

A GROWTH AND YIELD STUDY OF INTERIOR DOUGLAS-FIR IN BRITISH COLUMBIA

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ABSTRACT

To assess the growth of the uneven-aged stands of Douglas-fir in the Interior Douglas-fir (IDF) zone and the factors influencing the growth, data from 92 permanent sample plots were obtained. Volumes ranged from 3-453 m³/ha, with a mean of 94 m³/ha. Annual growth rates varied from -1.8 to 9.5 m³/ha, with a mean of 3.3 m³/ha. The plots varied considerably in the quality and quantity of data provided, having been established at different times, by different agencies, using different measurement methods.

Factors included in the analysis were: harvesting method or treatment (three classes), biogeoclimatic subzone (two classes), time since treatment, and the stand variables of stocking, basal area per hectare, and quadratic mean diameter. Statistical analyses and visual examinations of scattergrams were used in the assessment. Results indicated significant differences among harvesting methods and biogeoclimatic subzones. Hence, the data were divided into four groups with statistically significant differences.

A volume growth equation was next derived for each group using the stand variables as independent variables. For two groups (Diameter Limit Harvest, and No Harvest of subzone DK), stocking was statistically significant while for a third (No Harvest, subzone XH), stocking as well as mean diameter were significant. The last group (Fallers Selection method) had no significant independent variables. Multiple coefficients of correlation ranged from 0.28-0.60.

These results indicate that while some trends are apparent they are not well defined and growth predictions are unreliable. This result is attributed to deficiencies in the data and to natural variability within IDF stands.

The growth equations comprise a simple stand growth model. To use the model, the following data must be available: harvesting method; biogeoclimatic subzone if no harvest has occurred in the stand; and stocking and quadratic mean diameter.

Keywords: Stand volume growth, harvesting methods, site classes

INTRODUCTION

The Interior Douglas-fir (IDF) zone of British Columbia covers over 4 million ha (10 million ac) and is of considerable economic importance to the forest industry.

The main portion of the IDF zone is situated in the Fraser and Thompson Plateau's, extending from Williams Lake in the

north to the southern end of the Okanagan Valley (Figure 1). To the east, a narrow band follows the Columbia River.

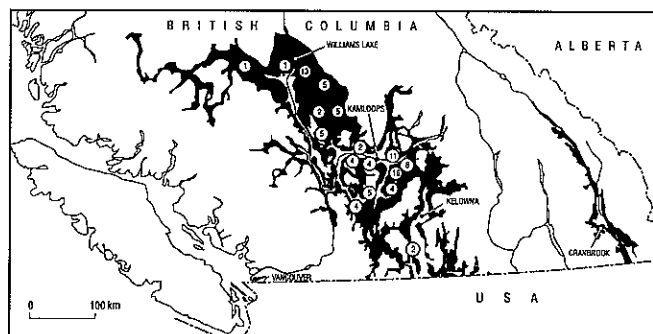


Figure 1.—Interior Douglas-fir zone in British Columbia.

The IDF is divided into subzones and variants according to temperature, precipitation and site quality. The most extensive and economically important subzones—in which the plots of this study are located—are subzones dk (dry, cool) and xh (xeric, hot). Subzone dk (Table 1) is the largest one, at 2.5 million ha (6 million ac). It occupies the highest elevation and as a result is the coolest, has the shortest frost free period and the most precipitation. It has two variants: the Thompson Plateau variant in the Kamloops Forest Region, and the Fraser Plateau variant in the Cariboo Forest Region.

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *glauca*) is a commercially important species in the British Columbia interior. It has been harvested extensively during the last half century, mostly for lumber. Harvesting methods have ranged from high grading through Diameter Limit cutting to the current Faller's Selection Method.

Interior Douglas-fir occurs naturally in uneven-aged stands and should be managed accordingly. Better knowledge of the growth and silviculture of the Douglas-fir is necessary for that purpose, and to increase productivity and economic returns. However, the scarcity of permanent sample plots and research installations has resulted in a lack of reliable information.

The purpose of this study is to develop a data base containing Douglas-fir stand growth data, to use this data base to assess the effect on stand growth of differences in harvesting method, time since harvest, site quality and selected stand parameters, and to use the outcome of the assessment to derive a simple stand growth model.

In scope, the study is limited to pure Douglas-fir stands of the B.C. Interior "Dry Belt". Site quality assessment is limited by data scarcity to the two main biogeoclimatic subzones, IDF dk and xh (Lloyd *et. al.* 1989). Stand parameters

Table 1.—Characteristics of major IDF subzones

Biogeoclimatic Subzone	Area (1000 ha)	Elevation* (m)	Precipitation* (mm/yr)	Soil Moisture Deficit* (months/yr)	Frost Free Period* (days)	Mean Annual Temperature* (degrees C)
DK	2450	1200	425	5	75	4
XH	600	1000	375	5	100	6
Both	3050					

* Based on Lloyd *et. al.* (1989), and Mitchell and Erickson (1989).

comprise stocking per hectare, basal area per hectare, and quadratic mean diameter. Harvesting methods (treatment) comprise Control (no harvest), Diameter Limit cutting (all trees above a specified diameter are harvested), and the Faller's Selection method, which is similar to the Diameter Limit cutting except that the residual stand is spaced.

Data Sets

Three data sets were acquired:

- (1) British Columbia Ministry of Forests permanent sample plots (PSP's). Data from 63 plots were obtained. All had been remeasured once, hence data from 63 measurement intervals were available. Most plots were established in 1977 as part of the Ministry's inventory program, and remeasured in 1987; a few came from research installations.
- (2) Data from five plots with eight measurement intervals, from Lignum Ltd. of Williams Lake. In essence, the data were derived from stem analyses: harvest operations were undertaken, and plots were established 6-7 years later, at which time trees were felled for stem analysis and growth estimation before and after treatment.
- (3) In cooperation with R. L. Korol of the University of Montana, data from 24 plots were obtained. As for the Lignum data, stem analysis was used to estimate volume growth.

In some cases, where clusters of small plots had been established, they were combined to form one plot each. Size of the plots ranged from 500-1500 m² (0.12-0.36 ac).

Plot locations are shown in Figure 1. The numbers inside the circles refer to the number of plots in that general location. While the central portion of the IDF zone is well covered, few are near the limits and none are in the Columbia River Valley. Of the 92 plots, 65 (and 119 measurement intervals) are located in subzone dk, while 27 (and 54 measurement intervals) are in subzone xh.

Data Evaluation and Compilation

Having acquired the data sets, the classification of each plot was carefully checked. Particular attention was paid to the treatment type and date, including visual inspection, talking to local foresters, and examination of old cutting permits.

One concern was that the plots might differ in their characteristics due to the methodology used to obtain the data, i.e., that they might differ by ownership. A scattergram of volume growth (VGR) over volume (VOL) by ownership categories was produced. It revealed no trends or patterns; hence no significant differences due to methodology were assumed to exist.

Having ensured proper plot classification, the individual tree data were used to compile tree and plot volumes and increment, as follows:

- (1) Ministry of Forests procedures were used to develop a height-diameter equation which was used to derive a height for each tree lacking a measured height.
- (2) Ministry of Forests tree volume equations (1976 whole stem cubic metre volume equations) were used to calculate individual tree volumes.
- (3) Tree volumes were summarized within plots and converted to per hectare values.
- (4) Growth data were obtained by subtracting volumes measured on successive dates. To facilitate comparisons, a 5-year growth interval was adopted as standard. This required a conversion from other intervals for some plots.

The Lignum and Korol data sets, being constructed from increment cores and stem analysis data, did not have any data on ingrowth and mortality. Mortality estimates were obtained by constructing, from the remeasured Ministry of Forests PSP's, equations giving the probability of mortality by 5-cm diameter classes for specified periods. These equations were used to add 'mortality trees' to the initial Lignum and Korol data sets. No corrections for ingrowth were attempted since any changes in volume and increment would be minimal.

Figure 2 provides a visual check of the plot data and an opportunity to spot outliers. While most plots cluster around a

volume growth of 4 m³/ha.yr (57 ft³/ac.yr) and a volume of 150 m³/ha (2150 ft³/ac.yr), a few plots deviate significantly. One plot shows a negative growth rate because a large tree died between measurements.

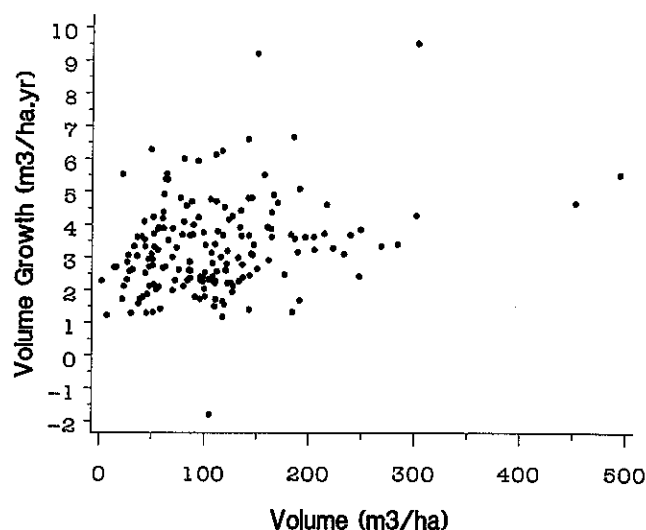


Figure 2.—Distribution of sample plot values by volume and volume growth.

Plot characteristics are summarized in Table 2 by treatment. The low averages for the DL method are probably a result of the treatment itself, i.e. removal of the largest trees. The small ranges of the FS method are likely related to the small sample size. The untreated plots have, as expected, more stems per hectare than the treated plots. The large volume range of the untreated plots is caused by one plot, the Lignum old-growth plot, having a volume of 453 m³/ha. Apart from that plot, the range is similar to that for the DL and FS treatments.

The final step was the creation of a data base containing a standard set of data for each plot:

Plot number;
 Plot location: UTM Zone, Easting and Northing;
 Owner of data: Ministry of Forests, R.L. Korol, or Lignum Ltd.;
 Biogeoclimatic subzone (BGC): DK or XH;
 Treatment type (TRT): Diameter limit (DL), Faller's Selection method (FS), or None (NO);
 Initial measurement date;
 Time since treatment (TST), in years;
 Number of trees per hectare (TPH);
 Basal area (BAH), in m²/ha;
 Quadratic mean diameter (QMD), in cm.;
 Volume (VOL), in m³/ha;
 Measurement interval, in years; and
 Volume growth (VGR), in m³/ha.yr.

ANALYSES AND RESULTS

As previously stated, a primary purpose of this study is to assess the effect on stand growth of differences in harvesting method (TRT), time since harvest (TST), site quality (BGC) and stand parameters (TPH, BAH and QMD). Given an ideal data set such as would be obtained from an experimental design, this purpose would be comparatively easy to accomplish. However, the present data set is far from ideal; data are deficient or absent from many combinations of parameters.

For statistical analyses, the General Linear Model Procedure (PROC GLM) (SAS User's Guide: Statistics, 1985) was used. It will handle discrete classification variables as well as continuous independent variables. Considering the incomplete cross

Table 2.—Plot Characteristics*, by Treatment.

Treatment Type	Stocking (no. of stems/ha)		Basal Area (m ² /ha)		Quadratic Mean Diameter (cm)		Volume (m ³ /ha)		No. of Plots	No. of Measurement Intervals
	ave.	range	ave.	range	ave.	range	ave.	range		
Diameter Limit	443	67-1367	14	1-45	20	11-46	84	3-303	66	84
Faller's Selection	532	383-800	19	9-40	21	15-32	131	48-303	9	11
Untreated	742	200-1650	19	2-60	18	11-30	114	8-453	17	78
ALL	507	67-1650	15	1-60	20	11-46	94	3-453	92	173

* At initial measurement. Trees >9.0 cm in dbh.

classification of the data set, orthogonal contrasts were used in GLM to separate cell means. In addition to GLM, regression analysis was carried out using procedures STEPWISE and RSQUARE for exploratory analysis and procedure REG for confirmatory analysis, followed by plotting (using procedure GPLOT) with visual inspection of the plots.

The first set of analyses was to determine if significant differences existed among the discrete variables of treatment and biogeoclimatic zone. The following effects were found to be significant:

- Treatment difference FS-DL, regardless of BGC;
- Treatment difference FS-NO, regardless of BGC;
- Interaction effect DL-NO (TRT) by DK-XH (BGC).

These results may be interpreted by reference to the mean growth values of Table 3: the FS values, at 5.0 and 4.1 m³/ha.yr (71 and 59 ft³/ac.yr), are higher than the DL values while the NO-XH value (2.6 m³/ha.yr, 37 ft³/ac.yr) is lower. While the NO-DK average is not significantly different from the DL averages, subsequent regression analyses revealed that the equations were. Therefore, the three treatments were grouped separately and, within the NO treatment, the two subzones were separated. This resulted in the following four Groups:

- Group A: all FS plots;
- Group B: all DL plots;
- Group C: NO-DK plots; and
- Group D: NO-XH plots.

Table 3.—Stand Growth (in m³/ha.yr) by Biogeoclimatic Subzone and Treatment*.

Biogeoclimatic Subzone	Diameter Limit (DL)	Treatment		ALL
		Faller's Selection (FS)	Untreated (NO)	
DK	3.2	5.0	3.5	3.4
XH	3.6	4.1	2.6	3.2
Both	3.3	4.4	3.2	3.3

* Trees >9.0 cm in dbh.

A second analysis which included the new groups as well as the previous independent variables (TST, BAH, TPH and QMD) was run. The analysis showed that TST had no significant effect on VGR, explaining only 9% of the total variance. The remaining three variables did have significant effects on VGR. Regression on TPH alone explained 29% of the total variance. In the presence of TPH, neither BAH nor QMD was significant. However, they jointly explained 33% of the total variance.

To convert these assessments into usable equations, a set of stepwise regressions was run. For each group, up to two variables (of TPH, BAH and QMD) having a statistically significant correlation with VGR were selected for inclusion in the equation. The results are shown in Table 4.

For Group A, no independent variable was significant. For Groups B and C, the variable stocking was significant while for Group D, the significant variables were stocking and mean diameter; however, the analyses showed that the other independent variables were almost equally good.

The equations of Table 4 were plotted (Figure 3) and used to derive growth rate tables for different values of stocking and mean diameter (Table 5).

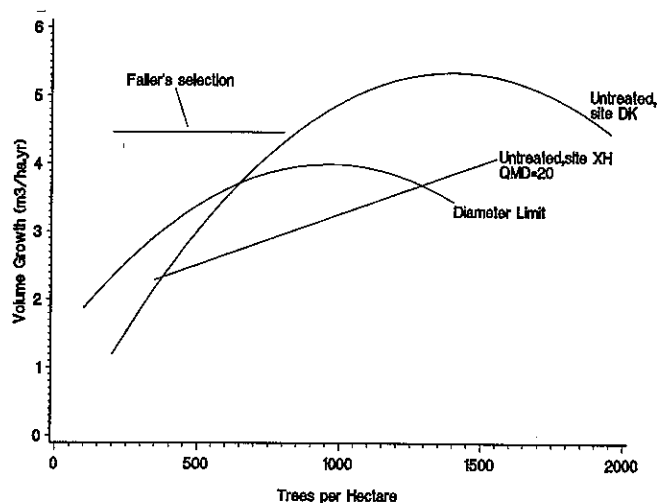


Figure 3.—Volume growth equations.

DISCUSSION AND CONCLUSIONS

The basic data set suffers from a number of deficiencies: incomplete coverage of parameter combinations and geographic locations, different measurement periods and procedures, and variability in treatment intensity and quality. As an example, the stem analysis methods used to obtain the Korol and Lignum data cannot provide ingrowth and mortality data. Hence, such data are available only from the Ministry of Forests plots. Fortunately, ingrowth is of little consequence in estimating volume growth and mortality is minor (less than 1%), so this deficiency does not disqualify the Korol and Lignum PSP's from use.

The deficiencies create considerable "noise" in the data which make it difficult to determine real relationships and trends, and decrease the accuracy of the estimates.

To the deficiencies is added a natural variability within IDF stands. For example, some uneven-aged stands include pockets of dense, small, seemingly even-aged trees. However, analyses indicate that they are indeed uneven-aged.

Despite the deficiencies, several results are apparent:

- (1) Growth of stands treated according to the Faller's Selection (FS) method at 4.5 m³/ha.yr (64 ft³/ac.yr) is higher than that of stands treated according to the Diameter Limit (DL) method, at 3.3 m³/ha.yr (47 ft³/ac.yr). These growth rates do not appear to vary with biogeoclimatic subzone. For untreated stands (NO), growth rates do vary with subzone: for DK, the growth is about the same as for DL stands while for XH it is lower, at 2.6 m³/ha.yr (37 ft³/ac.yr).

Table 4.—Volume Growth Equations*.

Group	Equation	Sample Size	R ²	S.e.e.	
				(m ³ /ha.yr)	(% of mean)
A: Fallers selection	VGR=4.46	11	--	2.3	51
B: Diameter Limit	VGR=1.35+0.00550*TPH-0.00000286*TPH**2	81	0.28	0.8	25
C: Untreated, subzone DK	VGR=-0.314+0.00812*TPH-0.00000291*TPH**2	38	0.60	1.0	28
D: Untreated, subzone XH	VGR=-1.90+0.00152*TPH+0.183*QMD	24	0.47	0.7	24

* Trees >9.0 cm in dbh.

Table 5.—Growth Values (m³/ha.yr) from Volume Growth Equations.*

GROUP	No. of trees per hectare (TPH)								Quadratic mean diameter (QMD)
	100	300	500	700	900	1100	1300	1500	
A: Faller's selection	-----4.5-----								
B: Diameter limit	1.9	2.7	3.4	3.8	4.0	3.9	3.6		—
C: Untreated, subzone DK		1.9	3.0	3.9	4.6	5.1	5.3	5.3	—
D: Untreated, subzone XH			1.6	1.9	2.2	2.5	2.8	3.1	15
			2.5	2.8	3.1				20
			3.4	3.7					25

* Trees <9.0 cm in dbh.

- (2) Stand growth is not related to the time since treatment (TST).
- (3) Growth of FS stands are not related to stand parameters, while growth of DL and NO stands are.
- (4) The most important stand parameter is stocking (TPH).

These results must be interpreted in light of the data deficiencies and of past experience. First, it is reasonable to expect higher growth rates for the FS method than for the DL method; while the DL method merely removes the largest trees, the FS method also spaces the residual stand, giving more room for individual trees to grow and for more moisture to reach the ground. The untreated (NO) stands benefit from neither, hence no growth increase can be expected.

It is not reasonable to expect FS growth to be independent of stand parameters while DL and NO stand growth are dependent of them. More likely, the small sample size (11 plots) has prevented any trend from appearing for the FS data. The same small sample size—and short time since treatment, less than five years—are also the likely reasons why growth does not show any variation with TST for the FS method. For the DL method, these reasons do not apply; both sample size and time span are larger. If there is a trend, it may be obscured by the variability in intensity and quality of the operational treatments.

Site quality is known to have considerable influence on tree and stand growth, yet the results emerging from this study are

not clear. Analyses of the NO stands indicate that Douglas-fir grows better on sites of the DK type than on XH sites. However, this indication is not supported by the results for the two treatments. One possible reason is that the BGC subzones are too broad to quantify differences in VGR, another may be that treatment and site quality effects are confounded: the best stands are usually harvested (and treated) first.

The relationships between volume growth and stems per hectare for Groups B and C (Tables 4 and 5) appear reasonable: as TPH increases, so does VGR up to a point where the stand becomes too dense, then VGR levels off or decreases. For Group D the results are also reasonable: VGR increases with TPH and QMD, and the values remain within acceptable levels.

What is the precision of the estimates? For the FS equation (Table 4) the standard error is 51% indicating that, two times out of three, the true value will be within 51% of the estimated mean, which is 4.46 m³/ha.yr (64 ft³/ac.yr). Figure 2 shows that the actual PSP values range from less than 2 to more than 9 m³/ha.yr (29-129 ft³/ac.yr). For the other equations (Table 4), the standard errors are considerably less, at 25, 28 and 24% for Groups B, C and D, respectively. The range in PSP values (Figure 2) is about the same for Group B, less for Groups C and D.

The growth rates obtained here are higher than some obtained previously. Clark (1952) found the growth rates to range from 2.8-3.9 m³/ha.yr (40-56 ft³/ac.yr), while Johnstone (1985)

derived a rate of 1.8 m³/ha.yr. However, mean annual increment values used by the Ministry of Forests in timber supply analysis reports currently range from 3.7-4.4 m³/ha.yr (53-63 ft³/ac.yr) for good sites. For medium sites, the range is 2.0-2.7 m³/ha.yr (29-39 ft³/ac.yr).

The results of this study provide additional information on Interior Douglas-fir growth rates in general, and some first estimates of growth rate variability with treatment and other factors. However, the results also indicate that, to obtain more reliable information on growth rate and the factors affecting it, the quality and quantity of basic growth data must increase.

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