A PROVISIONAL VARIABLE DENSITY YIELD TABLE FOR DOUGLAS FIR IN KAINGAROA

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SYNOPSIS

A provisional variable density yield table is presented for Douglas fir stands in Kaingaroa. It has been compiled from permanent sample plot data and covers a range of ages from 20 to 40 years and a range of stand densities from basal areas of 100 to 400 sq. ft.

Individual tables are presented for the separate projection of stand basal area, mortality and top height, and a table of volume increments is included to illustrate the growth pattern of Douglas fir at various ages and stand densities.

The method used to compile the tables is described and instructions are given for their use.

INTRODUCTION

Since 1964, assessment work at Kaingaroa has covered most of the major strata of the forest, and the need for specific variable density yield tables for the major species has now become pressing.

For the projection of Douglas fir assessment data, there have up till now been only two sources of tabulated increment information, namely Duff (1956) and Spurr (1963). Duff provides, in fact, a normal yield table, compiled for fully stocked unthinned stands, the application of which to understocked stands requires the subjective adjustment for "percentage stocking". It is also a general table, being based on information from stands throughout the country. Spurr does not provide, in itself, a yield table but rather a study of the growth rates of the species in New Zealand. Although the basic data for the study are presented in the form of graphs, only average trends are presented in smoothed tabular form.

The following presentation is an attempt to produce a specific, variable density yield table for Kaingaroa, which will cover the full range of variation exhibited by assessment data, so that all stand conditions can be projected forward in time. The accumulated data of all Kaingaroa's Permanent Sample Plots (both Conservancy R10 plots and FRI thinning plots) were used, including much of the plot information used by Spurr in his paper.

The approach is very simple, no attempt being made to impose a mathematical model on the plot measurements. Basically the raw data have been arranged into the form of the final table and, with as little smoothing as possible, the gaps

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in the coverage have been filled in, to cover a range of ages from 20 to 40 years, and a range of stand density from 100 to 400 sq. ft of basal area. Beyond this range the plot data are too scanty to provide any solid predictions, and even within the boundaries of the table the concentration, in certain regions, is barely sufficient. It must be stressed that the table is merely provisional. As existing plots are remeasured, and new growth plots established, the existing data will be supplemented and the table will be checked, extended and, if necessary, modified.

Tables have been produced for the separate projection of gross basal area and top height, and an attempt has been made to predict mortality in basal area and stems per acre. Net basal area increment has been avoided because mortality data are erratic and make direct trends of this parameter unreliable.

To obtain stand volume at any future age within the body of the table, the current stand parameters of basal area and top height, as obtained in an assessment, are projected separately, adjustment is made for mortality, and the regression of volume per square foot of basal area against top height is used to combine the resulting values.

A table of volume increments has also been prepared, being a combination of the gross basal area increment table and the *mean* top height trend. This is not intended for use in yield prediction but rather to illustrate the variation in volume growth with age and stand density.

The Basic Data

No. of Plots:

(a) Controlled by Conservancy	25
(b) FRI thinning sub-plots	24
Total	49

No. of Measurements:

Conservancy	85
FRI	135
Total	220

Range of Planting Years

Year	*No. of Plots*
1915-20	8
1921-25	23
1926-30	5
1931-36	13
Total	49

Range of Site Index (Top height at 30 years):

Site Index	*No. of Plots*
65	1
70	0
75	4
80	19
85	24
90	1
95	0
Total	49

Range of Altitude:

Altitude (ft)	*No. of Plots*
500-1,000	5
1,000-1,500	9
1,500-2,000	27
2,000-2,500	8
Total	49

Thinning plots	39
Unthinned	10
Total	49

The limitations of the basic data must be stressed. The plots are located in two regions; north of Wairapukao and south of the Napier-Taupo Highway, and are restricted to the better stocked stands of these regions. In fact, the increment data are almost wholly from the north of the forest because the Southern Conservancy plots have received no more than two measurements and there is only one FRI thinning plot in this region.

The middle region of the forest, where stocking is generally poor, is so far not represented by growth plots.

Consequently all low stockings are due to thinning and not to very low initial stocking. It is more than possible that there will be a significant difference between the basal area increment of stands thinned to a low stocking and unthinned stands of the same stocking and age. Unfortunately, unthinned data are scanty and are restricted to reasonably well stocked stands. They have been added to the data of the thinned plots with which they are quite compatible, there being no significant difference between the increments of unthinned plots and lightly thinned plots.

TABLE 1: DOUGLAS FIR, KAINGAROA

NET BASAL AREA Squ.ft/ac.	AGE IN YEARS 20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	MORTALITY 3 YRS. TOTAL FOLLOWING
390						11	11	10	10	9	9	9	9	9	9	8	8	8	8	8	4
380						11	11	10	10	10	9	9	9	9	9	8	8	8	8	8	
370						11	11	11	10	10	9	9	9	9	9	9	8	8	8	8	
360						11	11	11	10	10	9	9	9	9	9	9	8	8	8	8	
350						11	11	11	10	10	9	9	9	9	9	9	8	8	8	8	
340						12	11	11	10	10	10	9	9	9	9	9	8	8	8	8	3
330						12	11	11	11	10	10	9	9	9	9	9	8	8	8	8	
320						12	11	11	11	11	10	9	9	9	9	9	8	8	8	8	
310						12	12	11	11	11	10	10	9	9	9	9	8	8	8	8	
300						12	12	11	11	11	10	10	9	9	9	9	9	9	8	8	
290	13	13	13	13	13	12	12	11	11	11	10	10	10	9	9	9	9	9	8	8	½
280	14	13	13	13	13	12	12	12	11	11	11	10	10	9	9	9	9	9	9	8	
270	14	14	13	13	13	13	12	12	11	11	11	10	10	10	9	9	9	9	9	8	
260	14	14	14	13	13	13	12	12	12	11	11	11	10	10	10	9	9	9	9	9	
250	14	14	14	14	13	13	13	12	12	12	11	11	10	10	10	9	9	9	9	9	
240	14	14	14	14	13	13	13	12	12	12	11	11	10	10	10	9	9	9	9	9	0
230	15	14	14	14	14	13	13	12	12	12	11	11	10	10	10	10	9	9	9	9	
220	15	15	14	14	14	13	13	12	12	12	11	11	10	10	10	10	9	9	9	9	
210	15	15	14	14	14	13	13	12	12	12	11	11	10	10	10	9	9	9	9	9	
200	15	15	14	14	14	13	13	12	12	12	11	11	10	10	10	9	9	9	9	9	
190	15	14	14	14	13	13	13	12	12	11	11	10	10	10	9	9	9	9	9	9	0
180	14	14	14	14	13	13	13	12	12	11	11	10	10	10	9	9	9	9	8	8	
170	14	14	14	13	13	13	12	12	12	11	11	10	10	9	9	9	9	8	8	8	
160	14	14	13	13	13	12	12	12	11	11	11	10	10	9	9	9	9	8	8	7	
150	14	13	13	13	12	12	12	12	11	11	11	10	10	9	9	9	8	8	7	7	
140	13	13	12	12	12	12	12	11	11	11	10	10	9	9	9	8	8	8	7	7	0
130	13	12	12	12	11	11	11	11	11	10	10	10	9	9	8	8	8	7	7	6	
120	12	12	12	11	11	11	11	10	10	10	10	9	9	8	8	8	7	7	7	6	
110	12	11	11	11	11	10	10	10	10	9	9	9	9	8	8	8	7	7	6	6	
100	11	11	11	10	10	10	10	9	9	9	9	9	8	8	8	7	7	7	6	6	

SHOWING GROSS ANNUAL BASAL AREA INCREMENT FOR ANY GIVEN NET BASAL AREA AND AGE

NOTE: *Values of gross b.a. increment are derived as the means of the 3 following years i.e. to use the table for projection purposes the stand basal area should be projected forward 3 years at a time using the value given for the required b.a. and age.*

DETAILS OF METHOD

(1) *Summary of Plot Data*

Most plot measurements had been processed by computer and summarized data were available on output forms. However, owing to the delay in processing conservancy plot measurements, caused by the need to convert from card to tape input, the Conservancy plot measurements made since 1965 had to be hand calculated. This involved the computation of approximately 30 remeasurements.

(2) *The Compilation of the Basal Area Increment Table*

For each measurement of each plot, the age, net basal area and the gross basal area increment between that measurement and the next were tabulated. This gross increment was then divided by the number of years between measurements and those data were re-arranged in the form of Table 1. This table has net basal area in 10 ft intervals down the left-hand side and age in years along the top. The annual gross basal area increment for each measurement was inserted into the body of the table at the cross-reference of its age, and net basal area.

The form of Table 1, which is based on the assumption that gross basal area increment is a function of age and net basal area combined, is that of the required final table. All that was required was the existing plot data to be expanded and smoothed. To do this the table was first divided into cells of 5 years by 5 basal area classes (25 increment entries). Then smoothed trends were obtained by graphing increment against age at the mid-point of each basal area cell and increment against basal area at the mid-point of each age cell. This produced a gridwork of entries with 9 out of 25 entries filled for each cell. The gaps were filled in using the existing data as a guide, and finally the table was checked against the total original data to ensure that the final presentation followed as closely as possible to the evidence provided by the actual field measurements. The final table is shown as Table 1.

Note that gross basal area increment is derived as the mean of the three following years — *i.e.*, to use the table for projection, the stand basal area should be projected forward three years at a time.

e.g., b.a. 250, age 25, project forward to age 30 years;
250 sq. ft, age 25, b.a. increment = 13 sq. ft/annum;
age 25 + 3 = 28 = 250 + 13 × 3 = 289 sq. ft gross;
mortality 25 to 28 yr, 250 sq. ft = 0.5 ∴ 288.5 sq. ft net;
age 30 — 289 + 11 × 2 = 311 sq. ft gross;
mortality 28 to 30 yr — 0.5 × $\frac{2}{3}$ = 0.3 (negligible)

The check of the completed table gave the following results:

Positive deviations (gross)	61	sq. ft
Negative deviations (gross)	60	sq. ft
Total positive bias	1	sq. ft
Number of checks	106	
Total deviations	121	sq. ft
Mean deviation	±1.15	sq. ft

TABLE 2: DOUGLAS FIR (KAINGAROA). DISTRIBUTION OF DEVIATIONS OF TABLE 1 FROM THE BASIC PLOT DATA

(Total positive deviations 61 sq. ft, negative deviations 60 sq. ft; total number of observations 106.)

Net basal area	*Age in years* 20 21 22 23 24	25 26 27 28 29	30 31 32 33 34	35 36 37 38 39
350-390 sq. ft p.a.		Deviations (0, 0) 0 Observations 1	Deviations (+ 1 — 1) 0 Observations 3	Deviations (0, 0) 0 Observations 2
300-340 sq. ft p.a.		Deviations (+ 2 — 3) — 1 Observations 5	Deviations (+1 , 0) + 1 Observations 4	Deviations (0 — 2) — 2 Observations 1
250-290 sq. ft p.a.	Deviations (+ 1, 0) + 1 Observations 3	Deviations (+ 1, — 1) 0 Observations 5	Deviations (0, — 3) — 3 Observations 2	Deviations (+ 2 — 5) — 3 Observations 4
200-240 sq. ft p.a.	Deviations (+ 2 — 2) 0 Observations 2	Deviations (+ 6 — 4) + 2 Observations 4	Deviations (+ 3, 0) + 3 Observations 4	Deviations (+ 6, — 7) — 1 Observations 9
150-190 sq. ft p.a.	Deviations (+ 3 — 3) 0 Observations 6	Deviations (+ 8 — 10) — 2 Observations 14	Deviations (+ 5, — 8) — 3 Observations 12	Deviations (+ 12 — 7) + 5 Observations 11
100-140 sq. ft p.a.	Deviations (+ 2 — 1) + 1 Observations 3	Deviations (0 — 1) — 1 Observations 4	Deviations (+ 3 — 2) + 1 Observations 4	Deviations (+ 1, 0) + 1 Observations 3

The distribution of the deviations is shown for each 25 entry cell in Table 2. It will be seen that the errors are reasonably well distributed.

(3) *The Compilation of Mortality Trends in Basal Area*

Using the same format as the table of gross basal area increment, mortality in basal area was tabulated against age and net basal area. The mortality used was the *3-year* total which occurred between measurements and this was coupled with the age and net basal area at the first measurement. There appeared to be no definite relationship of mortality against age, so the mean mortality was calculated for each basal area class regardless of age, and is shown in heavy print on the right of Table 1.

Note: The mortality shown refers to the 3-year period after measurement.

(4) *The Graphs of Stems per acre against Age*

Trends of stems per acre against age were drawn for each plot, regardless of thinning treatment. Smoothed trend lines were then drawn through the range of data, using the strongest plot trends as guides. The resulting relationships are shown as Fig. 1.

(5) *The Height/Age Graph and Table*

Mean top height and age were extracted direct from the computer printouts, but where no printouts were available predominant height was calculated from the plot data. To convert predominant height to mean top height, a graph of mean top height against predominant height was drawn using those plots for which both parameters had been computed. Mean top height was graphed against age for each plot. There is a fairly narrow range of height growth, and the cluster of lines shown on the graph are approximately centred on the height/age relationship derived by Spurr (1963). Figure 2 was derived by drawing smooth trend lines through the centre and the extremes of the range. By extrapolation between these three lines any top height encountered can be projected forward in time.

(6) *The Compilation of the Gross Volume Increment Table*

This table (Table 3) was produced by combining the data from gross basal area increment table, the *mean height/age* trend, and the regression of *V/B* against top height. Each entry in this table was calculated as follows:

(1) Top height for any given age was derived from the medium trend in Fig. 2.

(2) The *V/B* value* corresponding to this height was multiplied by the corresponding net basal area.

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*The regression used was specially derived for Kaingaroa from permanent sample plot data. It is:

$$V/B = 0.0335 + 0.369 \text{ top height.}$$

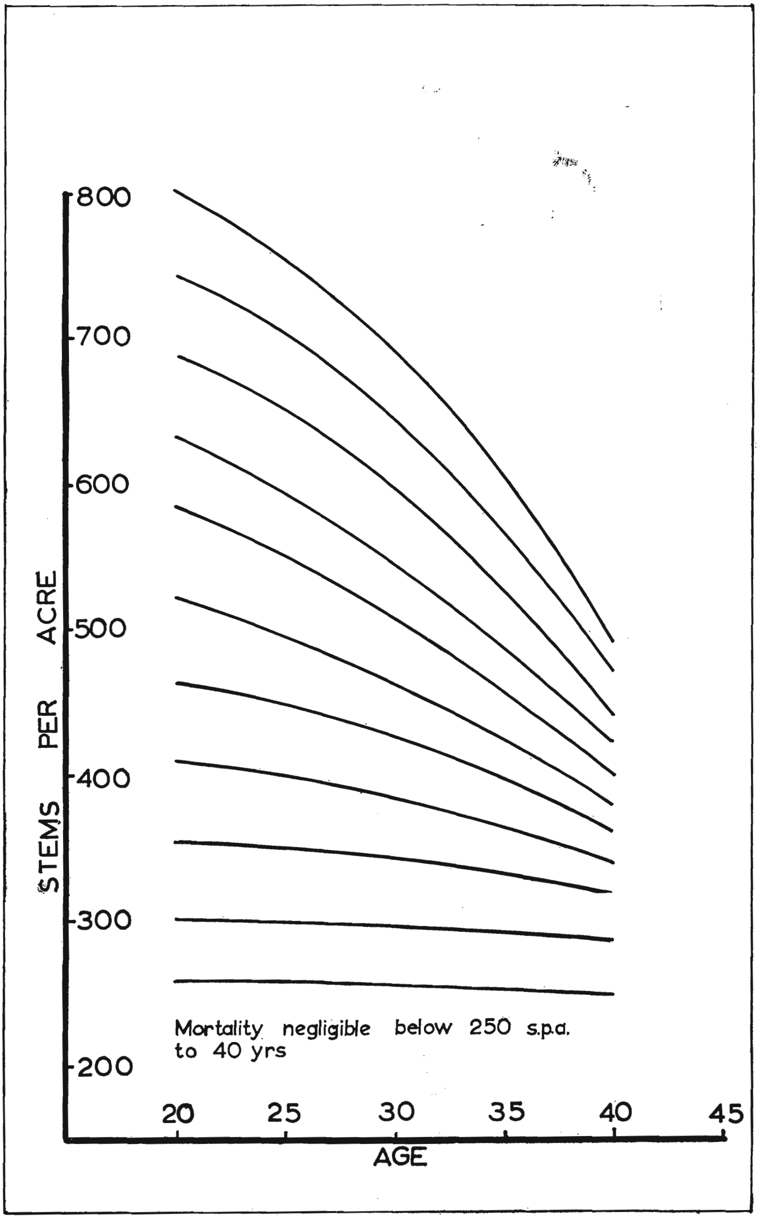

FIG. 1: *Douglas fir (Kaingaroa). Trends in mortality of stems per acre.*

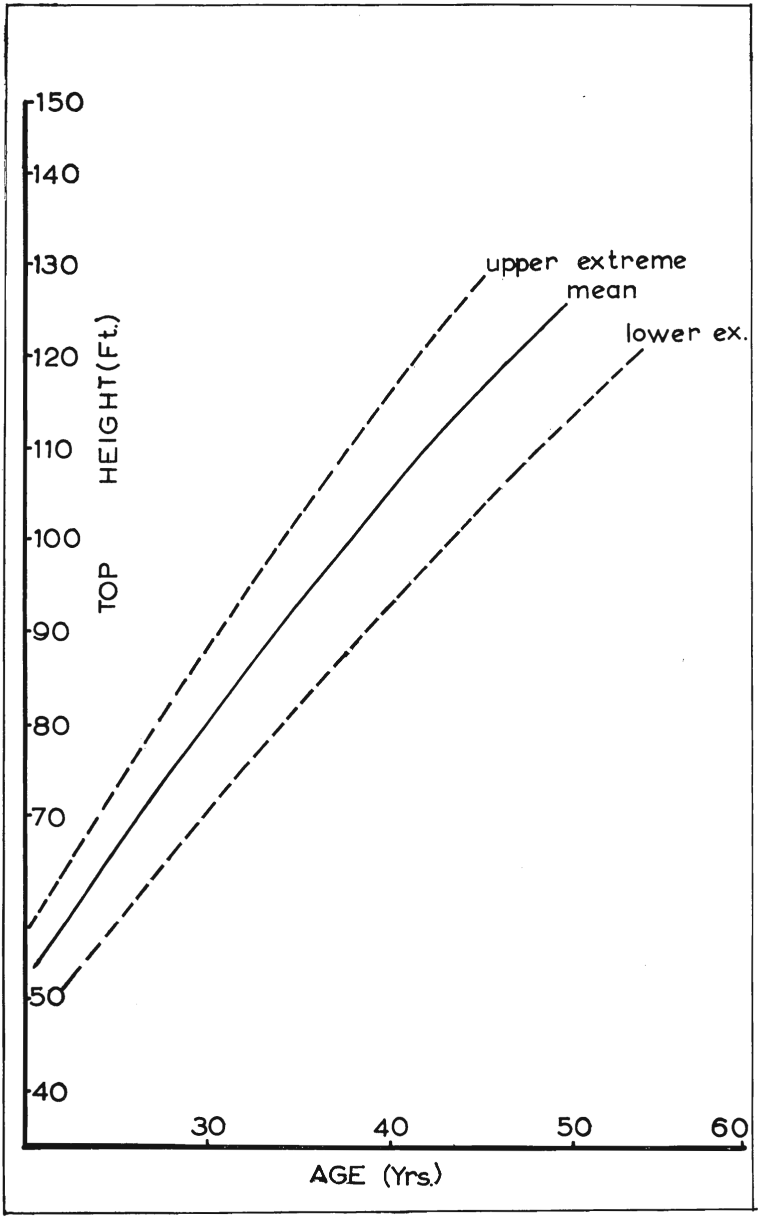

FIG. 2: *Douglas fir (Kaingaroa). Height/age trend.*

TABLE 3: DOUGLAS FIR (KAINGAROA) SHOWING GROSS VOLUME INCREMENT AGAINST NET BASAL AREA AND AGE

Mortality (where significant) is shown in parentheses.

	Age in years			
Net basal area	*20-24*	*25-29*	*30-34*	*35-39*
350-390 sq. ft p.a.		660 (— 35)	680 (— 40)	610 (— 50)
300-340 sq. ft p.a.		630 (— 30)	650 (— 35)	590 (— 40)
250-290 sq. ft p.a.	580 (— 5)	590 (— 5)	610 (— 5)	550 (— 5)
200-240 sq. ft p.a.	550	550	570	510 (— 5)
150-190 sq. ft p.a.	490	500	510	450 (— 5)
100-140 sq. ft p.a.	400	400	420	360

(3) Basal area one year hence was derived by adding gross basal area increment.

(4) Top height one year hence was derived from the medium trend in Fig. 2.

(5) The V/B value corresponding to the new top height was multiplied by the basal area derived in (3).

(6) The volume derived under (2) was subtracted from that derived under (5).

Values have been calculated for the mid-point of each 25 entry cell, smoothed by graphing increment against net basal area for the ages 22, 27, 32 and 37, and rounded to the nearest 10 cu. ft. The resulting table is shown as Table 3.

(7) *Mortality in Volume*

These have been calculated for the mid-point of each 25 entry cell. They have been calculated by multiplying the annual basal area mortality by the V/B corresponding to the required age + ½. The values, rounded to the nearest 5 cu. ft, are shown with volume increments in Table 3.

The tables will serve to predict the growth of Douglas fir at Kaingaroa as long as predictions are restricted to the range of the table. As further plot data are collected, the table will be checked, and, if necessary, altered and extended.

For detailed predictions, the collection of tables suffers from the absence of:

(1) Relationship between mean d.b.h. and the diameters distribution for thinned and unthinned stands, and

(2) Relationship between the mean d.b.h. and the percentage 6 in. and 4 in. top volume to total volume.

Until these relationships have been established for Kaingaroa, those derived by Duff (1956) for unthinned Douglas fir can be used.

Refinement of these tables, which will be carried out as time permits, may necessitate modifications and will require additions.

CONCLUSIONS

The conclusions drawn from the set of tables prepared must be qualified by a further reference to the limitations of the basic data. They refer only to the better stocked stands in the north and far south of Kaingaroa and may be inapplicable to poorly stocked stands generally. Furthermore, the quantity of basic observations is low and the following notes must be taken as tentative.

(1) *Basal Area Increment*

The gross basal area increment table suggests that maximum basal area production occurs when the stand density is between 200 and 250 sq. ft and that above this range increment drops off. Spurr's statement that thinning treatment does not affect total B.A. production is contradicted by the evidence of the B.A. increment table, which suggests that a maximum B.A. production can be obtained by thinning to maintain a standing net basal area between 200 and 250 sq. ft/acre.

(2) *Height Increment*

Height increment shows no signs of rounding off within the range of ages studied, and the few plots extending to 50 years indicate that even at this age height increment is maintained at the same rate.

(3) *Mortality*

This is hard to predict because of the normal erratic variation in the basic data. However, all indications are that mortality in basal area and stems per acre is negligible up to a stand density of 250 to 300 sq. ft. Above 300 sq. ft there is a sudden incidence of mortality. Note that the small difference between basal area mortality at 320 and 370 sq. ft is probably misleading and is a reflection of the scarcity of data.

(4) *Volume Increment*

The tabulation of volume increments indicates that maximum volume increment occurs between the ages of 30 and 34 years. Gross volume increment also increases steadily with increasing basal area, but above 300 sq. ft mortality probably counteracts any increase in growth rate.

REFERENCES

Duff, G., 1965. Yield of unthinned Douglas fir, Corsican pine and ponderosa pine in New Zealand. *N.Z. For. Res. Notes No. 5.*

Spurr, Stephen H., 1965: Growth of Douglas fir in New Zealand. *N.Z. For. Ser. Tech. Paper 43.*