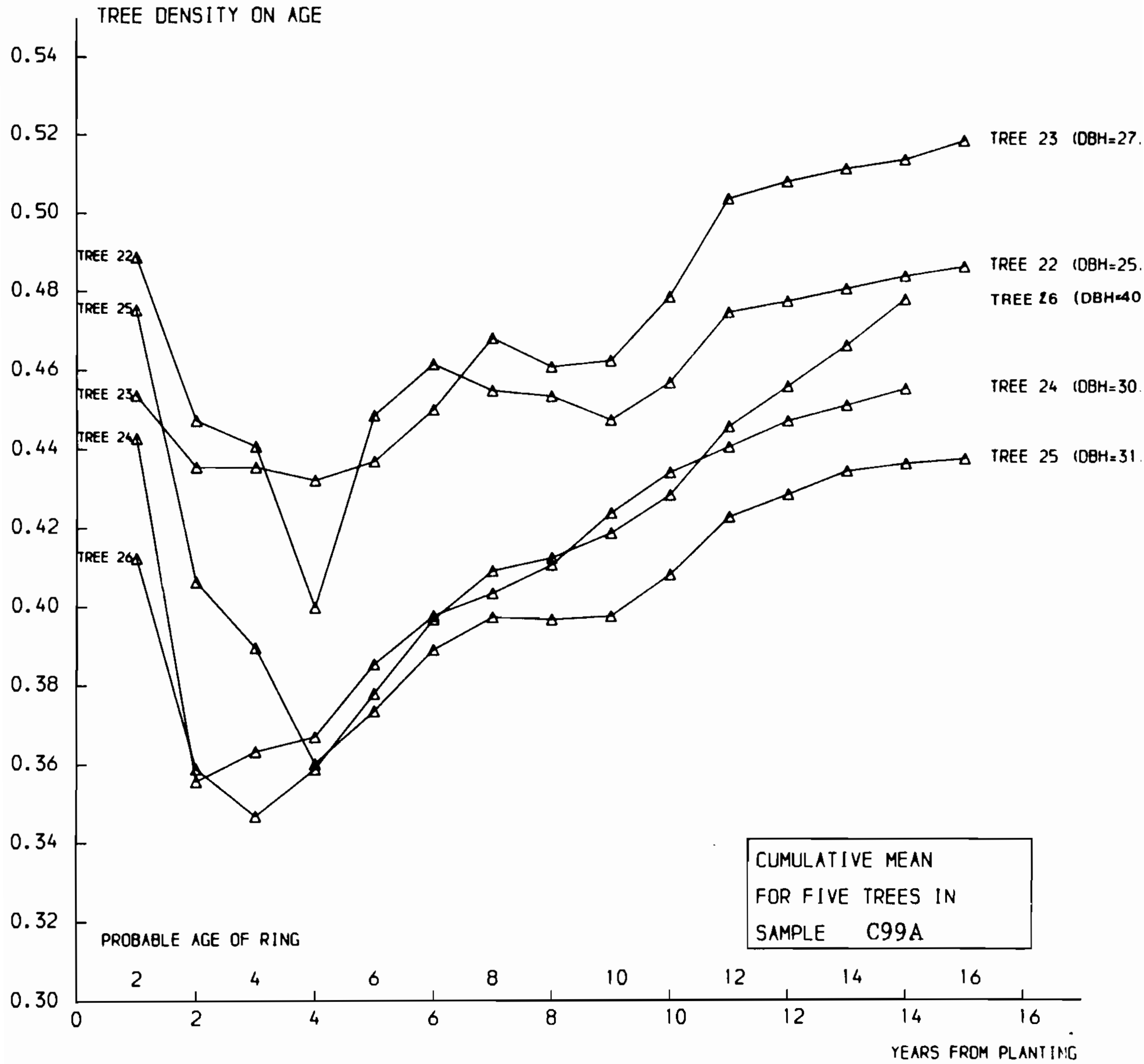

Figure 6.

Annual cumulative mean densities for five trees from a single site in stratum 2.

APPENDIX I

Sample tree and site data as at end of 1972/73 growing season

TREE No.	COMP. No.	SAMPLE POINT No.	DATE OF[1] 1st RING Year	TREE DATA[2] Dbh cm	Ht m	Volume m^3	Density g/cm^3	SITE DATA[3] Topog. 1-5	Exp. 1-3	Slope %	STAND[4] SPACING INDEX %
1	2	3	4	5	6	7	8	9	10	11	12
Stratum 1:											
1	N2A	16	63	26.6	19.0	0.414	0.465	2	2	8	21
2	N13A	2	59	29.9	26.4	0.834	0.480	3	2	10	18
3	N43A	3	64	21.8	16.5	0.201	0.431	2	2	0	19
4	N46A	2	63	21.9	18.7	0.263	0.418	2	2	20	15
5	L9A	10	62	32.6	18.0	0.311	0.414	2	1	5	23
6	L19A	4	63	27.9	16.1	0.404	0.515	1	1	0	54
7	L21A	8	64	22.5	10.9	0.241	0.511	1	1	0	32
8	L36B	1	64	23.4	17.2	0.246	0.439	3	2	15	25
9	L81D	6	65	22.5	14.5	0.284	0.412	3	2	15	21
Stratum 2:											
10	C151B	5	55	36.1	21.3	0.918	0.571	2	2	0	21*
11	C87B	1	57	38.0	24.4	0.746	0.474	1	1	4	20
12	C158C	10	62	24.0	20.4	0.340	0.400	2	2	6	18*
13	C158C	10	57	27.0	21.6	0.396	0.528	2	2	6	18*
14	C158C	10	57	28.2	22.5	0.734	0.493	2	2	6	18*
15	C158C	10	58	34.0	25.0	1.019	0.428	2	2	6	18*
16	C158C	10	58	36.9	25.9	1.317	0.490	2	2	6	18*
17	C98A	16	60	27.0	21.0	0.195	0.535	2	1	25	22
18	C98A	16	60	24.4	22.3	0.182	0.484	2	1	25	22
19	C98A	16	60	23.0	18.8	0.209	0.543	2	1	25	22
20	C98A	16	60	19.1	20.4	0.289	0.446	2	1	25	22
21	C98A	16	62	16.8	19.5	0.331	0.443	2	1	25	22
22	C99A	8	59	25.0	19.2	0.407	0.486	3	2	15	24
23	C99A	8	59	27.0	19.5	0.446	0.518	3	2	15	24
24	C99A	8	60	30.0	18.9	0.503	0.455	3	2	15	24
25	C99A	8	59	31.0	21.9	0.666	0.437	3	2	15	24
26	C99A	8	59	40.0	22.9	0.985	0.487	3	2	15	24

[1],[2],[3] & [4] See Notes on Page 13.

1	2	3	4	5	6	7	8	9	10	11	12
Stratum 2 (cont.):											
27	C94A	6	59	35.0	21.6	0.684	0.496	3	2	20	26*
28	C193A	8	60	27.4	18.9	0.428	0.463	2	2	3	23*
29	C182A	4	60	32.0	20.4	0.605	0.394	1	1	18	17*
30	C45A	8	61	31.0	21.6	0.542	0.453	3	2	7	17
31	C181B	12	62	20.0	16.3	0.156	0.520	3	2	8	18*
32	C181B	12	61	23.0	19.5	0.297	0.471	3	2	8	18*
33	C181B	12	61	21.0	18.9	0.257	0.530	3	2	8	18*
34	C181B	12	61	28.0	19.5	0.489	0.466	3	2	8	18*
35	C181B	12	61	27.0	20.1	0.450	0.484	3	2	8	18*
36	C48A	1	60	35.0	19.9	0.502	0.522	2	1	0	20
37	C89A	6	62	27.8	17.4	0.352	0.435	2	2	16	19*
38	C1A	-	62	24.4	17.2	0.326	0.423	3	2	5	23*
39	C4A	-	63	24.0	15.7	0.278	0.414	3	2	5	23*
40	C13A	1	63	28.5	18.7	0.514	0.397	2	1	5	24
41	C14A	2	66	28.4	15.0	0.263	0.418	3	2	15	23
42	C176A	4	62	31.5	19.2	0.448	0.418	3	1	-	23
43	C178B	7	64	17.8	15.2	0.171	0.494	1	1	6	31
44	C59A	5	65	31.5	17.8	0.356	0.359	4	3	11	19
45	C15A	12	65	23.0	16.6	0.185	0.448	3	3	2	19
46	C19A	2	65	23.5	20.8	0.197	0.441	4	3	20	14
47	C171A	4	63	22.0	15.2	0.178	0.442	1	1	10	31
48	C191B	9	66	14.6	23.4	0.223	0.467	3	1	5	23
Stratum 4:											
49	C76A	8	66	17.1	10.2	0.072	0.514	3	2	5	26
50	C78A	17	67	16.1	7.1	0.070	0.473	3	2	2	20
51	C79A	-	66	22.5	14.5	0.168	0.422	3	1	10	24*
52	C81C	11	67	17.6	11.1	0.067	0.463	3	2	12	32
53	C194A	17	67	17.0	8.5	0.046	0.456	2	1	0	24*
54	C194B	6	66	18.6	10.1	0.081	0.406	2	1	8	22
55	C202B	7	69	11.0	6.7	0.019	0.465	2	1	15	27
56	C199A	17	67	16.0	10.8	0.058	0.427	1	1	5	23*

APPENDIX I (Cont.)

1	2	3	4	5	6	7	8	9	10	11	12
Stratum 4 (cont.)											
57	L82A	9	66	17.1	11.2	0.100	0.450	3	1	15	25
58	L94A	6	67	24.0	15.5	0.268	0.400	2	2	2	22
59	L87A	18	67	22.0	13.1	0.142	0.378	1	1	3	24
60	L102A	-	67	19.6	13.9	0.140	0.421	1	1	5	26*
Stratum 5:											
61	N52A	16	69	20.6	16.2	0.196	0.407	5	3	30	15
62	Z91A2	12	67	20.5	15.5	0.161	0.396	3	2	10	16
Stratum 6:											
63	Z46AC	2	67	22.7	16.3	0.194	0.415	3	2	15	17
64	Z52AE	18	68	20.8	11.9	0.114	0.387	2	2	-	19
Stratum 7:											
65	C70A	6	67	21.0	15.0	0.107	0.475	2	1	10	26
66	C71A	12	68	17.2	11.0	0.097	0.383	3	1	10	41
Stratum 8:											
67	N53A	10	68	16.3	14.3	0.099	0.415	2	2	50	15
68	Z77A	-	68	19.4	13.4	0.088	0.354	3	2	0	20
Stratum 9:											
69	Z23A	14	68	19.7	14.2	0.082	0.441	3	3	10	21
70	Z67A	1	68	14.3	9.9	0.051	0.368	4	2	25	24
Stratum 10:											
71	C63A	7	68	10.9	7.1	0.026	0.469	2	1	5	54
72	Z34A	16	68	20.5	12.5	0.107	0.372	3	2	8	19

APPENDIX I (Cont.)

1	2	3	4	5	6	7	8	9	10	11	12
Stratum 11:											
73	N80A	16	69	10.4	6.0	0.018	0.410	2	2	0	21*
74	Z58A	14	69	12.6	6.2	0.024	0.409	1	1	10	49
Stratum 12:											
75	N61A	6	69	16.2	9.3	0.062	0.378	2	2	11	37
76	C198AB	6	69	17.4	9.8	0.045	0.344	2	2	18	35*
77	C204A	20	69	13.7	9.3	0.019	0.384	2	2	25	33
Stratum 13:											
78	Z104A	14	70	10.1	6.1	0.006	0.366	1	2	0	60*

Notes: Date first ring analysed: this is always at least 1 year later than the planting year of the stand. In some older stands it is several years later than the nominal planting year: this may be due to loss of material from the samples but can be mainly attributed to late 'beating up' in the stand.

2. Tree data: diameter at breast height (DBH) and total tree height (Ht) measured on the felled tree. Volume is calculated from the tree ring data measured on the densitometer on two radii at six levels on each stem. Density is a weighted mean tree density derived from the same 12 samples per tree.

3. Site Data: Topographic position (Topog.) is scored from 1-5

1 Ridge crest
2 Ridge - midslope
3 Midslope
4 Midslope - valley
5 Valley

Exposure (Exp.) is scored from 1-3

1 Very exposed
2 Average exposure
3 Protected site

4. Stand spacing index: a/hdom x 100 where: $a = \frac{1000}{n \times 0.866}$

and: hdom is dominant height of stand; n is number of stems per ha.

* Spacing estimate is average for compartment in these cases.
Otherwise it has been calculated for the immediate region of the sample point.

APPENDIX II

TREE DENSITY OF ANNUAL GROWTH RINGS FOR ALL SAMPLE TREES

Note:

Trees are numbered consecutively from No. 1. within each stratum. Correspondence to tree numbers in the body of the paper is as follows:-

Stratum	Tree Number	
	Appendix II	Elsewhere
1	1 - 9	1 - 9
2	1 - 39	10 - 48
4	1 - 12	49 - 60
5	1 - 2	61 - 62
6	1 - 2	63 - 64
7	1 - 2	65 - 66
8	1 - 2	67 - 68
9	1 - 2	69 - 70
10	1 - 2	71 - 72
11	1 - 2	73 - 74
12	1 - 2	75 - 77