TFL46

Vegetation Resources Inventory Statistical Analysis

Whole Stem Volume Bias Assessment

Prepared For:
Forest Analysis and Inventory Branch
Ministry of Forests, Lands and
Natural Resource Operations

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Executive Summary

The objective of this project was to assess the total-, model- and attribute-bias associated with whole stem volume estimates from the Phase I inventory of TFL46. A previous analysis of the bias associated with volume net of decay, waste and breakage showed relatively high model-related bias for the mature stratum. This project investigates whether the same trends observed in volume net of decay, waste and breakage are observed in whole stem volume.

The total volume net of decay, waste and breakage bias was decomposed into the following components.

Total bias vol_nwb = WSV model bias + WSV attribute bias + decay bias

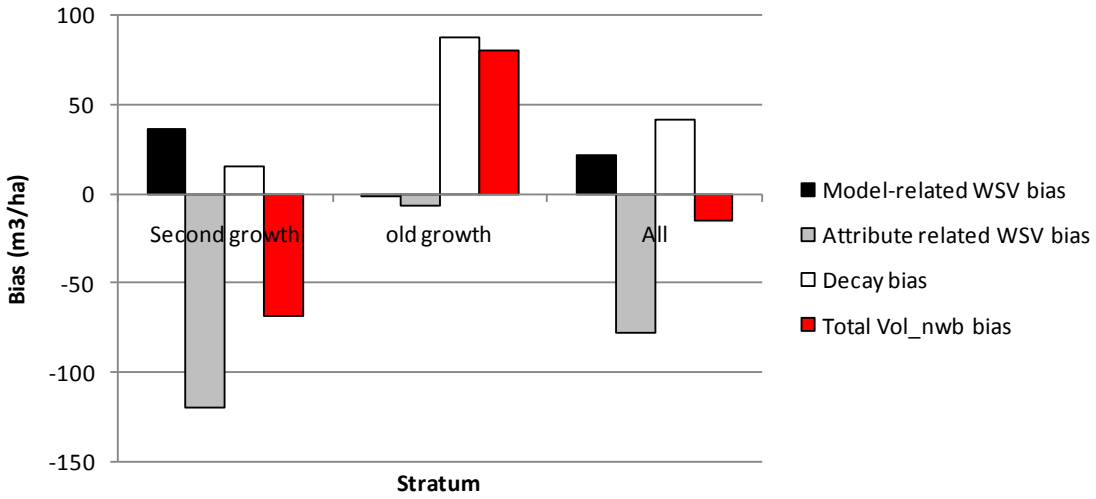

Figure 1. The model bias associated with adjusted whole stem volume (Adj WSV) and volume net of decay, waste and breakage (vol_nwb) is given by maturity and leading species.

For the immature stratum (age < 80), the total bias is dominated by attribute-bias. In immature stands, decay is generally minimal to nonexistent and there are relatively few incidents of pest infestation and the loss factors used to estimate net volume for the samples used to fit VDYP7 reflect this. So, the close agreement between the decay, waste and breakage estimates for the immature stratum is not surprising.

For the mature stratum, the total bias for volume net of decay, waste and breakage was dominated by decay-related bias. The large bias associated with decay factors suggests the loss factors in VDYP7 are not predicting decay well in this management unit. Decay conditions in mature stands range from minimal to heavy and the loss factors, contrary to the relative accuracy of the immature ones, indicate moderate to heavy loss. This fact has been evident since the advent of unbiased decay sampling in the early 1990's.

This analysis is based on a relatively small number of samples (26 samples in the mature stratum) in a small localized area of the province (TFL 46) and only in Douglas fir and hemlock leading stands. Further whole stem volume bias assessment analysis should be carried out using a larger dataset from a broader area to see if the trends noted in this report are seen in other units and stand types.

Acknowledgements

This project was coordinated by Graham Hawkins. Thank you to the Forest Analysis and Inventory Branch for providing the data. Particular thanks to Bob Krahn and Will Smith for processing the data to provide unbiased Phase II estimates of whole stem volume.

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1. Introduction

Recently, a VDYP7-based VRI statistical analysis for TFL 46 was completed. For the mature stratum (Phase I age 80+), the model-related bias for volume net of decay waste and breakage (vol_nwb) was quite high (133.4 m^3/ha Table 4) while the model-related bias for whole stem volume (vol_wsv) was considerably smaller (-18.0 m^3/ha).

Net volume adjustment factoring (NVAF) is designed to provide unbiased Phase II estimates of Vol_nwb. The same NVAF sample data was used to provide unbiased estimates of gross whole stem volume referred to here as adjusted whole stem volume.

1.1 Scope and objectives

The objective of this project is to compare unbiased estimates of Phase II whole stem volume and quantify the model- and attribute-related volume bias.

1.2 Background

Details of the ground sample planning for TFL 46 are given in *"Teal Cedar Products Ltd. Tree Farm Licence 46 Vegetation Resources Inventory Phase II Project Implementation Plan Updated for the NVAF program only"* (J.S. Thrower & Associates Ltd. 2008) available from the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO). The complete VRI statistical analysis is available from the MFLNRO and includes more detail on data screening and the bias associated with the other attributes.

2. Data

The Phase I inventory is from aerial photography flown in 2005.

For the Phase II ground sampling, pre-stratification was carried out based on age groupings: Immature (30-80 years) and mature (greater than 80 years old). Further sub-stratification, by leading species group, was applied by strata to ensure adequate representation of the samples across the target population (Table 1). Sample 33 was omitted and the sample weights recalculated.

In the Mature stratum, in Phase II, 5 polygons did not have a height associated with the leading species and could not be processed by VDYP7. These 5 plots were dropped from the analysis here.

Table 1. The sample weights for TFL 46 are given. One plot was dropped. The stratification is based on the Phase I age and leading species.

Land base Age class	Stratum	Area (ha) (A)	% of area	Planned		Actual	
				Number of samples (n)	Weight = A/n	Number of samples (n)	Weight = A/n
Immature	Fd	24,220	46%	42	577	42	577
Age 30-80	Hemlock	7,679	14%	13	591	13	591
	Other	2,491	5%	4	623	3	830
	Subtotal	34,390	65%	59		58	
Mature	Fd	1,893	4%	3	631	3	631
Age 81+	Hemlock	10,365	19%	17	610	17	610
	Other	6,568	12%	11	597	11	597
	Subtotal	18,826	35%	31		31	

3. METHODS

3.1 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 age or 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.

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

3.2 Phase I Inventory projection

The Phase I data were provided by the MFLNRO. The data had been projected to 2011. The data were projected backwards to 2007 (the year of ground sampling) using VDYP7 Console version 7.7a.33.

3.3 Phase II ground sample data

The Phase II ground samples were provided by the MFLNRO. All were measured in 2007. The Phase II ground SI was estimated as the average SI of the T, L, X and O trees. The MFLNO undertook additional analysis on the TFL46 ground sample data. The usual Net Volume Adjustment Factoring (NVAF) was undertaken to produce unbiased estimates of volume net of decay waste and breakage. In addition, Gross Volume Adjustment Factors (GVAFs) were calculated and used to obtain unbiased estimates of gross whole stem volume.

4. Results and Discussion

Results are given by maturity, leading species class within maturity and overall results. The sample sizes by leading species within maturity class are generally small and the results are highly variable and are given for information only.

Model-related bias is the bias arising from using different models to estimate volume. For the Phase I inventory, volumes are estimated using VDYP7. For the Phase II ground sample, volumes are estimated using the VRI ground compiler. The ground compiler is considered more accurate and the difference between the Phase I VDYP7 volume and the Phase II ground compiler volume is the total bias. The model-bias is assessed using VDYP7 to estimate the volume using the Phase II ground summaries (column C in Table 2) and comparing the volume to the ground compiler volume (column A). The difference between total bias and model-related bias is termed attribute-related bias.

There was considerable variation in bias among leading species substrata. The immature stratum has higher total bias (consistent overestimation in Phase I) then the mature stratum (Table 2). The total bias results for the mature stratum are excellent with much variation by leading species. The total bias is dominated by attribute bias except for the Immature-Other substratum.

The bias can also be evaluated by examining the ratios between volume estimates (Table 3). Ratios close to one indicate very low bias.

Table 2. Weighted mean whole stem volume (Dbh ≥ 12.5 cm) by stratum for TFL 46. For the bias, the mean is followed by the mean expressed as a percentage of the Phase I volume (B). Leading species with substrata generally have higher sample errors and the results are less reliable.

Stratum	Leading species substratum	n	Weighted mean whole stem volume (m^3/ha) estimates 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	Fd	42	417.6	490.8	365.9	51.7 (11%)	-124.9 (-25%)	-73.3 (-15%)
Age 30-80	Hemlock	13	469.4	570.3	445.7	23.7 (4%)	-124.6 (-22%)	-100.9 (-18%)
	Other	3	546.4	695.8	669.5	-123.1 (-18%)	-26.3 (-4%)	-149.4 (-21%)
	Subtotal	58	436.5	520.3	400.8	35.7 (7%)	-119.5 (-23%)	-83.8 (-16%)
Mature	Fd	3	1266.6	1056.9	1251.5	15.1 (1%)	194.5 (18%)	209.6 (20%)
Age 81+	Hemlock	15	1159.9	1137.9	1197.5	-37.6 (-3%)	59.6 (5%)	22 (2%)
	Other	8	903.2	1018.3	849.6	53.7 (5%)	-168.8 (-17%)	-115.1 (-11%)
	Subtotal	26	1081.2	1088.1	1081.6	-0.4 (0%)	-6.5 (-1%)	-6.9 (-1%)
All		84	667.2	723.5	645.5	21.7 (3%)	-78 (-11%)	-56.3 (-8%)

Table 3. The ratios of mean whole stem volumes (Dbh ≥ 12.5cm) representing total, model and attribute bias, with associated sampling error % at a 95% confidence level for TFL 46. Leading species with substrata generally have higher sample errors and the results are less reliable.

Stratum	Leading species substratum	n	Ratio of weighted mean whole stem volume/ha 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	Fd	42	0.851 (13.3%)	1.141 (6.5%)	0.745 (13.9%)
Age 30-80	Hemlock	13	0.823 (26.8%)	1.053 (11.8%)	0.781 (26.4%)
	Other	3	0.785 (59.6%)	0.816 (6.2%)	0.962 (54.6%)
	Subtotal	58	0.839 (12.0%)	1.089 (5.6%)	0.770 (12.3%)
Mature	Fd	3	1.198 (55.8%)	1.012 (9.3%)	1.184 (65.1%)
Age 81+	Hemlock	15	1.019 (23.2%)	0.969 (9.6%)	1.052 (22.9%)
	Other	8	0.887 (34.3%)	1.063 (10.3%)	0.834 (25.2%)
	Subtotal	26	0.994 (19.1%)	1.000 (6.8%)	0.994 (18.0%)
All		84	0.922 (10.3%)	1.035 (4.3%)	0.891 (10.2%)

The same model- and attribute-related bias is given for volume net of decay, waste and breakage.

Table 4. Weighted mean volumes net DWB (Dbh ≥ 12.5 cm) by stratum for TFL 46. For the bias, the mean bias is followed by the bias 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	Fd	42	374.2	435.3	319.7	54.5 (13%)	-115.5 (-27%)	-61.1 (-14%)
Age 30-80	Hemlock	13	425.3	504.2	386.2	39.1 (8%)	-117.9 (-23%)	-78.9 (-16%)
	Other	3	504.9	618.4	600.8	-95.9 (-16%)	-17.5 (-3%)	-113.5 (-18%)
	Subtotal	58	393.1	461.1	375.5	17.5 (4%)	-85.5 (-19%)	-68.0 (-15%)

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*
Mature Age 81+	Fd	3	1047.2	883.4	938.2	109 (12%)	54.8 (6%)	163.8 (19%)
	Hemlock	15	1014.8	890.7	950.8	63.9 (7%)	60.1 (7%)	124.1 (14%)
	Other	8	772.4	785.5	636.7	135.7 (17%)	-148.8 (-19%)	-13.1 (-2%)
	Subtotal	26	933.5	853.3	800.2	133.4 (16%)	-53.2 (-6%)	80.2 (9%)
All		84	586.5	601.5	527.5	59.0 (10%)	-74.0 (-12%)	-15.0 (-2%)

Table 5. 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 46.

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 Age 30-80	Fd	42	0.860 (13.5%)	1.17 (6.3%)	0.735 (14.1%)
	Hemlock	13	0.844 (27.4%)	1.101 (12.6%)	0.766 (27.4%)
	Other	3	0.816 (59.4%)	0.84 (5.5%)	0.972 (56.2%)
	Subtotal	58	0.852 (12.2%)	1.047 (11.2%)	0.814 (7.1%)
Mature Age 81+	Fd	3	1.185 (57.8%)	1.116 (17.9%)	1.062 (75.7%)
	Hemlock	15	1.139 (24.0%)	1.146 (14.9%)	0.983 (26.0%)
	Other	8	1.045 (34.0%)	1.439 (24.9%)	0.623 (40.0%)
	Subtotal	26	1.094 (20.6%)	1.167 (15.0%)	0.938 (11.7%)
All			0.975 (10.9%)	1.112 (8.8%)	0.877 (6.1%)

The bias data from Table 2 and Table 4 are plotted in Figure 2. Generally, the attribute related bias (Figure 2b) is the similar for whole stem volume and vol_nwb except the vol_nwb is slightly smaller. Mature Douglas-fir is the exception but has only 3 samples.

The differences in model-bias between whole stem and vol_nwb (Figure 2a) do not show clear trends, particularly for the mature stratum and the relatively high model-bias for mature vol_nwb compared to the almost negligible model-bias for mature whole stem is somewhat surprising. It appears the VDYP7 algorithms to net down whole stem to obtain vol_nwb for immature polygons work very well while the algorithms for mature conditions are quite poor.

The volumes in the mature stratum are high and the average age of the mature stratum is about 266 years.

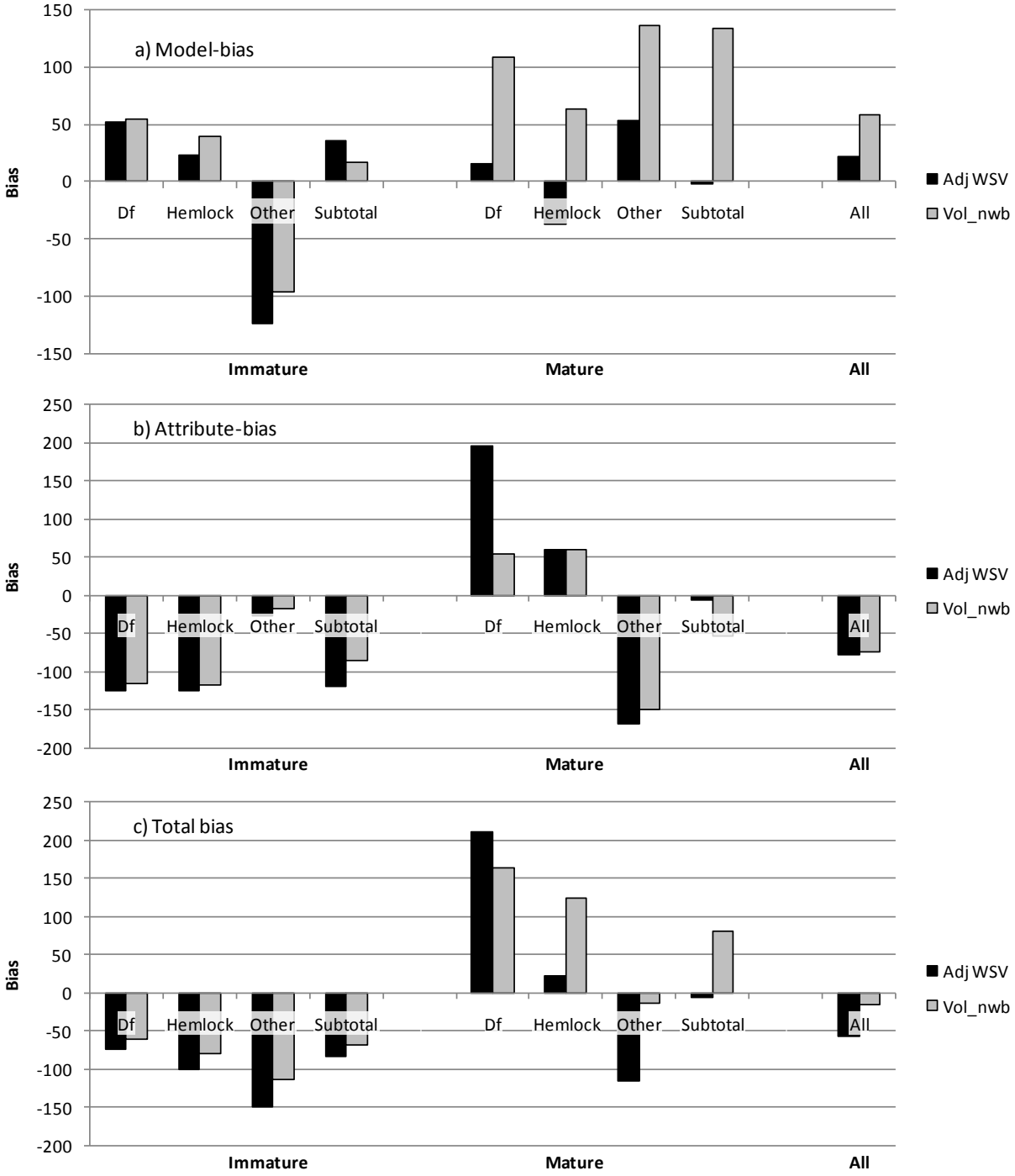

Figure 2. The biases associated with adjusted whole stem volume (Adj WSV) and volume net of decay, waste and breakage (Vol_nwb) are compared.

The total volume net of decay, waste and breakage was decomposed into the following components.

Total bias vol_nwb = WSV model bias + WSV attribute bias + decay bias

Rewritten using the column headings in Table 2 and Table 4

$A^* - B^* = (A - C) + (C - B) + (A^* - A) - (B^* - B)$

For second growth, the total bias is dominated by attribute bias while for old growth the bias is dominated by decay bias (Table 6 and Figure 3). The same data are presented in Figure 7.

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 46.

Stratum	Leading species substratum	n	Weighted mean volume (m^3/ha) estimates net DWB for Dbh ≥ 12.5cm			
			Model-related WSV bias A - C	Attribute-related WSV bias C - B	Decay Estimation bias (A* - A) – (B* - B)	Total Vol_nwb bias A*-B*
Immature	Fd	42	51.7	-124.9	12.2	-61.1
Age 30-80	Hemlock	13	23.7	-124.6	22.1	-78.9
	Other	3	-123.1	-26.3	36.0	-113.5
	Subtotal	58	35.7	-119.5	15.8	-68.0
Mature	Fd	3	15.1	194.5	-45.9	163.8
Age 81+	Hemlock	15	-37.6	59.6	102.1	124.1
	Other	8	53.7	-168.8	102.0	-13.1
	Subtotal	26	-0.4	-6.5	87.1	80.2
All			21.7	-78.0	41.3	-15.0

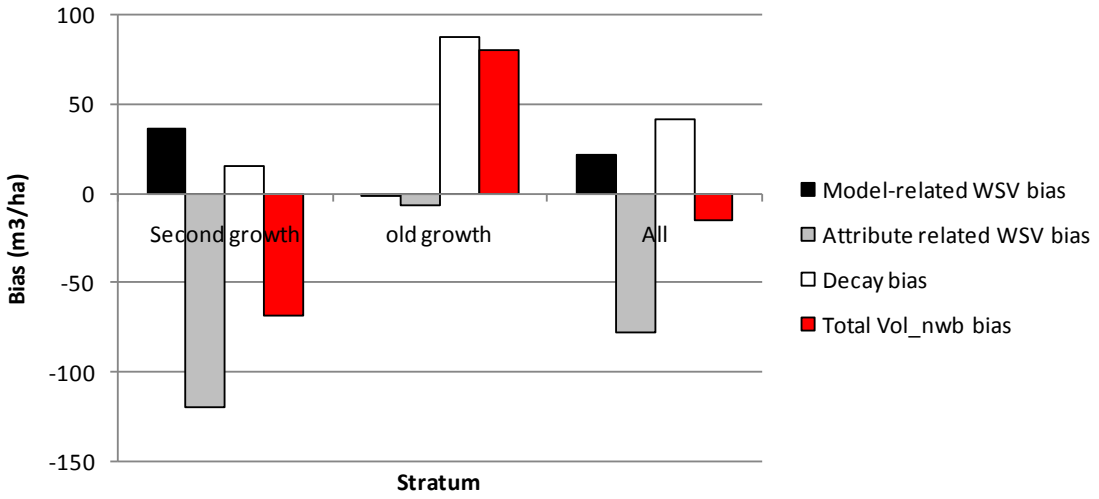

Figure 3. The total Volume bias (net of decay, waste and breakage) is given as well as the component biases.

There were differences in species composition between the Phase I photo inventory and the Phase II ground sampling. One hypothesis is that some of the variation in model-bias may be related to differences in leading species and different net down factors by species. If this hypothesis is true, samples where the Phase I and Phase II leading species are the same should have smaller model-bias than samples where the leading species were different. The samples were separated into those where the Phase I and Phase II leading species was the same and those where the leading species was different. The matching was at the genus level. The bias was again split into model- and attribute-bias (Figure 4). Again, there is substantial variation at the leading species substrata but the results are contrary to expectations – the model-bias is slightly higher when the Phase I and Phase II species are the same compared to when the leading species are different.

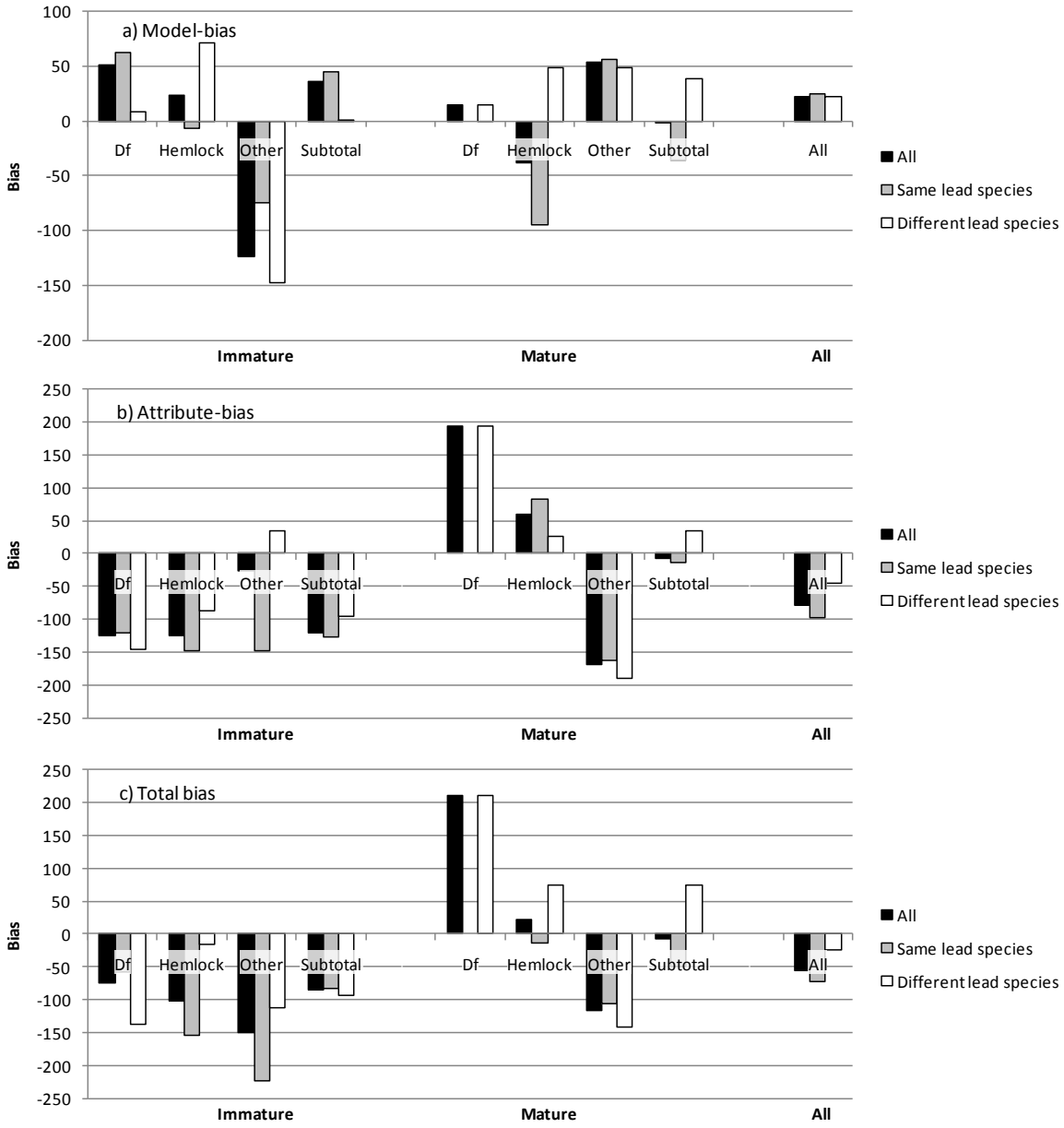

Figure 4. The biases associated with adjusted whole stem volume (Adj WSV) are given for all the samples (All), the samples where the Phase I and Phase II leading species are the same (Same lead species) and the rest (Different lead species). The sample sizes are given in Table 7.

Table 7. The sample sizes associated with Figure 4 are given.

Stratum	Leading species	Leading species		
		All	Same	Different
Immature	Fd	42	34	8
Age 30-80	Hemlock	13	8	5
	Other	3	1	2
	Subtotal	58	43	15

Stratum	Leading species	Leading species		
		All	Same	Different
Mature	Fd	3		3
Age 81+	Hemlock	15	9	6
	Other	8	6	2
	Subtotal	26	26	11
All		84	58	26

5. Conclusions and recommendations

For the immature stratum, the total bias is dominated by attribute-bias and similar biases were observed for whole stem volume and volume net of decay, waste and breakage. In immature stands, decay is generally minimal to nonexistent and there are relatively few incidents of pest infestation and the loss factors used to estimate net volume for the samples used to fit VDYP7 reflect this. So, the close agreement between the decay, waste and breakage estimates for the immature stratum is not surprising.

For the mature stratum, the total bias for volume net of decay, waste and breakage was dominated by decay-related bias. The model- and attribute-related biases associated with whole stem volume were considerably smaller and did not show consistent trends across leading species substrata. The large bias associated with decay factors suggests the loss factors in VDYP7 are not predicting decay well in this management unit. Decay conditions in mature stands range from minimal to heavy and the loss factors, contrary to the relative accuracy of the immature ones, indicate moderate to heavy loss. This fact has been evident since the advent of unbiased decay sampling in the early 1990's.

It was expected that samples with the same leading species in Phase I and Phase II would show lower model-bias for the mature stratum but this was not the case.

This analysis is based on a relatively small number of samples in a small localized area of the province (TFL 46) and only in Douglas fir and hemlock leading stands. Further whole stem volume bias assessment analysis should be carried out using a larger dataset from a broader area to see if the trends noted in this report are seen in other units and stand types.

6. Literature cited

Churlish & Jahraus. 2011. 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.

J.S.Thrower and Associates. 2008. Teal Cedar Products Ltd. Tree Farm Licence 46 Vegetation Resources Inventory Phase II Project Implementation Plan updated for the NVAF Program Only. Version 3.2. Dated March 31, 2008. 13p + app.

7. Appendix E: Scatterplots and residuals

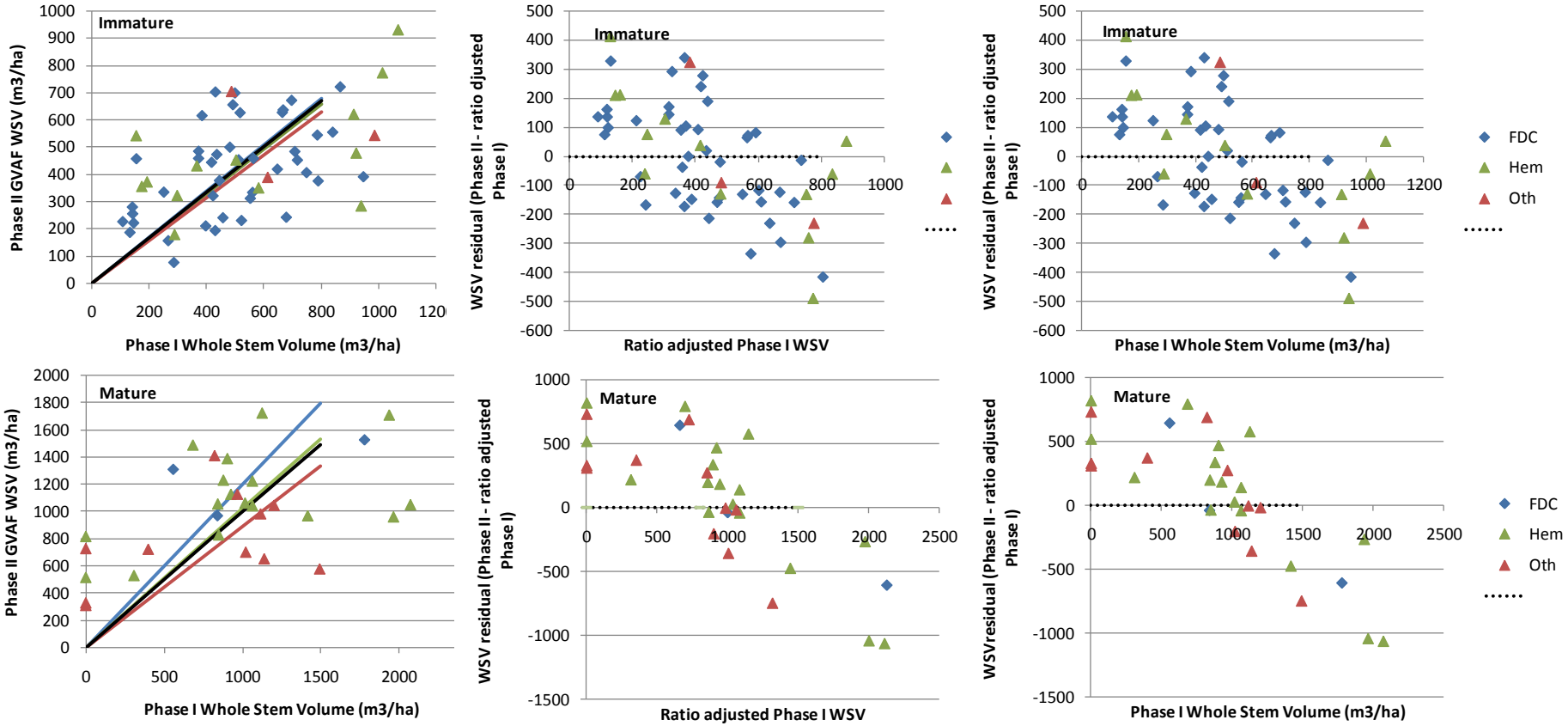

Figure 5. The scatterplots for adjusted whole stem volume are given (Dbh ≥ 12.5cm). The top left graph gives the Phase I photo and Phase II ground estimates of whole stem volume for the immature stratum with lines representing the ratios by leading species. The black line is the stratum ratio (all leading species combined). The top middle graph plots the residuals against the adjusted Phase I whole stem volume. The top right graph plots the residuals against the Phase I whole stem volume. 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 but are for the mature stratum

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

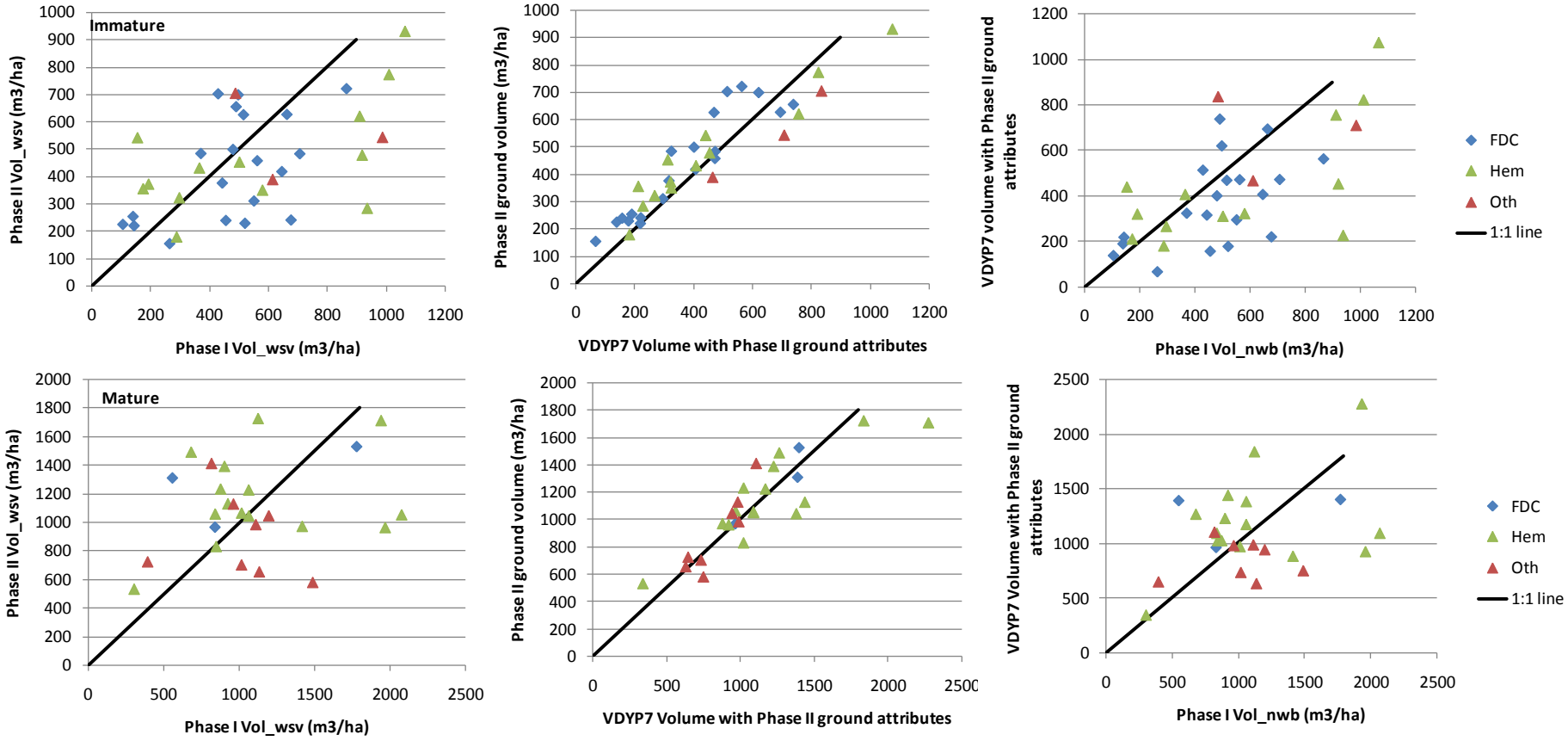

Figure 6. The left column of graphs illustrates the total volume error (Phase I vs. Phase II volume, Dbh ≥ 12.5cm). There are two potential sources of volume error in Phase I. First, the attributes fed into VDYP7 could be incorrect (attributed-related volume error). Second, the volume estimation routines 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). In the top graph, the points are generally above the line indicating a positive bias. The points are generally clustered tightly around the line indicating a small sampling error. 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.

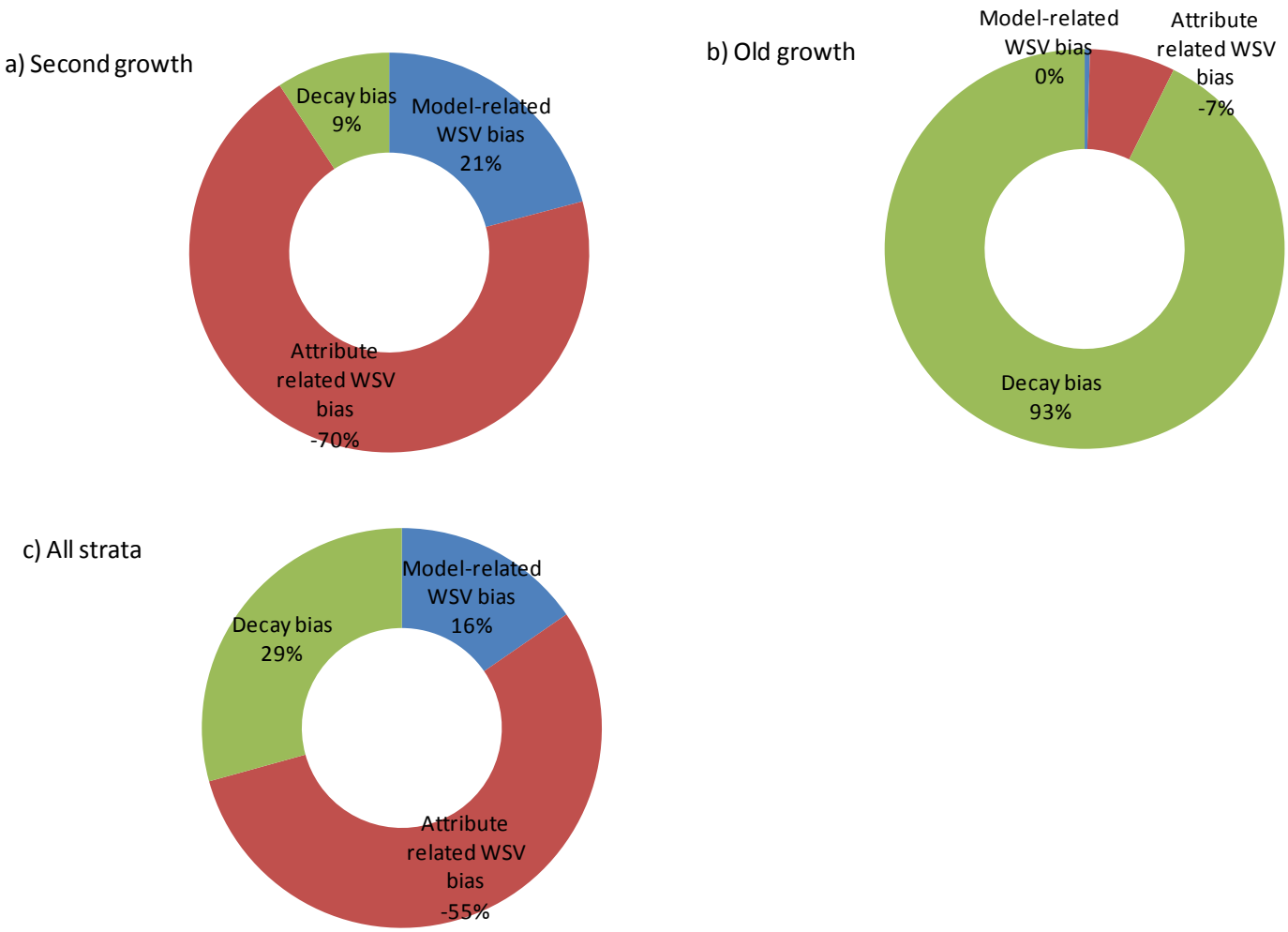

Figure 7. The WSV model-related and attribute-related bias are given along with decay bias by stratum. The data are given in Figure 3. Note the attribute-related bias is negative and the others are positive.