TFL53

Documentation of
Vegetation Resources Inventory Statistical Analysis

Prepared For:
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Executive Summary

The objective of this project was to provide an assessment of the accuracy of the Phase I inventory of TFL53 by completing a VRI statistical analysis of selected Phase I inventory attributes in the target population of interest. The analysis was based on current Ministry of Forests, Mines & Lands (MFLNRO) standards.

The analysis focused on seven attributes: age, height, basal area of trees with Dbh ≥ 7.5 cm, trees/ha of trees with Dbh ≥ 7.5 cm, Lorey height, volume/ha net of decay waste and breakage of trees with Dbh ≥ 12.5 cm and site index. The ratios of Phase II Ground and Phase I Inventory means are given in Table 1. A ratio greater than 1 indicates that, on average, the Phase I inventory is underestimating an attribute, based on the Phase II ground sample. Similarly, a ratio < 1 indicates overestimation. A ratio close to 1 indicates little bias (Phase I is accurate). A small standard error indicates the bias is relatively consistent (Phase I is precise).

Table 1. The ratios of means (Phase II Ground/Phase I Inventory) are given by strata for seven attributes for TFL 53. Shaded cells are associated with small sample sizes and the ratios should be used with caution.

Stratum	Leading species substratum	n	Ratio of weighted means (with 95% sampling error shown as % of the ratio)						
			Age (years)	Height (m)	Basal area (m^2/ha)	Trees/ha	Lorey height (m)	Volume net dwb (m^3/ha)	SI (m)
Immature	All	20	1.084 (8.2%)	1.551 (16.7%)	1.370 (26%)	0.385 (43.3%)			1.264 (9.7%)
Mature	Balsam	16	0.964 (23.3%)	0.894 (12.4%)	1.041 (17.2%)	1.746 (22.9%)	1.016 (7.1%)	1.036 (18.4%)	0.951 (19.7%)
Mature	Deciduous	3	0.848 (14.7%)	0.954 (19.4%)	0.751 (37.4%)	1.018 (53%)	0.865 (23.7%)	0.830 (40.6%)	1.072 (18.3%)
Mature	Douglas-fir/pine	2	0.928 (3.6%)	0.818 (22.5%)	0.929 (18.5%)	2.096 (115.9%)	0.818 (42.6%)	0.805 (16.8%)	0.849 (21.3%)
Mature	Spruce	29	1.032 (8.3%)	1.000 (5%)	0.846 (10.2%)	1.215 (23.8%)	1.042 (7.7%)	0.880 (12.1%)	1.006 (8.7%)
	Subtotal	50	1.003 (8.6%)	0.954 (4.3%)	0.891 (8.4%)	1.387 (16.6%)	1.015 (5.8%)	0.907 (9.4%)	0.981 (7.2%)

Based on 50 samples in the mature stratum (age 51+), the Phase I inventory leading species age, Lorey height and site index are particularly well estimated (bias < 5%). Basal area is less well-estimated (bias of 10%) and stems/ha is not well estimated (the Phase II estimated is approximately 1/3 the Phase I estimate). The volume net of decay, waste and breakage at the 12.5 cm+ utilization level is overestimated by approximately 9%. This volume error was further divided into model-related error (due to the volume estimation routines in VDYP7) and attribute-related error (errors in the Phase I attributes used as input into VDYP7). Model-related bias was positive (the Phase II volume estimates using VDYP7 were lower than the Phase II volume estimates using the ground compiler) and approximately 6% of the Phase II ground volume for the mature stratum. Attribute-related volume was negative and approximately -15 % of the Phase II ground volume. Most of the volume overestimation is due to basal area overestimation. The model-related error was more consistent (lower standard error) compared to the attribute-related error.

Based on 20 samples in the immature stratum, the biases are generally larger and the standard errors also larger. In general, the Phase I inventory estimates represent a younger development stage (younger, shorter, lower basal area, higher stems/ha). In 19 of 20 samples, the VDYP7 projections of Lorey height and volume were blank, indicating the polygon was too short to produce estimates. As a consequence, it is recommended that Lorey height and volume ratios not be calculated for immature strata.

Based on the statistical analysis here, the following recommendations are made.

- With the exception of the Balsam substratum, the Phase I volume estimates for the mature stratum should be used with caution as they tend to overestimate the volume by approximately 9%.
- Investigate methods for improving Phase I basal area estimates.
- For the immature stratum, Lorey height and volume are less important and should be omitted from the statistical analysis.
- Some of the sample sizes are small and the assumed t-value of 1.96 is not appropriate and should be replaced by the actual t-value.

The audit results are very good. Several factors may contribute to the good agreement between the Phase I photo interpretation and the Phase II ground sampling.

- The Phase I photo interpretation was done by one photo interpreter (consistent)
- The Phase I photography is all recent and close to the year of ground sampling.
- There is relatively little variability in the forest cover over the population of interest (vegetated, treed polygons 15 years and older).

Acknowledgements

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Table of Contents

EXECUTIVE SUMMARY ..... **I**

ACKNOWLEDGEMENTS ..... **II**

TABLE OF CONTENTS ..... **III**

1. INTRODUCTION **1**
1.1 Background 1
1.2 Description of the Target Population Area 1
1.3 Scope and objectives 1

2. METHODS **1**
2.1 Overview of VRI Statistical Analysis 1
2.2 Population for Analysis 2
2.3 Phase II Sample Selection Pre-Stratification and Weights 2
2.4 Data Sources 3
2.4.1 Phase I photo-interpreted inventory data 3
2.4.2 Phase II ground sample data 3
2.4.3 Data issues 3
2.4.4 Height and Age matching 3
2.4.5 Site index 3

3. RESULTS AND DISCUSSION **4**
3.1 Attribute bias 4
3.2 Model and Attribute-related volume bias 6
3.3 Leading species comparison 8
3.4 Issues 9

4. CONCLUSIONS AND RECOMMENDATIONS **11**

5. LITERATURE CITED **11**

6. APPENDIX A: PHASE I INVENTORY ATTRIBUTES **13**

7. APPENDIX B: PHASE II COMPILED GROUND ATTRIBUTES **18**

8. APPENDIX C: SCATTERPLOTS TO FIND POTENTIAL OUTLIERS **20**

9. APPENDIX D: HEIGHT AND AGE MATCHING **21**

10. APPENDIX E: SCATTERPLOTS AND RESIDUALS **24**

11. APPENDIX F: SCATTERPLOTS OF TOTAL VOLUME BIAS, MODEL BIAS AND ATTRIBUTE BIAS. **30**

1. Introduction

1.1 Background

Details of the ground sample planning for TFL 53 are given in *"Tree Farm Licence 53 Vegetation Resources Inventory Project Implementation Plan for Ground Sampling and Net Volume Adjustment Factor Sampling"* (Nona Philips Forestry Consulting 2011) available from the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO).

1.2 Description of the Target Population Area

The target population for TFL 53 is the vegetated treed portion of the TFL and the immature and mature strata within this population.

- Mature – 51 years and older, and
- Immature – 15 to 50 years.

The landbase is summarized in Table 1. The majority of the target population (Vegetated treed polygons ≥ 15 years old) is dominated by spruce leading polygons (61%), followed by balsam (21%) and then pine (11%) and other mainly deciduous species (7%).

Table 1. The land base of TFL 53 is summarized.

Land Classification	Area (ha)	% of TFL	% of Vegetated
Total area	87,850	100%	
Non-vegetated	2,190	2%	
Vegetated	85,660	98%	
Non-treed	11,933	14%	14%
Treed	73,727	84%	86%

1.3 Scope and objectives

The objective of this project was to provide a VDYP7-based VRI statistical analysis for TFL 53, based on current MFLNRO standards (FAIB 2011) and the Churlish (2011a) analysis of Quesnel East. The analysis is based on 70 Phase II samples established in the 2011 field season. All attribute values are based on live trees only. The analysis includes examining model and attribute-related components of volume bias.

2. METHODS

2.1 Overview of VRI Statistical Analysis

The goal of the VRI statistical analysis is to evaluate the accuracy of the Phase I photo-interpreted inventory data using the Phase II ground sample data as the standard for comparison.

The process involves first projecting Phase I inventory data to the year of ground sampling using the VDYP7 growth model. The Phase I inventory data corresponding to the Phase II ground samples are identified and data screening is undertaken to identify potential data errors and/or inappropriate matching of Phase I and II data. Analysis is usually undertaken at the stratum level, where strata are typically defined by leading species. After calculating and applying the appropriate sampling weights, mean values of the ground sample attributes and the corresponding Phase I inventory attributes are computed. The ratio of these two values (i.e. the mean Phase II ground sample value / the mean Phase I inventory value) is then calculated along with the corresponding sampling errors, by stratum.

These ratios of means form the basis of the inventory assessment. The sampling errors for these ratios are an indication of the risk and uncertainty associated with the sampling process.

Seven timber attributes are considered in the current VRI ground sample data analysis:

- Age of the first species,
- Height of the first species,
- Basal area at 7.5 cm+ Dbh utilization (BA7.5),
- Trees per hectare at 7.5 cm+ Dbh utilization (TPH7.5),
- Lorey height at 7.5 cm+ Dbh utilization (LH7.5),
- Volume net top, stump (CU), decay, waste and breakage at 12.5 cm+ Dbh utilization, and
- Site index.

The analysis of model and attribute-related components of volume bias follow the Strathcona TSA analysis by Churlish and Jahraus (2011b).

2.2 Population for Analysis

The population of interest for this analysis consists of the vegetated treed polygons, 15 years of age and greater. There were no exclusions made from the TFL53 land base in deriving the sampling population. The total area of this population of interest was approximately 66,000 ha (see Table 2 for details).

2.3 Phase II Sample Selection Pre-Stratification and Weights

For the sample selection, pre-stratification was carried out based on age groupings: Immature (15-50 years) and mature (greater than 50 years old). Further sub-stratification, by leading species group, was applied in the mature age class to ensure adequate representation of the samples across the target population (Figure 1 and Table 2).

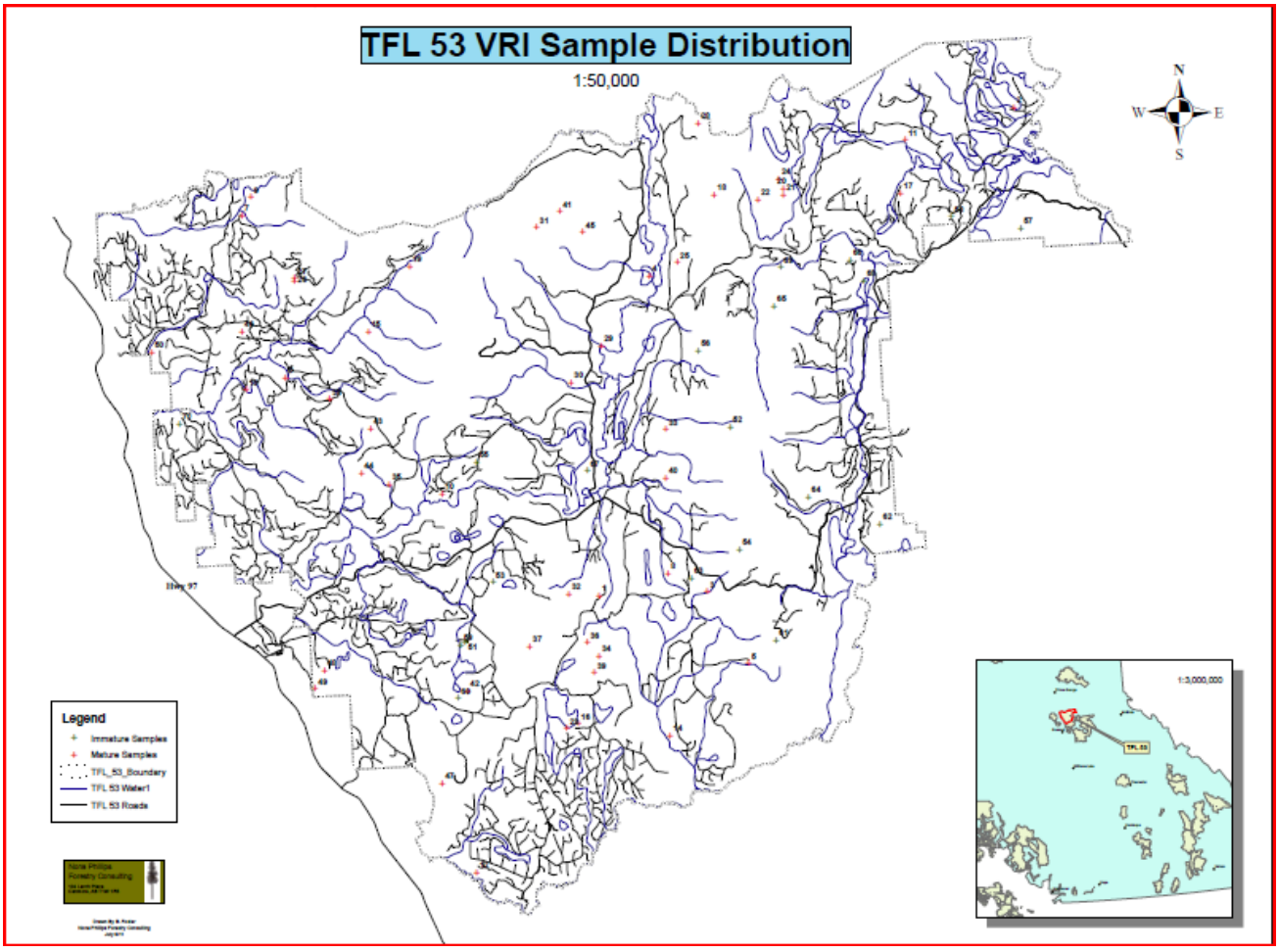

Figure 1. The locations of the Phase II ground samples are given.

Table 2. The sample weights for TFL 53 are given. There were no departures from the ground sampling plan.

Land base Age class	Stratum	Area (ha) (A)	% of area	Number of samples (n)	Weight = A/n
Mature	Spruce	24,164	58	29	833
	Balsam	13,606	32	16	850
	Douglas-fir, Pine	1,652	4	2	826
	Deciduous	2,350	6	3	783
	Total	41,772	100	50	
Immature	All	21,931	100	20	1,097

2.4 Data Sources

2.4.1 Phase I photo-interpreted inventory data

The Phase I data were provided by the MFLNRO and correspond to the photo acquisition year of 2009. The data were projected to 2011 using VDYP7 Console version 7.7a.33. The leading species site index (SI) was estimated using SiteTools 3.3 and the projected height and age of the leading species. The SI for the secondary species was also estimated. In some cases the VDYP7 volume was blank. This only occurred in the immature stratum, generally for short polygons. These blanks were interpreted as zeroes. In some cases the VDYP7 Lorey height was missing. Again, this happened in the immature stratum for short polygons. For Lorey height, blanks were interpreted as missing values.

2.4.2 Phase II ground sample data

The Phase II ground samples were provided by the MFLNRO. All were measured in 2011. The Phase II ground SI was estimated as the average SI of the T, L, X and O trees.

2.4.3 Data issues

There were no data issues.

2.4.4 Height and Age matching

The data matching followed the FAIB (2011) procedures and standards document. For each VRI sample polygon, the Phase II ground sample data was matched with the corresponding Phase I inventory data for the same polygon. The ground heights and ages used in the analysis were based on the average values for the T, L, X & O trees for the ground leading species (by basal area at 4 cm + Dbh utilization) on the ground. 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 leading species match could not be made at the sp0 level, conifer-to-conifer (or deciduous-to-deciduous) matches were allowed. However, conifer-deciduous matches were not considered acceptable. Section 9 (Appendix D) provides the details for the height and age data matching. Section 3.3 provides a comparison between the Phase I inventory leading species and the Phase II ground sample leading species.

Of the 70 samples used in the analysis, 55 (or 76%) had a match between the inventory leading species and the ground leading species at 4 cm+ Dbh utilization (Table 8). A further 10 samples (14%) were matched based on the ground leading and inventory secondary species. Three (3) samples were matched on a conifer-to-conifer or deciduous-to-deciduous basis. Two samples could not be matched and were therefore excluded from the development of the age and height comparison ratios. However, all samples were used in the development of basal area, trees/ha, Lorey height and volume ratios.

2.4.5 Site index

The height and age matching rules were used for site index were used but only cases 1 and 2 were considered satisfactory matches. That is, if the Phase I and Phase II leading species were the same, the

Phase I SI and Phase II leading species SI were matched. Also, if the Phase I leading species and Phase II secondary species were the same, the Phase I SI (leading species) and Phase II secondary species SI were matched. No other cases were considered matches.

3. Results and Discussion

3.1 Attribute bias

The Phase I inventory and Phase II ground sample weighted means were computed by strata for the seven key attributes identified in section 2.1 and are given in Table 3. The ratios of means were calculated for the seven key attributes and are given in 0.

Table 3. The weighted means for the Phase I inventory and Phase II ground samples are given for TFL 53. Shading indicates conditions with small sample sizes.

Attribute	Statistic	Immature	Mature				
			Balsam	Decid	Df/pine	Spruce	Subtotal
Age	n	20	15	3	2	28	48
(years)	Phase II Ground mean	29	115	68	78	136	123
	Phase I inventory mean	26	119	80	84	132	123
Height	n	20	15	3	2	28	48
(m)	Phase II Ground mean	10.3	19.4	22.2	22.8	27.3	24.3
	Phase I inventory mean	6.6	21.7	23.3	27.9	27.3	25.3
Basal area	n	20	16	3	2	29	50
(m^2/ha)	Phase II Ground mean	16	31	27	34	35	33
at 7.5 cm+ Dbh	Phase I inventory mean	12	29	36	37	42	37
Trees/ha	n	20	16	3	2	29	50
at 7.5 cm+ Dbh	Phase II Ground mean	977	934	647	1099	707	793
	Phase I inventory mean	2539	535	636	524	582	567
Lorey height	n	1[1]	16	3	2	29	50
(m)	Phase II Ground mean	8.6	17.5	18.6	19.3	23.8	21.2
	Phase I inventory mean	12.7	17.2	21.5	23.6	22.8	20.9
Volume (m^3/ha)	n	20[2]	16	3	2	29	50
at 12.5 cm+ Dbh	Phase II Ground mean	48	189	181	218	282	244
net dwb	Phase I inventory mean	7	183	218	271	321	268
SI	n	18	14	3	2	28	47
(m)	Phase II Ground mean	21.6	13.3	19.5	18.8	16.3	15.7
	Phase I inventory mean	17.1	14.0	18.1	22.2	16.2	15.9

[1] In the immature stratum, for 19 out of 20 samples the Phase I Lorey height was blank. These were set to missing values and not used in calculating the means.

[2] In the immature stratum, for 19 out of 20 samples the Phase I volume was blank. These were set to zero and used in calculating the ratios.

Table 4. The ratios of means (Phase II Ground/Phase I Inventory) are given by strata for TFL 53.

Stratum	Leading species substratum	n	Ratio of weighted means (with 95% sampling error shown as % of the ratio)						
			Age (years)	Height (m)	Basal area (m^2/ha)	Trees/ha	Lorey height (m)	Volume net dwb (m^3/ha)	SI (m)
Immature	All	20	1.084 (8.2%)	1.551 (16.7%)	1.370 (26.0%)	0.385 (43.3%)			1.264 (9.7%)
Mature	Balsam	16	0.964 (23.3%)	0.894 (12.4%)	1.041 (17.2%)	1.746 (22.9%)	1.016 (7.1%)	1.036 (18.4%)	0.951 (19.7%)
Mature	Deciduous	3	0.848 (14.7%)	0.954 (19.4%)	0.751 (37.4%)	1.018 (53.0%)	0.865 (23.7%)	0.830 (40.6%)	1.072 (18.3%)
Mature	Douglas-fir/pine	2	0.928 (3.6%)	0.818 (22.5%)	0.929 (18.5%)	2.096 (115.9%)	0.818 (42.6%)	0.805 (16.8%)	0.849 (21.3%)
Mature	Spruce	29	1.032 (8.3%)	1.000 (5.0%)	0.846 (10.2%)	1.215 (23.8%)	1.042 (7.7%)	0.880 (12.1%)	1.006 (8.7%)
	Subtotal	50	1.003 (8.6%)	0.954 (4.3%)	0.891 (8.4%)	1.387 (16.6%)	1.015 (5.8%)	0.907 (9.4%)	0.981 (7.2%)

For the mature stratum subtotal (all leading species combined), the Phase I means are all within about 10% of the Phase II means except for trees/ha. Age, Lorey height and SI were particularly well estimated (with mean differences < 2%) while height, basal area and volume are overestimated.

Within the mature stratum, at the substratum level (leading species within the mature stratum), spruce is the major substratum and the results for spruce are close to those for the stratum and the Phase I and Phase II estimates are generally close. The results for Balsam are similar except that basal area and consequently volume have much lower bias (slight underestimation).

The samples sizes for the Deciduous and Douglas-fir/Pine substrata are very small. The summaries and ratios are given for these substrata but the sampling errors are large and estimates for these substrata should be used with caution. The overall estimates for the mature stratum are more reliable..

For the immature stratum the ratios show considerably more variability. This is due, in part, to a smaller sample size. Another contributing factor is the effect of slightly different definitions of attributes. The Phase I basal area is the total cross sectional area, at breast height, of all living trees visible to the photo interpreter in the dominant, codominant and high intermediate crown positions for each tree layer in the polygon (FAIB 2010). For Phase II, it is the cross sectional area of all living trees with Dbh > 7.5 cm. The Phase I leading species height is the average height, weighted by basal area, of the dominant, codominant and high intermediate trees for the leading species of each layer. Phase I density is the average number of living trees visible to the photo interpreter in the dominant, codominant and high intermediate crown positions in each tree layer in the polygon. The differences in definitions of Phase I and Phase II attributes are expected to have a larger effect on the immature stratum where more trees are expected to be below the 7.5 cm Dbh utilization limit. Within the immature stratum, Age, Height, basal area and SI were underestimated while trees/ha was overestimated. The overestimation and underestimation was higher than in the mature stratum and the sample size was smaller. Age and SI were closest to the Phase II ground estimates and also had the smallest sampling errors. Trees/ha was considerably overestimated while basal area was underestimated indicating the photo interpreters were including more, smaller stems in the estimates. In summary, for the immature stratum, the Phase I estimates appear to be a slightly younger development stage than the Phase iI estimates – younger, shorter, and more numerous small trees.

For the immature stratum, the VDYP7 estimates of volume and Lorey height are blank for 19 of the 20 samples (none of the mature stratum estimates are blank). This raises the issue of the value of the ratios for these attributes. Volume and Lorey height are not photo interpreted attributes and not needed as input to VDYP7. In the immature stratum, the volumes are relatively small. In addition, most of the plots have a Phase I volume of zero and over or underestimation by a given percent is zero. As a result, it is recommended that, for the immature stratum, the ratios for Lorey height and volume not be calculated.

3.2 Model and Attribute-related volume bias

This section focuses on the mature stratum (ages 50+) and volume net of decay, waste and breakage at the 12.5 cm utilization level. In the immature stratum, some of the Phase II ground plots were too short for VYPD7 to estimate volumes for Table 5. For these plots, the VDYP7 volume based on Phase II attributes (column C of Table 5) was set to zero.

The ratio for volume for the mature stratum is 0.907 with a standard error of 9.4% indicating the Phase II ground volumes are approximately 90% of the Phase I inventory volumes. Within the mature stratum there is a slight underestimation of Balsam volume in Phase I and a larger overestimation of the remaining substrata (primarily spruce).

The volume bias was partitioned into model-related and attribute-related bias. VDYP7 was run using the Phase II ground attributes as input (column C of Table 5). The difference between the Phase II ground volume (column A) and column C is assumed to be model-related bias, due to errors in the volume estimation routines in VDYP7. The difference between the VDYP7 volume estimates using the Phase I attributes (column B) and column C is assumed to be attribute-related bias.

Table 5. Weighted mean volumes net DWB (Dbh ≥ 12.5 cm) by stratum for TFL 53. For the bias, the mean is followed by the mean expressed as a percentage of the Phase I volume (B).

Stratum	Leading species substratum	n	Weighted mean volume (m^3/ha) estimates net DWB for Dbh ≥ 12.5cm					
			Phase II ground A	VDYP7 Phase I (VRIStart) attributes) B	VDYP7 with Phase II attributes as input C	Model-related volume bias A-C	Attribute-related volume bias C-B	Total volume bias A-B
Immature	All	20	47.8	6.8	40.9	7 (103%)	34.1 (502%)	41 (604%)
Mature	Balsam	16	189.2	182.6	166.7	22.5 (12%)	-15.9 (-9%)	6.6 (4%)
Mature	Deciduous	3	180.6	217.6	152.0	28.6 (13%)	-65.6 (-30%)	-37.0 (-17%)
Mature	Df/pine	2	218.3	271.2	194.3	24.1 (9%)	-76.9 (-28%)	-52.8 (-19%)
Mature	Spruce	29	282.3	320.7	270.1	12.2 (4%)	-50.6 (-16%)	-38.4 (-12%)
	Subtotal	50	243.7	268.0	226.8	16.9 (6%)	-41.2 (-15%)	-24.2 (-9%)

The relationship between the bias components is given in Figure 2.

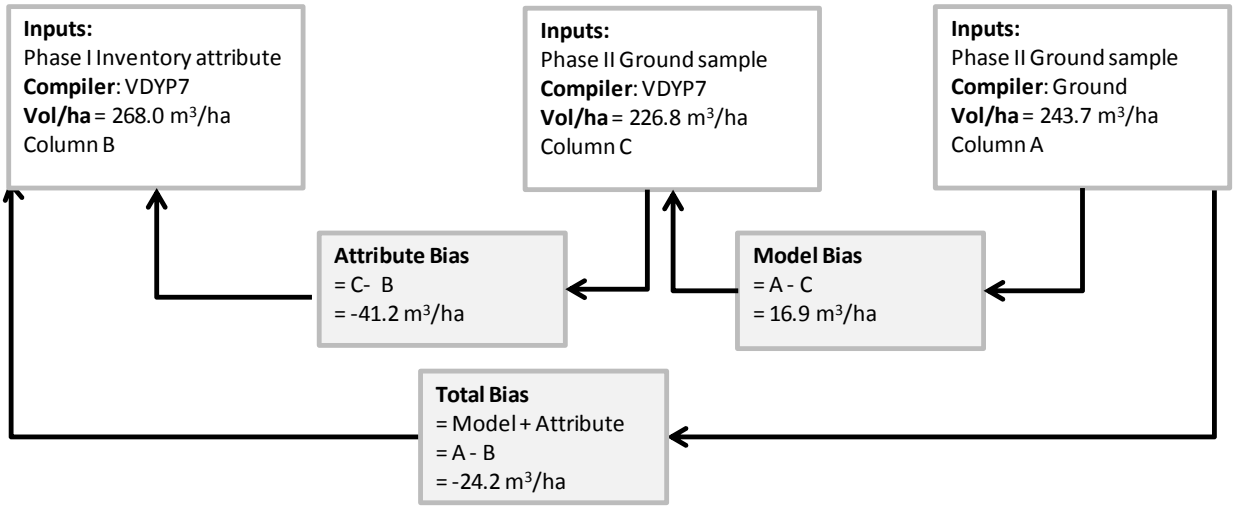

Figure 2. The relationship between the volume and bias estimates is given for the mature stratum in Table 5. A negative bias indicates overestimation and a positive bias indicates underestimation.

The model-related volume bias is positive, indicating VDYP7 is underestimating volume. The underestimation is relatively small for the Spruce plots (< 5%) and greater for the other plots in the

mature stratum. The attribute-related volume bias is negative for the mature stratum indicating the Phase I attributes are overestimated and smaller for the balsam substratum. This is confirmed by the ratios in Table 4 which are generally less than 1 for the mature stratum for height and basal area, key drivers in VDYP7. The model-related volume tends to cancel some of the attribute-related bias resulting in a smaller, generally negative total volume bias. Attribute bias tends to dominate the total bias except for the balsam substratum. This is further illustrated in Figure 14.

The same conclusions are reached examining the ratios in Table 6. For example, the Mature stratum bias ratio (0.907) indicates the mature volume is overestimated (by about 9%). The model bias ratio is greater than one, indicating the VDYP7 slightly underestimates volume. The attribute bias ratio is less than 1 indicating inaccuracies in the Phase I estimates lead to an overestimation of volume. Table 6 and Figure 14 also illustrate the higher variability in the attribute bias compared to the model bias. The standard error associated with the model bias is about half that of attribute bias and can be seen the variability around the 1:1 line in Figure 14. In practical terms, this means that, for instance, the model bias for the mature stratum is about 6% of the Phase I volume and it is consistently close to 6% where as the attribute bias is about -15% of the Phase I volume but is highly variable.

Table 6. The ratios of mean volumes (net DWB Dbh ≥ 12.5cm) representing total, model and attribute bias, with associated sampling error % at a 95% confidence level for TFL 53. VRIStart was used.

Stratum	Leading species substratum	n	Ratio of weighted mean volume/ha net DWB Dbh ≥ 12.5cm		
			Total bias: ground/Inventory (A/B)	Model bias: Ground/VDYP7(Ground attributes) (A/C)	Attribute bias: VDYP7 (Ground attributes)/Inventory (C/B)
Immature	All	20	7.045 (177.4%)	1.171 (8.1%)	6.017 (174.1%)
Mature	Balsam	16	1.036 (18.4%)	1.135 (5.4%)	0.913 (17.4%)
Mature	Deciduous	3	0.830 (40.6%)	1.188 (27.5%)	0.698 (13.7%)
Mature	Df/pine	2	0.805 (16.8%)	1.124 (3.4%)	0.716 (20.2%)
Mature	Spruce	29	0.880 (12.1%)	1.045 (6.4%)	0.842 (13.8%)
	Subtotal	50	0.907 (9.4%)	1.075 (4.7%)	0.846 (10.3%)

Basal area (m^2/ha) is an important driver of volume in VDYP7. In order to assess the contribution of errors in the Phase I basal area estimates to the volume bias, a number of additional VDYP7 projections were undertaken.

- VDYP7 was run using the Phase II ground measurements as input except the Phase II basal area was replaced with the Phase I basal area (projected to 2011) (column D in Table 7).
- VDYP7 was run using the Phase I attributes projected to 2011 as inputs except Phase I basal area was replaced with the Phase II basal area (column E in Table 7).

In Table 7, columns C and E use the same basal area as input (Phase II) but the remaining attributes are from Phase II for column C and Phase I for column E. The two predictions are very close indicating the importance of basal area in predicting volume in VDYP. Columns B and E use the same Phase I inputs except column E uses the Phase II basal area. The volumes are not as close, indicating again the importance of basal area to the VDYP7 volume estimates.

Table 7. The influence of basal area on attribute-related volume bias for TFL 53.

Stratum	Leading species substratum	n	Weighted mean volume/ha net DWB Dbh ≥ 12.5cm				
			Phase II ground A	VDYP7 Phase I (VRIStart) attributes) B	VDYP7 with Phase II attributes as input C	VDYP7 with Phase II attributes except BA is from VRIStart D	VDYP7 with Phase I attributes except BA from Phase II E
Immature	All	20	47.8	6.8	40.9	20.5	15.0
Mature	Balsam	16	189.2	182.6	166.7	159.3	180.8
Mature	Deciduous	3	180.6	217.6	152.0	210.8	159.4
Mature	Df/pine	2	218.3	271.2	194.3	209.1	252.3
Mature	Spruce	29	282.3	320.7	270.1	311.1	270.9
	Subtotal	50	243.7	268.0	226.8	252.0	234.6

The results are similar to those of Churlish and Jahraus (2011b) for Strathcona in that the total bias was dominated by attribute-related bias and basal area dominates the attribute-related bias.

3.3 Leading species comparison

Tables 8 to 10 summarize the correspondence between the leading species from the Phase I inventory and the leading species from the Phase II ground sample compilation. For the immature stratum, 85% (17 out of 20) of the inventory and the ground samples had the same leading species. For the immature stratum, 78% (39 out of 50) of the samples had the same leading species.

Table 8. The Phase I and Phase II leading species are cross tabulated by maturity.

Maturity	Phase I Species	Phase II species						
		At	BL	Ep	FD	PL	S (Sb/Sx)	Total
Immature	BL					1		1
	PL					5		5
	SX		2				12	14
	Subtotal	0	2	0	0	6	12	20
Mature	AT	2					1	3
	BL		12	1			3	16
	FD				2			2
	S (Sb/Sx)	1	6				22	29
	Subtotal	3	18	1	2	0	26	50
Grand total		3	20	1	2	6	38	70

Table 9. The Phase I and Phase II leading species are cross tabulated by maturity. Each cell is expressed as a percent of the row (Phase I) total.

Maturity	Phase I Species	Phase II species						
		At	BL	Ep	FD	PL	S (Sb/Sx)	Total
Immature	BL	0%	0%	0%	0%	100%	0%	100%
	PL	0%	0%	0%	0%	100%	0%	100%
	SX	0%	14%	0%	0%	0%	86%	100%
	Subtotal	0%	10%	0%	0%	30%	60%	100%
Mature	AT	67%	0%	0%	0%	0%	33%	100%
	BL	0%	75%	6%	0%	0%	19%	100%
	FD	0%	0%	0%	100%	0%	0%	100%
	S (Sb/Sx)	3%	21%	0%	0%	0%	76%	100%
	Subtotal	6%	36%	2%	4%	0%	52%	100%
Grand total		4%	29%	1%	3%	9%	54%	100%

Table 10. The Phase I and Phase II leading species are cross tabulated by maturity. Each cell is expressed as a percent of the column (Phase II) subtotal. If the subtotal is zero, the cell is left blank.

Maturity	Phase I	Phase II species						
	Species	At	BL	Ep	FD	PL	S (Sb/Sx)	Total
Immature	BL		0%			17%	0%	5%
	PL		0%			83%	0%	25%
	SX		100%			0%	100%	70%
	Subtotal		100%			100%	100%	100%
Mature	AT	67%	0%	0%	0%		4%	6%
	BL	0%	67%	100%	0%		12%	32%
	FD	0%	0%	0%	100%		0%	4%
	S (Sb/Sx)	33%	33%	0%	0%		85%	58%
	Subtotal	100%	100%	100%	100%		100%	100%
Grand total		100%	100%	100%	100%	100%	100%	100%

Overall, the leading species was correctly identified by the Phase I inventory 80% of the time. Most of the confusion (11 of the 15 disagreements) was between fir and spruce (the most common species). In 8 of the 11 confusions between fir and spruce, the Phase I leading species is the Phase II ground secondary species. Most of the differences in the leading species identification appear to be due to differences in the relative proportions of species rather than incorrect species identification. Some of this may be due to the Phase I description applying to the entire polygon while the Phase II description applies to the plot within the polygon.

3.4 Issues

Manually calculated ratios were compared to those generated by the VRI Analysis Workbook and macro. The ratios and the standard errors of the ratios were the same. The sampling error expressed as a percentage was slightly higher. The macro appears to use a t value of 1.96 rather than the t-value corresponding to n-1 degrees of freedom. The analysis workbook uses a combined ratio estimator. Section 9.1.1.4 of FAIB seems to indicate a separate ratio estimator should be used (although $Var(R_s)$ is never given although $Var(Y_{RS})$ is). If the separate ratio estimator is recommended, the workbook should be modified to replace the combined ratio estimator with the separate ratio estimator.

Sample 32 appears to be an outlier on the age graph (Figure 3) and on the height graph (Figure 4). This plot falls in a polygon with intermediate utilization logging (Figure 5) for which it is difficult to get a good inventory description and difficult to characterize with a single ground sample. Nevertheless, the sample is valid and was retained in the analysis.

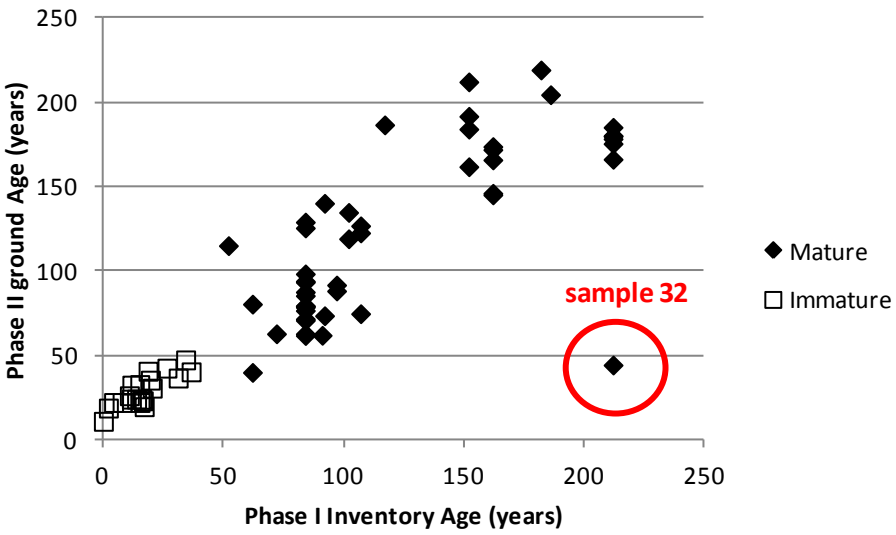

Figure 3. The Phase I Inventory and Phase II ground data ages are plotted by maturity.

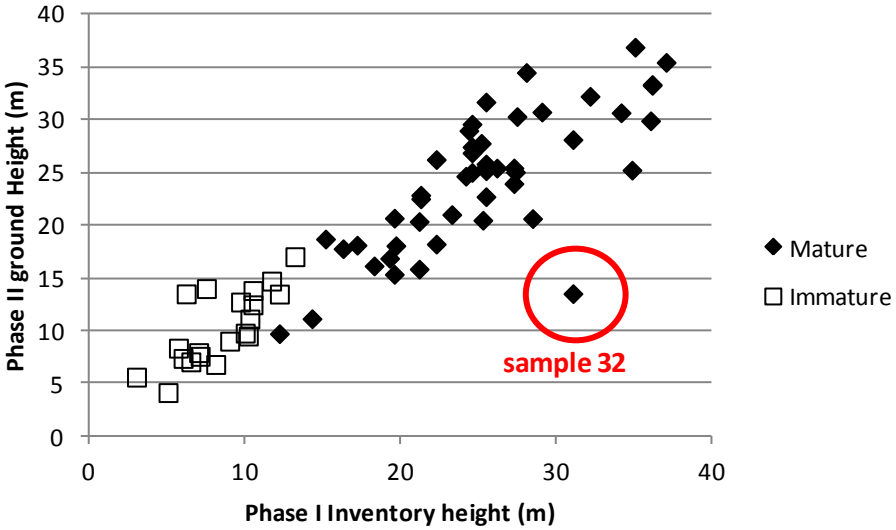

Figure 4. The Phase I Inventory and Phase II ground data height are plotted by maturity.

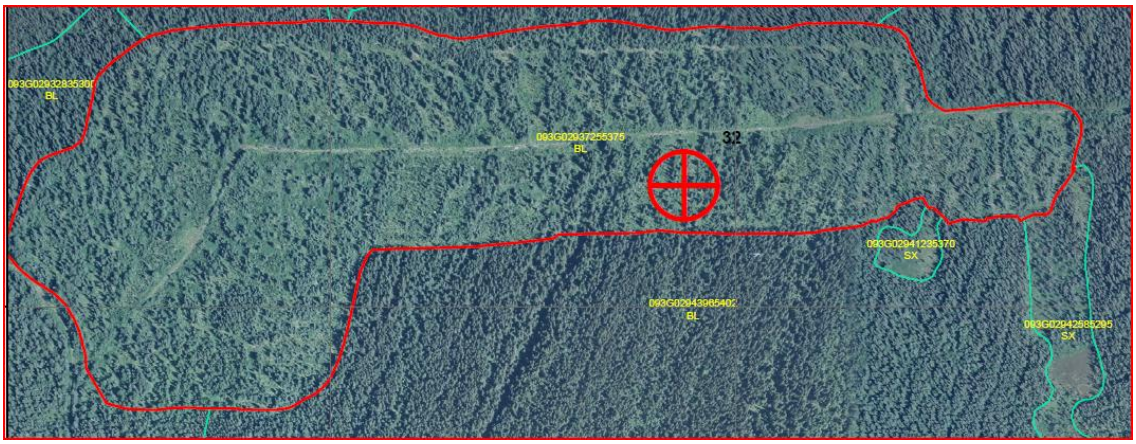

Figure 5. Sample 32 is located in a polygon with intermediate utilization logging.

4. Conclusions and recommendations

The VRI statistical analysis for TFL 53 suggests, for the mature stratum, that the inventory age and height are very well estimated. As a consequence, Lorey height and SI are also well estimated. Basal area is overestimated by about 10% leading to an overestimation of volume of about 9%. Trees/ha was the worst attribute and was underestimated by about 40%. The standard error for all ratios was less than the target of 10% except for trees/ha.

The volume bias for the mature stratum was further analyzed. Volume was overestimated by about 24 m^3/ha or about 9%. The contribution of the attribute error (photo interpretation error) was -41 m^3/ha and the contribution of the VDYP7 volume estimation algorithm (model estimation error) was about 17 m^3/ha, Most of the attribute estimation error is due to basal area as confirmed by the basal area ratio and the bias analysis. The standard error associated with the model estimation error was about 5% for the mature stratum compared to about 10% for attribute error indicating the model estimation errors were more consistent.

Overall, the leading species was correctly identified by the Phase I inventory 80% of the time. Most of the disagreement was the relative abundance (leading vs. secondary species) rather than incorrect species identification.

Most of the Phase I inventory attributes used by VDYP7 are estimated well with bias < 5%. The bias associated with basal area is higher (10%) and is largely responsible for the volume bias of 9%.

Based on the statistical analysis here, the following recommendations are made.

- With the exception of the Balsam substratum, the Phase I volume estimates for the mature stratum should be used with caution as they tend to overestimate the volume by approximately 9%.
- Investigate methods for improving Phase I basal area estimates.
- For the immature stratum, Lorey height and volume are less important and should be omitted from the statistical analysis.
- Some of the sample sizes are small and the assumed t-value of 1.96 is not appropriate and should be replaced by the actual t-value.

The audit results are very good. Several factors may contribute to the good agreement between the Phase I photo interpretation and the Phase II ground sampling.

- The Phase I photo interpretation was done by one photo interpreter (consistent)
- The Phase I photography is all recent and close to the year of ground sampling.
- There is relatively little variability in the forest cover over the population of interest (vegetated, treed polygons 15 years and older).

5. Literature cited

Churlish. 2011a.. Quesnel TSA East – Documentation of vegetations resources inventory statistical analysis. Prepared by Churlish Consulting Ltd. and Jahraus & Associates Consulting Inc. Nov. 2011. 18p + app.

Churlish. 2011b. Strathcona TSA: VRI Statistical analysis addendum: Analysis of model and attribute-related components of volume bias. Prepared by Churlish Consulting Ltd. and Jahraus & Associates Consulting Inc. Dec. 2011. 6p + app.

FAIB. 2010. Vegetation Resources Inventory – Photo Interpretation Procedures Version 2.6. Dated April 2010. 98 p + appendices.

FAIB 2011. Vegetation Resources Inventory – VRI sample data analysis procedures and standards. Version 1, June 2011. Ministry of Forests and Range, Forest Analysis and Inventory Branch. 23p. + app.

Nona Philips Forestry Consulting. 2011. Tree Farm License 53 – Vegetation resources inventory project implementation plan for ground sampling and net volume adjustment factor sampling. July 6, 2011. 13p + app.

6. Appendix A: Phase I inventory attributes

Table 11. The Phase I input (unprojected) attributes are given.

SAMPLE	FEATURE_ID	BEC	Stratum 1	Sample weight	inventory standard	Measurement year (for projections)	Reference Year	Input Age sp1	Input Height sp1	Input Age sp2	Input Height sp2	Input CC%	Input BA7.5	Input TPH7.5	sp01	pct1	sp02	pct2	sp03	pct3	sp04	pct4	sp05	pct5	sp06	pct6
1	8382773	SBS	Spruce		V	2011	2009	198	19	82	17	55	32	832	SX	60	BL	40		0		0		0		0
2	8395012	SBS	Spruce		V	2011	2009	150	16	150	21	20	10	450	SB	75	SX	25		0		0		0		0
3	8392113	SBS	Spruce		V	2011	2009	150	26	105	18	25	20	325	SX	60	BL	40		0		0		0		0
4	8376850	SBS	Spruce		V	2011	2009	190	24	115	22	40	40	725	SX	55	BL	40	SB	5		0		0		0
5	8392094	SBS	Spruce		V	2011	2009	82	14	82	17	15	8	250	SB	90	PL	10		0		0		0		0
6	8385053	SBS	Spruce		V	2011	2009	82	25	82	21	55	28	450	SX	56	EP	20	FD	10	AT	9	BL	5		0
7	8397406	SBS	Spruce		V	2011	2009	82	24	82	29	65	45	850	SX	65	FD	20	AT	10	BL	5		0		0
8	8382819	SBS	Spruce		V	2011	2009	190	28	160	21	55	45	750	SX	60	BL	40		0		0		0		0
9	8398234	SBS	Spruce		V	2011	2009	82	24	82	31	65	42	800	SX	60	FD	20	AT	15	BL	5		0		0
10	8403820	SBS	Spruce		V	2011	2009	210	29	160	26	50	45	800	SX	65	BL	25	FD	10		0		0		0
11	8396619	SBS	Spruce		V	2011	2009	210	37	130	29	27	30	275	SX	75	BL	25		0		0		0		0
12	8375929	SBS	Spruce		V	2011	2009	82	24	82	28	65	45	900	SX	90	AC	5	BL	5		0		0		0
13	8385186	SBS	Spruce		V	2011	2009	82	27	80	30	35	40	600	SX	94	FD	2	AT	2	AC	2		0		0
14	8383593	SBS	Spruce		V	2011	2009	82	25	75	24	45	40	700	SX	80	BL	10	AT	5	FD	5		0		0
15	8402622	SBS	Spruce		V	2011	2009	95	24	95	24	65	52	1400	SX	70	BL	20	FD	10		0		0		0
16	8382318	SBS	Spruce		V	2011	2009	82	25	82	24	55	42	750	SX	95	BL	5		0		0		0		0
17	8396369	SBS	Spruce		V	2011	2009	210	35	160	24	50	40	450	SX	75	BL	25		0		0		0		0
18	8396709	ESSF	Spruce		V	2011	2009	210	30	160	25	38	50	650	SX	55	BL	45		0		0		0		0
19	8376830	ESSF	Spruce		V	2011	2009	210	28	160	24	60	55	950	SX	74	BL	25	FD	1		0		0		0
20	8395889	SBS	Spruce		V	2011	2009	150	36	130	33	35	52	550	SX	70	BL	30		0		0		0		0
21	8396181	ESSF	Spruce		V	2011	2009	150	34	130	27	40	52	575	SX	70	BL	30		0		0		0		0
22	8395878	ESSF	Spruce		V	2011	2009	150	32	130	21	45	55	700	SX	71	BL	29		0		0		0		0
23	8383473	SBS	Spruce		V	2011	2009	105	27	100	25	55	46	800	SX	75	BL	25		0		0		0		0
24	8395889	SBS	Spruce		V	2011	2009	150	36	130	33	35	52	550	SX	70	BL	30		0		0		0		0

SAMPLE	FEATURE_ID	BEC	Stratum 1	Sample weight	inventory standard	Measurement year (for projections)	Reference Year	Input Age sp1	Input Height sp1	Input Age sp2	Input Height sp2	Input CC%	Input BA7.5	Input TPH7.5	sp01	pct1	sp02	pct2	sp03	pct3	sp04	pct4	sp05	pct5	sp06	pct6
25	8396606	SBS	Spruce		V	2011	2009	210	36	160	24	35	52	650	SX	65	BL	35		0		0		0		0
26	8397816	SBS	Spruce		V	2011	2009	82	25	82	29	70	50	800	SX	75	FD	15	BL	5	AT	5		0		0
27	8397816	SBS	Spruce		V	2011	2009	82	25	82	29	70	50	800	SX	75	FD	15	BL	5	AT	5		0		0
28	8442808	SBS	Spruce		V	2011	2009	210	29	160	25	50	50	675	SX	65	BL	35		0		0		0		0
29	8403761	SBS	Spruce		V	2011	2009	184	34.8	54	22.6	50	54	584	SX	80	BL	20		0		0		0		0
30	8403632	SBS	Balsam		V	2011	2009	100	19	45	14	60	23	918	BL	73	SX	24	AT	3		0		0		0
31	8376841	ESSF	Balsam		V	2011	2009	180	12	0	0	15	5	375	BL	100		0		0		0		0		0
32	8382414	SBS	Balsam		V	2011	2009	65	15	210	31	17	8	375	BL	90	SX	10		0		0		0		0
33	8402958	SBS	Balsam		V	2011	2009	90	16	45	13	33	15	575	BL	90	SX	10		0		0		0		0
34	8382846	SBS	Balsam		V	2011	2009	160	15	190	18	25	10	575	BL	90	SX	10		0		0		0		0
35	8403373	SBS	Balsam		V	2011	2009	60	19	50	21	45	38	900	BL	77	AC	10	AT	5	SX	5	EP	3		0
36	8383004	SBS	Balsam		V	2011	2009	65	19	55	18	55	32	1100	BL	78	SX	15	EP	7		0		0		0
37	8382844	SBS	Balsam		V	2011	2009	105	21	55	21	55	35	850	BL	80	SX	15	AC	5		0		0		0
38	8384026	SBS	Balsam		V	2011	2009	60	19	47	23	35	30	650	BL	90	AC	10		0		0		0		0
39	8383117	SBS	Balsam		V	2011	2009	50	19	40	17	65	38	1200	BL	79	SX	10	PL	5	AC	3	AT	3		0
40	8402822	SBS	Balsam		V	2011	2009	95	21	155	22	35	35	500	BL	93	SX	7		0		0		0		0
41	8377040	ESSF	Balsam		V	2011	2009	160	24	210	29	30	40	450	BL	55	SX	45		0		0		0		0
42	8382700	SBS	Balsam		V	2011	2009	89	20.8	155	26	65	44	1300	BL	80	SX	15	EP	5		0		0		0
43	8402626	SBS	Balsam		V	2011	2009	90	27	90	35	50	45	850	BL	85	SX	12	FD	3		0		0		0
44	8402568	SBS	Balsam		V	2011	2009	100	25	95	26	40	40	750	BL	90	SX	10		0		0		0		0
45	8377386	ESSF	Balsam		V	2011	2009	160	28	210	31	40	45	650	BL	60	SX	40		0		0		0		0
46	8397881	SBS	Df_Pin		V	2011	2009	82	28	82	24	20	22	350	FD	60	SX	35	AT	5		0		0		0
47	8382625	SBS	Df_Pin		V	2011	2009	82	27	82	24	65	52	850	FD	75	SX	15	BL	5	EP	5		0		0
48	8376344	SBS	Decid		V	2011	2009	70	22	70	19	35	25	550	AT	80	EP	20		0		0		0		0
49	8376432	SBS	Decid		V	2011	2009	82	23	82	21	55	38	800	AT	60	EP	20	SX	10	FD	10		0		0
50	8384903	SBS	Decid		V	2011	2009	82	25	82	24	40	45	700	AT	45	SX	35	FD	15	BL	3	EP	2		0
51	8382903	SBS	Other		V	2011	2009	33	9.5	32	11	25	12	1501	SX	77	BL	15	AT	5	PL	3		0		0
52	8388267	ESSF	Other		V	2011	2009	19	5.7	0	0	45	4	1478	SX	100		0		0		0		0		0

SAMPLE	FEATURE_ID	BEC	Stratum 1	Sample weight	inventory standard	Measurement year (for projections)	Reference Year	Input Age sp1	Input Height sp1	Input Age sp2	Input Height sp2	Input CC%	Input BA7.5	Input TPH7.5	sp01	pct1	sp02	pct2	sp03	pct3	sp04	pct4	sp05	pct5	sp06	pct6
53	8402863	SBS	Other		V	2011	2009	22	7.5	24	12	60	6	1400	SX	85	AC	10	BL	5		0		0		0
54	8388005	ESSF	Other		V	2011	2009	30	9.2	45	14	50	10	1100	SX	66	BL	30	AC	4		0		0		0
55	8403054	SBS	Other		V	2011	2009	32	12	45	15	65	32	1100	SX	53	BL	25	EP	10	AT	5	PL	5	AC	2
56	8388148	SBS	Other		V	2011	2009	20	6	20	5.5	60	6	2114	SX	90	BL	10		0		0		0		0
57	8395013	ESSF	Other		V	2011	2009	26	9.7	35	12	45	7	971	SX	63	BL	28	PL	8	AT	1		0		0
58	8395760	SBS	Other		V	2011	2009	34	10	45	11	60	28	3371	SX	76	BL	20	AC	4		0		0		0
59	8382903	SBS	Other		V	2011	2009	33	9.5	32	11	25	12	1501	SX	77	BL	15	AT	5	PL	3		0		0
60	8383133	SBS	Other		V	2011	2009	39	5.7	39	6.7	60	5	3400	SX	60	PL	20	AT	20		0		0		0
61	8392291	SBS	Other		V	2011	2009	16	6.5	16	6.5	35	10	2980	SX	70	BL	20	AC	10		0		0		0
62	8388100	SBS	Other		V	2011	2009	13	3	13	2.5	45	3	4565	SX	40	BL	30	PL	20	AT	10		0		0
63	8392449	SBS	Other		V	2011	2009	32	11	33	10.5	60	13	1369	SX	70	BL	20	PL	10		0		0		0
64	8388050	SBS	Other		V	2011	2009	19	7.1	19	9.7	40	8	2075	SX	90	AT	10		0		0		0		0
65	8396077	ESSF	Other		V	2011	2009	17	8.1	17	7	60	14	2767	PL	70	SX	30		0		0		0		0
66	8396677	SBS	Other		V	2011	2009	20	9	20	8	65	9	1806	PLI	55	SX	43	AT	1	AC	1		0		0
67	8403904	SBS	Other		V	2011	2009	18	10.2	18	6.7	70	22	2554	PLI	95	SX	5		0		0		0		0
68	8396680	SBS	Other		V	2011	2009	20	10	20	9.4	60	15	1831	PLI	50	SX	40	AT	10		0		0		0
69	8396648	SBS	Other		V	2011	2009	14	7	14	6	65	17	5173	PL	82	SX	10	BL	8		0		0		0
70	8384150	SBS	Other		V	2011	2009	21	2.7	7	1.3	23	5	7914	BL	60	SX	10	EP	10	PL	10	AT	10		0

Table 12. The Phase I Projected attributes are given (from VDYP7, using VRIStart).

Sample	Leading species Age	Leading species height	Second species Age	Second species height	(Dbh ≥ 7.5 cm)			(Dbh ≥ 12.5 cm)
					Basal area (m^2/ha)	Trees/ha	Lorey height (m)	Volume net DWB (m^3/ha)
1	57	19.7	35	10.8	30	636	15.5	151
2	152	16.2	152	21.2	9	290	12.7	35.8
3	152	26.2	107	18.3	19	254	19.9	122
4	192	24.2	117	22.3	39	614	19.3	242
5	84	14.3	84	17.2	8	201	13.1	32.9
6	84	25.5	84	21.3	28	417	22.8	206
7	84	24.6	84	29.4	45	743	22.5	326
8	192	28.2	162	21.2	44	602	21.3	299
9	84	24.6	84	31.5	42	701	23.1	311
10	212	29.1	162	26.2	44	698	24.2	355
11	212	37.1	132	29.2	30	257	30.6	292
12	84	24.6	84	28.3	45	789	20.4	302
13	84	27.5	82	30.5	40	553	22.9	304
14	84	25.5	77	24.5	40	629	21.7	288
15	97	24.4	97	24.3	50	1116	20.4	353
16	84	25.5	84	24.5	42	679	21.1	298
17	212	35.1	162	24.2	40	395	28.4	361
18	212	30.1	162	25.2	49	564	22.9	362
19	212	28.1	162	24.2	54	835	22.6	415
20	152	36.2	132	33.2	52	511	29.9	508
21	152	34.2	132	27.2	51	516	27.2	463
22	152	32.2	132	21.2	54	578	24.1	420
23	107	27.3	102	25.3	46	702	22.9	353
24	152	36.2	132	33.2	52	511	29.9	508
25	212	36.1	162	24.2	51	536	25.6	408
26	84	25.5	84	29.4	50	719	22.7	371
27	84	25.5	84	29.4	50	719	22.7	371
28	212	29.1	162	25.2	49	601	23.6	373
29	186	34.9	56	23.3	53	516	27.5	472
30	102	19.3	47	14.8	21	583	15.1	109
31	182	12.2			3	133	8.8	9.4
32	67	15.5	212	31.1	8	230	15.2	45.4
33	92	16.3	47	13.8	14	375	13.4	65.8
34	67	17.5	67	21.4	8	258	11.9	32.1
35	62	19.6	52	21.6	38	692	16.5	200
36	67	19.5	57	18.7	31	742	15.7	167
37	107	21.3	57	21.8	34	633	18.1	202
38	62	19.6	49	23.4	31	517	16.6	162
39	52	19.7	42	18.1	37	839	16.0	206
40	97	21.3	157	22.2	35	435	18.1	201
41	162	24.2	212	29.1	39	397	23.1	286
42	91	21.2	157	26.2	42	891	17.7	253
43	92	27.3	92	35.4	45	675	23.4	349
44	102	25.3	97	26.4	40	606	20.6	269
45	162	28.1	212	31.1	44	553	25.0	365
46	84	28.5	84	24.6	22	314	24.3	171
47	84	27.4	84	24.6	52	734	22.8	371
48	72	22.3	72	19.3	25	523	20.2	134

Sample	Leading species Age	Leading species height	Second species Age	Second species height	(Dbh ≥ 7.5 cm)			(Dbh ≥ 12.5 cm)
					Basal area (m^2/ha)	Trees/ha	Lorey height (m)	Volume net DWB (m^3/ha)
49	84	23.3	84	21.3	38	747	21.3	220
50	84	25.3	84	24.6	45	637	23.1	299
51	35	10.5	34	12	12	1501		
52	21	5.7			4	1478		
53	24	7.5	26	12	6	1400		
54	32	10.3	47	14.7	10	1100		
55	34	13.2	47	15.8	34	904	12.7	136
56	22	6	22	5.5	6	2114		
57	28	9.7	37	12.9	7	971		
58	36	11	47	11.7	28	3371		
59	35	10.5	34	12	12	1501		
60	41	6.2	41	7.1	5	3400		
61	18	6.5	18	6.5	10	2980		
62	15	3	15	2.5	3	4565		
63	34	12.2	35	11.1	13	1369		
64	21	7.1	21	9.7	8	2075		
65	19	8.1	19	7	14	2767		
66	22	9	22	8	9	1806		
67	20	10.2	20	6.7	22	2554		
68	22	10	22	9.4	15	1831		
69	16	7	16	6	17	5173		
70					5	7914		

7. Appendix B: Phase II compiled ground attributes

Table 13. The Phase II compiled ground attributes are given.

Sample	Species composition At Dbh ≥ 4.0 cm	Basal area (m^2/ha) Dbh ≥ 7.5 cm	Trees/ha Dbh ≥ 7.5 cm	Lorey height (m) Dbh ≥ 7.5 cm	Live volume net DWB (m^3/ha) Dbh ≥ 12.5 cm
1	Bl 74 Sx 26	29.4	1182	11.7	152.6
2	At 50 Sx 17 Bl 17 Pl 16	12.0	989	14.6	33.8
3	Bl 100	15.0	621	15.4	73.2
4	Bl 52 Sx 48	33.6	1574	19.2	180.0
5	Sx 80 Pl 20	9.0	578	11.3	25.7
6	Sx 58 Fd 31 Ep 08 Bl 03	46.8	986	28.8	339.3
7	Sx 57 At 17 Ac 09 Ep 09 Fd 08	32.2	771	24.2	229.6
8	Bl 59 Sb 23 Sx 18	39.6	1594	16.4	213.0
9	Sx 79 At 17 Fd 04	43.2	643	28.2	351.8
10	Bl 57 Sx 29 Fd 14	32.7	659	30.9	272.3
11	Sx 60 Bl 40	21.0	358	25.8	167.6
12	Sx 76 At 16 Pl 04 Bl 04	35.0	784	24.1	259.0
13	Sx 80 Ac 10 Bl 10	28.0	513	26.0	221.0
14	Sx 90 At 10	28.0	200	24.4	251.8
15	Sx 68 Bl 27 Pl 03 Fd 02	66.6	1519	22.7	464.1
16	Sx 75 Bl 21 Pl 04	33.6	616	21.3	241.6
17	Sx 62 Bl 38	50.4	1662	31.6	421.3
18	Bl 61 Sx 39	43.2	216	29.9	444.4
19	Sx 85 Bl 15	48.0	415	25.7	489.5
20	Sx 82 Bl 18	52.8	304	32.5	564.6
21	Sx 68 Bl 32	39.6	205	27.1	402.6
22	Sx 68 Bl 32	39.6	200	33.7	411.4
23	Sx 58 Bl 39 Ep 03	43.4	621	23.4	350.4
24	Sx 75 Bl 25	28.8	210	34.6	310.8
25	Sx 56 Bl 39 Mv 05	30.6	490	16.0	257.6
26	Sx 54 At 29 Fd 17	41.4	589	26.1	303.9
27	Sx 76 Pl 12 Bl 06 At 06	30.6	619	22.2	204.5
28	Sx 61 Bl 39	41.4	499	27.7	385.6
29	Sx 60 Bl 40	25.2	890	13.8	162.8
30	Bl 74 Sx 26	34.0	1622	14.7	151.0
31	Bl 100	15.0	729	9.7	64.8
32	Sx 50 Bl 33 Pl 17	6.0	303	11.0	21.2
33	Bl 76 Sx 24	28.0	755	14.3	165.5
34	Bl 75 Sx 25	19.0	774	15.3	98.2
35	Sx 79 Bl 17 Pl 04	33.6	984	16.1	187.2
36	Ep 33 Bl 33 Sx 19 Pl 10 Ac 05	25.2	1403	14.4	93.6
37	Bl 77 Sx 13 Ac 05 Ep 05	51.8	1325	20.1	343.7
38	Bl 64 Sx 24 Ac 08 Ep 04	32.2	447	21.4	243.7
39	Bl 64 Ep 23 Sx 13	29.4	774	16.6	172.9
40	Bl 57 Sx 43	19.6	247	20.4	146.5
41	Bl 81 Sx 19	28.8	644	24.4	232.7
42	Bl 57 Sx 30 Ac 13	29.4	1183	13.1	161.9
43	Bl 75 Sx 25	41.4	725	24.4	296.4
44	Bl 61 Ep 24 Fd 09 Sx 06	46.2	1894	17.9	240.8
45	Sx 81 Bl 19	50.4	1136	25.6	407.7
46	Fd 55 Sx 25 At 10 Bl 10	23.8	1308	15.7	118.9
47	Fd 62 Sx 23 Ep 15	45.0	889	22.9	317.8

Sample	Species composition At Dbh ≥ 4.0 cm	Basal area (m^2/ha) Dbh ≥ 7.5 cm	Trees/ha Dbh ≥ 7.5 cm	Lorey height (m) Dbh ≥ 7.5 cm	Live volume net DWB (m^3/ha) Dbh ≥ 12.5 cm
48	At 100	27.0	671	17.2	177.2
49	At 43 Sx 30 Ep 27	30.8	969	14.7	179.9
50	Sx 50 At 33 Fd 17	23.8	301	24.0	184.7
51	Sx 56 Bl 20 At 17 Ep 07	18.6	976	10.7	65.8
52	Sx 95 Fd 03 Pl 02	16.6	1226	6.9	21.1
53	Bl 42 Sx 35 At 20 Ac 02 Pl 01	20.3	1076	10.3	79.1
54	Sx 64 Bl 36	15.1	826	8.5	41.0
55	Sx 41 Bl 38 At 10 Pl 09 Ep 02	36.5	2076	12.2	155.8
56	Sx 100	11.7	1351	6.4	4.3
57	Sx 55 Bl 45	26.4	1051	11.0	97.9
58	Bl 60 Sx 40	34.2	1001	13.8	172.5
59	Sx 67 At 25 Bl 05 Pl 03	11.8	675	9.7	37.9
60	Sx 70 Ac 12 At 11 Ep 06 Bl 01	19.6	1176	11.3	57.9
61	Sx 100	4.2	550	5.9	0.4
62	Sx 85 Bl 15	2.1	325	4.8	0.0
63	Sx 99 Fd 01	31.1	1176	11.4	108.1
64	Sx 100	10.8	751	7.2	13.0
65	Pl 77 Sx 23	15.2	1201	6.6	14.1
66	Pl 70 Sx 28 Bl 02	15.9	1201	8.3	25.4
67	Pl 100	7.8	550	8.4	13.4
68	Pl 90 Sx 10	13.8	826	8.7	32.3
69	Pl 96 Ac 03 At 01	17.0	1526	6.9	17.0
70	Pl 87 Bl 13	0.0	0	3.8	0.0

8. Appendix C: Scatterplots to find potential outliers

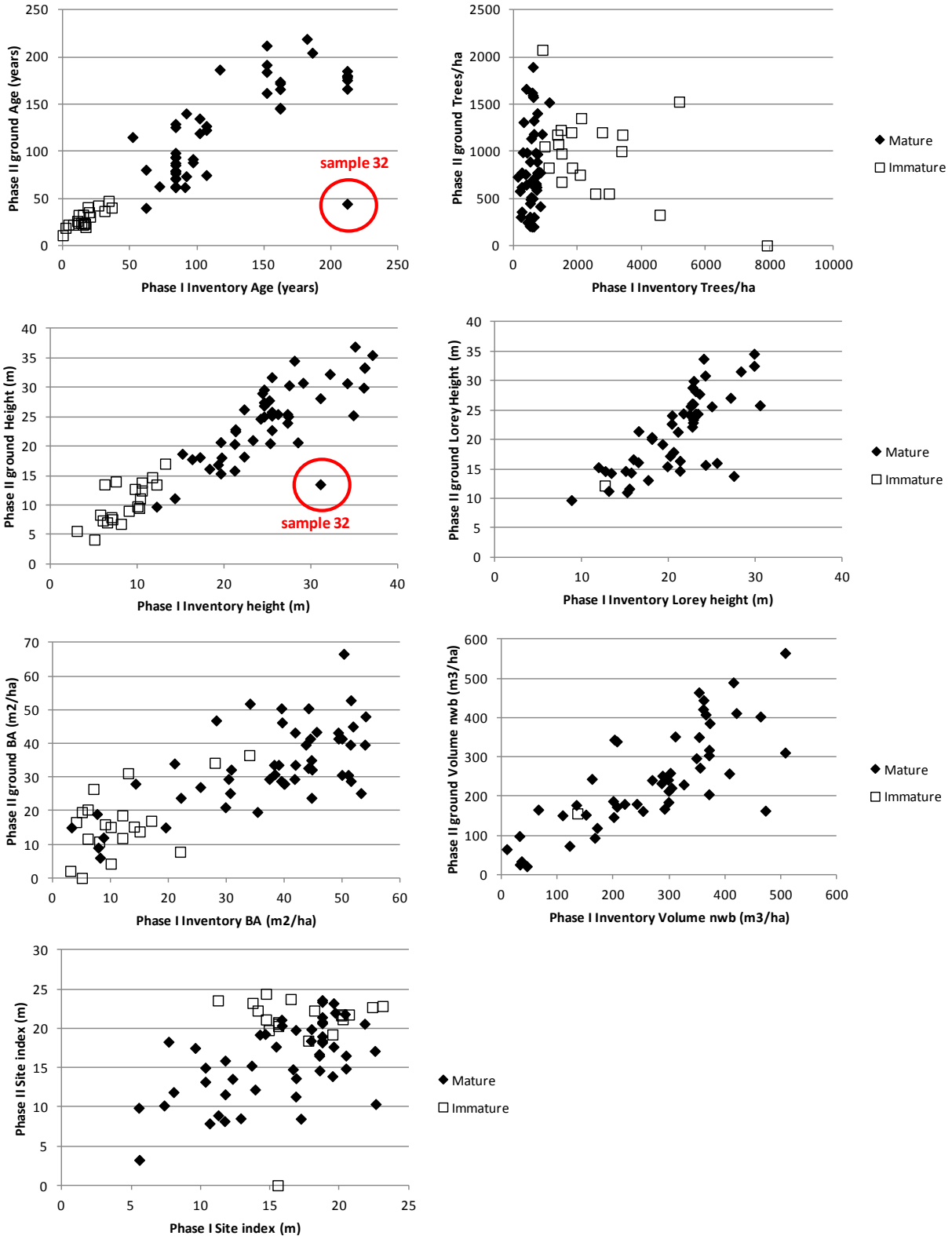

Figure 6. The Phase I inventory and Phase II Ground data are plotted for the seven attributes of interest. Potential outliers are identified. Sample 32 is discussed in section 3.4.

9. APPENDIX D: HEIGHT AND AGE MATCHING

The current standard for Phase II ground age and height is based on the average of the T, L, X and O trees. The five possible matching cases are as follows:

Case 1: Phase I leading species matches the Phase II leading species at the Sp0 level
Case 2: Phase I second species matches the Phase II leading species at the Sp0 level
Case 3: Phase I leading species matches the Phase II leading species on a conifer-to-conifer (or deciduous-to deciduous) basis
Case 4: Phase I second species matches the Phase II leading species on a conifer-to-conifer (or deciduous-to deciduous) basis
Case 5: No match

Table 14. The Sp0 groupings are given.

Sp0 Code	Species	Description
AC	AC	Poplar
AT	AT	Trembling Aspen
B	B, BA, BG, BL	Fir
C	CW	Western Red Cedar
D	DR	Alder
E	E, EA, EP	Birch
F	FD	Douglas Fir
H	H, HM, HW	Hemlock
L	L, LA, LT, LW	Larch
MB	MB	Broadleaf Maple
PA	PA, PF	Whitebark & Limber Pine
PL	PJ, PL	Lodgepole & Jack Pine
PW	PW	Western White Pine
PY	PY	Yellow Pine
S	S, SB, SE, SS, SW, SX	Spruce
Y	Y	Yellow Cedar

Table 15. The results of matching the Phase I inventory and Phase II ground heights and ages.

Sample	Phase II (ground) leading species attributes					Phase I (Inventory)				
	Species @ 4cm Dbh	Mean		Sample size		Leading species	Secondary species	Case of match	Age for match	Height for match
		Age[3]	Height[4]	Age[5]	Height[6]					
1	Bl	126	18.1	6	5	SX	BL	2	84	17.2
2	At	85	14.9	2	2	SB	SX	5	NA	NA
3	Bl	127	16.2	4	4	SX	BL	2	107	18.2
4	Bl	187	26.2	5	5	SX	BL	2	117	22.2
5	Sx	71	11.1	5	5	SB	PL	1	84	14.3
6	Sx	93	31.7	6	6	SX	EP	1	84	25.5
7	Sx	98	26.9	4	4	SX	FD	1	84	24.5
8	Bl	174	20.4	5	5	SX	BL	2	162	21.2
9	Sx	129	29.6	6	6	SX	FD	1	84	24.5
10	Bl	146	25.4	3	3	SX	BL	2	162	26.1
11	Sx	178	35.5	5	5	SX	BL	1	212	37.1
12	Sx	72	25.0	5	5	SX	AC	1	84	24.5

[3] Age = age_tlxo
[4] Height = ht_tlxo
[5] Sample size for age = n_age_tlxo
[6] Sample size for height = n_ht_tlxo

Sample	Phase II (ground) leading species attributes					Phase I (Inventory)				
	Species @ 4cm Dbh	Mean Age[3]	Mean Height[4]	Sample size Age[5]	Sample size Height[6]	Leading species	Secondary species	Case of match	Age for match	Height for match
13	Sx	94	30.3	5	5	SX	FD	1	84	27.5
14	Sx	79	25.8	5	5	SX	BL	1	84	25.5
15	Sx	92	29.0	7	7	SX	BL	1	97	24.4
16	Sx	63	22.7	6	6	SX	BL	1	84	25.5
17	Sx	180	36.9	6	6	SX	BL	1	212	35.1
18	Bl	172	27.8	6	5	SX	BL	2	162	25.1
19	Sx	185	34.5	6	5	SX	BL	1	212	28.2
20	Sx	212	33.4	5	5	SX	BL	1	152	36.2
21	Sx	184	30.7	5	5	SX	BL	1	152	34.2
22	Sx	192	32.2	5	5	SX	BL	1	152	32.2
23	Sx	75	24.0	5	5	SX	BL	1	107	27.3
24	Sx	162	33.3	6	6	SX	BL	1	152	36.2
25	Sx	180	29.9	5	5	SX	BL	1	212	36.1
26	Sx	85	25.5	7	7	SX	FD	1	84	25.5
27	Sx	88	25.2	5	5	SX	FD	1	84	25.5
28	Sx	166	30.8	6	6	SX	BL	1	212	29.1
29	Sx	205	25.2	5	5	SX	BL	1	186	34.9
30	Bl	119	16.9	6	6	BL	SX	1	102	19.3
31	Bl	219	9.7	6	5	BL		1	182	12.2
32	Sx	44	13.5	5	5	BL	SX	2	212	31.5
33	Bl	73	17.8	5	5	BL	SX	1	92	16.3
34	Bl	145	18.7	5	5	BL	SX	1	162	15.2
35	Sx	40	15.4	6	6	BL	AC	3	62	19.6
36	Ep	63	17.2	6	6	BL	SX	5	NA	NA
37	Bl	123	22.5	6	6	BL	SX	1	107	21.3
38	Bl	80	20.7	5	5	BL	AC	1	62	19.6
39	Bl	115	18.1	6	6	BL	SX	1	52	19.7
40	Bl	88	22.9	5	5	BL	SX	1	97	21.3
41	Bl	166	24.7	5	5	BL	SX	1	162	24.2
42	Bl	62	15.9	6	6	BL	SX	1	91	21.2
43	Bl	140	25.4	5	5	BL	SX	1	92	27.3
44	Bl	135	20.5	5	6	BL	SX	1	102	25.3
45	Sx	175	28.1	6	6	BL	SX	2	212	31.1
46	Fd	77	20.6	5	5	FD	SX	1	84	28.5
47	Fd	79	25.1	6	6	FD	SX	1	84	27.4
48	At	63	18.2	5	5	AT	EP	1	72	22.3
49	At	62	21.0	5	5	AT	EP	1	84	23.3
50	Sx	79	27.4	5	5	AT	SX	2	84	24.3
51	Sx	41	13.8	7	7	SX	BL	1	35	10.5
52	Sx	23	8.4	4	4	SX		1	21	2.7
53	Bl	31	14.0	6	7	SX	AC	3	24	4.2
54	Sx	33	11.1	8	8	SX	BL	1	32	10.3
55	Sx	40	17.0	3	4	SX	BL	1	34	13.2
56	Sx	24	7.4	4	4	SX	BL	1	22	3.0
57	Sx	42	12.7	8	8	SX	BL	1	28	5.0
58	Bl	47	14.7	8	8	SX	BL	2	47	12.0
59	Sx	32	12.5	5	5	SX	BL	1	35	10.5
60	Sx	35	13.5	4	4	SX	PL	1	41	6.2
61	Sx	22	7.1	4	4	SX	BL	1	18	2.4

Sample	Phase II (ground) leading species attributes					Phase I (Inventory)				
	Species @ 4cm Dbh	Mean		Sample size		Leading species	Secondary species	Case of match	Age for match	Height for match
		Age[3]	Height[4]	Age[5]	Height[6]					
62	Sx	19	5.6	5	5	SX	BL	1	15	1.5
63	Sx	37	13.5	5	5	SX	BL	1	34	12.2
64	Sx	26	7.6	4	4	SX	AT	1	21	2.7
65	Pl	22	6.8	8	8	PL	SX	1	19	6.1
66	Pl	24	9.0	8	8	PLI	SX	1	22	6.5
67	Pl	22	9.5	4	4	PLI	SX	1	20	8.4
68	Pl	24	9.8	4	4	PLI	SX	1	22	6.5
69	Pl	20	7.9	4	4	PL	SX	1	16	4.2
70	Pl	11	4.1	3	3	BL	SX	3	23	5.0

10. Appendix E: Scatterplots and residuals

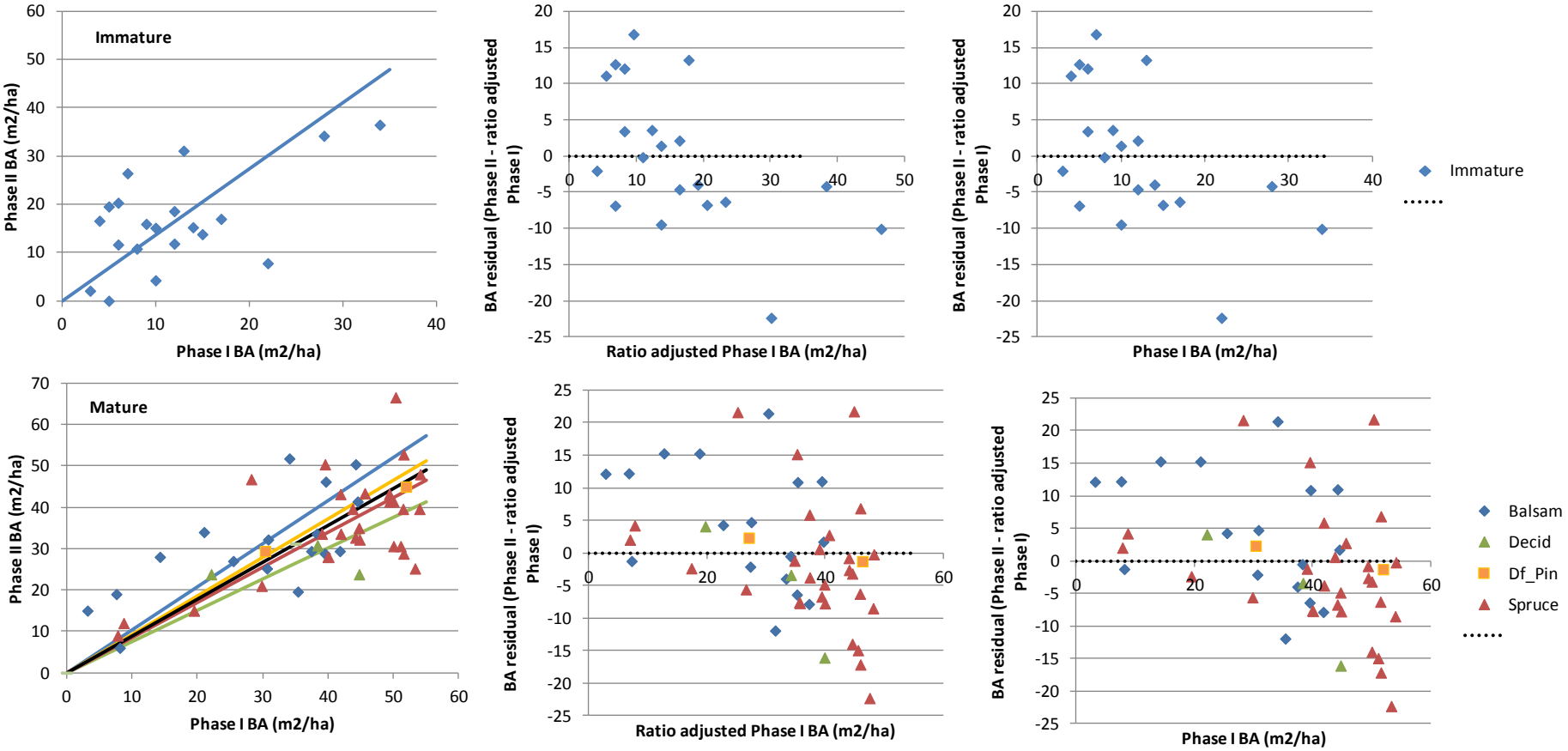

Figure 7. The scatterplots for BA are given. The top left graph gives the Phase I photo and Phase II ground estimates of basal area with a line representing the ratio. The top middle graph plots the residuals against the adjusted Phase I BA. The top right graph plots the residuals against the Phase I BA. Ideally the residuals would be scattered uniformly around the x-axis. The slight downward trend is not uncommon and may indicate the need for a regression estimator rather than a ratio (i.e., the need for an intercept). The bottom graphs are similar except in the bottom left, the ratios are given by leading species. The black line is the ratio for all mature samples.

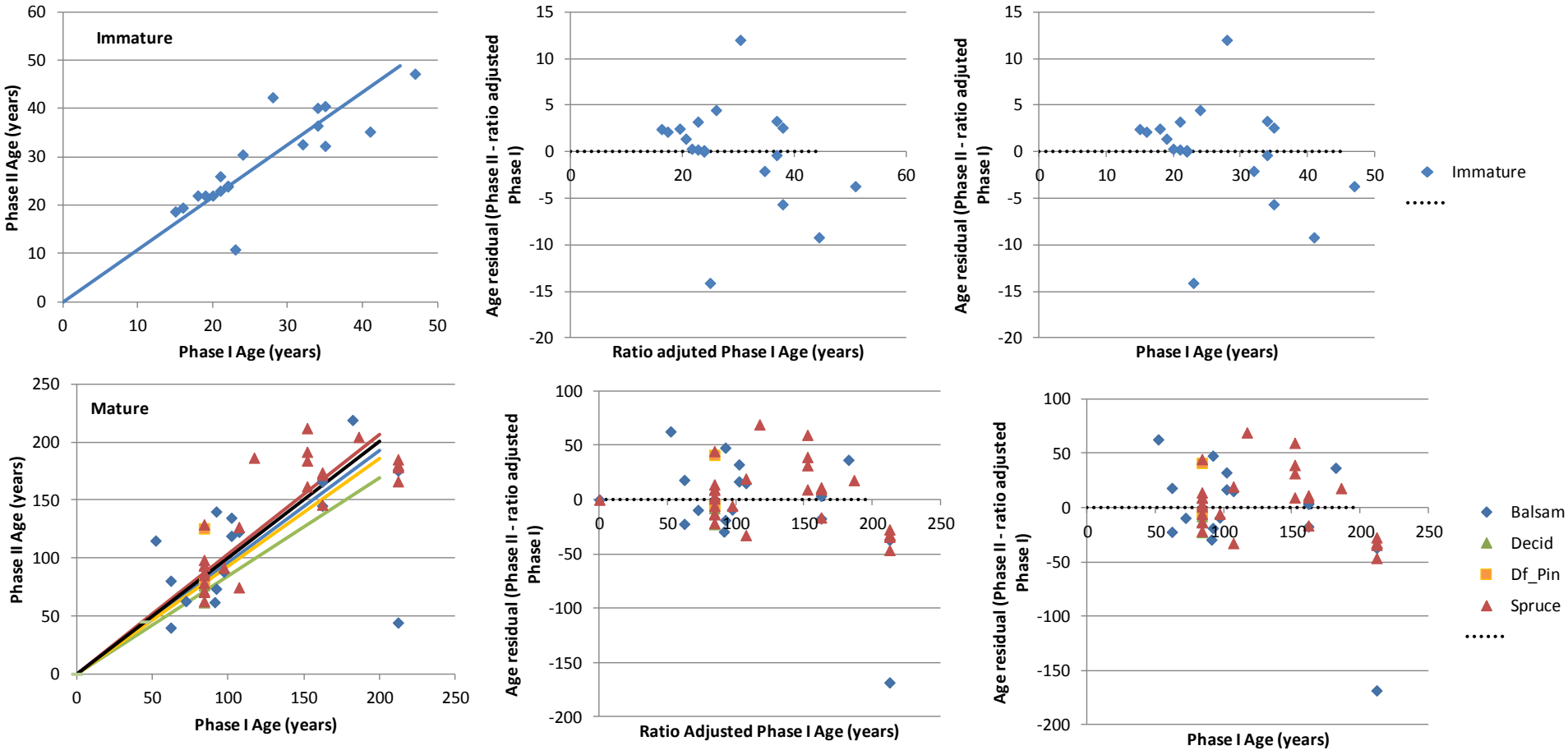

Figure 8. The scatterplots for Age are given.

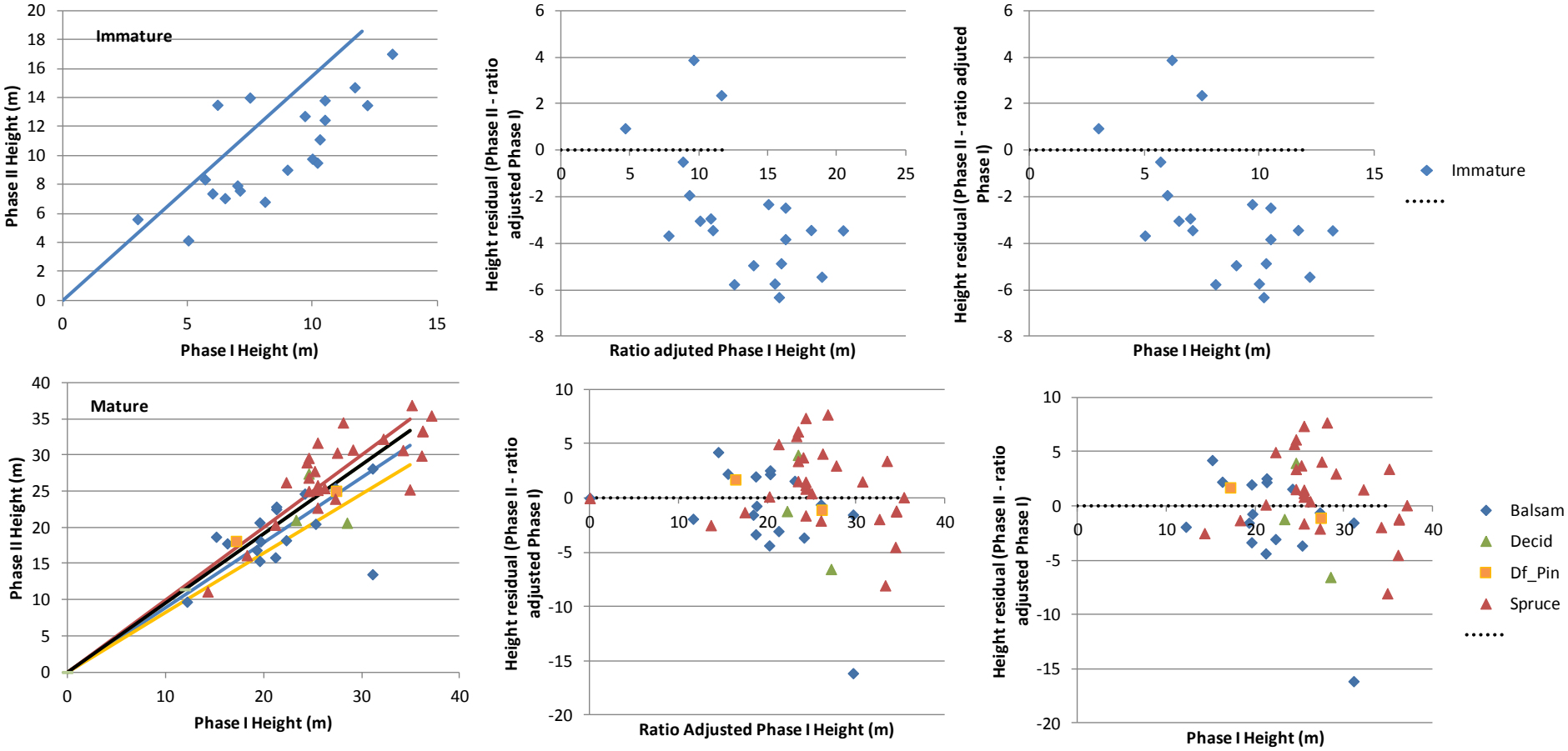

Figure 9. The scatterplots for Height are given.

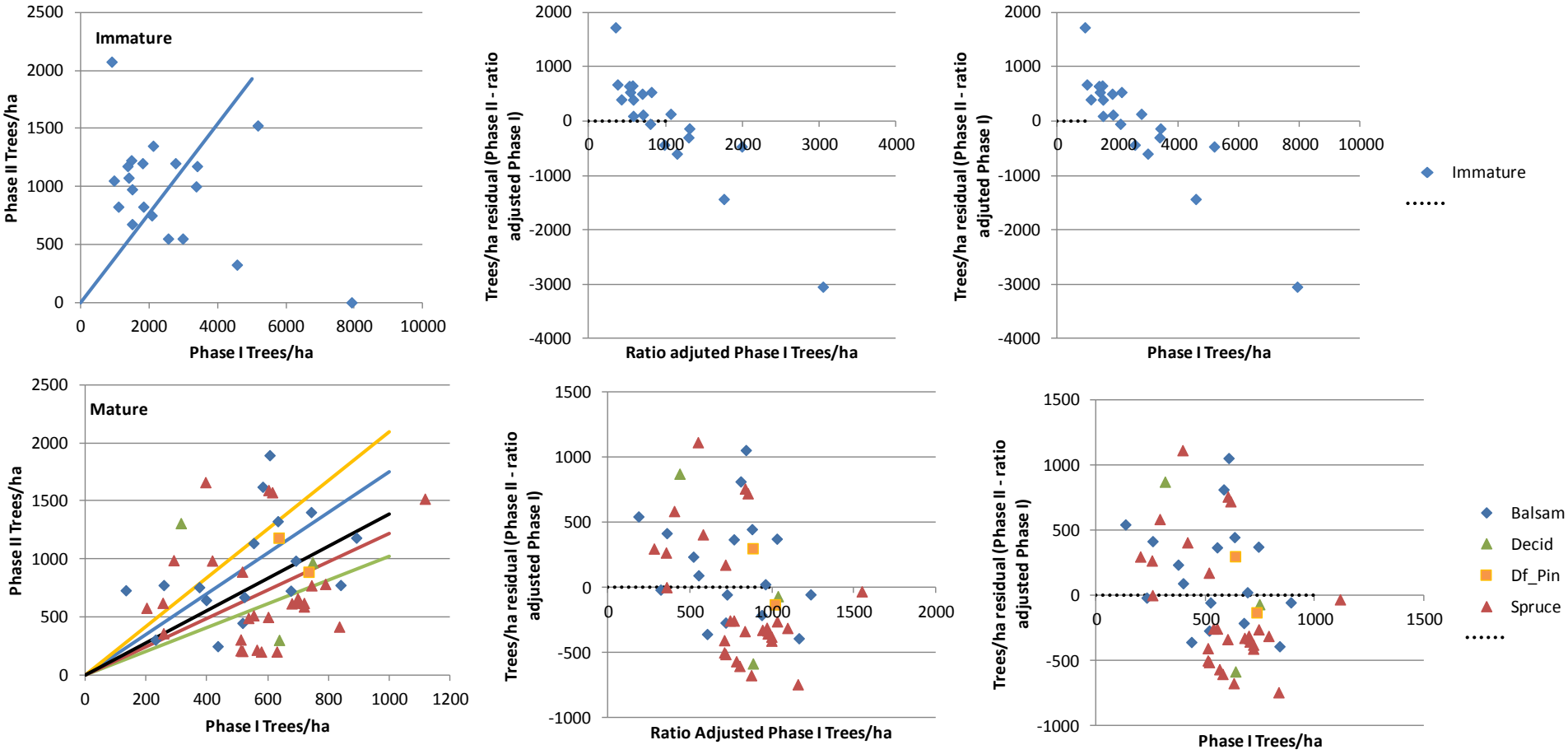

Figure 10. The scatterplots for Trees/ha are given.

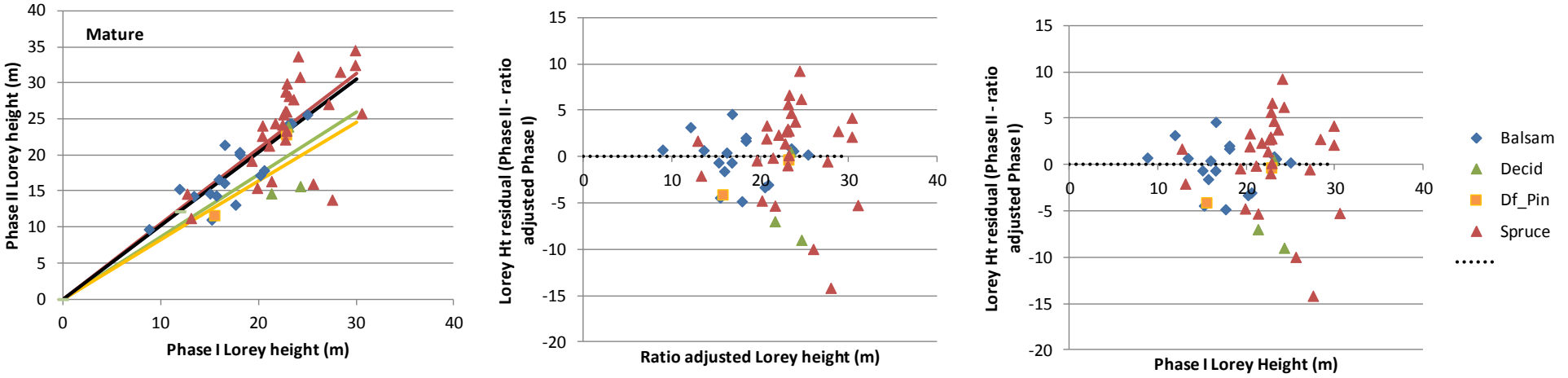

Figure 11. The scatterplots for Lorey height are given for the mature stratum only. The immature stratum is not plotted. In the immature stratum, 19 of 20 plots had missing values for Phase I Lorey height.

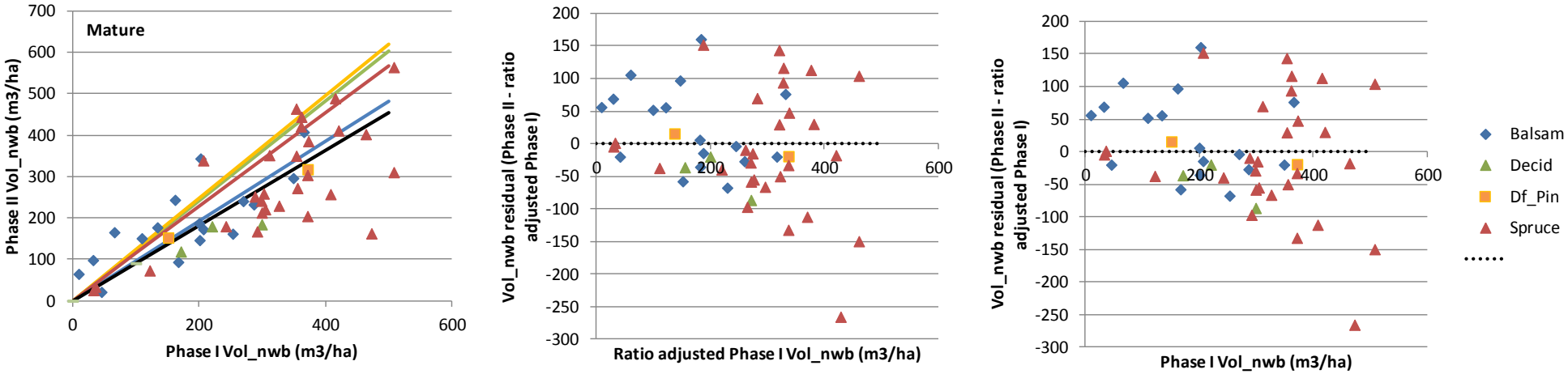

Figure 12. The scatterplots for Vol_nwb are given for the mature stratum only. The immature stratum is not plotted. For the immature stratum, 19 of 20 plots had missing values for Phase I volume.

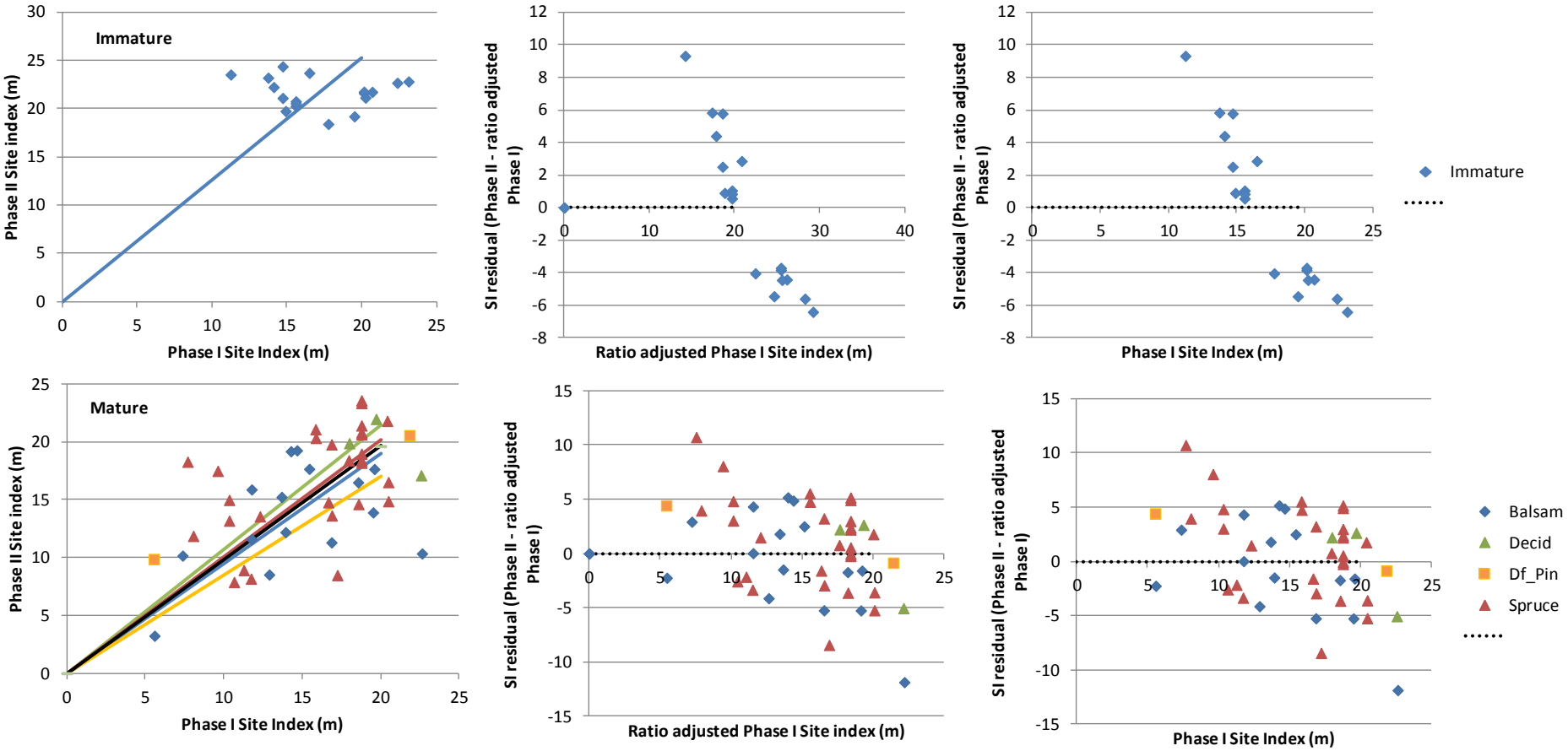

Figure 13. The scatterplots for Site index are given.

11. Appendix F: Scatterplots of total volume bias, model bias and attribute bias.

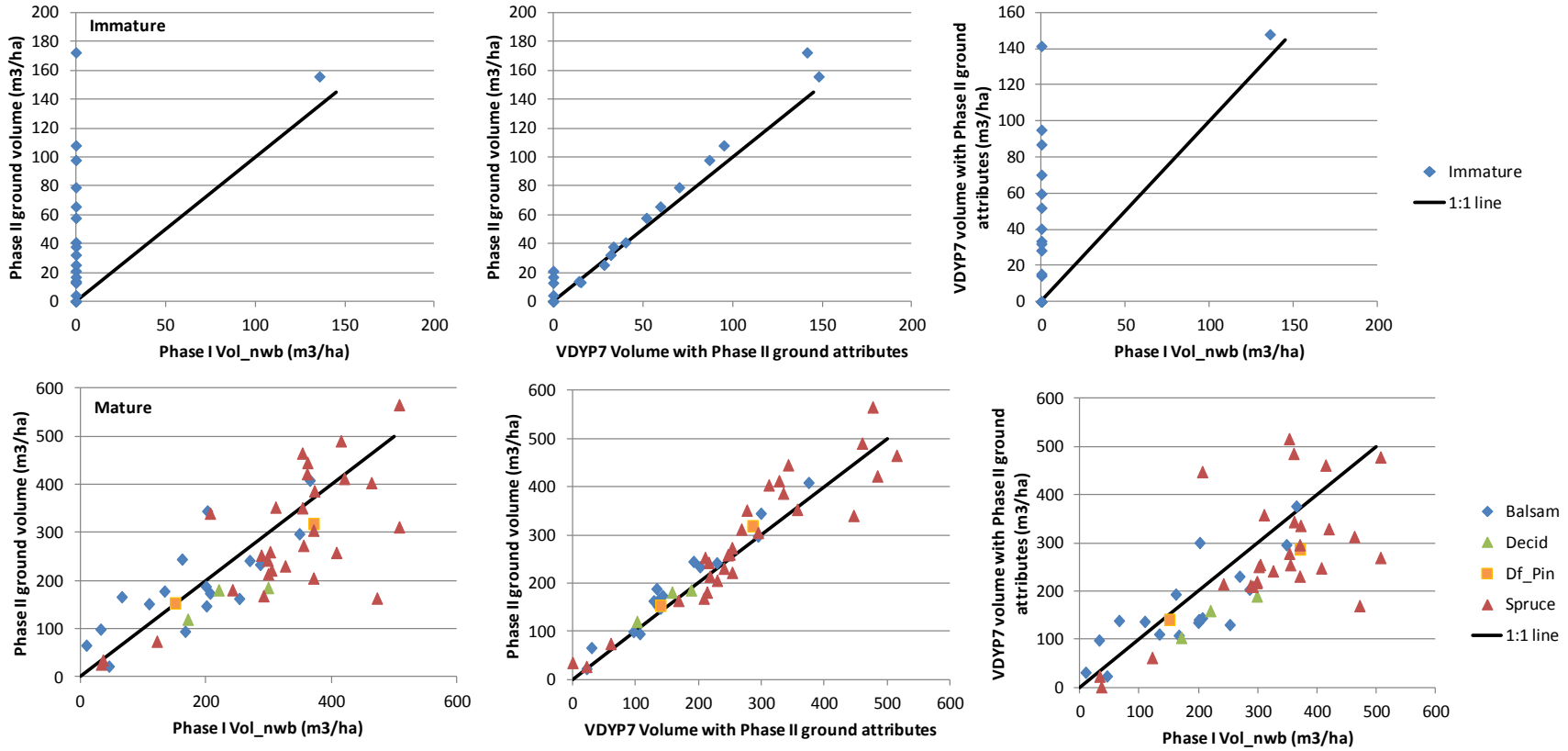

Figure 14. The left column of graphs illustrates the total volume error (Phase I vs. Phase II volume). There are two potential sources of volume error in Phase I. First, the attributes fed into VDYP7 could be incorrect (attributed-related volume error). Second, the volume estimation routines in VDYP7 could be biased (model-related volume error). Total volume error = attribute-related volume error + model-related volume error. The centre column of graphs illustrates model-related volume error (VDYP7 volume using Phase II inputs vs. Phase II volume). The model-related volume error is small indicating the VDYP7 volume estimates are similar to those from the ground compiler. The right column of graphs illustrates the attribute-related volume error (Phase I volume vs. VDYP7 volume using Phase II inputs). The attribute-related volume error dominates the total volume error indicating that most of the differences in volume between Phase I and Phase II are due to differences in the input values to VDYP7. In the immature stratum, 19 of 20 plots were short and the VDYP7 volumes were missing and set to zero.