Statistical Adjustment of
Tree Farm Licence 37
Vegetation Resources Inventory

Prepared for

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Executive Summary

Canadian Forest Products Ltd. (Canfor) is completing a Vegetation Resources Inventory (VRI) on Tree Farm Licence (TFL) 37. Eighty (80) VRI timber emphasis ground sample plots were randomly selected and installed in the Vegetated Treed (VT) land base considered economically or marginally economically harvestable. Sixty-eight (68) ground plots located in VT stands 30 years and older were used to statistically adjust this part of the population. Non-Vegetated (NV), Vegetated Non-Treed (VN), VT polygons considered non-economically harvestable, and VT polygons less than 30 years were left unadjusted.

Following adjustment, the overall average merchantable volume less decay, waste, and breakage was 331 m^3/ha on the entire TFL. In mature (polygons 61 years or older), economically and marginally economically harvestable polygons, the average volume was 637 m^3/ha.

		Volume (m^3/ha)	
Population	Maturity	Pre-Adjustment	Post-Adjustment
Adjusted	Mature	609	637
	All	530	580
Entire TFL	All	304	331

The average VRI ground volume was comparable to the 1994 Ministry of Forests (MOF) audit ground volume. We recommend that Canfor use these adjusted height, age, and volume estimates for forest management and timber supply planning on TFL 37.

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1. INTRODUCTION

1.1 BACKGROUND

The Vegetation Resources Inventory (VRI) is a three-phase process. In the first phase (Estimation Phase), aerial photos are used to delineate polygon boundaries in an inventory unit and to assign attributes to these polygons. In the second phase (Ground Sampling Phase), sample locations are randomly generated and VRI timber emphasis clusters are installed throughout the inventory unit to produce field estimates for each sampled polygon. In the final phase (Statistical Adjustment), a ratio adjustment for different attributes is developed between the ground and photo estimates, and the original photo estimates are adjusted to reflect the results of the ground sample.

Canadian Forest Products Ltd. (Canfor) began implementing this VRI program on Tree Farm Licence (TFL) 37 in 1996. Olympic Resource Management Ltd. (ORM, formerly Simons, Reid, Collins Ltd.) completed the Estimation Phase in 1997.[1] The Ground Sampling Phase occurred during the 2000 and 2001 field seasons. The Ministry of Sustainable Resources Management (MSRM) compiled the ground data in preparation for the statistical adjustment of the estimated attributes.

1.2 PROJECT OBJECTIVES

The objectives of this project are:

1. *To develop unbiased average inventory estimates of height, age, and net merchantable volume for the economically and marginally economically harvestable vegetated treed polygons, 30 years and older on TFL 37.*
2. *To develop polygon-level estimates of height, age, and net merchantable volume.*

1.3 TERMS OF REFERENCE

Pat Bryant, *RPF* of Canfor was the project leader. Guillaume Thérien, *PhD* of J.S. Thrower & Associates Ltd. (JST) completed the statistical adjustment and compiled this report. This project was funded through Forest Renewal BC.

2. STUDY AREA

TFL 37 is located on northern Vancouver Island, approximately 100 kilometres north of the town of Campbell River. The TFL covers 190,669 ha (Table 1), of which about 144,000 ha (75%) is Vegetated Treed (VT). The sampled land base was the economic and marginally economic areas of the VT land base. The MSRM procedures for adjusting the younger stands (less than 30 years) are still being developed and so only polygons in the older segment of the economic VT area (102,405 ha, 54% of the TFL) were adjusted.

Table 1. TFL 37 land base net down statistics.

	Area	
Description	(ha)	(%)
TFL land base	190,669	
Non-Vegetated Treed	47,082	25%
Vegetated Treed (VT)	143,587	75%
Uneconomic VT	15,561	8%
Economic/Marginally Economic	128,026	67%
< 30 years	25,621	13%
>= 30 years	102,405	54%

[1] The Estimation Phase was a retro-fit of a recent inventory to VRI standards.

3. METHODS

3.1 ESTIMATION PHASE DATA

ORM completed the Estimation Phase using 1996 aerial photography. The inventory was updated for depleted areas to December 2001. The Estimation Phase showed an average volume[2] of 530 m^3/ha for the total sampled land base (54% of the entire TFL), while the mature[3] portion of the sampled land base was 609 m^3/ha (79,260 ha). The average volume for the entire TFL was 304 m^3/ha (all ages), and 541 m^3/ha for the mature component of the TFL.

3.2 GROUND SAMPLING PHASE DATA

Eighty (80) VRI ground sample plots were established in the 2000 and 2001 field seasons. Nine of the originally selected plots were replaced because they were located in previously harvested cut-blocks (therefore, non-treed vegetated). One original plot location was relocated for safety reasons; a second plot was dropped for safety reasons and replaced with another plot because a similar location could not be found in the selected polygon. The remaining 69 plots were established at their original locations. Forty (40) plots were sampled during each sampling season but for this study we assumed that all plots were sampled in 2001.

Sixty-eight (68) plots were used in the analysis. Ten (10) plots were rejected because they were installed in stands younger than 30 years total age, one was in a non-vegetated treed polygon, and another was established in a non-vegetated polygon.

3.3 STATISTICAL ADJUSTMENT

The statistical adjustment was completed according to MSRM standards and procedures for attribute adjustment.[4] Only one adjustment ratio for height and volume was computed for the entire sampled land base since the sample size was too small to post-stratify. For the age attribute, photo-interpreted values did not exceed 300 years. Therefore, the value “300” for age represented more a categorical attribute for “old-growth” than an actual age estimate. For that reason, an adjustment ratio was computed for stands less than 300 years while an average age (estimated from the ground plots only) was applied to stands in the 300-year category.

Ideally, volume should be adjusted using the net merchantable volume corrected through the Net Volume Adjustment Factor (NVAF) process. The NVAF-corrected volume is free of taper or decay estimation bias. However, NVAF sampling will only be completed after the 2002 field season. Therefore, volume was adjusted using the MSRM loss-factor net merchantable volume.

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[2] For the purpose of this project, volume was defined as whole-stem volume minus stump (30 cm height), top (the section above a diameter inside bark of 10 cm), decay, waste, and breakage at a utilization level of 17.5 cm+. Decay and waste were estimated using the MSRM loss-factor equations.

[3] Stands older than 60 years were considered mature.

[4] Ministry of Sustainable Resources Management. 2001. Vegetation Resources Inventory Attribute Adjustment Procedures. Draft Version 4.2, September 2001. 37 pp.

4. RESULTS AND DISCUSSION

4.1 OVERVIEW

The MSRM assumes that the Estimation Phase inventory volume is biased due to two sources of error: an attribute bias associated with the photo-interpreted height and age, and a model bias inherent to the growth and yield model used to estimate volume (*VDYP version 6.6d*). The MSRM assumes that the other attributes used by VDYP (species composition, stocking class, and crown closure) are free of error.

The attribute adjustment procedure is a two-step process. In the first step, the Estimation Phase height and age bias are corrected using the adjustment ratio estimated from the ground and the Estimation Phase height (or age). An attribute-adjusted volume can then be estimated using VDYP. In the second step, the model bias in the attribute-adjusted volume is corrected using the adjustment ratio estimated from the ground and the attribute-adjusted volume. All adjustment ratios are estimated using the ratio of means (ROM) method.

4.2 HEIGHT AND AGE

Sixty-five (65) of the plots had data for a species that matched the leading species in the Estimation Phase using the MSRM criteria.[5] On nine plots, an age, but no height was obtained. Estimation Phase height tended to be over-estimated while Estimation Phase age was under-estimated (Table 2). After age adjustment, the mature sampled land base was 66,377 ha, a decrease of about 16% compared to the initial Estimation Phase age.

The relationship between ground and Estimation Phase age was slightly better than the height relationship (Figure 1 and Figure 2). The sampling error was about 14% for height, 25% for age below 300 years, and 15% for the 300-year age category. Plot 18 had a map height and age of 12 m and 30 years, respectively while the corresponding ground values were 34.5 m and 369 years. This is due to the plot landing in a two-layer stand. The main layer was the shorter one, but ground values were derived from the taller layer.

Table 2. Height and age adjustment statistics for TFL 37 VT, economically and marginally economically harvestable polygons over 30 years.

	Population		Sample					Adj. Pop.	
Attribute	Area (ha)	Avg.	Size	Grnd. Avg.	Map. Avg.	R^2	ROM	Avg.	Std. Err.
Height (m)	102,405	32.0	57	28.0	30.7	32%	0.915	29.2	1.9
Age (yrs) <300	36,028	69.4	29	122.1	83.3	53%	1.466	101.7	12.5
Age (yrs) >300	66,377	300.0	36	451.6				451.6	33.1

[5] First, a match was attempted at the species level (case 1); second at the genus level (case 3); and third at the conifer/deciduous level (case 5). Canfor did not have a height/age for the second species in their inventory (cases 2 and 4).

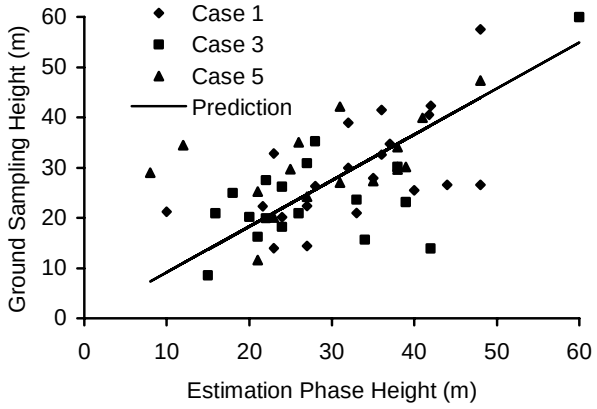

Figure 1. Ground Sampling vs. Estimation Phase height.

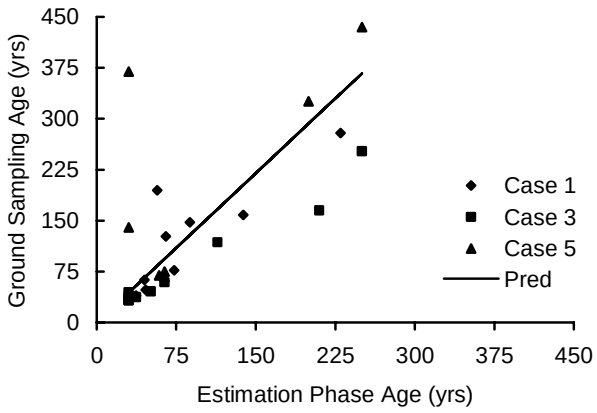

Figure 2. Ground Sampling vs. Estimation Phase age.

4.3 VOLUME

A volume, called the attribute-adjusted volume, was generated with VDYP using the Estimation Phase attributes and the adjusted height and age. The average attribute-adjusted volume for the entire sampled land base was approximately 431 m^3/ha (Table 3). This decrease of almost 20% from the Estimation Phase volume (530 m^3/ha) can be explained by the attribute adjustment. The attribute-adjusted volume tended to under-estimate the ground volume. After adjustment, the average sampled population volume was about 580 m^3/ha, an increase of about 35% compared to the attribute-adjusted volume.

Table 3. Volume adjustment statistics for TFL 37 VT, economically and marginally economically harvestable polygons over 30 years.

	Population		Sample					Adj. Pop.	
Attribute	Area (ha)	Avg. (m^3/ha)	Size	Grnd. Avg. (m^3/ha)	Map. Avg. (m^3/ha)	R^2	ROM	Avg. (m^3/ha)	Std. Err. (m^3/ha)
Volume (m^3/ha)	102,405	430.6	68	547.4	406.3	52%	1.347	580.2	32.4

The adjusted volume showed an increase of about 9% when compared to the Estimation Phase volume (Table 4). When only the mature land base is considered, the average adjusted volume was 637 m^3/ha (when maturity is based on the adjusted age). For the entire TFL land base the average volume is 331 m^3/ha (all ages) and 572 m^3/ha for the mature polygons.

Table 4. Estimation Phase and Adjusted volumes.

Population	Maturity	Volume (m^3/ha)		Diff. (%)
		Est. Phase	Adjusted	
Sampled	Mature	609	637	5%
	All	530	580	9%
Entire TFL	Mature	541	572	6%
	All	304	331	9%

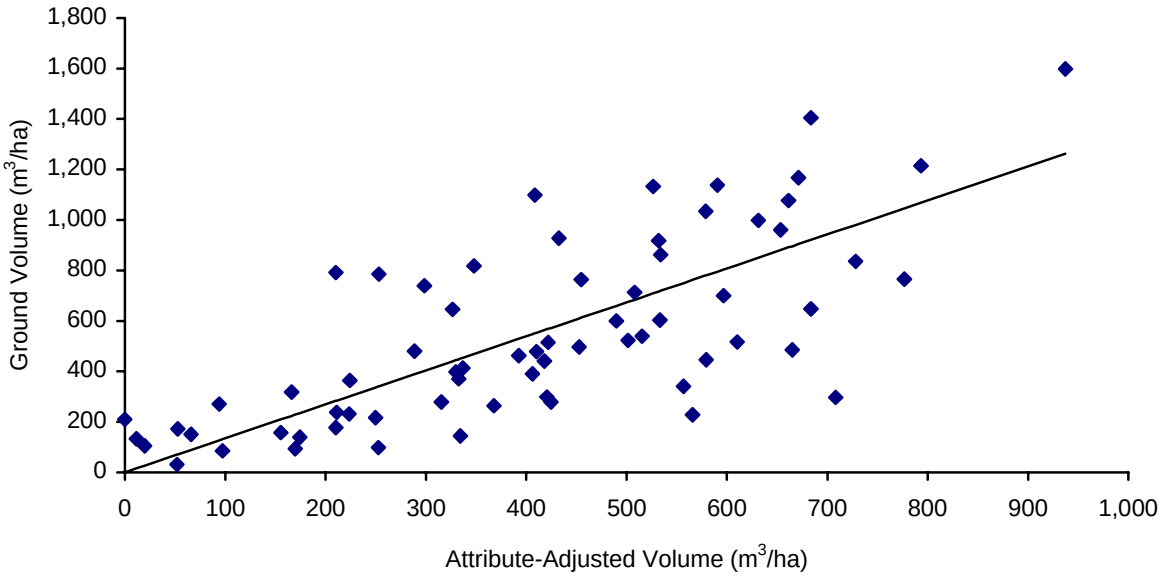

Figure 3. Ground versus attribute-adjusted volume for TFL 37 VT, economically and marginally economically harvestable polygons over 30 years.

4.4 COMPARISON WITH MSRM AUDIT

The MSRM (then the Ministry of Forests [MOF]) audited the net merchantable volume on TFL 37 in 1994. The ground volume in the audit and the VRI is not directly comparable since the sampled population changed between 1994 and 2001 and the sampling objectives and methods of the audit and the VRI differed. However, it can provide a level-of-comfort that the estimates obtained from the audit and VRI are similar.

Since only the whole-stem volume less decay was available for the ground volume audit, the same VRI volume was used for this comparison. The whole-stem volume less decay is slightly higher than the ground net merchantable volume reported in previous sections of this report. The audit ground samples showed more ground volume than the VRI, but the sample Estimation Phase average volume for audit plots was higher than the population Estimation Phase average. For VRI plots, the sample Estimation Phase average volume was lower than the population average. After correcting for the difference between the population and map average volumes, the adjusted volume between the audit and VRI are very similar (Table 5).

The 95% confidence interval reported for the ground average audit ([634 m^3/ha, 810 m^3/ha]) included both the adjusted Estimation Phase volume based on the 1994 audit and the 2001 VRI. This suggests that the audit sample was probably representative of the 1994 sampled population.

Table 5. TFL 37 MSRM audit versus VRI whole-stem volume less decay.

Source	Population		Sample				Adjusted
	Area (ha)	Est. Phase Avg. (m^3/ha)	Size	Ground. Avg. (m^3/ha)	Est. Phase Avg. (m^3/ha)	Ratio	Est. Phase Avg. (m^3/ha)
1994 Audit	73,858	484	41	722	508	1.421	688
2001 VRI	79,260	609	54	654	574	1.103	694

5. CONCLUSION

In this project, we adjusted the TFL 37 economic and marginally economic polygons over 30 years of age using the MSRM standard statistical adjustment procedures. The volume estimates obtained through this process are consistent with the 1994 audit volume estimates. Therefore, we recommend that:

Canfor use the adjusted height, age, and volume for TFL 37's VRI.