Some Patterns in Crop Structure and Productivity for Unthinned Sitka Spruce

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ABSTRACT

Patterns of crop structure in unthinned Sitka spruce stands are examined by multiple and polynomial regression. Productivity categories for top height are evolved on the basis of confidence belts. Wide variation in volume to 8cm top diameter amounting to 160–200m³/ha is shown within a range of top heights 7m to over 20m. Volume production per ha to 8 cm top diameter for top height is greater in young unthinned stands in Ireland than indicated in the Forest Management Tables (1971). Total stem-wood volume is equivalent to timber volume plus 20m³/ha. Top height/age patterns indicate a range of Yield classes to over 24m³/ha/an. Mortality is not severe up to 14m top height. Variation in site conditions meant that volume/top height patterns could not easily be explained by the site factors. elevation, aspect and slope.

INTRODUCTION

Forest yield classification by height and age alone has limitations in that crops cannot be readily identified with their productive capacities. This difficulty has been already largely overcome with the concept of yield classes or classes of maximum mean annual increment. (Bradley, Johnston and Christie 1967, Hamilton and Christie 1971). The identification of volume producing forest categories is not always a straightforward process due to variation within apparently similar crops (Gallagher 1970). Difficulties can arise in expressing variation in yield by equations and graphs (Christie 1970). The study of crop productivity and the problems of correlating this with site factors in regions and localities has been undertaken with varying degrees of success. (Page 1970, Oswald 1969).

In Ireland the limiting factor in crop production studies has been

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the lack of permanent plots. Continuous records still cover a relatively short period.

More information on cumulative volume production, maximum increments and rotation lengths under Irish conditions is required. This is especially true for the two species Sitka spruce and contorta pine which together now comprise 85% of the annual planting programme.

BACKGROUND TO SITKA SPRUCE SURVEY

When the yield class system of crop definition was adopted a pilot project was set up at Kinnitty Forest, Co. Offaly, to control an annual thinning programme based on crop production potential. This was a joint project between research and management staffs of the Forest and Wildlife Service. During the exercise it became apparent that, for Sitka spruce there were large variations in volume within yield classes which had been identified by height and age.

This variation appeared to be more than could be accounted for by local production classes (Bradley, Johnston and Christie 1967) or by past management of thinnings. In order to assemble data on total volume production for that species, and in the absence of long-term permanent sample plot records, it was decided to investigate unthinned stands.

BASIS

A list of fully stocked unthinned but measurable stands was drawn up. This included stands at first thinning stage—and those in which, for different reasons, thinning had not been carried out. Stands were differentiated by age and forest compartment. The area of all stands assembled was 405 ha. (1,000 ac.). These stands were listed randomly and a .08 ha. plot was allocated to each 2 ha. (5 acres) on the list. This constituted a 4% sampling of the total assembled area and .04% approximately, of all Sitka spruce in the country over 10 years old.

Stand maps were prepared for all areas to be sampled. Plot locations were determined using a random grid.

FIELD WORK

Field work was commenced in Winter 1966 and finished by Summer 1967. 198 plots were measured in 16 counties over 36 forests, 32 of which were located south of a line from Dublin to Limerick. The plots were square. All trees 3cm. diameter at breast

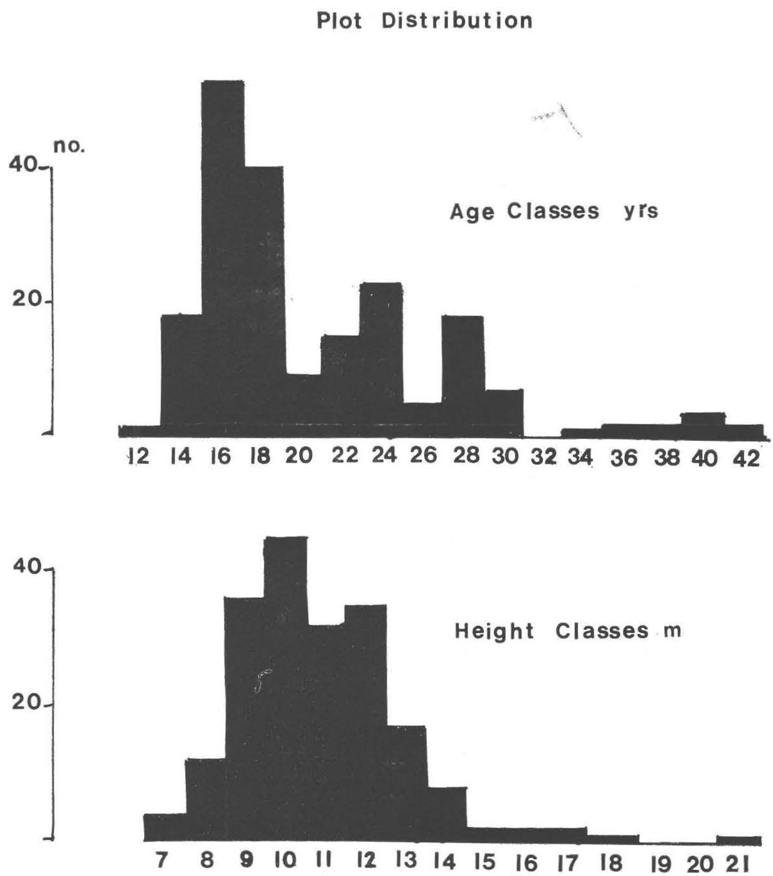


Fig. 1. Distribution of unthinned Sitka spruce plots by age and top height.

height (D.B.H.) and over were girthed (with a steel tape). Trees were grouped in assortments of 3cm. and over and 7cm and over. Heights of dominant trees were measured by a Blume Leiss hypsometer. A sample of dominant trees (defined as the 100 largest girthed trees per ha.) were felled and analysed for height age patterns. A sample in the 7cm. D.B.H. and over assortment were felled and measured in sections for volume.

A wide range of site conditions was encountered; elevations varied from 30–500 m., soils from brown earths to peaty podsols and gleys. Topographical features included flat sites and slopes in excess of 20°.

The distribution of height and age categories is given in Figure 1.

VARIABLES

These are defined in Table 1.

COMPUTATION AND ANALYSIS

Data were analysed with the aid of the I.B.M. 360 computer. Three stages were involved.

(i) Calculation of crop volumes.
(ii) Correlation of crop and site variables.
(iii) Explanation in detail of the relationship of some of the crop variables.

TABLE 1
PLOT VARIABLES PER HECTARE

Variable	Definition	Mean	Standard Deviation
V_8 (m^3)	Vol. of All * stems to 8cm. top diameter	232	74
Vt (m^3)	Vol. of All * stems 3cm. D.B.H. and over to tip	256	75
A (Yrs.)	Age Since planting	21	6
S (No.)	Number of All * stems 3cm. D.B.H. and over	3816	510
$\bar{H}d$ (m)	Mean Height of 100 largest diameter stems	11.3	2.1
$\bar{\bar{H}}$ (m)	Mean Height of 240 volume sample stems	9.9	1.6
$\bar{D}d$ (cm)	Diameter of 100 largest diameter stems	20.3	2.8
$\bar{D}$ (cm)	Mean Diameter of all trees 3cm. and over	13.0	1.2
G (m^2)	Basal area of all * stems 3cm. D.B.H. and over	40.0	7.0
Sdd (%)	$\frac{\text{Stems dead} \times 100}{\text{S}}$	3.9	6.4
Gdd (%)	$\frac{\text{Basal area dead} \times 100}{\text{G}}$	0.9	2.1
Alt (m)	Height above sea level	265.9	96.1
h (ratio)	Height at 6 yrs./6	1.04	0.29
v (ratio)	V_8/B.F.C+. vol. from 'b' curve	1.29	0.28
Slp (o)	Slope in degrees	7.7	6.3
Asp	Aspect N-NW clockwise coded 1-8	3.4	2.6
F	$\frac{V_8}{G \times H}$ Form factor	.461	.037

* Living and deat trees.
\+ British Forestry Commission Management Table (1971).

TABLE 2

MATRIX OF CORRELATION COEFFICIENTS GREATER THAN .6

	V_8	Vt	A	S	$\overline{Hd}$	$\overline{H}$	$\overline{D}$d	$\overline{D}$	G	Sdd	Gdd	Alt	*h*	*v*	Slp	Asp	F
V_8	+	+			+	+	+	+	+	+	+						
Vt	+	+			+	+	+	+	+	+	+						
A			+				+			+	+		—				
S				+				—									
Hd	+	+			+	+	+			+							
$\overline{H}$	+	+			+	+	+										
$\overline{D}$d	+	+	+		+	+	+	+	+	+							
$\overline{D}$	+	+		—			+	+	+								
$\overline{G}$	+	+					+	+	+								
Sdd	+	+	+		+	+				+	+						
Gdd	+	+	+							+	+						
Alt												+					
h			—										+				
														+			
															+		
																+	
F																	+

TAB

VARIABLES CONTRIBUTING MORE THAN .01 TO PROPORTION
IN AN 11 SELECTION 17 VARIABLE

Selection	Step	Dependent variable				Independent Variables			
		Y	X1	t1	X2	t2	X3	t3	X4
1	1	V8	Vt	126.14					
2	1	Vt	V8	126.14					
3	1	$\bar{H}$d	$\bar{H}$	33.05					
	2		,,	31.69	v	—7.87			
	3		,,	6.03	,,	—22.98	V8	19.84	
4	1	$\bar{D}$d	$\bar{D}$	17.67					
	2		,,	14.07	$\bar{H}$d	12.96			
	3		,,	15.27	,,	0.02	A	7.55	
	4		,,	16.20	,,	6.77	,,	8.51	Alt
5	1	$\bar{D}$	$\bar{D}$d	17.67					
	2		,,	14.72	S	—8.35			
	3		,,	2.46	,,	—28.63	G	26.86	
6	1	G	V8	21.77					
	2		,,	20.17	$\bar{H}$d	—7.52			
	3		,,	18.55	,,	—6.36	Alt	4.60	
	4		,,	19.65	,,	—7.30	,,	4.74	F
	5		,,	15.44	,,	—6.95	,,	4.64	,,
	6		,,	3.44	,,	—1.58	,,	3.14	,,
7	1	Sdd	Gdd	36.93					
	2		,,	30.66	A	10.94			
8	1	Gdd	Sdd	36.93					
	2		,,	39.21	S	5.47			
	3		,,	31.39	,,	4.99	A	—4.97	
9	1	h	A	—12.20					
	2		,,	—16.91	$\bar{H}$d	8.89			
	3		,,	—17.49	,,	7.07	$\bar{D}$	3.15	
10	1	*v*	Dd	—8.94					
	2		,,	—34.45	V8	28.05			
11	1	F	A	5.23					
	2		,,	6.16	*v*	4.34			
	3		,,	6.18	,,	4.80	S	—3.21	
	4		,,	6.86	,,	5.60	,,	—3.05	,,
	5		,,	6.68	,,	5.08	,,	—3.12	,,
	6		,,	4.82	,,	0.97	,,	—3.48	,,
	7		,,	4.32	,,	1.90	,,	—2.97	,,

5% t=1.96

LE 3

OF SUMS OF SQUARES REDUCED AND THEIR t VALUES
STEPWISE MULTIPLE REGRESSION

and Computed t Values									Proportion sum of reduced	Cumulative proportion squares reduced
t4	X5	t5	X6	t6	X7	t7	X8	t8		
									.988	.988
									.988	.988
									.848	.848
									.037	.885
									.077	.962
									.614	.614
									.178	.973
									.047	.840
—3.72									’011	.851
									.614	.716
									.102	.716
									.224	.940
									.708	.708
									.066	.774
									.022	.796
—4.17									.017	.813
—4.43	$\overline{D}$	3.42							.011	.823
—1.12	,,	14.00	S	13.32					.085	.908
									.874	.874
									.048	.922
									.874	.874
									.017	.891
									.012	.903
									.432	.432
									.164	.596
									.020	.615
									.290	.290
									.569	.859
									.123	.123
									.077	.200
									.040	.240
—2.91									.032	.272
—3.10	$\overline{H}$	—1.23							.006	.278
—3.64	,,	—5.07	V8	5.08					.085	.363
—2.09	,,	—5.97	,,	7.13	G	—4.73			.067	.480

1%=2.58t

(a) Volumes

Linear regressions of the form v=a+bg were calculated from sample tree data for all plots where v=mean tree volume, g=mean tree basal area, and a and b are constants. For volume to 8 cm. top diameter[1] v and g were computed from a sample of trees 7 cm. D.B.H. and over. For total stemwood volume, the volume of a cone, $\frac{1}{3}$ (.005 × length of top) was added to each tree within the sample and small trees were included in the basal area calculation.

(b) Correlations

Stepwise multiple regressions were calculated from all variables to see if any general trends were evident. Selections were made with each of the following eleven as independent variables V_8, V_t, $\bar{H}_d$, $\bar{D}_d$, $\bar{D}$, G, S_{dd}, G_{dd}, F, *v* and h.

Table 2 shows the correlation matrix. Only coefficients greater than ·6 are indicated (+or—). As correlations were fairly predictable the values of the coefficients are not shown. Table 3 summarises some of the relationships which featured during steps of each selection. Only variables contributing .01 and more to the reduction of sums of squares are included in the table. In fact, many crop variables are interrelated and this is shown in the equations from the eleven selections. These can be outlined:

(i) *Volume to 8 cm. top diameter* (V_8): The inter-relationship between V_8 and V_t accounts for virtually all regression sums of squares.

(ii) *Volume total stemwood* (V_t): V_8 contributed most to the regression. Later in the calculation (not illustrated), S shows a low positive relationship suggesting that V_t rather than V_8 increased with stocking.

(iii) *Dominant height* ($\bar{H}_d$): $\bar{H}$ (+) is the first variable to enter the regression. There is a low negative relationship with *v* (—) suggesting lower ratios with taller stands. There is also a low correlation with Alt (not illustrated).

(iv) *Dominant diameter* ($\bar{D}_d$): Correlations with $\bar{D}$ (+), $\bar{H}d$ (—) and A (+) contribute most to the regression.

(v) *Mean diameter* ($\bar{D}$): Best correlation are with $\bar{D}_d$ (+), S (—) and G (+). The influence of stems on diameter is shown here.

(vi) *Basal area* (*G*): V_8 and Alt are positively correlated $\bar{H}_d$ and F negatively. V_8 accounts for most variation in G.

(vii) *Percent Stems dead* (*Sdd*): Best correlations are with G_{dd} (+) and A (+).

[1] Much of the early data were recorded in Imperial measure before metrication and 8 cm. is used as the equivalent of 3 ins top diameter.

(viii) *Percent basal area dead* (*Gdd*): Stems dead (+) and stems (+) are best; for some reason A is negative here.

(ix) *Height ratio* (*h*): Total proportion of sums of squares due to regression is low. Predictably heights and age account for most.

(x) *Volume ratio* (*v*): $\bar{D}_d$ is correlated most highly (+). V_8 (+) is next due to interaction between variables.

(xi) *Form Factor* (*F*): Total sums of squares due to regression is low. Contributing to the regression are A (+), v (+), V_8 (+), S (-), Alt (—), $\bar{H}$ (—), G (—).

The very small influence of site variables, altitude, slope and aspect means that regression equations do not offer much to explain high volume ratios other than suggesting their association with stands where top height growth has been slow—which in turn might be related to high elevations. The regression does suggest that high volumes are associated with high dominant diameters and may be recognised through them. The remainder of the study concerns the expression in more detail of the relationship between crop variables.

CROP STRUCTIRE OF UNTHINNED STANDS

The following variables were considered worth examining in detail from a crop productivity point of view:

V_8, V_t, G, S_{dd}, G_{dd} and $\bar{H}_d$.

Polynomial equations were calculated to express the relationship of V_8, V_t, D_d, and G individually with top height. These were of the order $Y=a+bx+cx^2+dx^3$ . . .

So that the range of variation for single dependent variables (Y's) on any top height could be determined, the confidence belts for individual observations on the independent variable were calculated. This was done by first calculating the mean square.

$Sy^2=Sy_{123}2\ (\frac{1}{2}+C_{11}X^2+C_{22}X^3+C_{33}X^2_3+2C_{12}X_1\bar{X}_2+2C_{13}X_1X_3+2C_{23}X_2X_3)$, where, Sy^2_{123} is the variance the X's are deviations from means and the C's are the Gauss multiplyers from the solution of the normal equations in the polynomial. Sy^2 was then added to Sy^2_{123} and Sy was multiplied by the 95% t value. This value ($t_{.05}Sy$) was then added to or subtracted from each estimate of Y. It is expected that 95% of sampled plots would fall within these bands (Snedecor 1952, Davis 1961).

The following are the 4 polynomial equations which emerged:

(1) V_8 on $\bar{H}_d$

$$V_8=-529.6865+143.3328\ \bar{H}_d-9.5919\ \bar{H}_d^2+0.25449\ \bar{H}_d^3 \quad (F=165)$$

(2) Vt on $\bar{H}_d$

$$Vt=-480.2878+135.9794\ \bar{H}_d-8{\cdot}9884\ \bar{H}_d^2+0.2406\ \bar{H}_d^3 \quad (F=180)$$

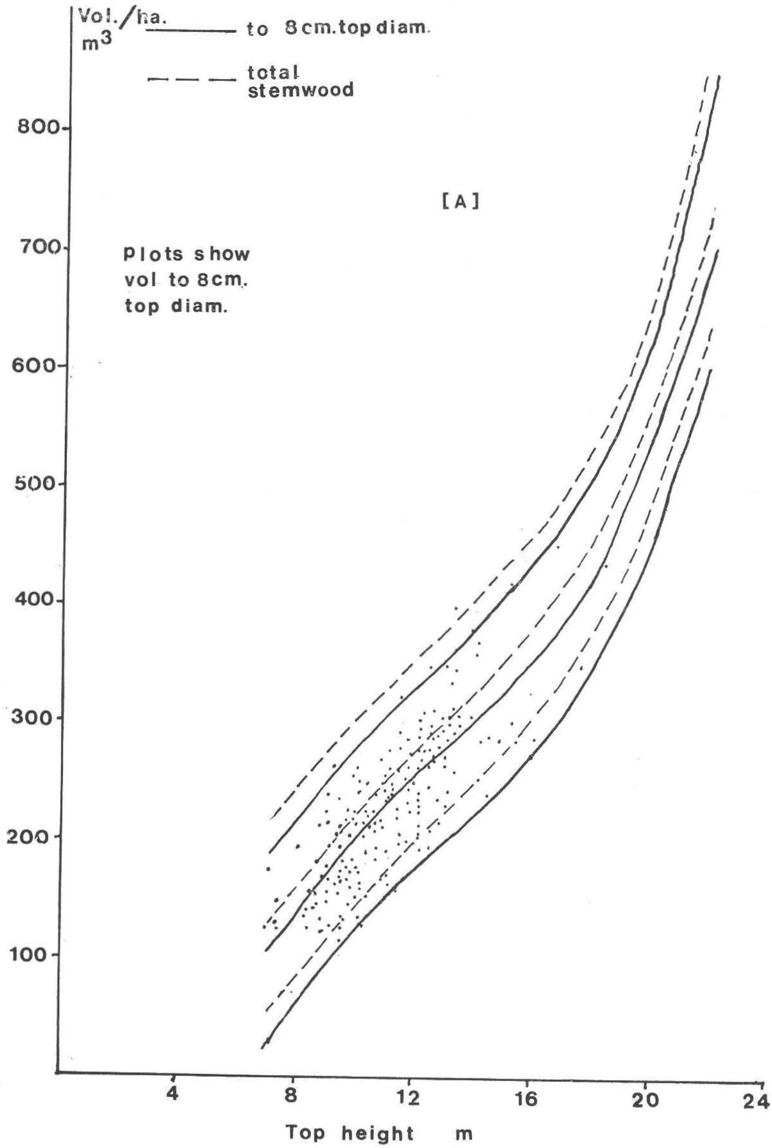


Fig. 2. Productivity range of unthinned Sitka spruce for top height based on confidence belts: a) Volume to 8cm. top diam. and total stemwood volume per hectare. b) Basal area per hectare. c) (Page 44). diameter per hectare.

(3) $\bar{D}_d$ on $\bar{H}_d$

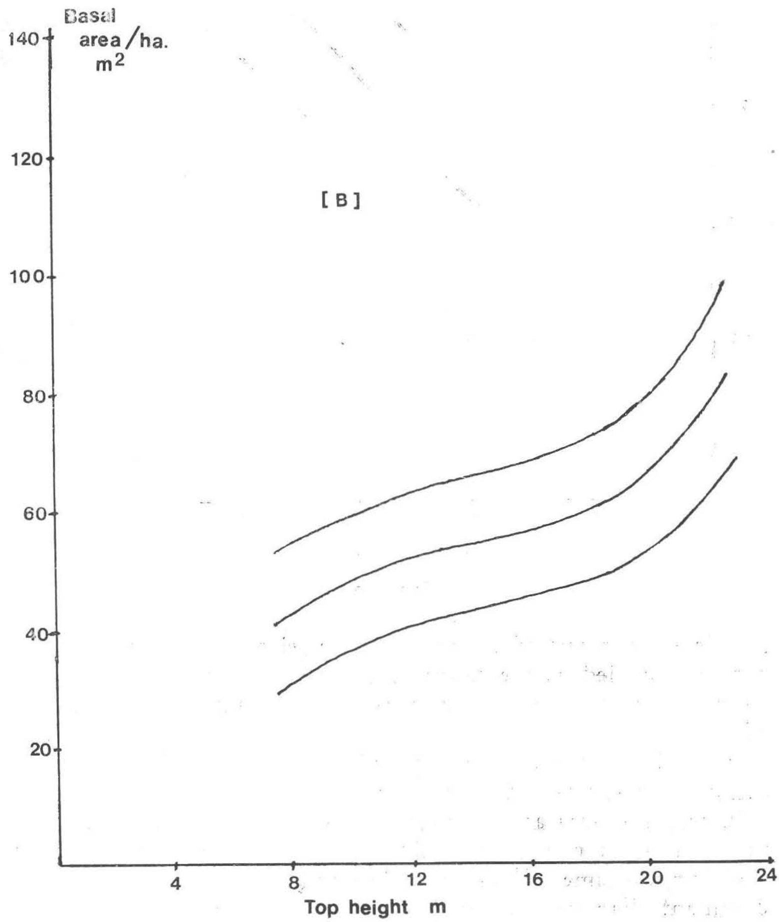
$$\bar{D}d = 20.8673 - 2.8972\bar{H}_d + 0.4427\,\bar{H}_d^2 - 0.2404\,H_d^3 + 0.00034\,\bar{H}d^4 \qquad (F=68)$$

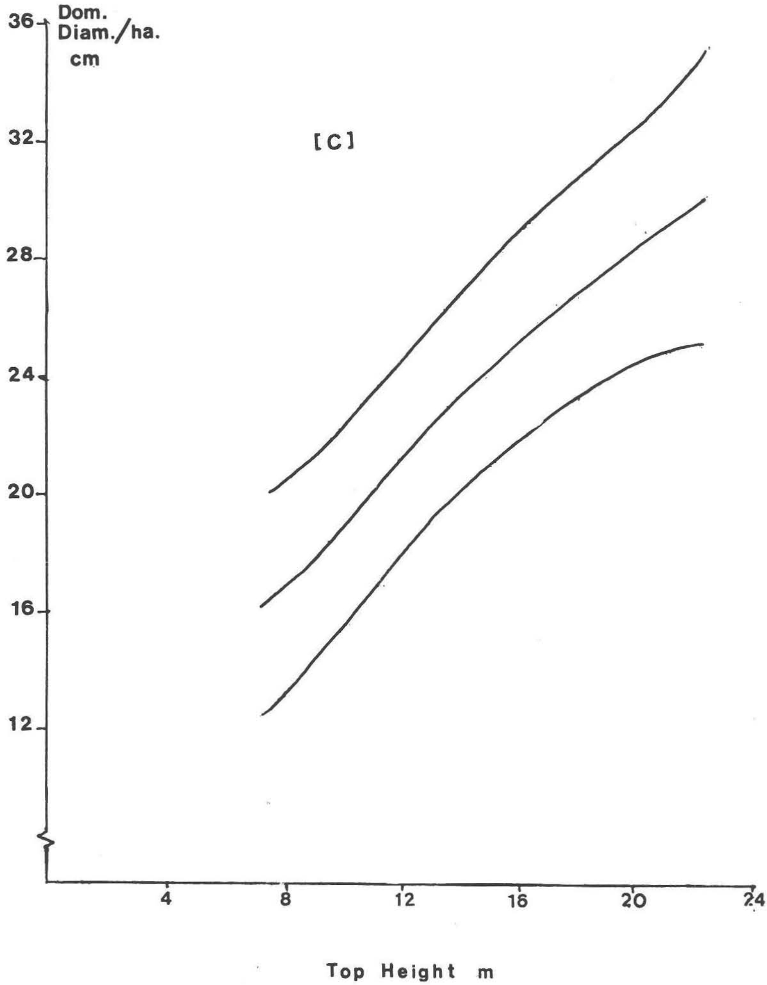
(4) G on $\bar{H}_d$

$$G = 23.0205 - 0.0404\,\bar{H}_d + 0.6727\,\bar{H}_d^2 - 0.0559\,\bar{H}_d^3 + .00138\,\bar{H}_d^4 \qquad F=22)$$

(.1% F=10.8)

These with the 95% confidence bands for observed values are expressed graphically on figures 2 (A, B, C). The distribution of plots according to V_8 is given on figure 2A. Though the scatter of data is wide for each curve all regressions are statistically significant at the





.1% level. In terms of a single variable related to top height these can be regarded as the range of production categories. The high values on these curves must be regarded with caution due to sparsity of data.

While the relationship between individual variables and top height can give a graphical indication of productivity categories in terms of volume, basal area and diameter, it was felt that a combination of these variables combined could provide a better instrument for predicting volume. It was also desirable to see if basal area, or dominant diameter—as easily measurable variables, were more closely related to volume productivity. Finally it was necessary to see if the main remaining crop variable likely to influence production, i.e. stems per ha. (S) might improve volume/height and basal area/ht. relationships. Some comparisons were made.

To see which of the two productivity categories, basal area or dominant diameter, was more closely related to volume at any top height, the residuals of the Y estimates from observed values in equation (1) were compared with those in (3) and (4). (1) and (3) volume—basal area, compared best.

To determine the best relationship of volume to basal area, to top diameter and to top height in terms of more than one variable a regression of volume on basal area was first calculated giving the following equation:

(5) $V_8 = -833.8008 + 54.0466 - 1.9267G^2 + .0074G^3$ (F=167)

Basal area was then combined with $\bar{H}d$ and G. The best fit was the multiple linear equation:

(6) $V_8 = -46.05122 + 1.5803G + .3472\ \bar{H}_d G$ (F=1069)

Combination of G with $\bar{D}d^2$ were less promising the best of these being:

(7) $V_8 = 132.1615 + .0123\ \bar{D}_d^2 G - .3953 \bar{D}_d^2$ (F=475)

and with $\bar{D}_d$ and $\bar{H}_d$.

(8) $V_8 = 17.8757 + 11.4782 \bar{H}_d + .01693\ \bar{D}_d^2$ (F=275).

Number of stems (S) was combined with $\bar{H}_d$, G and Dd but its inclusion with these variables made no improvement on equations (6) to (8). Equations relating to V_t to the above variables were similar to those mentioned above, differing slightly in intercepts and coefficients.

It can be seen then that a production class range of volumes, basal areas, and diameters for top height can be calculated on the basis of a range of curves within which 95% of the crops sampled would fall. Total stemwood volume is of the order of 20m.^{3} greater than volume to 8 cm. top diameter over the range of top heights sampled. Basal area is more closely related to volume than is dominant diameter and is a better index by which to determine productivity class. Best calculations for volume involve a linear combination of basal area and top height. The variation in volume per hectare for a top height ranges from 160 m.^{3} to about 200 m^3.

YIELD CLASSES

Considerable problems were encountered when trying to estimate yield classes or classes of potential maximum mean annual increment from the stands sampled. The main limitation was the sparsity of crops at or near rotation age.

From the data assembled, however, an attempt has been made to find out if volume production (from fig. 2) could be equated with a yield class. This required some comparison with the Forest Management Tables of Hamilton and Christie (1971).

The first problem was to assemble plots in order of their volume productivity. This was done by classifying each plot according to a ratio of volume $(V_8)/Age^2$ or Mean annual increment/age. This ratio lay between 0.1 and 1.2 in plots sampled. An arbitrary classification of five categories according to this ratio was imposed i.e. 0.1–0.2, 0.3–0.4, 0.5–0.6, etc. The height age curves were then calculated from height analysed sampled trees (600 in all) for plots in each of the height categories. Again polynomial curves were used. Though these curves are not very systematically distributed and are weak at their higher values they do indicate a range of yield classes placed in ascending order according to mean annual increment capacity at any given age. Only the two lower curves are continued to anything near rotation age, so deductions are tentative (Fig. 3).

Equation (1) would suggest a range of mean annual increments by 'Yield Classes' as shown in Table 4.

TABLE 4—Approximate Yield Classes (M^3/ha/An) for unthinned Sitka spruce, compared with Forest Management Table (1971) Classes

Age yrs.	M^3/Ha./Annum				
10	7	5 (4)*	—	—	—
20	16	14 (14)	12 (10)	9 (7)	5 (4)
30	—	—	—	10 (12)	8 (6)
40	—	—	—	14 (15)	9 (10)
	Y.C.	(24)	(20)	(16)	(12)

*(4) Forest management table classes (1971).

On this basis the 5 classes can be approximated to intervals of $4m^3$/ha/an. when compared with those of Hamilton and Christie. Again deductions for older classes are only as good as the volume/height curve at these points.

OTHER COMPARISONS

As all the crops dealt with were unthinned it was felt desirable to investigate natural mortality. Mortality expressed as a percentage of the number of all stems is up to 3 times that expressed as a percentage of basal area. Age and number of stems are the most important influencing factors; top height to a lesser degree. The relationship of % basal area dead against top height is shown on fig. 4. Mortality increases beyond 14m. top height. The highest

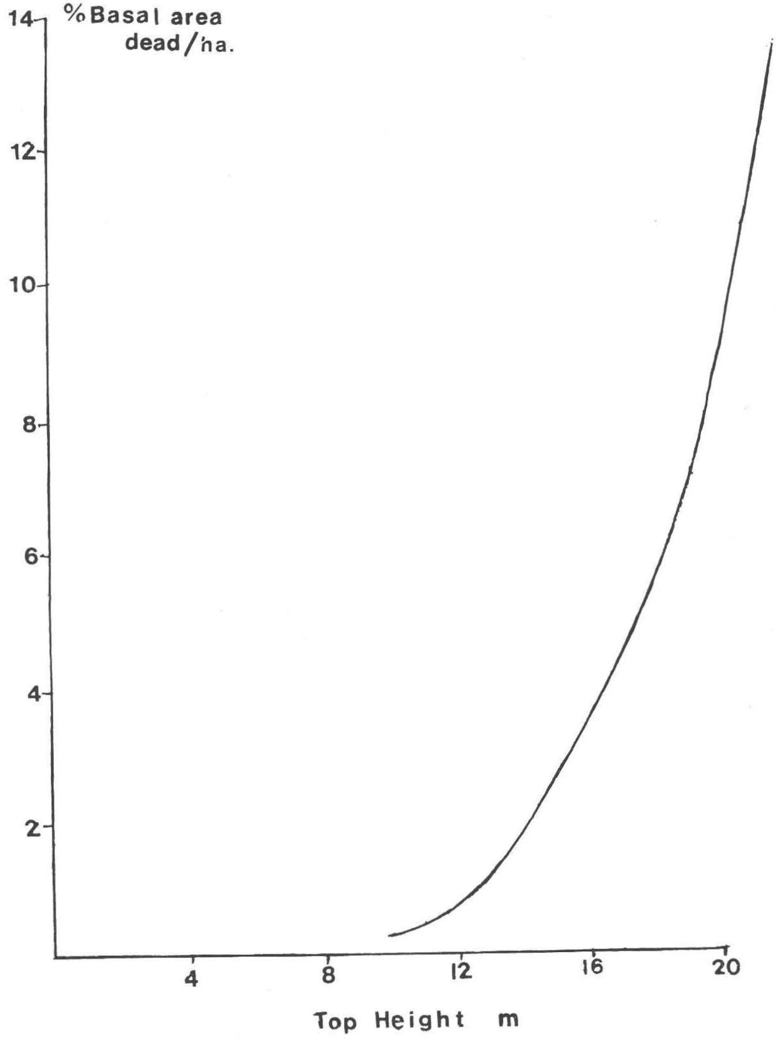


Fig. 3. Percentage basal area mortality in unthinned Sitka spruce for top height.

mortality figures encountered were approximately 40% of stems dead, equivalent to 20% of basal area at a high stocking level (over 5,000 per ha.) in a 36 year crop

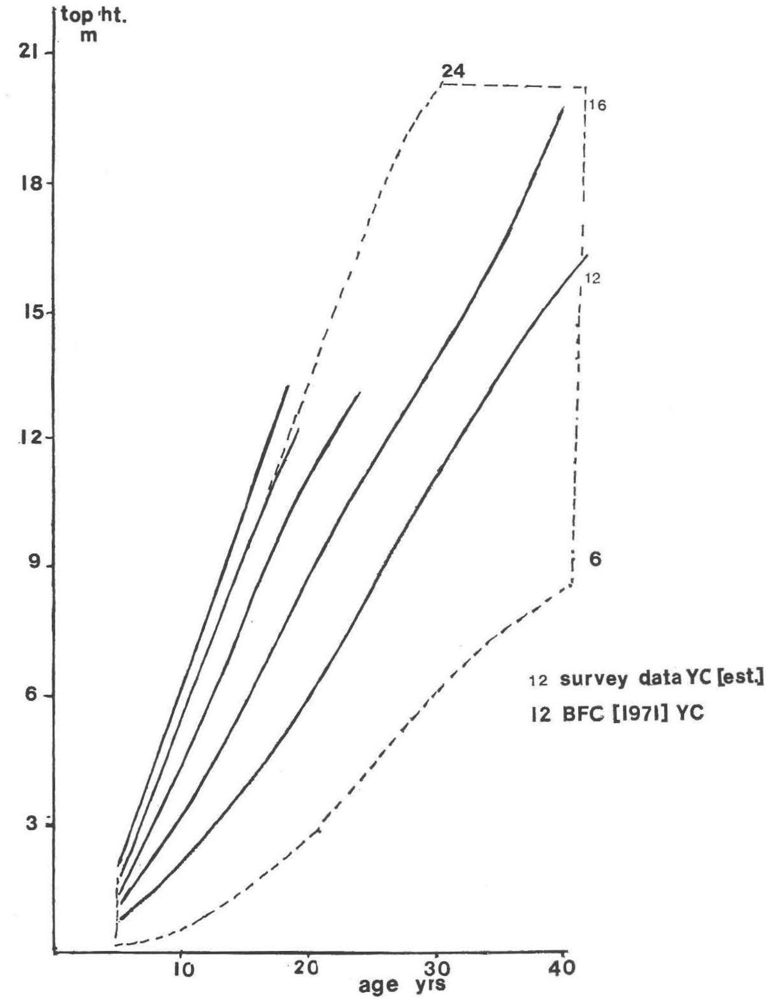


Fig. 4. Height/age categories of unthinned Sitka spruce for yield classes defined by volume production per annum at any age.

DISCUSSION ON YIELD AND PRODUCTIVITY CLASSES

The productivity classes which have been calculated represent a wider range of production for top height, especially in young crops that has heretofore, been realised in this country. Patterns for unthinned stands are not quite the same as shown by Hamilton and Christie (1971) for thinned stands. In figure 5 production

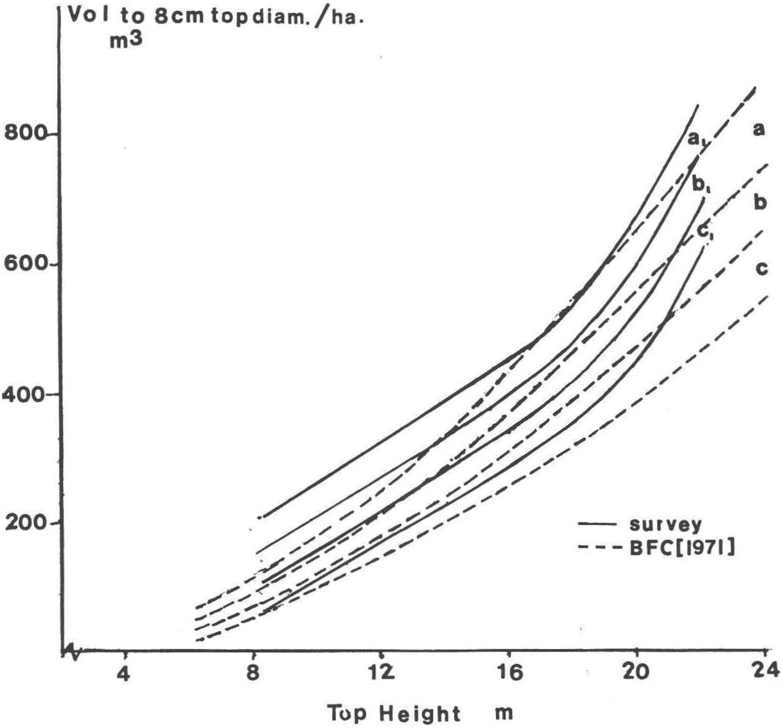


Fig. 5. Calculated productivity classes for unthinned Sitka spruce compared with production classes of the Forest Management Tables (1971).

bands (a^1, b^1, c^1) derived from the curves shown in figure 2 are compared with bands shown in the Forest management tables (a, b, c). The "b^1", band runs along the "a" band for most of its length except in the 16–20m. top height area. Beyond 16m. top height data become scarce so that the rest of the band must not be given undue importance. The few measured plots over 16m. top height occur both over and under the average production curve so it is not really possible to conclude if beyond this top height the average production is similar to the average of that in the Forest Management Tables, or if it remains above it. It is evident, however, that in young unthinned stands average production is some 60m^3 per ha. greater for top height than shown in the tables of Hamilton and Christie. Though very high relative production for top height can be found in young unthinned stands they tend to approach standards in the Forest Management Tables (1971) as they grow older. The average production however, ("b[1]" band) here remains a little higher than the Tables, in the order of 20-40m.^{3}/ha.

Arising from the exercise in constructing yield classes from the unthinned spruce stands it would seem that classes well over 24m^3/ha./annum might be obtained. The evidence for this figure is the rate of M.A.I. at early stages and the similarity in shape between the height/age curves got from plots and those from Hamilton and Christie (1971) (fig. 3). The increments within these categories have been obtained from the volume/top height curve (fig. 3 Equation 1) so again the question as to the validity of this curve at top heights over 16m. must be considered. Two possibilities arise here: (1) If the volume curve falls back to the Management Table (1971) curve or below it, the possibility of shorter rotations for approximately the same yield classes might be entertained; (2) but on the indications of the sparse data above 16m. top height rotations might be longer but yield higher. The only way to verify this will be to moniter permanent plots to 45 years or over. Another point to be considered is whether the reduction in volume increment for top height at 16m. is related to growth potential or to stand condition. More open stocking might achieve better production at this point and the increase of mortality for top heights between 12-16m. will be of interest here.

SUMMARY OF MAIN CONCLUSIONS

(1) Crop structure pattern for top height in terms of one variable, volume, basal area or top diameter can be determined by curves and the areas within which 95% of samples fall. Best volume predictions can be made through equations including both top height and basal area.

(2) There is likely to be a wide variation in volume productivity for top height which can be as much as ± 100m^3/ha. This is reflected in basal area and dominant diameter.

(3) Average production for top height in all young unthinned stands is likely to be higher than indicated in the Forest Management Tables (1971). Average production of lower yield class stands is likely to be higher in both young and and older stands.

(4) Sampled stands suggest yield classes up to over 24m^3/ha./annum with each yield class having a range of at least ± 2m.^{3}. Height age curves approximate the Forest Management Tables curves (1971).

(5) The volume/top height relationships suggest some reduction in productivity at 14–16m. top height due possibly to limitations in data or to crop conditions. This has some implications:

(I) The possibility of equivalent yield classes but shorter rotations than indicated in the Forest Management Tables (1971).

(II) The possibility of a temporary reduction in productivity due possibly to stand conditons, with greater final production.

(6) Total stemwood production is equivalent to V_8 plus approximately 20m.^{3}/ha. This comes from small sized trees and tops.

(7) Mortality is not high up to 16m. top height (some 5%). There is tentative evidence that it increases fairly rapidly from then on.

(8) Altitude, Aspect and Slope did not correlate well with either volume or height.

MISCELLANEOUS OBSERVATIONS

(1) The data suggested a slight inverse correlation between high volume ratios and top height and also between altitude and top height. Considerable leader breakage was observed during the survey so that there may be some link between exposure, leader breakage, and high production for top height

(2) When the survey was undertaken, plots were grouped according to four arbitrary regions.

(I) East
(II) Northwest
(III) Midlands
(IV) Southwest.

The percentage of stands with high volumes for top height were greater in the order (I) to (IV).

Overall differences between crop structure in unthinned stands and that shown by the tables of Hamilton and Christie for thinned stands appear to exist. These might well influence the future management of the species here and investigations on potential increment at rotation age are warranted. There is a need to study stands at varying stocking levels, especially those approaching culmination of increment.

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