Tree Farm Licence 3
Slocan Forest Products

Documentation of Analysis for Vegetation Resources Inventory Statistical Adjustment

PREPARED FOR:

SLOCAN FOREST PRODUCTS LTD
SLOCAN, BC

PREPARED BY:

Jahraus & Associates Consulting Inc.
Victoria BC

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EXECUTIVE SUMMARY

Ninety VRI Phase II ground samples were established in TFL 3 in the 2001 field season, based on the PPSWR sample design specified in the VRI Project Implementation Plan (VPIP). The population of interest for this study was vegetated, treed polygons with inventory age greater than 20 years. TheVRI data was analyzed to provide statistical adjustment factors that could be used to support a timber supply analysis. The adjustment factors were developed using the interim “Fraser Protocol” according to current MSRM standards. Age, height and volume adjustment ratios were provided for each of four leading-species based strata that corresponded with the sample design pre-stratification. For the balsam leading stratum, an age-related bias was observed in the adjusted volumes. To correct for this bias, the balsam leading stratum was sub-stratified using a 120 year age break. Ground volumes were compiled using loss factors and net factoring. However, NVAF sampling was not carried out in this unit hence the net factored volumes could not be adjusted for taper and hidden decay. The overall ratio of ground loss factor volume to unadjusted inventory volume was 0.88. This was similar to the ratio of 0.87 that was observed in the Inventory Audit for TFL 3 (note that the audit population of interest for the audit was slightly different). The sampling error for the VRI loss factor ratio of 0.88 was 11.8% at a 95% confidence level. This was slightly higher than the target sampling error of 10% that was set in the VPIP.

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1. INTRODUCTION

1.1 Background

A VRI Project Implementation Plan (VPIP), prepared by Ministry of Forests-Nelson Forest Region in consultation with Slocan Forest Products and Resources Inventory Branch (RIB), outlined ground sampling activities for the timber emphasis Vegetation Resources Inventory (VRI) ground sampling in TFL 3[1]. The timber emphasis VRI was, in part, motivated by the results of the 1995 Inventory Audit for TFL 3 that suggested an overestimation in inventory height for stands over 60 years of age. Although the TFL 3 inventory recently underwent a VRI retrofit[2], the issue of height overestimation has not been addressed. The rationale for the VPIP was that ground sampling and a statistical adjustment of the inventory would correct for any observed bias in the inventory. According to the VPIP, the main objective of the timber emphasis inventory was to:

> *"Install an adequate number of VRI sample clusters to adjust the timber emphasis inventory in the TFL 3 Vegetated Treed (VT) areas greater than 20 years of age, to achieve a sampling error of ±10% (95% probability) for overall net timber volume."*

Samples were selected using probability proportional to size with replacement (PPSWR). Ninety VRI Phase II ground samples were established in the 2001 field season. Sampling to determine a Net Volume Adjustment Factor (NVAF) for this unit was not carried out. For further details regarding the ground sampling, please refer to the VPIP document.

1.2 Scope and Objectives

The objective of this analysis was to analyze the VRI ground sample data and provide statistical adjustment factors for TFL 3 based in the current Ministry of Sustainable Resource Management (MSRM) methodological standards. The actual adjustment of the inventory file is not within the scope of this contract and will be completed under separate contract by Timberline Forest Inventory Consultants Ltd.

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[1] "Tree Farm Licence 3 Slocan Forest Products: Timber Emphasis VRI Ground Sampling Project Implementation Plan", April 27, 2001, Ministry of Forests, Nelson Forest Region.

[2] In the retrofit process, FIP files are converted to VIF file formats and missing VRI attributes are photo-estimated. However, no new polygon delineation is completed and the original photo-interpreted attributes are not changed.

2. METHODS

2.1 Overview of statistical adjustment

Statistical adjustment is the process of adjusting the values of the photo-interpreted variables in the inventory using information from the ground sampling observations. The statistical adjustment factors for TFL 3 were developed using the current MSRM approach known as the “Fraser Protocol”.

In the Fraser Protocol, ground observations are compared with photo-estimated values[3] for each sampled polygon. A statistical model, typically ratio of means[4], is then used to develop the adjustment factors. These factors are applied to all polygons in the photo-interpreted inventory database to produce the final adjusted inventory database. Under the current MSRM standard, only three inventory attributes are adjusted: age, height and volume. The Fraser Protocol is a sequential approach where adjustment factors for inventory age and height are computed first, a new “attribute-adjusted” inventory volume (based on the adjusted age and height) is calculated next, and finally, a volume adjustment factor is computed based on the “attribute-adjusted” inventory volume. This process is shown diagrammatically in Figure 1 below.

[3] In VRI terminology, the ground sample values are referred to as PHASE II values and the photo-interpreted inventory values are referred to as PHASE I values.

[4] Ratio-of-means is generally appropriate if the relationship between y (ground attribute, in this case) and x (inventory attribute) is linear and passes through the origin. If these conditions are not met alternative adjustment approaches (such as linear regression, geometric mean regression, non-linear regression) may be explored. However, these alternatives also have their limitations and may produce undesirable characteristics in the adjusted population.

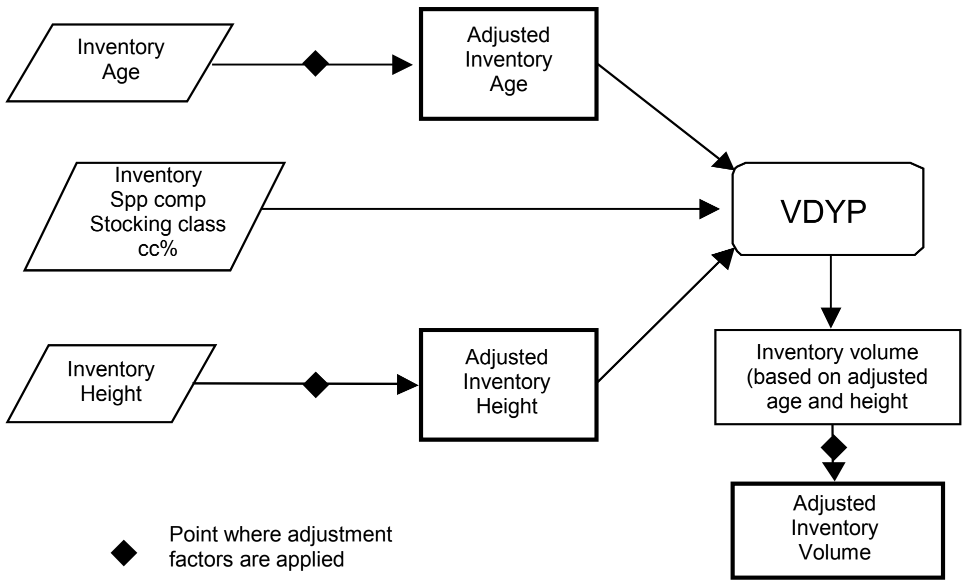

Figure 1: Overview of the Fraser Protocol for statistical adjustment of inventories.

2.2 Population for adjustment

The population of interest for TFL 3 was defined as vegetated, treed[5] (VT) polygons greater than 20 years of age on the inventory file. The adjustment factors apply to all polygons in the inventory meeting these criteria.

2.3 Data sources

2.3.1 Phase I photo-interpreted inventory data

The TFL 3 inventory data was provided by MSRM in Vegetation Inventory File (VIF) format. The TFL 3 inventory was "retrofit", that is, the existing inventory in FIP (Forest Inventory Planning) format was translated into VIF format and additional attributes required by VRI were re-estimated from the aerial photos. No new polygon delineation or re-estimation of existing attributes was carried out. With the exception noted in section 2.4 below, inventory data used in the adjustment was based on the rank 1 layer. Inventory data was projected to 2001 to correspond with the year of ground sampling.

[5] VT as defined by the BC Land Classification System.

2.3.2 Phase II ground sample data

All 90 of the originally planned VRI ground samples were established in the 2001 field season. The samples were validated and the data compiled by MSRM. The final compiled data was provided for analysis on November 15, 2001. Net timber volumes were compiled using the 1976 Ministry of Forests Forest Inventory Zone Decay, Waste and Breakage factors to estimate decay, waste and breakage. In addition, volumes were also compiled using the standard VRI call grading/net factoring. However since there was no NVAF sampling carried out in this unit, the net factored volumes were not adjusted with an NVAF.

2.3.3 Data matching

For each VRI sample polygon, the ground sample data was matched with the corresponding inventory data for the same polygon. The ground and inventory data used in the development of the adjustment factors for TFL 3 are provided in Appendix A.

The ground heights and ages used in the adjustment were based on the average values for the T, S & L[6] trees for the leading species (by basal area at 4cm + dbh utilization) on the ground. In the Vegetation Inventory File (VIF) format, inventory data (i.e. height and age) is available for the leading and second species. The objective in the matching process was to choose an inventory height and age (i.e. for either the leading or second species) so that the ground and inventory species “matched”. If a match could not be made at the sp0[7] level, conifer-to-conifer matches were allowed. However, conifer-deciduous matches were not considered acceptable. Details of the species matching process are provided in the VRI Draft Attribute Adjustment Procedures document available from the MSRM. Note that where second species inventory ages and heights were required[8], these attributes were projected to 2001 using Sitetools.

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[6] T or “top height” tree is the largest DBH in 0.01 ha plot, regardless of species; L or “leading species” tree is the largest DBH in 0.01 ha plot, of leading species; S or “second species” is the largest DBH in 0.01 ha plot, of second species. T and S trees are selected and measured at the IPC only whereas L trees are selected at the IPC and all auxiliary plots. For details, refer to Section 4.8 in the MSRM document “VRI Ground Sampling Procedures”, January 2001 version 4.2.

[7] sp0 refers to the 16 major species codes and is roughly equivalent to the genus level.

[8] For 50% of the samples, the inventory and ground leading species matched. For a further 28.5% of the samples, the ground leading species matched the inventory second species. The remaining 21.5% of the samples were matched based on conifer-to-conifer.

2.4 Data issues related to the analysis

Two samples were excluded from the analysis since they were outside of the population of interest (i.e. they were less than 20 years of age) and had been established inadvertently[9]. Sample #13 was identified as a potential "outlier" based on a large discrepancy between the observed ground age and the inventory age. Further examination of this sample indicated that the ground plots appeared to have captured the rank 2 layer in this polygon. Although adjustment is normally based on the rank 1 layer, an exception was permitted in this case[10] and the rank 2 age and height data for this polygon were used in the development of the height and age ratios. Note, however, that the adjustments were subsequently applied to the rank 1 layer and the "attribute-adjusted" volume was computed based on the rank 1 layer. The volume adjustment factors were developed based on the rank 1 "attribute-adjusted" volume.

2.5 Pre-stratification and sub-stratification

Polygons were selected for sampling using PPSWR (probability proportional to size with replacement) methodology. Prior to sample selection, the population was pre-stratified based on inventory leading species into four strata:

- Polygons leading in Douglas-fir, pine, larch or deciduous
- Polygons leading in spruce
- Polygons leading in hemlock or cedar
- Polygons leading in balsam.

The analysis and the development of the adjustment factors maintained the sampling pre-stratification. In addition, further sub-stratification based on age groupings was investigated in all strata. These results are presented in the sections that follow.

2.6 PPSWR formulae used to compute adjustment ratios and sampling error

When analyzing the data it is important that the formulae used to derive the adjustment factors correspond with the sample design. Details on the appropriate adjustment methodology for the PPSWR sample design can be found in the document "The Statistical Estimation and Adjustment

[9] Samples #54 and #110 were excluded from the analysis since they were less than 20 years of age on the inventory.

[10] As per instructions from Dr. Sam Otukol, MSRM Mensurationist (e-mail December 19, 2001).

Process using a PPSWR Sampling Design in the Vegetation Resource Inventory"[11]. The formulae applied in this analysis were provided by Dr. Peter Ott[12] and are shown in Appendix B.

3. RESULTS AND DISCUSSION

3.1 Age and height adjustment

Ground ages and/or heights were missing for three samples. Hence 85 samples were available for the development of the age and height adjustment factors. As shown in Appendix B, the PPSWR formula[13] for computation of the adjustment ratio of means in each stratum can be simplified to the following:

$$\hat{R}_h = \frac{\bar{y}_h}{\bar{x}_h} \qquad [1]$$

where $\bar{y}_h$ is the mean ground height (or age) in stratum h and $\bar{x}_h$ is the mean inventory height (or age) in stratum h.

This formula was used to compute the adjustment ratios for height and age shown in Tables 1 and 2.

Table 1 shows that height in the TFL 3 inventory was consistently overestimated in all strata. The average height overestimation ranged from 1.5 m for the cedar/hemlock stratum to 3.5 m in the fir/pine/larch/deciduous stratum. The trends for age were less consistent. The relationship between ground height (and age) and inventory height (and age) by stratum are shown graphically in Appendix C.

Potential age-related trends in adjustment bias were examined within each of these strata using plots of residual values[14] (see Appendix C). Balsam was the only stratum where a noticeable trend in the bias was apparent. In the balsam stratum, adjusted attributes appeared to be, on average, slightly underestimated in younger stands and slightly overestimated in older stands. Based on graphical inspection, 120 years appeared to be a reasonable approximation for an age break related to the bias. The height and age adjustment factors for the balsam stratum based on sub-stratification using

[11] "The Statistical Estimation and Adjustment Process using a PPSWR Sampling Design in the Vegetation Resource Inventory", 2001, prepared by Carl James Schwarz for the Ministry of Forests, Resources Inventory Branch.

[12] Biometrician, Research Branch, Ministry of Forests.

[13] Refer to Appendix B for further details.

[14] Plots of "residual" values for adjusted attributes (ground value minus the adjusted value) can be used to assess potential bias problems associated with an adjustment model.

a 120 year age break are shown in Tables 1 and 2. By sub-stratifying the balsam stratum and applying separate adjustment factors based on a 120 year age break, the age-related trends in bias in this stratum were diminished[15].

Table 1: Descriptive statistics and ratio of means adjustment factors for height, by stratum.

Stratum	*n*	*Mean ground height*	*Mean Inventory height*	*Correlation*	***Height adjustment ratio of means***
FPLD[16]	27	22.019	25.552	0.542	***0.862***
Cedar/Hemlock	11	21.036	22.564	0.824	***0.932***
Balsam	25	17.240	19.540	0.691	***0.882***
Balsam < 121 years	*12*	*15.600*	*15.925*	*0.795*	***0.980***
Balsam > 120 years	*13*	*18.754*	*22.892*	*0.685*	***0.819***
Spruce	22	24.459	27.314	0.764	***0.895***

Table 2: Descriptive statistics and ratio of means adjustment factors for age, by stratum.

Stratum	*n*	*Mean ground age*	*Mean inventory age*	*Correlation*	***Age adjustment ratio of means***
FPLD	27	86.348	84.741	0.678	***1.019***
Cedar/Hemlock	11	101.176	109.364	0.956	***0.925***
Balsam	25	120.504	138.880	0.621	***0.868***
Balsam < 121 years	*12*	*96.683*	*81.083*	*0.391*	***1.192***
Balsam > 120 years	*13*	*142.492*	*192.231*	*0.725*	***0.741***
Spruce	22	184.227	180.409	0.764	***1.021***

3.2 Volume adjustment

To develop the volume adjustment ratios, the height and age adjustment factors (Tables 1 and 2) were applied to the rank 1 inventory ages and heights for the samples. These adjusted heights and ages, together with the unadjusted species composition, crown closure, and stocking class, were

[15] Based on a visual comparison of figures C11 & C17, and C15 & C18 in Appendix C.

[16] FPLD stratum includes fir, pine, larch and deciduous leading polygons.

input into VDYP v6.6d to produce “attribute-adjusted” inventory volumes. The adjustment ratios for volume were then calculated based on the ratio of ground volume to “attribute-adjusted” inventory volume.

The utilization used in the analysis of the TFL 3 VRI data was live stems 17.5cm + dbh for all polygons except for polygons where the inventory indicated lodgepole pine as the leading species; for these polygons the utilization was 12.5cm + dbh. Volumes were calculated net of decay, waste and breakage (dwb). This utilization applied to both inventory and ground volumes.

Ground net volumes were compiled using the 1976 Ministry of Forests Forest Inventory Zone Decay, Waste and Breakage factors to estimate decay, waste and breakage. In addition, ground volumes were also compiled using the standard VRI call grading/net factoring. However since there was no NVAF sampling carried out in this unit, the net factored volumes were not adjusted with an NVAF.

Table 3 below presents volume adjustment factors based on loss factor volumes whereas Table 4 provides adjustments based on net factored (without NVAF) volumes.

Table 3: Loss factor (LF) volume adjustment factors by stratum (based on Table 1 & 2 age and height adjustments). Utilization: 17.5cm + dbh except 12.5cm + dbh for lodgepole pine leading, net dwb.

Stratum	*n*	*Mean ground vol/ha (Loss factors)*	*Mean “attribute-adjusted” inventory vol/ha*[17]	*Correlation*	***Volume adjustment ratio of means (LF)***
FPLD	27	221.300	163.063	0.476	***1.357***
Cedar/Hemlock	12	216.841	210.533	0.585	***1.030***
Balsam	27	132.717	107.237	0.714	***1.238***
Balsam < 121 years	*14*	*124.841*	*94.286*	*0.738*	***1.324***
Balsam > 120 years	*13*	*141.198*	*123.377*	*0.755*	***1.144***
Spruce	22	229.778	273.736	0.565	***0.839***

[17] “Attribute-adjusted” inventory volume/ha is volume from VDYP based on *adjusted* inventory heights and ages.

Table 4: Net factored (NF) volume adjustment factor by stratum (based on Table 1 & 2 age and height adjustments). Utilization: 17.5cm + dbh except 12.5cm + dbh for lodgepole pine leading, net dwb.

Stratum	*n*	*Mean ground vol/ha (Net factored)*	*Mean "attribute-adjusted" inventory vol/ha*	*Correlation*	***Volume adjustment ratio of means (NF)***
FPLD	27	235.269	163.063	0.428	***1.443***
Cedar/Hemlock	12	263.750	210.533	0.633	***1.253***
Balsam	27	145.500	107.237	0.742	***1.357***
Balsam < 121 years	*14*	*130.956*	*94.286*	*0.741*	***1.389***
Balsam > 120 years	*13*	*161.163*	*123.377*	*0.761*	***1.306***
Spruce	22	264.580	273.736	0.639	***0.967***

The "attribute-adjusted" inventory volumes were adjusted based on the factors in Tables 3 and 4. The resulting "final" adjusted inventory volumes were then compared with the ground volumes in each stratum. The plots of the "residual" values (i.e. ground value minus adjusted value) were used to evaluate the volume adjustments. Graphs showing the volume relationships and the residuals are provided in Appendix D. As was observed for height and age, there appeared to be an age-related bias associated with the adjustment in the balsam stratum. In general, adjusted volumes appeared to be underestimated in young stands and overestimated in older stands. Hence, alternative adjustment factors, based on a 120 year age break, were developed for the balsam stratum. These are also shown in Tables 3 and 4. Further residuals plots for the balsam stratum suggested that using the age-specific volume adjustment factors in Tables 3 and 4 reduced the age-related bias in the adjustment[18].

3.3 Overall volume impact

The volume factors in Tables 3 and 4 represent volume adjustments after inventory heights and ages have been adjusted. To determine the overall volume impact of the set of adjustments (age, height and volume), the ground volumes were compared with the unadjusted inventory volumes (i.e. inventory volumes prior to any age or height adjustment). These overall volume impact ratios are shown for loss factor volumes (Table 5) and for net factored volumes (Table 6).

[18] Based on a visual comparison of figures D13 & D16 in Appendix D.

Table 5: Overall volume impact by stratum based on loss factor volumes. Utilization: 17.5cm + dbh except 12.5cm + dbh for lodgepole pine leading, net dwb.

Stratum	*n*	*Mean ground vol/ha (Loss factors)*	*Mean unadjusted inventory vol/ha*	*Correlation*	***Overall volume impact (LF)***
FPLD	27	221.300	215.437	0.498	***1.027***
Cedar/Hemlock	12	216.841	239.075	0.598	***0.907***
Balsam	27	132.717	133.237	0.714	***0.996***
Inventory age <121 yrs	14	124.841	97.750	0.737	***1.277***
Inventory age >120 yrs	13	141.198	171.454	0.758	***0.824***
Spruce	22	229.778	318.182	0.594	***0.722***

Table 6: Overall volume impact by stratum based on net factored volumes. Utilization: 17.5cm + dbh except 12.5cm + dbh for lodgepole pine leading, net dwb.

Stratum	*n*	*Mean ground vol/ha (Net factored)*	*Mean unadjusted inventory vol/ha*	*Correlation*	***Overall volume impact (NF)***
FPLD	27	235.269	215.437	0.453	***1.092***
Cedar/Hemlock	12	263.750	239.075	0.647	***1.103***
Balsam	27	145.500	133.237	0.742	***1.092***
Inventory age <121 yrs	14	130.956	97.750	0.740	***1.340***
Inventory age >120 yrs	13	161.163	171.454	0.764	***0.940***
Spruce	22	264.580	318.182	0.666	***0.832***

Tables 5 and 6 show the stratum differences between an adjustment based on loss factor versus net factored volumes. In all strata, net factoring indicates higher volumes compared with loss factors. The difference between net factored volumes and loss factor volumes is greatest in the cedar/hemlock stratum and least in the young (inventory age <121 years) balsam stratum.

The results for net factored volumes clearly suggest that loss factors underestimate the actual ground volumes. However, in the VRI standard procedures, net factored volumes must be further adjusted using the NVAF to correct for taper and hidden decay. Province-wide, studies to date indicate that net factoring without applying the NVAF typically overestimates volumes by about

2%[19]. Hence while the loss factor adjustments (Table 5) may be underestimating volume, the adjustment based on net factored volumes (Table 6) may be overestimating volume. Without completion of an NVAF study in TFL 3, the exact magnitude of the volume bias cannot be quantified.

3.4 Sampling error

The original VPIP specified a target sampling error of 10% (at a 95% probability level) for the vegetated, treed portion of TFL 3 greater than 20 years of age. To provide an indication of the sampling error achieved in the adjustment process, a comparison of the overall ground volume and the overall unadjusted inventory volume was made. The overall ratio and its standard error were computed using the formula for a combined ratio estimate after a pre-stratified PPSWR sample (see Appendix B). The combined ratio estimate is computed as the ratio of the estimated total ground volume for the entire unit divided by the estimated total unadjusted inventory volume for the entire unit. The results are summarized in the tables below.

The overall loss factor volume impact of 0.88 (Table 8) is similar to the loss factor volume ratio of 0.87 that was reported in the 1995 inventory audit[20] for TFL 3. Tables 7 and 8 also illustrate the overall impact of using loss factor volumes versus net factored volumes in the adjustment. Net factoring results in about 12% more volume overall compared with using loss factors.

Table 7: Combined ratio estimate and its sampling error (no age sub-stratification for balsam). Utilization: 17.5cm + dbh except 12.5cm + dbh for lodgepole pine leading, net dwb.

Volume	*n*	*Overall estimated total ground vol/ha*	*Overall estimated total unadj'd inventory vol/ha*	*Ratio of means*	*95% CI for ratio*	*Sampling error (as % of ratio)*
Loss factor volume	*88*	*11625345*	*13060587*	*0.890*	*0.785 – 0.995*	*11.8%*
Net factored volume	*88*	*13016066*	*13060587*	*0.997*	*0.876 – 1.118*	*12.1%*

[19] Keith Tudor, Will Smith (pers. comm.)

[20] The Inventory Audit population of interest was productive forest, 60+ years of age. This differs from the TFL 3 VRI population of interest which was vegetated treed, greater than 20 years of age.

Table 8: Combined ratio estimate and its sampling error with age sub-stratification for balsam. Utilization: 17.5cm + dbh except 12.5cm + dbh for lodgepole pine leading, net dwb.

Volume	*n*	*Overall estimated total ground vol/ha*	*Overall estimated total unadj'd inventory vol/ha*	*Ratio of means*	*95% CI for ratio*	*Sampling error (as % of ratio)*
Loss factor volume	*88*	*11655172*	*13194994*	*0.883*	*0.779 – 0.987*	*11.8%*
Net factored volume	*88*	*13071151*	*13194994*	*0.991*	*0.871 – 1.111*	*12.1%*

The sampling errors achieved exceed the target level (10%) that was specified[21] by about 2%. This slight deviation from the target level should be considered acceptable in that it does not increase the risk of drawing wrong inferences from the data beyond reasonable limits. However, the stakeholders should consider establishing more samples in the TFL to reduce the sampling error to a level within the specified standard.

4. RECOMMENDATIONS

There appear to be significant age-related trends in the bias observed for adjusted inventory volume when a single adjustment factor is applied to the balsam leading stratum. As a result, the adjustment factors for this stratum based on a 120 year age break (see Tables 1, 2, 3 & 4) are recommended. No obvious age-related bias trends were observed in any strata other than balsam. Volume adjustment ratios based on loss factor volumes and net factored volumes were provided. Using the loss factor ratios would provide a more conservative estimate of volume, consistent with the status quo. Using the net factored volume without an NVAF would likely overestimate volume. The magnitude of this overestimation cannot be determined without NVAF sampling. The difference between the loss factor and the net factored volumes in TFL 3 is about 12% on average. Based on results to date observed elsewhere in the province, loss factors have tended to underestimate volume by about 10%

[21] The 95% confidence interval and the sampling error are dependent on the t-value that is multiplied by the standard error of the ratio. Tables 7 and 8 assumed a *z*-value of 1.96 to construct the confidence interval and hence the sampling error. An alternative approximate method to calculate an "effective" degrees of freedom for a *t*-value was also examined, based on formulae provided in Cochran's "Sampling Techniques" (1977). For Table 8, the calculated effective degrees of freedom of 67 and its corresponding *t*-value resulted in sampling errors of 12.0% and 12.3% for loss factors and net factoring respectively.

whereas net factoring (without NVAF) has overestimated volumes by about 2%. However, without NVAF sampling in TFL 3, it is not known if similar trends would hold in this unit.

The scope of this analysis was limited to analysis of the VRI data and development of a set of inventory adjustment factors for TFL 3. The next step in the VRI process is applying these factors in the adjustment of the TFL 3 inventory file. Once the inventory file is adjusted, it is recommended that the pre-adjustment total unit volume and the post-adjustment volume be compared to determine the actual impact of the adjustment on the TFL 3 standing volume.

5. APPENDIX A: INVENTORY AND GROUND ATTRIBUTES USED IN THE ADJUSTMENT

			Inventory Attributes								Ground Attributes				
Mapsheet	***Poly***	***Sample ID code***	***Species Composition***	***Proj'd Age***	***Proj'd Height***	***Proj'd 2nd spp Age***	***Proj'd 2nd spp Height***	***CC %***	***Proj'd Stk Cls***	***Vol/ha 17.5cm+ net dwb***	***Leading spp at 4cm+dbh***	***Ground Age***	***Ground Height***	***NVAF vol/ha "mixed" utiln***	***LF vo/ha "mixed" utiln***
082F051	2238	3031-0001-QO1	BL 60 SE 40	139.0	18.9			30	1	138.3	BL	97	6.2	0.0	0.0
082F061	1902	3031-0002-QO1	B 60 S 30 PL 10	209.0	27.6			50	1	281.9	HW	212	20.6	307.4	281.3
082F071	2011	3031-0003-QO1	PL 100	93.0	24.9			70	3	321.3	PL	74	22.1	286.6	263.1
082F061	2462	3031-0005-QO1	B 80 L 20	44.0	8.3			20	0	18.9	S	.	.	164.6	164.6
082F062	1846	3031-0006-QO1	FD 40 PL 30 L 30	104.0	28.4			50	0	231.2	FD	72	26.1	381.8	376.4
082F062	1796	3031-0007-QO1	S 40 L 30 H 20 CW 10	99.0	25.7			30	0	261.2	CW	146	14.6	71.5	68.8
082F062	2642	3031-0008-QO1	B 80 S 20	104.0	22.5			40	0	210.1	BL	202	16.4	124.7	113.1
082F051	1571	3031-0010-QO1	H 40 S 30 B 20 CW 10	49.0	11.6			50	0	44.6	HW	53	10.3	131.4	131.7
082F061	2427	3031-0011-QO1	L 50 CW 30 FD 10 S 10	74.0	22.2	74.0	25.3	70	0	159.5	CW	59	15.5	301.1	267.0
082F072	1783	3031-0012-QO1	CW 60 S 30 BL 5 HW 5	249.0	38.5			30	1	574.2	CW	187	30.5	913.3	564.4
082F062	1611	3031-0013-QO1	L 80 FD 20	279.0	40.1			40	1	315.5	FD	72	22.0	408.4	430.1
082F062	2311	3031-0014-QO1	L 60 PL 20 FD 15 EP 5	73.0	28.1			70	0	225.7	CW	70	11.0	69.8	65.9
082F071	2173	3031-0015-QO1	L 50 FD 40 PW 10	73.0	25.0			75	0	176.6	HW	72	15.3	99.4	89.2
082F061	1863	3031-0016-QO1	S 60 B 40	69.0	20.8			20	0	155.9	SE	50	17.4	91.4	92.4
082F062	1864	3031-0017-QO1	FD 80 CW 10 L 5 H 5	138.0	31.9	108.0	28.2	65	1	327.1	CW	197	30.2	672.0	561.5
082F073	1526	3031-0020-QO1	AT50 PL25 FD10 EP10 S5	69.0	19.5	79.0	21.3	30	0	73	FD	58	24.7	52.1	49.3
082F071	2011	3031-0021-QO1	PL 100	93.0	24.9			70	3	321.3	PL	77	20.3	232.1	211.1
082F051	1901	3031-0022-QO1	S 80 B 20	189.0	30.6	169.0	22.8	20	1	297.6	BL	135	18.9	164.6	124.8
082F072	1727	3031-0023-QO1	SE 90 BL 10	209.0	30.6			40	1	341.4	SE	221	32.8	176.1	152.6

082F061	2561	3031-0024-QO1	S30 FD20 B20 PL20 L10	99.0	28.7			40	0	301.6	BL	230	22.6	211.5	183.9
082F052	1768	3031-0025-QO1	S 50 B 50	209.0	30.6	189.0	24.7	40	1	295.5	BL	145	16.3	104.8	91.0
082F051	1905	3031-0027-QO1	S 60 B 40	189.0	34.6	169.0	20.7	35	1	353.3	BL	168	26.3	141.2	106.2
082F062	2442	3031-0028-QO1	FD 60 PL 30 S 10	99.0	25.4			60	0	233.5	SE	68	17.3	123.6	118.6
082F061	1894	3031-0029-QO1	B 60 PL 30 S 10	84.0	17.6	84.0	17.1	10	0	116.5	PL	33	10.8	47.5	41.1
082F081	1589	3031-0030-QO1	BL 80 S 20	219.0	25.0			40	1	249.9	BL	174	21.5	351.4	280.5
082F071	2094	3031-0031-QO1	S 50 B 50	209.0	32.5	189.0	27.7	30	1	307.1	BL	246	20.2	147.7	116.5
082F063	1505	3031-0032-QO1	B 50 S 30 PL 20	79.0	19.9			50	0	168.3	BL	106	24.5	265.8	261.5
082F051	2220	3031-0033-QO1	B 70 S 30	179.0	18.6			10	2	59.1	BL	94	9.9	50.3	48.8
082F061	2465	3031-0034-QO1	L 80 B 10 S 10	74.0	25.3			70	0	172.8	CW	56	20.2	227.2	227.2
082F051	2036	3031-0035-QO1	B 60 S 35 PW 5	209.0	26.6			25	1	228.5	BL	176	17.1	123.6	100.1
082F051	2045	3031-0036-QO1	BL 80 SE 20	159.0	14.6	159.0	17.0	10	2	42	SE	61	5.1	57.1	50.3
082F061	2019	3031-0037-QO1	B 90 S 10	189.0	21.6			40	1	194	BL	143	20.7	287.1	255.5
082F063	1556	3031-0038-QO1	S 70 L 20 B 10	119.0	30.3			55	0	354.8	HW	343	28.0	534.3	460.5
082F072	2166	3031-0039-QO1	S 55 B 30 PL 15	255.0	30.7	208.0	24.5	45	1	316.2	BL	131	21.2	344.1	313.7
082F071	1690	3031-0040-QO1	S 70 B 30	189.0	27.7	189.0	25.7	45	1	276.3	BL	133	22.6	178.3	148.8
082F072	2295	3031-0041-QO1	S 60 B 40	268.0	32.3	238.0	25.4	50	1	339.8	BL	146	23.1	268.0	232.7
082F052	1558	3031-0042-QO1	L 60 FD 40	108.0	23.1			50	0	133.4	CW	169	23.1	464.9	391.8
082F061	1762	3031-0043-QO1	H 50 CW 40 S 10	48.0	17.0			70	0	126.9	CW	.	.	171.4	172.7
082F082	1506	3031-0044-QO1	B 70 S 30	189.0	18.6			25	2	63.5	BL	142	19.5	70.7	53.1
082F071	1611	3031-0045-QO1	B 90 S 10	109.0	15.0			10	0	90.2	BL	103	18.6	146.4	142.4
082F052	1937	3031-0046-QO1	H 60 CW 30 FD 10	79.0	15.8	79.0	17.5	80	0	122.3	CW	57	21.3	414.4	416.0
082F061	1909	3031-0047-QO1	B 60 S 40	159.0	22.8			40	1	196.7	BL	88	20.7	117.2	115.8
082F052	1599	3031-0048-QO1	LW 80 FD 20	89.0	21.7			70	0	104.8	HW	99	22.6	291.7	258.5
082F052	1910	3031-0049-QO1	H 70 CW 20 PW 10	144.0	24.9			70	1	313.9	HW	114	28.7	433.5	340.4
082F052	1574	3031-0051-QO1	L 60 FD 30 PW 5 CW 5	93.0	33.6	88.0	31.9	70	0	318.2	FD	100	30.3	303.7	300.2
082F072	44	3031-0052-QO1	BL 70 SE 30	85.0	7.4			5	0	3.7	BL	64	8.4	10.5	8.7

082F071	1982	3031-0053-QO1	L 55 FD 25 S 15 H 5	73.0	25.0			70	0	179.2	LW	70	25.8	193.8	184.9
082F061	1505	3031-0055-QO1	S 50 B 50	229.0	37.4	229.0	27.6	55	1	413.9	BL	141	26.5	336.9	293.2
082F071	1647	3031-0057-QO1	FD 60 S 20 L 15 H 5	79.0	22.9			35	0	166.2	FD	74	17.9	177.7	173.8
082F072	1963	3031-0058-QO1	S 50 B 50	209.0	26.7	184.0	21.7	30	1	232.5	BL	163	23.0	153.6	130.4
082F062	2238	3031-0059-QO1	B 70 S 30	103.0	22.3			50	0	198.3	BL	116	22.3	322.2	317.0
082F051	1926	3031-0060-QO1	H 60 S 20 CW 20	258.0	35.3			50	1	595.1	HW	265	29.6	245.9	235.8
082F072	1586	3031-0061-QO1	BL 60 SE 40	209.0	18.5			20	2	62.1	BL	82	12.7	129.3	128.5
082F051	1534	3031-0062-QO1	S 60 CW 20 H 10 B 10	155.0	44.6	259.0	38.5	60	1	568.8	CW	230	31.1	496.5	395.2
082F061	1524	3031-0063-QO1	L 50 H 40 B 10	63.0	20.2			60	0	140	BL	69	18.1	167.5	170.2
082F071	1511	3031-0064-QO1	B 70 S 30	248.0	34.5	248.0	34.3	50	1	381	SE	214	26.5	348.0	313.7
082F061	1592	3031-0065-QO1	B 70 S 20 PL 10	79.0	16.7			10	0	105.3	BL	51	9.8	66.2	57.7
082F072	1704	3031-0066-QO1	BL 90 SE 10	44.0	7.0			30	0	9	BL	77	7.3	0.0	0.0
082F061	2106	3031-0067-QO1	FD 40 H 40 CW 10 L 10	144.0	31.9	89.0	27.8	50	1	395.5	HW	112	27.3	312.6	299.1
082F071	2139	3031-0068-QO1	S 90 B 10	209.0	37.4			50	1	475.9	SE	278	40.8	577.2	460.9
082F051	2062	3031-0069-QO1	S 70 B 30	238.0	27.5			60	1	292.7	SE	273	31.3	311.9	270.5
082F062	1740	3031-0070-QO1	EP55 FD20 PL10 L10 S5	68.0	20.9			65	0	101	EP	69	18.9	135.7	128.8
082F071	2158	3031-0071-QO1	H40L30PL10FD10CW10	79.0	25.1			70	0	274.6	HW	86	14.8	99.2	91.7
082F061	1523	3031-0072-QO1	L50FD25CW10HW10PW5	73.0	27.1	73.0	27.2	80	0	222.9	FD	71	24.0	181.2	181.2
082F071	1664	3031-0073-QO1	FD 50 PL 30 L 10 S 10	84.0	22.7	84.0	22.3	40	0	154.2	PL	66	17.3	115.3	99.9
082F051	1703	3031-0074-QO1	FD 90 SE 10	129.0	24.9			10	2	78.1	FD	133	16.5	35.5	31.9
082F061	2735	3031-0075-QO1	B 90 S 10	169.0	16.6	169.0	19.9	10	2	55.9	SE	170	20.9	95.8	82.2
082F072	1683	3031-0076-QO1	S 80 BL 20	288.0	30.4	208.0	21.5	15	2	117.1	BL	115	15.1	78.2	76.4
082F071	1783	3031-0077-QO1	S 60 B 30 PL 10	189.0	32.6	159.0	26.9	50	1	354	BL	125	16.8	110.5	89.9
082F062	2241	3031-0078-QO1	S 80 B 20	159.0	28.9			45	1	302.9	S	107	25.2	426.1	420.1
082F052	1511	3031-0079-QO1	S 60 B 40	169.0	27.8			40	1	263.8	SE	328	25.0	313.9	288.3
082F072	1966	3031-0080-QO1	S 70 B 20 H 10	209.0	35.5			25	1	377.7	SE	198	39.3	582.4	538.0
082F062	2368	3031-0081-QO1	FD 45 L 25 PL 15 PY 15	99.0	33.1			70	0	349	CW	109	30.1	186.8	191.2

082F061	1924	3031-0082-QO1	H 40 CW 30 L 20 FD 10	54.0	13.6			55	0	53.1	HW	66	16.9	110.7	110.7
082F062	1687	3031-0083-QO1	FD 89 CW 11	96.0	34.7			70	0	401.4	FD	94	34.3	340.8	332.3
082F061	1919	3031-0084-QO1	H 40 L 30 FD 20 CW 10	74.0	22.2	69.0	20.3	65	0	216.1	LW	67	24.0	197.7	190.9
082F072	1868	3031-0086-QO1	B 60 PL 30 S 10	69.0	11.9			20	0	51.1	S	147	17.0	100.6	90.3
082F062	2242	3031-0087-QO1	B 50 S 40 PL 10	104.0	23.5			50	0	220.4	BL	101	24.5	278.9	273.3
082F061	1929	3031-0088-QO1	PW 50 L 30 H 10 CW 10	69.0	24.2			80	0	220.9	HW	76	11.4	71.3	71.3
082F062	2330	3031-0089-QO1	FD 90 EP 10	83.0	25.7			55	0	186.8	FD	76	27.4	342.6	323.6
082F061	2472	3031-0090-QO1	L 80 CW 10 FD 10	59.0	20.8			80	0	107.7	LW	69	24.8	177.2	177.2
082F061	2213	3031-0091-QO1	B 60 PL 30 FD 10	69.0	19.5			50	0	150.5	BL	103	22.0	213.0	208.0
082F072	1689	3031-0092-QO1	BL 100	44.0	8.3			15	0	26.2	BL	58	5.6	0.0	0.0
082F081	1590	3031-0093-QO1	BL 76 S 24	222.0	28.2			40	1	276	BL	199	42.4	157.3	125.5
082F062	2556	3031-0105-QO1	H 50 FD 20 CW 20 L 10	104.0	27.4			70	0	342.7	CW	80	27.8	279.9	224.4
082F051	12	3031-0501-QO1	BL 50 SE 40 HW 10	30.0	3.5			10	0	0	CW	.	.	93.1	70.1
082F052	79	3031-0503-QO1	CW60EP10AT10HW10FD10	85.0	21.9			50	0	199.9	CW	95	20.3	100.6	140.0
082F052	43	3031-0504-QO1	HW37CW32SE15BL12FD4	33.0	9.7	33.0	12.1	30	0	5.5	CW	43	7.2	27.5	22.8

6. APPENDIX B: RATIO OF MEANS AND VARIANCE FORMULAE FOR PPSWR

The following description of the appropriate strata and overall ratio estimators for a PPSWR design were provided by Dr. Peter Ott (Ministry of Forests, Research Branch).

Combined Ratio Estimator after a Pre-Stratified PPSWR Sample

The population has been pre-stratified into H *strata and a PPSWR sample was taken within each stratum. Getting a ratio estimate is easy for each stratum (e.g. domain) but what if we want to obtain an overall estimate for the entire unit? Read on…*

Notation

n_h – number of polygons sampled from h^{th} stratum, $h = 1,2,\ldots,H$

Z_h – area within h^{th} stratum (hectares)

z_j – area of j^{th} polygon

p_j – selection probability for j^{th} polygon = $\dfrac{z_j}{Z_h}$

$\hat{y}_{hj}$ – estimated ground vol per ha of j^{th} observation in h^{th} stratum, $j = 1,2,\ldots,n_h$

x_{hj} – photo-interpreted vol per ha of j^{th} observation in h^{th} stratum

$\hat{Y}_{hj}$ – estimated ground total volume of j^{th} observation in h^{th} stratum = $z_j \cdot \hat{y}_{hj}$

X_{hj} – photo-interpreted total volume of j^{th} observation in h^{th} stratum = $z_j \cdot x_{hj}$

$\overline{y}_h$ – estimated mean ground vol per ha in h^{th} stratum $= \dfrac{1}{Z_h n_h}\displaystyle\sum_{j=1}^{n_h}\frac{\hat{Y}_{hj}}{p_j} = \frac{1}{n_h}\sum_{j=1}^{n_h}\hat{y}_{hj}$

$\overline{x}_h$ – estimated mean photo-interpreted vol per ha in h^{th} stratum $= \dfrac{1}{Z_h n_h}\displaystyle\sum_{j=1}^{n_h}\frac{X_{hj}}{p_j} = \frac{1}{n_h}\sum_{j=1}^{n_h}x_{hj}$

$\hat{Y}_h$ – estimated total ground volume in h^{th} stratum $= Z_h \cdot \overline{y}_h$

$\hat{X}_h$ – estimated total photo-interpreted volume in h^{th} stratum $= Z_h \cdot \overline{x}_h$

$\hat{Y}$ – estimated total ground volume for entire unit $= \displaystyle\sum_{h=1}^{H}\hat{Y}_h$

$\hat{X}$ – estimated total photo-interpreted volume for entire unit $= \sum_{h=1}^{H} \hat{X}_h$

X – total photo-interpreted volume of entire population $= \sum_{h=1}^{H} \sum_{j=1}^{N_h} x_{hj}$

Combined Ratio Estimator	**Its Standard Error**
$\hat{R}_c = \frac{\hat{Y}}{\hat{X}} = \frac{\sum_{h=1}^{H} Z_h \cdot \bar{y}_h}{\sum_{h=1}^{H} Z_h \cdot \bar{x}_h}$	$s.e.(\hat{R}_c) = \sqrt{\frac{1}{X^2} \sum_{h=1}^{H} \frac{Z_h^2}{n_h} s_h^2}$, where $s_h^2 = \frac{1}{n_h - 1} \sum_{j=1}^{n_h} (e_{hj} - \bar{e}_h)^2$, $e_{hj} = \hat{y}_{hj} - \hat{R}_c x_{hj}$, and $\bar{e}_h = \frac{1}{n_h} \sum_{j=1}^{n_h} e_{hj}$ or equivalently $s.e.(\hat{R}_c) = \sqrt{\frac{1}{X^2} \sum_{h=1}^{H} \frac{\tau_h^2}{n_h}}$, where $\tau_h^2 = \frac{1}{n_h - 1} \sum_{j=1}^{n_h} \left(\frac{\varepsilon_{hj}}{p_j} - \hat{\varepsilon} \right)^2$, $\varepsilon_{hj} = \hat{Y}_{hj} - \hat{R}_c X_{hj}$, and $\hat{\varepsilon}_h = \frac{1}{n_h} \sum_{j=1}^{n_h} \frac{\varepsilon_{hj}}{p_j}$ Note that for both versions, you may use $\hat{X}$ instead of X, if it is unavailable.

7. APPENDIX C: HEIGHT AND AGE RELATIONSHIPS AND RESIDUALS PLOTS

Height Relationships by Stratum

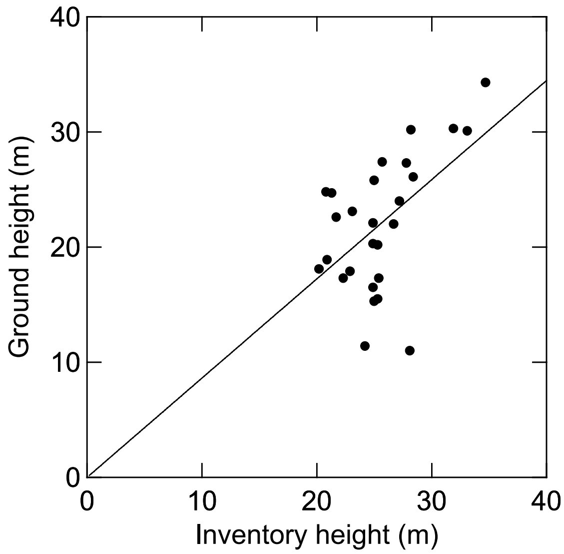

Fig. C1: Ground height versus inventory height for Fir/Pine/Larch/Deciduous stratum. Line on graph corresponds to height adjustment ratio.

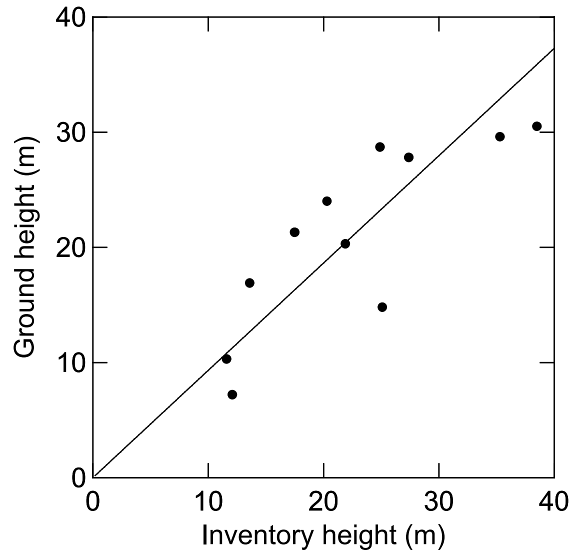

Fig. C2: Ground height versus inventory height for Cedar/Hemlock stratum. Line on graph corresponds to height adjustment ratio.

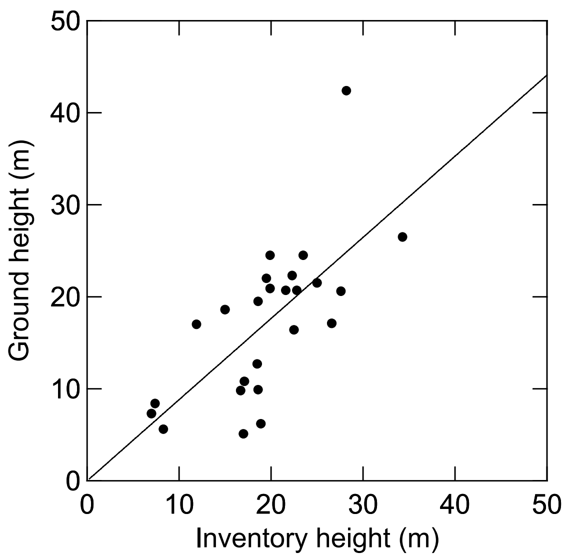

Fig. C3: Ground height versus inventory height for Balsam stratum. Line on graph corresponds to height adjustment ratio.

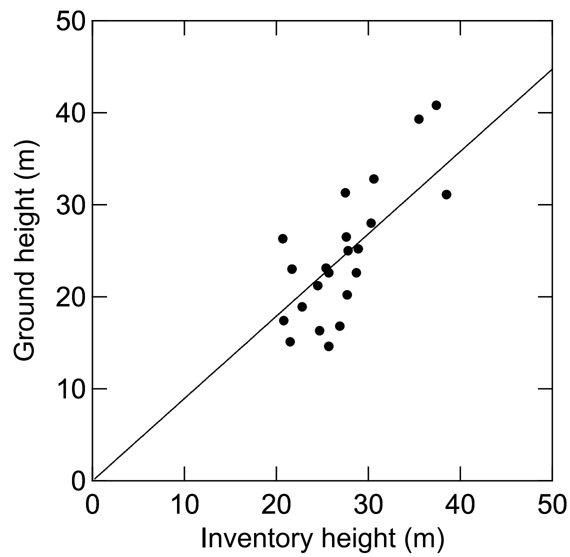

Fig. C4: Ground height versus inventory height for Spruce stratum. Line on graph corresponds to height adjustment ratio.

Age Relationships by Stratum

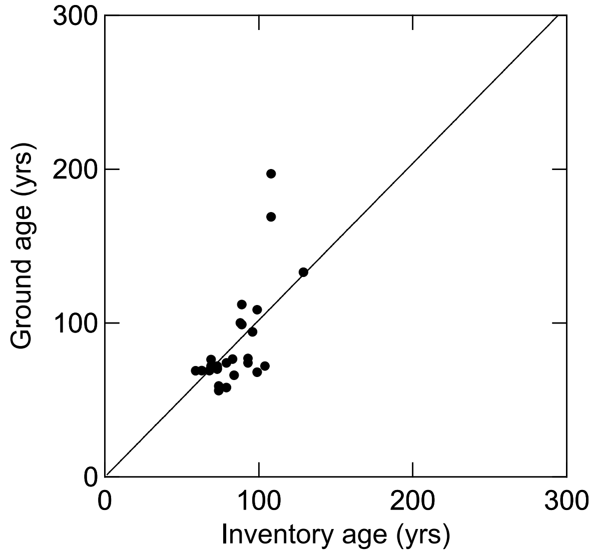

Fig. C5: Ground age versus inventory age for Fir/Pine/Larch/Deciduous stratum. Line on graph corresponds to age adjustment ratio.

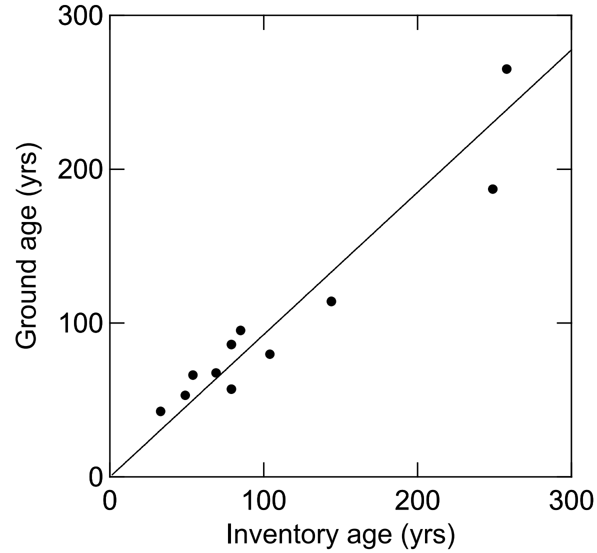

Fig. C6: Ground age versus inventory age for Cedar/Hemlock stratum. Line on graph corresponds to age adjustment ratio.

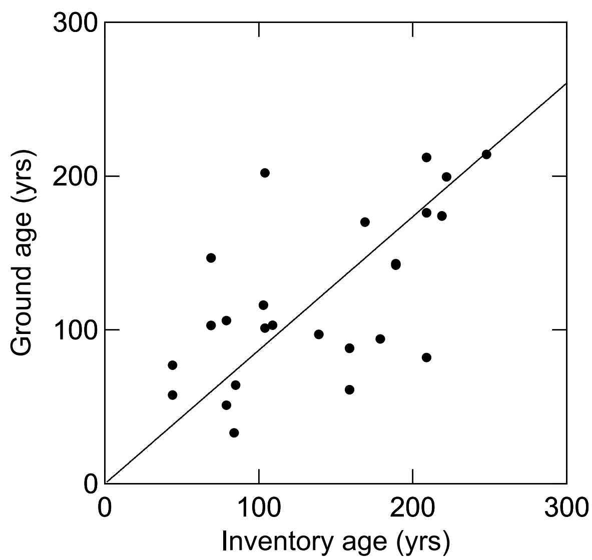

Fig. C7: Ground age versus inventory age for Balsam stratum. Line on graph corresponds to age adjustment ratio.

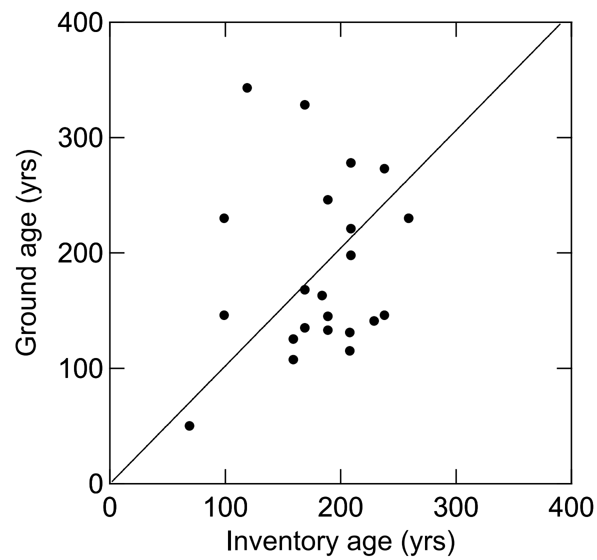

Fig. C8: Ground age versus inventory age for Spruce stratum. Line on graph corresponds to age adjustment ratio.

Height Residuals by Stratum

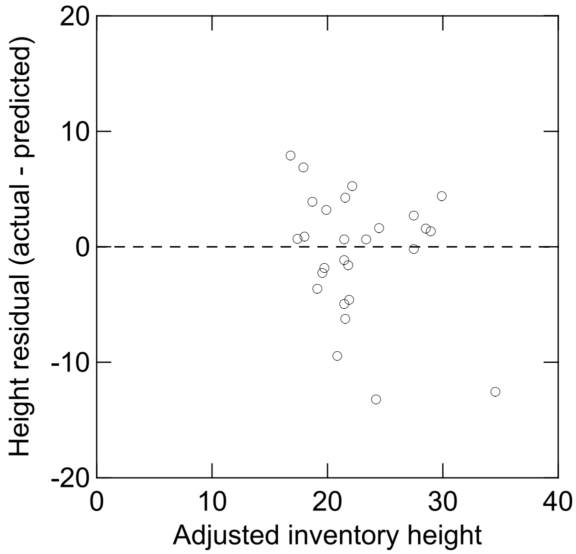

Fig. C9: Height residual (ground height – adjusted inventory height) versus adjusted inventory height for Fir/Pine/Larch/Deciduous stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

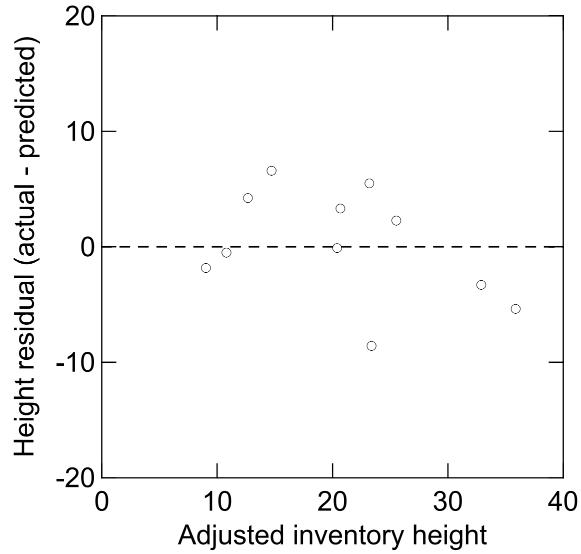

Fig. C10: Height residual (ground height – adjusted inventory height) versus adjusted inventory height for Cedar/Hemlock stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

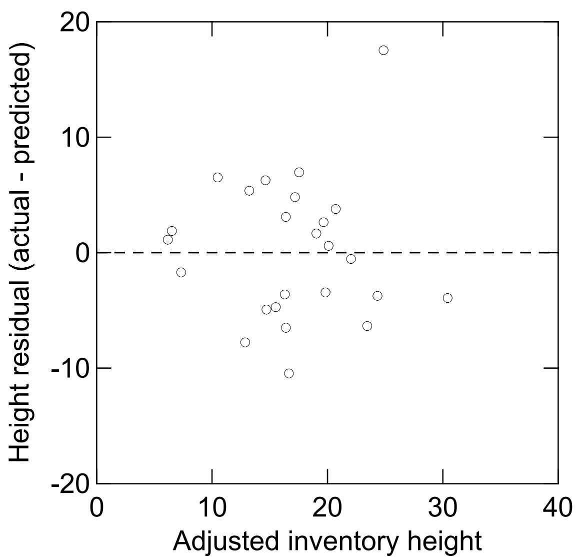

Fig. C11: Height residual (ground height – adjusted inventory height) versus adjusted inventory height for Balsam stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

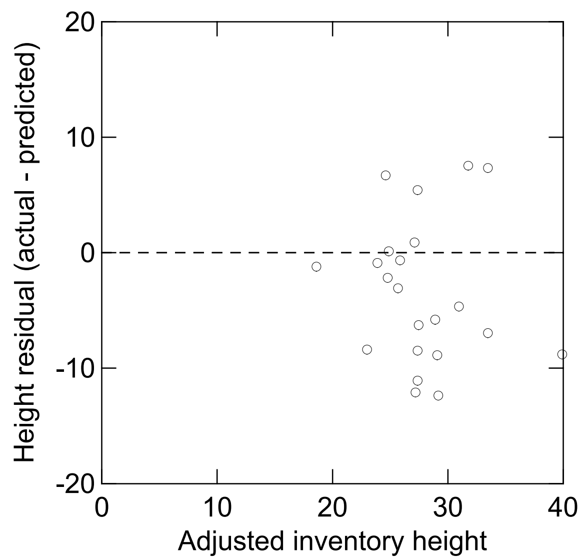

Fig. C12: Height residual (ground height – adjusted inventory height) versus adjusted inventory height for Spruce stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

Age Residuals by Stratum

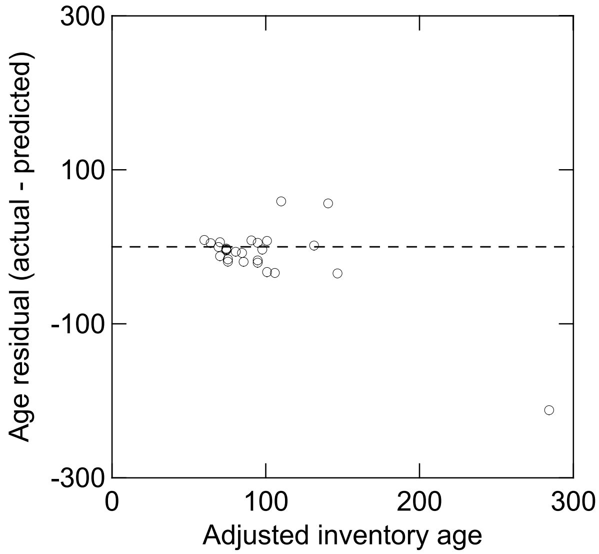

Fig. C13: Age residual (ground age – adjusted inventory age) versus adjusted inventory age for Fir/Pine/Larch/Deciduous stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

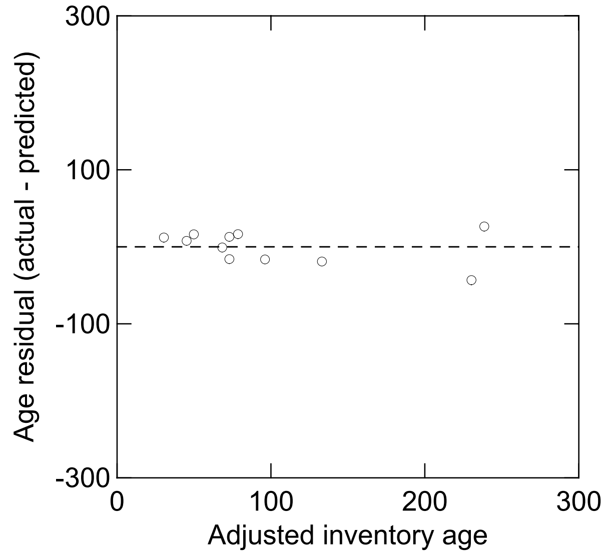

Fig. C14: Age residual (ground age – adjusted inventory age) versus adjusted inventory age for Cedar/Hemlock stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

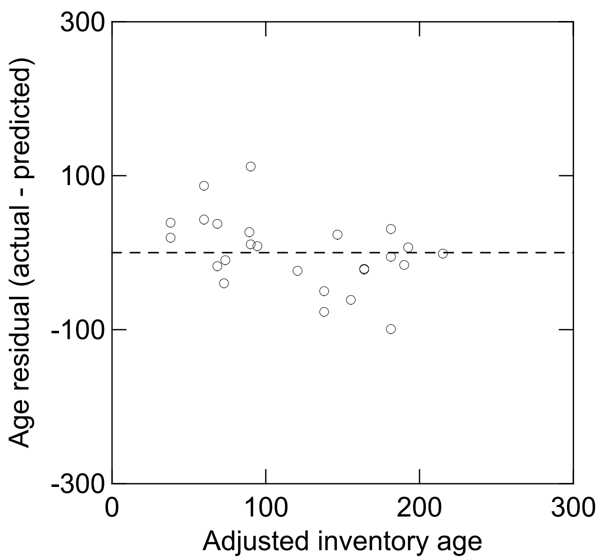

Fig. C15: Age residual (ground age – adjusted inventory age) versus adjusted inventory age for Balsam stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

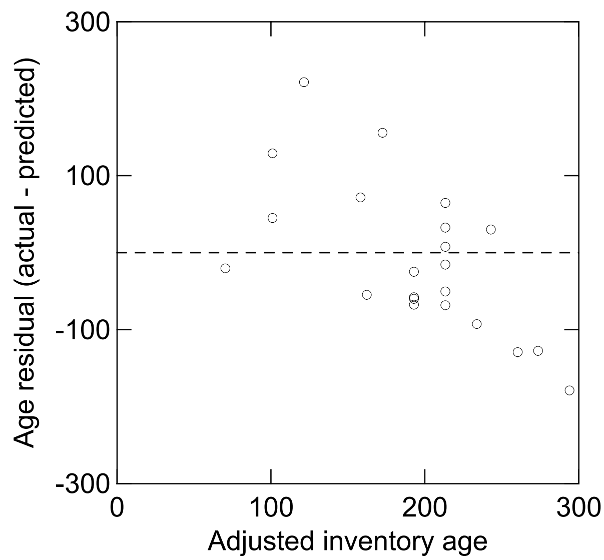

Fig. C16: Age residual (ground age – adjusted inventory age) versus adjusted inventory age for Spruce stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

Age and Height Residuals for Balsam Stratum with 2 Age Group Substrata

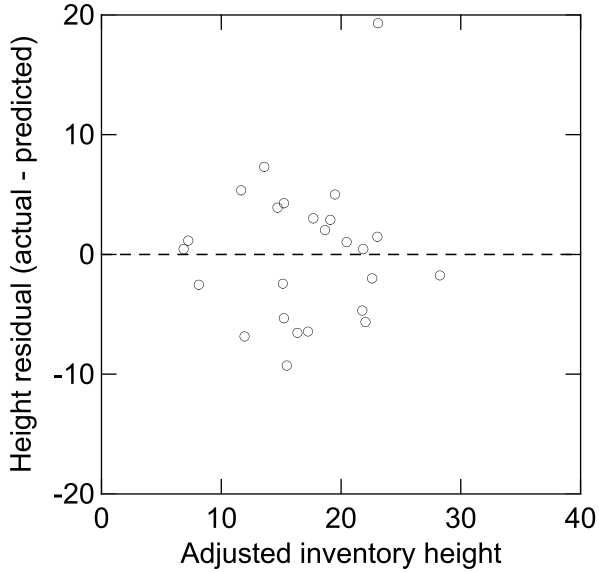

Fig. C17: Height residual (ground height – adjusted inventory height) versus adjusted inventory height for Balsam strata with 2 age substrata. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

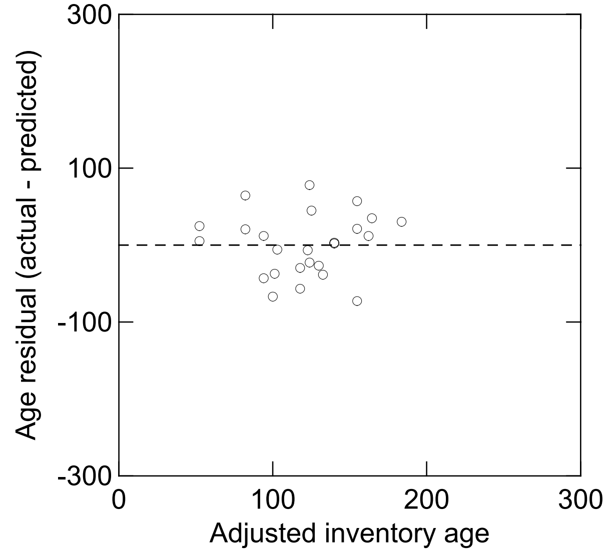

Fig. C18: Age residual (ground age – adjusted inventory age) versus adjusted inventory age for Balsam strata with 2 age substrata. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

8. APPENDIX D: VOLUME RELATIONSHIPS AND RESIDUALS PLOTS

Volume Relationships by Stratum

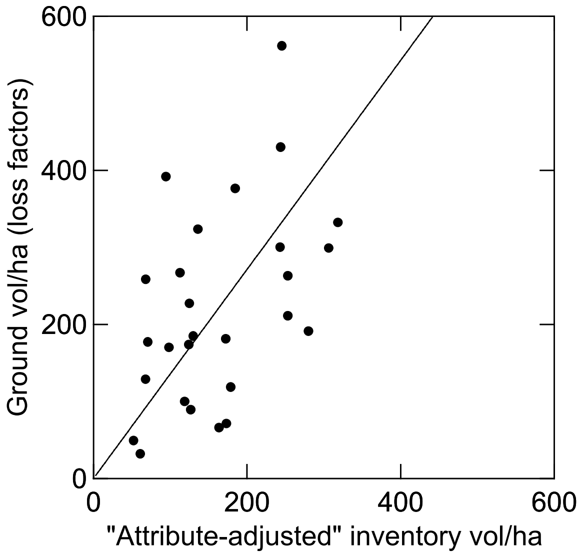

Fig. D1: Ground volume versus "attribute-adjusted" inventory volume for Fir/Pine/Larch/Deciduous stratum. Line on graph corresponds to volume adjustment ratio.

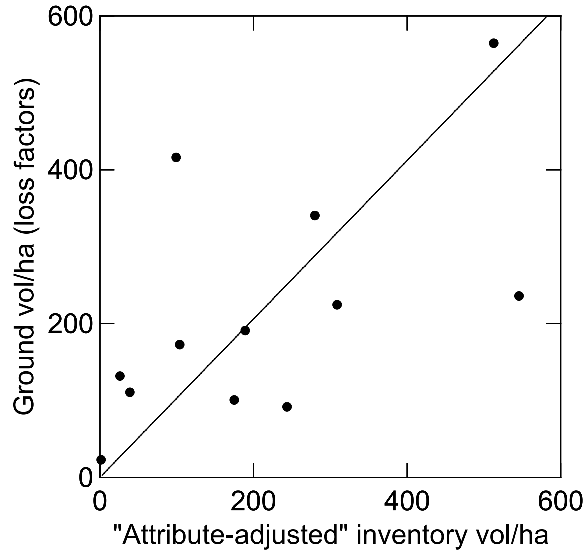

Fig. D2: Ground volume versus "attribute-adjusted" inventory volume for Cedar/Hemlock stratum. Line on graph corresponds to volume adjustment ratio.

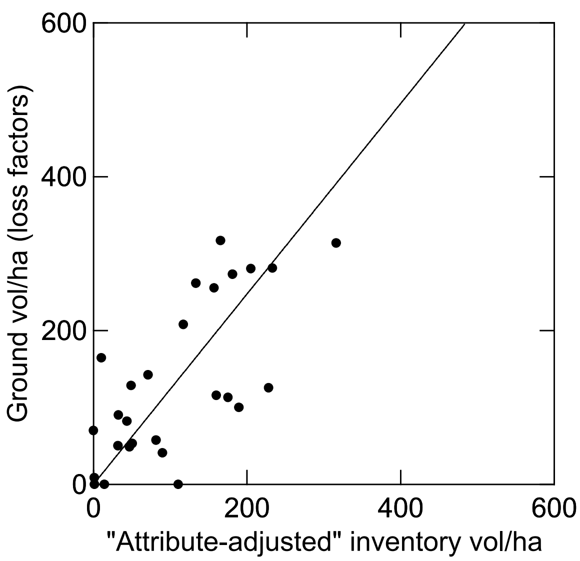

Fig. D3: Ground volume versus "attribute-adjusted" inventory volume for Balsam stratum. Line on graph corresponds to volume adjustment ratio.

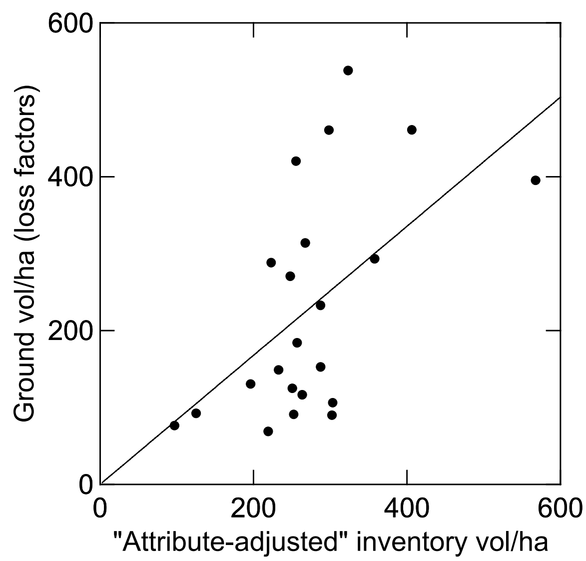

Fig. D4: Ground volume versus "attribute-adjusted" inventory volume for Spruce stratum. Line on graph corresponds to volume adjustment ratio.

Volume Relationships for Balsam Stratum with 2 Age Group Substrata

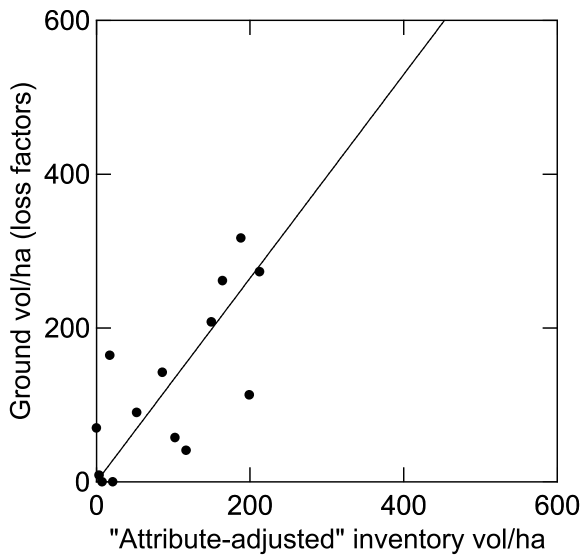

Fig. D5: Ground volume versus "attribute-adjusted" inventory volume for Balsam age <121 years stratum. Line on graph corresponds to volume adjustment ratio.

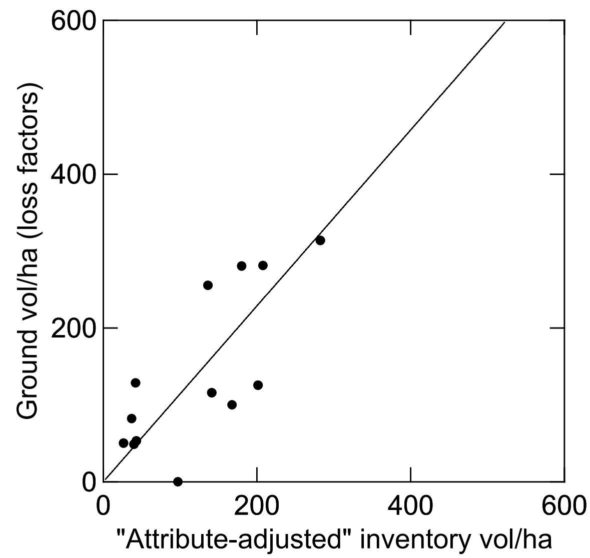

Fig. D6: Ground volume versus "attribute-adjusted" inventory volume for Balsam age >120 years stratum. Line on graph corresponds to volume adjustment ratio.

Scatter plots showing volume residuals by species stratum

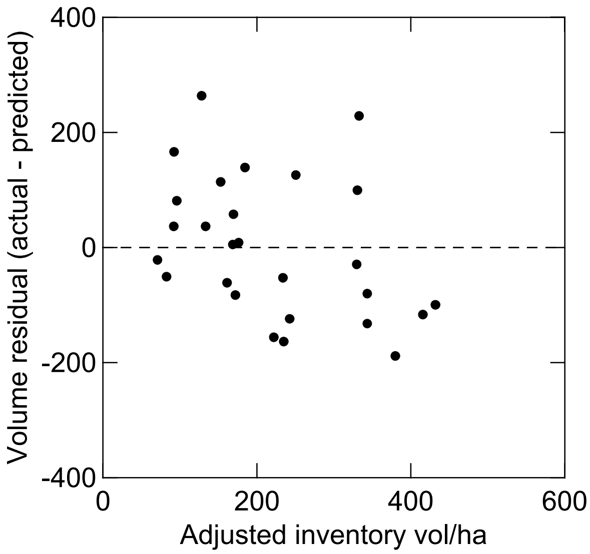

Fig. D7: Volume residual (ground vol/ha – adjusted inventory vol/ha) versus adjusted inventory vol/ha for Fir/Pine/Larch/ Deciduous stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

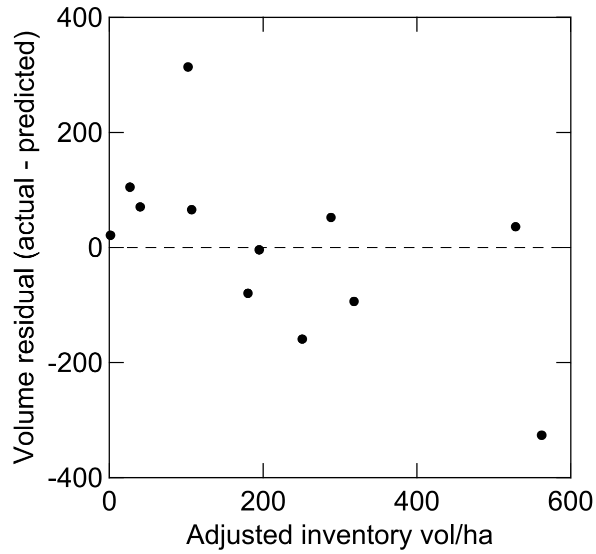

Fig. D8: Volume residual (ground vol/ha – adjusted inventory vol/ha) versus adjusted inventory vol/ha for Cedar/Hemlock stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

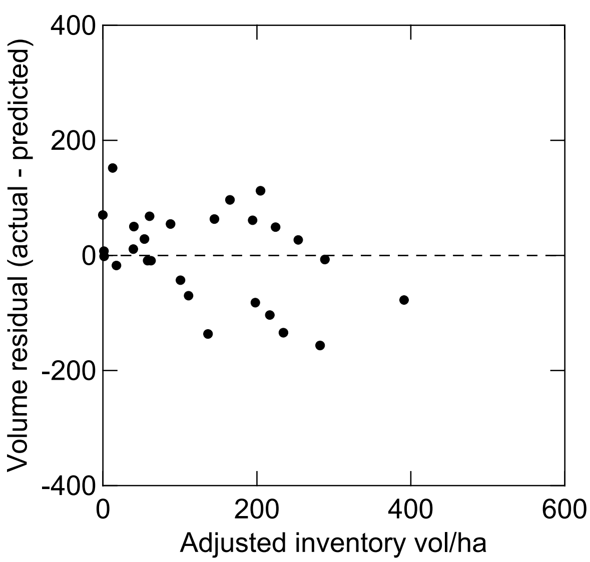

Fig. D9: Volume residual (ground vol/ha – adjusted inventory vol/ha) versus adjusted inventory vol/ha for Balsam stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

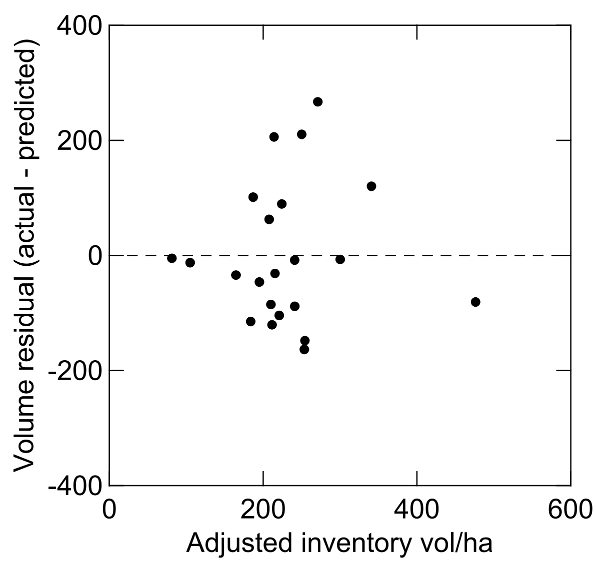

Fig. D10: Volume residual (ground vol/ha – adjusted inventory vol/ha) versus adjusted inventory vol/ha for Spruce stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

Scatter plots showing volume residuals as a function of adjusted inventory age, by species stratum

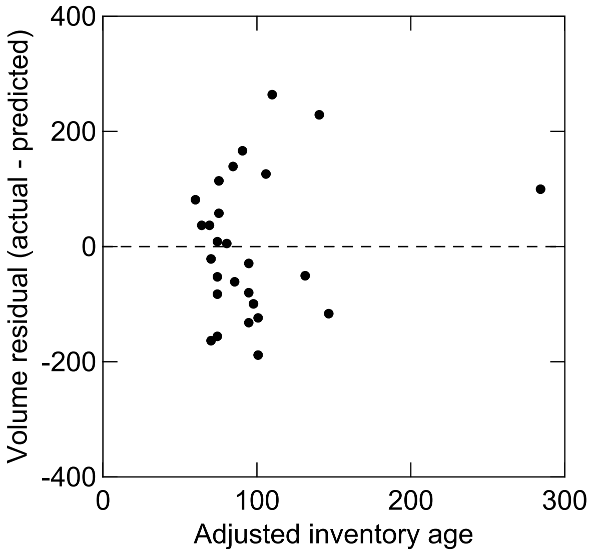

Fig. D11: Volume residual (ground vol/ha – adjusted inventory vol/ha) versus adjusted inventory age for Fir/Pine/Larch/ Deciduous stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

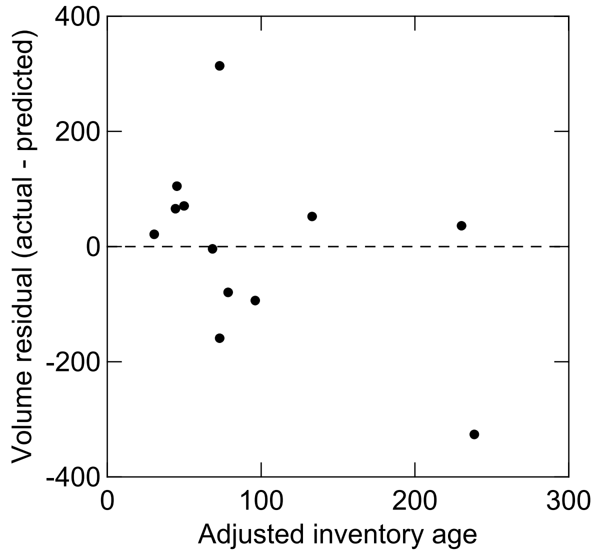

Fig. D12: Volume residual (ground vol/ha – adjusted inventory vol/ha) versus adjusted inventory age for Cedar/Hemlock stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

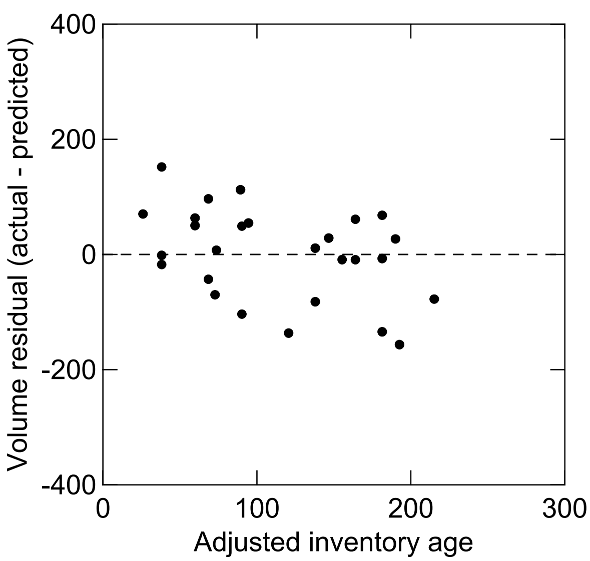

Fig. D13: Volume residual (ground vol/ha – adjusted inventory vol/ha) versus adjusted inventory age for Balsam stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

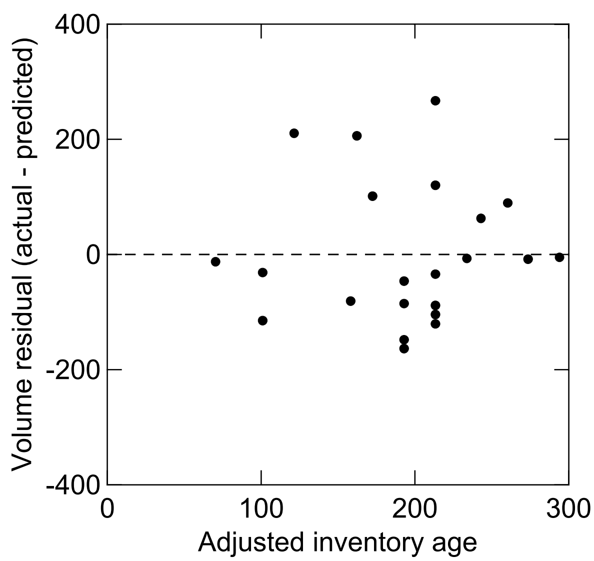

Fig. D14: Volume residual (ground vol/ha – adjusted inventory vol/ha) versus adjusted inventory age for Spruce stratum. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

Scatter plots showing residuals for Balsam stratum with 2 age group substrata

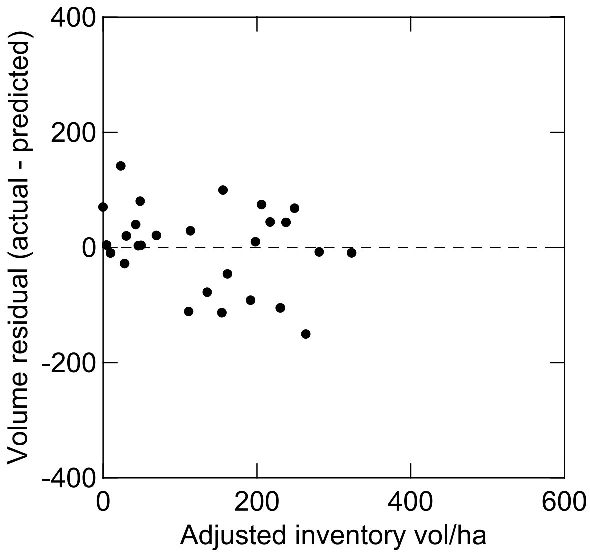

Fig. D15: Volume residual (ground vol/ha – adjusted inventory vol/ha) versus adjusted inventory vol/ha for Balsam strata with 2 age substrata. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.

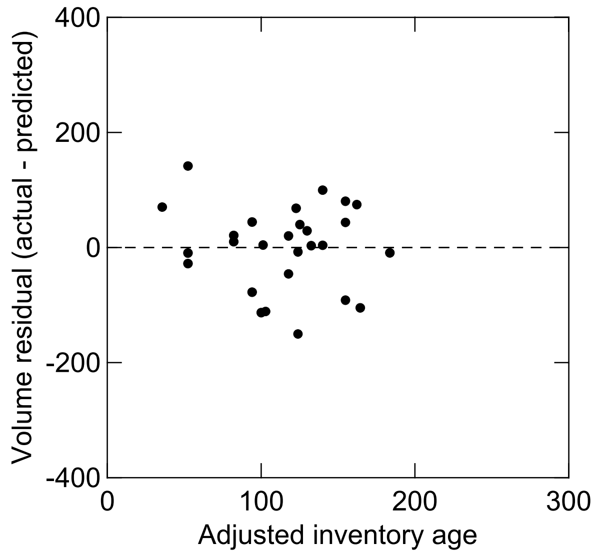

Fig. D16: Volume residual (ground vol/ha – adjusted inventory vol/ha) versus adjusted inventory age for Balsam strata with 2 age substrata. Horizontal line represents zero bias. Points above the line represent underestimates whereas points below the line represent overestimates.