The Lakes TSA

Documentation of

Vegetation Resources Inventory Analysis – Volume Audit (Mature)

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

Prepared By:
Margaret Penner
Forest Analysis Ltd.
Huntsville, ON

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Executive Summary

The objective of this project was to assess the accuracy of the Phase I inventory of the Lakes Timber Supply Area by completing a statistical analysis of selected Phase I inventory attributes. The target population of interest is the vegetated treed portion of the area, older than 50 years, excluding parks and private land. This is referred to the volume audit population. The analysis is based on current Vegetation Resources Inventory standards.

Ninety-four ground samples were established, predominantly in spruce leading polygons (n = 53), followed by pine (n = 19), balsam (n = 15) and aspen/cottonwood (n = 7).

The inventory (Phase I) estimates of age, height, and basal area are slightly higher than the ground (Phase II) estimates (Table 1) leading to slightly higher inventory estimates of volume. The Phase I estimates of age, height, basal area and volume are all within 10% of the Phase II estimates. The Phase I estimates of trees/ha are approximately one third lower than the ground estimates, similar to what has been observed in other TSAs.

Table 1. The sample size (N), mean, ratio of means (Phase II Ground/Phase I Inventory) and sampling error of the ratio expressed as a percent of the ratio (SE of ratio (%)) are given by attribute for the volume audit (mature) portion of the Lakes TSA. Ratios that differ from 1.0 by more than 10% are shaded.

Attribute	Statistic	Volume Audit
Leading species age (years)	N	88
	Mean Phase II Ground	132
	Mean Phase I inventory	144
	Ratio (Phase II/Phase I)	0.911
	SE of Ratio (%)	(7.7%)
Leading species height (m)	N	87
	Mean Phase II Ground	20.5
	Mean Phase I inventory	22.3
	Ratio (Phase II/Phase I)	0.921
	SE of Ratio (%)	(4.8%)
Basal area (m^2/ha) 7.5 cm+	N	93
	Mean Phase II Ground	21.3
	Mean Phase I inventory	22.3
	Ratio (Phase II/Phase I)	0.954
	SE of Ratio (%)	(10.6%)
Trees/ha 7.5 cm+	N	93
	Mean Phase II Ground	833
	Mean Phase I inventory	617
	Ratio (Phase II/Phase I)	1.35
	SE of Ratio (%)	(16.5%)
Lorey height (m)	N	89
	Mean Phase II Ground	17.6
	Mean Phase I inventory	18.7
	Ratio (Phase II/Phase I)	0.943
	SE of Ratio (%)	(5.1%)
Volume Net dwb (m^3/ha) 12.5 cm+	N	94
	Mean Phase II Ground	122
	Mean Phase I inventory	126
	Ratio (Phase II/Phase I)	0.967

Attribute	Statistic	Volume Audit
NVAF	SE of Ratio (%)	(13.1%)
Leading	N	22
species	Mean Phase II Ground	14.9
Site index	Mean Phase I inventory	11.6
(m)	Ratio (Phase II/Phase I)	1.284
Ages 10 - 20	SE of Ratio (%)	(11.2%)
Leading	N	22
species	Mean Phase II Ground	14.9
Site index	Mean PSPL	17.5
(m)	Ratio (Phase II/PSPL)	0.851
Ages 10 - 20	SE of Ratio (%)	(11%)

The ground estimates of site index (SI) are higher than the inventory estimates while the Provincial Site Productivity Layer (PSPL) SI estimates are generally higher than the ground estimates. The ground estimates of SI were restricted to sample trees identified as suitable SI trees by the field crews and with breast height ages from 10 to 120. As a result, only about a quarter of the samples have suitable SI trees. SI estimates in older stands, whether they originate from ground measurements or Phase I estimates are less reliable estimates of site productivity.

The leading species agreement for the Volume Audit population is slightly higher than results from other TSAs (69% or 65 out of 94).

Acknowledgements

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1. Scope and Objectives

This report documents the statistical analysis of the Vegetation Resources Inventory (VRI) for the volume audit portion of the Lakes Timber Supply Area (TSA).

2. Description of the Target Population Area

The following description is from the Allowable Annual Cut Rationale[1] for the Lakes TSA. The Lakes TSA covers about 1.1 million hectares of land in north-central British Columbia (Figure 1 and Table 2), ranging from Tweedsmuir Provincial Park in the southwest to the Tildelsy watershed in the north. The TSA contains the headwaters of important tributaries of both the Skeena and Fraser watersheds as well as numerous lakes, which include some of the largest freshwater bodies in British Columbia. The forest and range resources of the TSA are administered by the Nadina District office located in Burns Lake.

At the time of the allowable cut rationale (2011), pine-leading stands dominated the Lakes TSA with spruce, balsam and fir stands occupying the remainder of the area. The preponderance of mature pine stands was a significant factor contributing to the recent mountain pine beetle (MPB) epidemic. The infestation is believed to have begun slowly in the mid-1990s. By the year 2000, the beetle-affected pine volume was 900 000 cubic metres. By 2009, approximately 90 percent of the pine trees available for harvesting were dead. In 2011, it was assumed that MPB-killed pine remain a potential source of wood fibre as long as the trees remain standing, which is about 15 years in the Lakes TSA. It was estimated that by 2019, almost all of the beetle-killed pine stands will have been dead for more than 15 years.

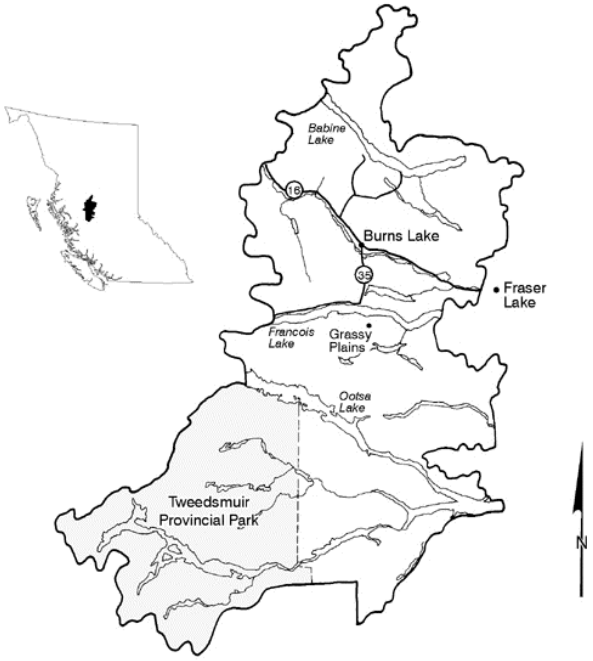

Figure 1. The location of the Lakes TSA is given (from FAIB).

The population of interest for this report is the vegetated treed (VT) landbase that is greater than 50 years old, excluding parks, conservancies and private land. VT is defined as forested polygons having a crown closure greater than 10%. The population is dominated by spruce-leading polygons (Table 3).

[1] BC MNFL&NRO. 2011. Lakes Timber Supply Area Rationale for Allowable Annual Cut Determination. Effective July 12, 2011 https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/stewardship/forest-analysis-inventory/tsr-annual-allowable-cut/lakes_tsa_rationale.pdf

Table 2. The area in each land class is given for the Lakes TSA.

Land Class	Area (ha)
Other Crown Land	796,111
Community Forest	120,437
Private	78,902
Park	22,976
Woodlots	20,784
Crown Reserves	6,537
Indian Reserve	1,043
UREP	959
Federal reserve	365
Crown Misc Leases	5
Total	1,048,122

Table 3. The population of interest for this report (the VT portion of het land based greater than 50 years old excluding parks) is given by leading species.

Species	Area (ha)	Area (%)
AC	2,839	1%
ACT	29	0%
AT	59,918	11%
B	208	0%
BL	73,052	13%
EP	1,014	0%
FD	36	0%
FDI	1,595	0%
H	1,017	0%
PL	51	0%
PLI	109,234	20%
S	2,513	0%
SB	8,903	2%
SE	41,936	8%
SW	18	0%
SX	251,644	45%
Total	554,007	100%

3. Data Sources

3.1 Phase I photo-interpreted inventory data

The VRI input files

- VEG_COMP_VDYP7_INPUT_POLY_TBL.csv
- VEG_COMP_VDYP7_INPUT_LAYER_TBL.csv

were provided and projected to the year of ground sampling using VDYP7 Console version 7.14b. VDYP7 allows for layer processing. There were 7 samples with more than one layer (Table 4). The second layer was not projected by VDYP7. The rank 1 layer (FOREST_COVER_RANK_CODE = 1) is used to define the target population.

Table 4. The samples with two layers are given.

clstr_id	Photo year	Forest cover rank code	Layer	VDYP7 Layer CD	Spp 1	Pct 1	Spp 2	Pct 2	BA (m^2/ha)	Ht (m)	Age (yrs)

clstr_id	Photo year	Forest cover rank code	Layer	VDYP7 Layer CD	Spp 1	Pct 1	Spp 2	Pct 2	BA (m^2/ha)	Ht (m)	Age (yrs)
0142-1811-MO1	2012	1	1	P	SX	100			15	28	180
0142-1811-MO1			2	Y	SX	100			4	18	65
0142-4301-MO1	2012	1	1	P	BL	95	SE	4	15	15	160
0142-4301-MO1			2		BL	100			2	6	115
0142-4301-MO1			D	D	PLI	100			6	28	180
0142-4926-MO1	2012		1		SX	100		.	7	24	145
0142-4926-MO1		1	2	P	SX	85	AT	15	9	16	75
0142-8051-MO1	2012	1	1	P	SX	60	AT	30	10	27	140
0142-8051-MO1			2		SX	90	AT	5	8	19	80
0143-5126-QO1	2015	1	1	P	SX	95	AT	5	16	24	160
0143-5126-QO1			2		SX	100			14	19.6	95
0143-6500-QO1	2012	1	1	P	SX	85	AT	15	19	18	75
0143-6500-QO1			2		PLI	85	SX	15	4	9	25
0143-8547-QO1	2012	1	1	P	AT	85	SX	15	25	27	218
0143-8547-QO1			2		SX	90	AT	10	1	17	50

For all polygons, the species composition, leading species age, height and site index were taken from the primary layer. VDYP7 does not project the height and age for the second species. In a separate run, the second species and its associated height and age were set as the primary species and projected to obtain the projected height, age and site index of the second species.

Generally, the Phase I inventory forest descriptions come originally from photo interpretation, updated to the year of ground sampling. Volumes are estimated using VDYP7. Outputs from VDYP7 have a utilization level specified by the user – usually 7.5 cm for most attributes and 12.5 or 17.5 cm for volume.

Inventory information for recently disturbed polygons generally comes from the RESULTS (Reporting Silviculture Updates and Land status Tracking System) layer. These are also processed by VDYP7 to project them to the year of ground sampling. For stands less than 7 m tall, VDYP7 will project the age and height until the height is 7 m and then generate the remaining attributes. None of the samples had an inventory height < 8 m.

3.2 Phase II Ground sample data

The target population for ground sampling is the volume audit portion of the operating area. The ground sample locations are given in Figure 2.

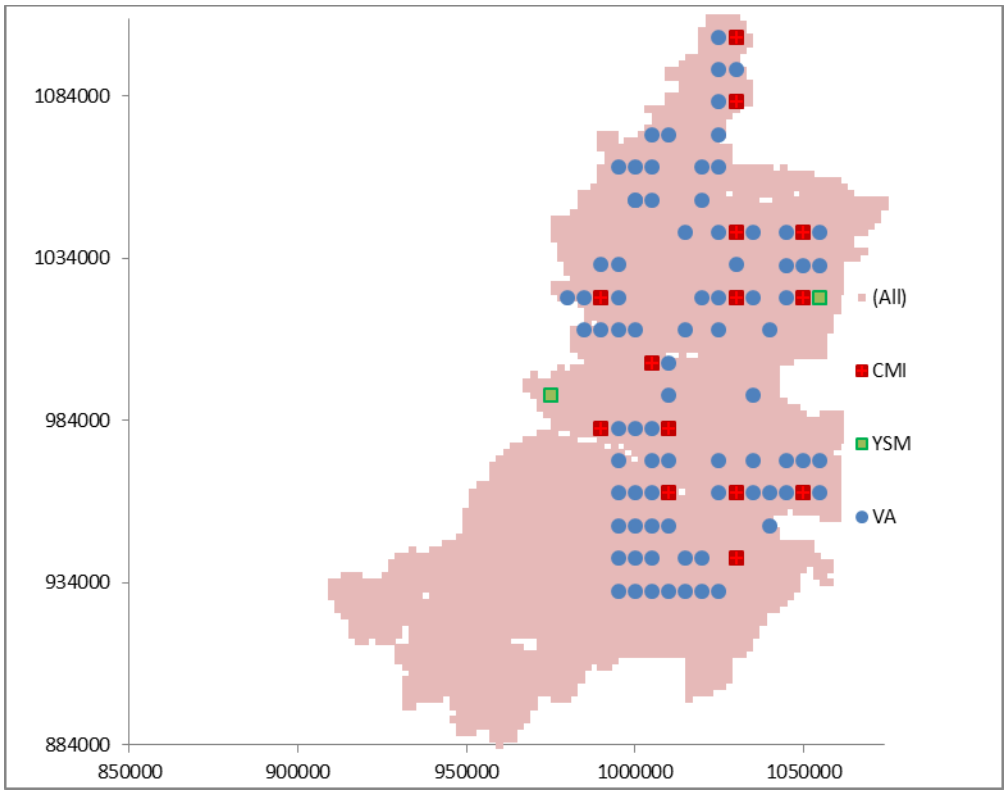

Figure 2. The location of the ground samples within the Lakes TSA (from FAIB).

3.2.1 Sample Selection

The ground sample data come from two data sources – volume audit (VA) ground samples and Change Monitoring Inventory (CMI, including National Forest Inventory) ground plots. The CMI samples were selected from a 20 x 20 km grid. The VA samples were located on an intensification of the CMI grid and include samples that meeting the VA definition. As a result, the sample weights (the area represented by each sample) are equal for each sample.

Within the VA population, there was no pre-stratification by tenure type or ownership nor was there stratification by operable vs. inoperable.

Table 5. The sampling programs are described.

Abbreviation	Sampling program	Description
VA	Volume Audit	Established on a 5 x 10 km intensification of the 20 x 20 km NFI grid. Temporary 5-point variable radius clusters
CMI	Change monitoring inventory	Established on the 20 x 20 km NFI grid. Circular, 0.04 ha fixed area plots. Includes NFI plots.

3.2.2 Plot Design & Establishment

VRI Mature Audit ground samples are temporary 5-point variable radius clusters, comprising both full measure & count plots. Ground samples were established as ***plot type 'T': Timber-Emphasis plus***

Succession plots'. Ground sample establishment and measurements followed provincial VRI Phase II standards and procedures[2].

Fourteen CMI ground plots were established in the VA population (Figure 3). Ground sample establishment and measurement follow provincial CMI standards and procedures[3].

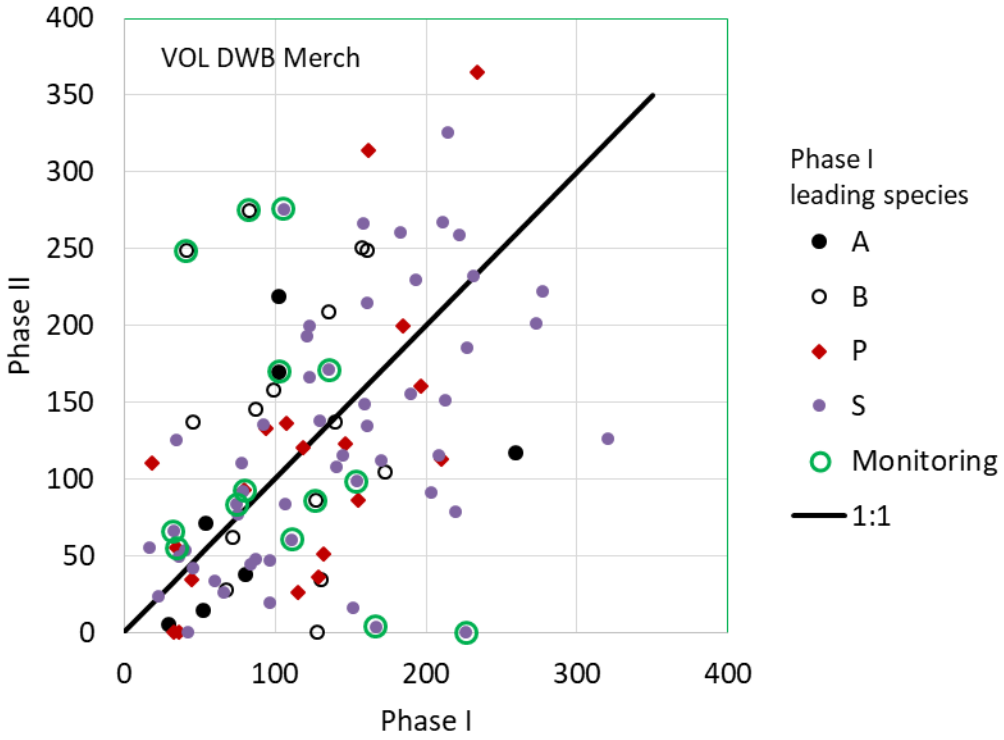

Figure 3. The Phase I inventory and Phase II ground volumes are compared by leading species. The CMI monitoring plots are circled in green.

3.3 THLB

The timber harvesting land base (THLB) as defined in the current TSR process is approximately 360,000 ha in size or about 45% of the Crown land within the Lakes TSA (Table 2) or approximately 65% of the volume audit population (Table 3).

The samples that fell within the THLB were analyzed separately.

[2] Vegetation Resources Inventory Sample Data Analysis Procedures and Standards, ver. 1.0 June 2011. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/standards-guidelines/risc/production_vri_analysis_procedures_final.pdf

[3] Change Monitoring Inventory BC. Ground Sampling Procedures. Ver. 2.5. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/standards-guidelines/risc/cmi_ground_sampling_procedures_2018.pdf.

4. METHODS

4.1 Overview of VRI Sample Data Analysis

The purpose of the VRI sample data analysis is to evaluate the accuracy of the Phase I photo-interpreted inventory data using the Phase II ground sample data as the basis for the comparison. The analysis includes the following steps.

1 Project the inventory attributes using VDYP7 in accordance with the most recent Ministry standards and procedures.
2 Identify any outliers and data issues with the Phase I and Phase II data files supplied by the Ministry.
3 Identify analysis strata in consultation with Ministry staff.
4 Calculate sample selection probability weights.
5 Compute ratio of means and related statistics for each stratum and overall for the attributes of interest. These ratios of means form the basis of the inventory assessment. The sampling errors for these ratios can be used to assess the risk and uncertainty associated with the sampling process.
6 Produce an analysis of the comparison of leading species.
7 Provide separate tables, graphs and ratios for all key attributes.

There are seven timber attributes that are considered in the current VRI ground sample data analysis:

- Age of the leading species,
- Height of the leading species,
- Basal area at 7.5+ cm DBH utilization,
- Trees per hectare at 7.5+ cm DBH utilization,
- Lorey height (LH) with no utilization level,
- Volume net top, stump (CU), decay, waste and breakage at 12.5+ cm DBH utilization for pine and 17.5 cm+ utilization for other species, and
- Site index.

The attributes and the field names from the source files are given in Table 6.

Table 6. The field names for the attributes are given.

Attribute	Utilization	Ground file	Ground table	VDYP7 file
Age of leading species	N/A	AGET_TXO	Smy_ncs	PRJ_TOTAL_AGE
Height of leading species	N/A	HT_TXO	Smy_ncs	PRJ_DOM_HT
SI of leading species	N/A	See section 4.6		PRJ_SITE_INDEX
Basal area	7.5 cm	Ba_ha	Smy_nc	PRJ_BA
Trees per hectare	7.5 cm	Stems_ha	Smy_nc	PRJ_TPH
Lorey height	N/A	Ht_lorey	Smy_heights	PRJ_LOREY_HT
Whole stem volume	7.5 cm	Vht_wsv	Smy_nc	PRJ_WSV
Merchantable volume	12.5 cm for pine 17.5 cm other Spp	Nvl_nwb	Smy_ncs	PRJ_VOL_DWB

For the ground measurements, Lorey height is calculated as the basal area weighted mean height of all live, standing, full measure trees, including broken top trees. For variable radius plots, this is equivalent to HT_MEAN1. It does not have a utilization level (it includes all trees that meet the criteria, regardless of DBH).

4.2 Data issues related to the analysis

Scatterplots comparing the Phase I and Phase II attributes were examined for potential outliers (Figure 11). Large differences between the ground sample and photo-based estimates were noted for a number of samples. On the ground, all trees for sample 0143-4855-QO1 are dead by fire while the Phase I inventory shows a live layer. Sample 0142-8696-QO1 has no ground trees. Sample 0142-0536-MO1 has a Phase I dead layer that is much taller than the live layer.

Trees with breast height ages < 10 or > 120 were not considered suitable SI trees. Trees that were identified in the field as not suitable height trees, suitable age or suitable SI trees were not considered suitable SI trees. As a result of this screening, only 22 samples had ground SI estimates.

No sample trees were omitted from SI calculations because they were too young.

4.3 Strata

The analysis strata are described in Table 7.

Table 7. The strata are defined based on the Phase I leading species and whether or not they are part of the THLB.

THLB	Stratum code	Lead species	N
All	A	AC/AT	7
All	B	Balsam	15
All	P	Pine	19
All	S	Spruce	53
THLB	B	Balsam	11
THLB	P	Pine	12
THLB	S	Spruce	23
Non THLB	Non-S	AC/AT, Balsam, Pine	18
Non THLB	S	Spruce	30
All	All		94

4.4 Layers

Seven samples were in polygons with more than one live layer (Table 4) identified in the Phase I inventory. Unless otherwise noted, only the primary layer is included in comparisons.

4.5 Height and Age data matching

Two height and age comparisons were undertaken – leading species and species matched. For the leading species comparison, the ground leading species age and height were compared to the Inventory leading species and height, regardless of whether the leading species were the same. For the species matched comparison, the MFLNRO data matching procedures (FAIB 2011) were followed to determine the appropriate Phase I and II heights and ages for the comparison ratios.

The objective of the species matching 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 (Table 17) level, conifer-to-conifer (or deciduous-to-deciduous) matches were allowed. However, conifer-deciduous matches were not considered acceptable. Appendix E provides the details for the height and age data matching.

In addition to comparing the leading species, the ground secondary species was compared to Phase I, using similar methods.

4.6 Site Index from the Phase II Samples

The Phase II site index (SI) was calculated as the arithmetic mean SI, by species, of the T, L, S, X and O trees in the "trees_h" file that met the suitability criteria including being suitable height, age and SI trees and meeting the age criteria. Overmature trees are generally not suitable for estimating SI as they may not always have been dominant/codominant trees, may have experienced suppression at young ages and may have had broken tops. This leads to lower SI estimates as trees get older (Figure 4). SI estimates may not be reliable for very young trees. The SIBEC standard (BC Ministry of Forests and Range, Research Branch 2009) of excluding trees with breast height age < 10 or > 120 was used here. Note that the Phase I

inventory estimates of SI are based on Phase I age and height and there are no restrictions on the age range.

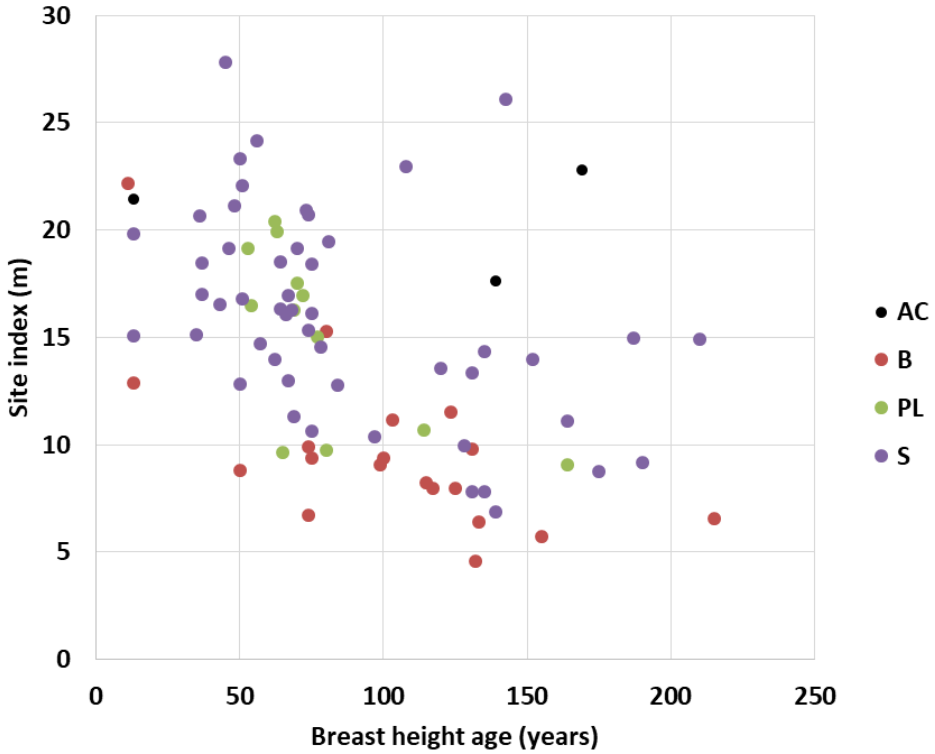

Figure 4. The trees with site estimates in the ground sample are given. There is a tendency for older trees to have lower site index estimates. The SIBEC standard of excluding trees with a breast height age > 120 and those with a breast height age < 10 from site index calculations is used here.

As a result of the screening, 22 out of 94 of the samples had Phase II estimates of SI.

4.7 Site Index from the VRI Phase I polygons

SI was compared at the leading species level and species matched level. For the species matched site index comparison, only Case 1 (samples where the Phase II and Phase I leading species were the same) and Case 2 (Phase II leading species and Phase I secondary species were the same and there was a height and age available for the Phase I secondary species) were included. No other cases were considered acceptable matches with respect to SI for the ground plots.

4.8 Site index from Provincial Site productivity layer

The provincial site productivity layer (PSPL[4]) provides an alternative source of site index estimates, particularly for younger polygons. This layer provides site index estimates for up to 22 species. For the Lakes TSA, the PSPL generally provides SI estimates for 5 to 6 species per polygon. A comparison of the PSPL to Phase II ground SI is included.

[4] http://www.for.gov.bc.ca/hts/siteprod/download/FLNR_Provincial_Site_Productivity_Layer.pdf

5. RESULTS AND DISCUSSION

The compilations from the Phase II ground sample are assumed to be accurate but are a small sample from a large population. The Phase I inventory is a complete enumeration of the population of interest but has unknown accuracy and precision. The Phase II samples are considered unbiased but have large sampling error. The Phase I polygon-based attributes have unknown bias. By comparing the Phase I inventory and Phase II ground samples, the bias of the Phase I estimates can be quantified. For quantitative attributes, unbiased population estimates with relatively small sampling error can be obtained.

The bias associated with the Phase I inventory is examined here for quantitative attributes and the agreement between the Phase I inventory and Phase II ground sample is examined for qualitative attributes.

5.1 Attribute bias

Attribute bias is the difference between the Inventory Phase I photo estimated attributes and the ground Phase II attributes measured to known precision on the ground. Attribute bias can be assessed as the ratio of the weighted mean Phase II ground sample attribute to the corresponding weighted mean Phase I inventory attribute, for example leading species height as estimated in Phase I and the corresponding ground measurements. Ratios were computed for the seven key attributes identified in Section 4.1 and additional attributes of interest. The stratification for the Volume Audit population is based on Phase I inventory leading species groups from the primary layer. The means are given in Table 8 and the ratios in Table 9. The attributes were analyzed by leading strata, leading species by THLB and overall.

Overall, the Phase I Inventory and Phase II ground heights, ages, basal area and volumes are close (within 10%). The Phase II ground age, height and basal area are smaller than the Phase I Inventory leading to a slightly smaller Phase II ground volume.

Means and ratios were also computed by leading species strata and THLB/leading species strata. Some of the sample sizes at the strata level are quite small (N < 30) and the sampling error associated with the strata ratios is higher than the sampling error associated with the overall ratio. As a result, the differences between the Phase I inventory and Phase II ground are greater at the strata level. For instance, overall the ratio for BA is 0.95 but at the strata level the ratio ranges from 0.79 (AC/AT strata) to 1.14 (THLB – B).

Table 8. Sample based weighted means for the Phase I inventory and Phase II ground sample for key inventory attributes, for the volume audit portion of the Lakes TSA. The Phase I attributes are from the primary layer only.

	Species Strata		THLB		Non THLB	

Attribute		AC/AT	B	P	S	B	P	S	NonS	S	All
Leading	N	7	14	17	50	10	11	20	17	30	88
Species	Phase II Ground	81	174	112	133	178	118	136	108	132	132
Age (years)	Phase I Inventory	126	181	102	151	174	101	156	136	148	144
Leading Species	N	7	14	17	50	10	11	20	17	30	88
Matched	Phase II Ground	81	174	112	133	178	118	136	108	132	132
Age(years)	Phase I Inventory	123	185	102	149	175	101	152	137	148	144
Second Species	N	2	1	2	7	1	2	3	2	4	12
Matched Age	Phase II Ground	50	138	114	136	138	114	137	50	135	118
(years)	Phase I Inventory	111	183	111	128	183	111	151	111	111	127
Leading	N	7	13	17	50	9	11	20	17	30	87
Species	Phase II Ground	19.1	17.7	19.5	21.8	17.1	19.3	20.1	19.4	22.9	20.5
Height (m)	Phase I Inventory	23.0	18.0	19.7	24.2	17.1	19.9	24.7	21.1	23.8	22.3
Leading Species	N	7	13	17	50	9	11	20	17	30	87
Matched	Phase II Ground	19.1	17.7	19.5	21.8	17.1	19.3	20.1	19.4	22.9	20.5
Height (m)	Phase I Inventory	23.0	18.9	20.0	23.7	17.2	20.4	23.7	21.8	23.7	22.2
Second Species	N	2	0	2	7	0	2	3	2	4	11
Matched Height (m)	Phase II Ground	12.0		21.7	20.7		21.7	20.2	12.0	21.1	19.3
	Phase I Inventory	24.8		21.0	21.4		21.0	24.3	24.8	19.3	22.0
Basal area	N	7	15	19	52	11	12	22	18	30	93
(m^2/ha)	Phase II Ground	16.7	31.4	18.4	20.1	30.5	19.5	20.5	20.4	19.8	21.3
7.5 cm+	Phase I Inventory	21.1	26.5	20.1	22.1	26.7	19.9	23.3	21.9	21.2	22.3
Trees/ha	N	7	15	19	52	11	12	22	18	30	93
7.5 cm+	Phase II Ground	577	1442	900	667	1455	956	789	850	578	833
	Phase I Inventory	505	875	706	525	903	668	523	674	526	617
Lorey	N	7	14	17	51	10	11	21	17	30	89
Height	Phase II Ground	16.7	14.9	17.4	18.6	14.7	17.1	17.2	16.8	19.7	17.6
(m)	Phase I Inventory	21.6	15.4	17.5	19.7	14.5	17.8	20.3	19.0	19.2	18.7
Volume net	N	7	15	19	53	11	12	23	18	30	94
Dwb (m^3/ha)	Phase II Ground	91	142	114	123	134	122	111	110	132	122
12.5 cm+ NVAF	Phase I Inventory	97	110	117	138	103	120	150	110	128	126
Leading species	N	7	13	17	50	9	11	20	17	30	87
Site index (m)	Phase II Ground	16.8	7.7	12.8	13.4	7.3	12.2	12.5	13.9	13.9	12.7
All ages	Phase I Inventory	14.9	6.9	14.7	12.0	6.4	14.7	12.0	13.2	12.0	12.0
Leading species	N	1	4	3	14	1	2	6	5	8	22
Site index (m)	Phase II Ground	17.3	10.4	13.6	16.3	11.2	12.9	15.8	12.5	16.7	14.9
Agebh 10 - 120	Phase I Inventory	13.6	8.3	15.2	11.7	5.7	15.4	10.8	11.1	12.3	11.6
Leading Species	N	6	13	14	43	9	9	18	15	25	76
Matched SI (m)	Phase II Ground	16.6	7.7	12.7	13.8	7.3	12.0	12.1	13.6	15.0	12.8
All ages	Phase I Inventory	14.7	7.4	14.5	12.0	6.8	14.6	11.4	13.0	12.4	11.9
Leading species	N	1	4	3	14	1	2	6	5	8	22
Matched	Phase II Ground	17.3	10.4	13.6	16.3	11.2	12.9	15.8	12.5	16.7	14.9
Site index (m)	Phase I Inventory	13.6	8.3	15.2	11.7	5.7	15.4	10.8	11.1	12.3	11.6
Second Species	N	0	1	0	4	0	0	3	1	1	5
Matched SI (m)	Phase II Ground		12.8		12.7			10.8	12.8	18.3	12.7
Agebh 10 - 120	Phase I Inventory		11.9		11.6			10.2	11.9	15.9	11.7
Site index	N	1	4	3	14	1	2	6	5	8	22
(m)	Phase II Ground	17.3	10.4	13.6	16.3	11.2	12.9	15.8	12.5	16.7	14.9
Site prod	Phase I Inventory	18.5	15.5	18.7	17.8	13.8	19.0	17.0	16.9	18.4	17.5

Table 9. Ratio of means comparisons (and sampling error % at a 95% confidence level) are given for the attributes in Table 8. The ratios are based on the Phase I primary layer. The ratios that differ from 1.0 by more than 10% are shaded.

	Species Strata				THLB			Non THLB		
Attribute	AC/AT	B	P	S	B	P	S	NonS	S	All
Leading Species	0.639	0.958	1.099	0.884	1.027	1.163	0.872	0.791	0.892	0.911
Age (years)	(19.6%)	(17.6%)	(10.2%)	(10.5%)	(13.6%)	(13.3%)	(18.3%)	(18.7%)	(12.4%)	(7.7%)
Leading Species matched	0.656	0.939	1.099	0.892	1.021	1.163	0.893	0.785	0.892	0.914
Age (years)	(18.7%)	(16.8%)	(10.2%)	(10.3%)	(14.1%)	(13.3%)	(17.8%)	(16.7%)	(12.4%)	(7.5%)
Second Species matched	0.446	0.756	1.029	1.061	0.756	1.029	0.91	0.446	1.215	0.93
Age (years)	(82.9%)	(0%)	(67.8%)	(15.2%)	(0%)	(67.8%)	(6.9%)	(82.9%)	(19%)	(20.2%)
Leading Species	0.831	0.982	0.988	0.902	1.003	0.972	0.812	0.916	0.964	0.921
Height (m)	(26.3%)	(11.1%)	(6%)	(6.3%)	(12.9%)	(8.5%)	(12.7%)	(12.8%)	(5.5%)	(4.8%)
Leading Species matched	0.831	0.936	0.972	0.92	0.997	0.949	0.848	0.89	0.969	0.924
Height (m)	(21.7%)	(10.8%)	(6.3%)	(6.3%)	(13%)	(8.8%)	(13%)	(10.6%)	(5.7%)	(4.6%)
Second Species matched	0.483		1.033	0.966		1.033	0.831	0.483	1.093	0.878
Height (m)	(29.6%)		(0.1%)	(21.9%)		(0.1%)	(18%)	(29.6%)	(30%)	(20.6%)
Basal area	0.79	1.184	0.914	0.909	1.141	0.983	0.88	0.93	0.933	0.954
(m^2/ha) 7.5 cm+	(33.7%)	(23.7%)	(26.9%)	(12.9%)	(30.3%)	(30.1%)	(22.4%)	(26.2%)	(15.1%)	(10.6%)
Trees/ha	1.143	1.647	1.275	1.271	1.612	1.431	1.508	1.261	1.099	1.35
7.5 cm+	(50.5%)	(38.4%)	(36.1%)	(19.7%)	(49%)	(36.7%)	(32.4%)	(37.7%)	(21.1%)	(16.5%)
Lorey Height	0.775	0.97	0.992	0.948	1.015	0.961	0.844	0.884	1.024	0.943
(m)	(24.9%)	(13.6%)	(8.3%)	(6.3%)	(16.8%)	(10.2%)	(11.3%)	(13.8%)	(6.1%)	(5.1%)
Volume net Dwb	0.931	1.292	0.966	0.897	1.309	1.013	0.745	0.995	1.032	0.967
(m^3/ha) 12.5 cm+ NVAF	(61.8%)	(35.9%)	(27.8%)	(16%)	(49.9%)	(34.5%)	(27%)	(29.4%)	(18.9%)	(13.1%)
Leading Species	1.126	1.118	0.874	1.117	1.138	0.831	1.043	1.052	1.166	1.06
Site index (m) All ages	(12.5%)	(18%)	(8.1%)	(8.5%)	(23.3%)	(10.2%)	(14.1%)	(8.9%)	(10.4%)	(6.2%)
Leading Species	1.268	1.256	0.896	1.4	1.955	0.838	1.463	1.124	1.359	1.284
Site index (m) age 10-120	(0%)	(36%)	(18.3%)	(10.3%)	(0%)	(23.8%)	(10.8%)	(17.7%)	(15.4%)	(11.2%)
Leading Species matched	1.13	1.041	0.875	1.148	1.072	0.824	1.061	1.045	1.206	1.074
Site index (m) All ages	(6.8%)	(19.4%)	(11.2%)	(9.2%)	(20.8%)	(15%)	(15.7%)	(9.4%)	(10.9%)	(6.8%)
Leading Species matched	1.268	1.256	0.896	1.4	1.955	0.838	1.463	1.124	1.359	1.284
Site index (m) age 10-120	(0%)	(36%)	(18.3%)	(10.3%)	(0%)	(23.8%)	(10.8%)	(17.7%)	(15.4%)	(11.2%)
Second Species matched		1.078		1.09			1.06	1.078	1.148	1.088
Site index (m) age 10-120		(0%)		(13.3%)			(19.7%)	(0%)	(0%)	(10.7%)
Site index (m)	0.935	0.671	0.728	0.917	0.809	0.68	0.931	0.74	0.908	0.851
PSPL age 10-120	(0%)	(11.9%)	(22%)	(13.2%)	(0%)	(29.9%)	(18.7%)	(15.9%)	(18.2%)	(11%)

5.2 Model-Related and Attribute-Related Components of Volume Bias

The ground volumes net of decay, waste and breakage are compared to Phase I inventory volumes in Table 10 and Table 11. The difference between the mean Phase I inventory volume and the mean Phase II ground sample volume is an estimate of the total volume bias.

The Phase I inventory estimates of volume for a polygon are generated by VDYP7. Generally, photo interpreted estimates of species composition, age, height, basal area and trees/ha are input into VDYP7. The remaining attributes required for VDYP7 (e.g., BEC zone, stockability, etc.) are taken from the Phase I inventory. These are projected to the year of ground sampling and various volumes estimated. There are two potential sources of bias that contribute to the total volume bias.

1 Attribute-related volume bias: This is the bias associated with providing VDYP7 with incorrect input attributes (i.e. species composition, height, age, basal area, trees/ha) as well as errors associated with

projecting these attributes to the year of ground sampling. In addition, the bias includes sampling error – comparing the Phase I polygon to the Phase II sample plot.

2 Model-related volume bias: This is the bias associated with predicting volume from projected species composition, height, age, basal area, trees/ha using the VDYP7 yield model compared to volume estimates generated by the ground compiler. Depending on the volume, it can include errors in estimation of decay, waste and breakage.

Estimates of the relative contribution of each of these bias components to the total inventory volume bias can be obtained by estimating a new volume using the attributes from the ground sample as inputs to the VDYP7 yield model. The model-related bias is evaluated by comparing this third volume to the ground volume. The total bias minus model bias is considered attribute bias.

VOL A – Phase II ground volume – assumed to be correct.

VOL B – Phase I inventory volume – based on the photo interpreted attributes, projected to the year of ground sampling, using VDYP7. It includes errors in original attributes, projection errors, and volume estimation errors.

VOL C– VDYP7 volume using the ground attributes. It includes only VDYP7 volume estimation errors.

Total bias = VOL A – VOL B

Model bias = VOL A – VOL C. Includes VDYP7 volume estimation errors but the input attributes are assumed to be correct.

Attribute bias = VOL C - VOL B. Does not include VDYP7 volume estimation errors but includes errors in original attributes, errors in attribute projection and sampling errors.

Five samples (0143-4855-QO1, 0143-4857-QO1, 0143-4859-QO1, 0142-8696-MO1, 0143-4856-QO1) did not have trees on the ground and were assigned a Vol C = 0 m^3/ha. Three samples had trees on the ground but were not projected by VDYP7. Sample 0142-0536-MO1 was too short (5.8m) to generate yields and Vol C was set to 0 m^3/ha. Sample 0143-4858-QO1 did not have any suitable age or height trees on the ground. Sample 0143-8062-QO1 did not have any suitable height trees on the ground. Samples 0143-4858-QO1 and 0143-8062-QO1 were excluded from the volume bias analysis but included in all other analyses.

Overall, the total bias is negligible (-2.4 m^3/ha or 2% of the ground volume). The attribute volume bias is -23.6 m^3/ha, or about 18% of the ground volume (Figure 5 and Table 10). The model bias is 21.2 m^3/ha.

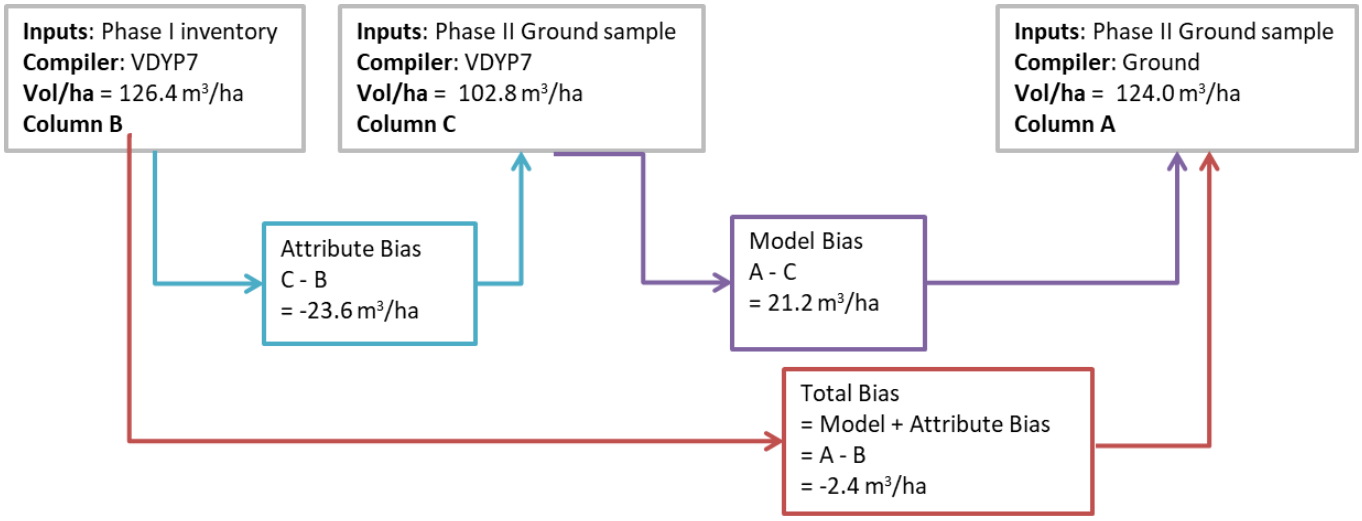

Figure 5. The relationship between the model and attribute components of total merchantable volume bias net of decay waste and breakage) for the mature target population in The Lakes TSA (from Table 10). A negative bias indicates Phase I overestimation whereas a positive bias indicates underestimation.

Attribute bias is largest in the Pine and in the Spruce strata (Table 10 and Table 11). These strata have been affected by mountain pine beetle and have relatively high dead volume. At the time of the Lakes VRI, the standard was to identify a dead layer when 30% or more of the trees (by crown closure) were dead. This was based on the 30% threshold for the original MPB model and the LandSat-based limit for determining the year of death. If the dead fraction was lower than 30%, a separate dead layer was not identified and the dead trees were noted in the VRI_DEAD_STEMS_PER_HA field. Dead volumes are only estimated for separate dead layers. The standard has been changed so that if there amore more than 100 dead stems/ha are present, a separate D layer is interpreted. If this new standard had been implemented in the Lakes TSA, estimated dead volume would likely be higher.

Model-related bias is greatest in the B strata, leading to a large total bias.

Table 10. Merchantable volumes are given for the model-related and attribute-related bias comparison. The sample size is less than that in Table 8 and the means are slightly different due to dropping two samples. The dead volume net of decay waste and breakage is also given.

THLB	Stratum	N	Weighted mean Live Volume (m^3/ha) net Dwb						Dead Volume	
			Phase II Ground	VDYP7 Phase I Inventory	VDYP7 volume with Phase II attributes as input	Model-related volume bias	Attribute-related volume bias	Total volume bias	Phase II Ground	Phase I Inventory
			A	B	C	A-C	C-B	A-B		
All	AC/AT	7	90.5	97.2	76.5	14.0	-20.7	-6.7	6.8	0.0
	B	14	149.8	112.7	111.6	38.2	-1.1	37.1	67.1	15.4
	P	19	113.5	117.5	91.5	22.0	-26.0	-4.0	99.9	53.9
	S	52	125.4	137.3	108.1	17.3	-29.2	-11.9	64.0	44.3
THLB	B	10	144.9	106.0	109.5	35.4	3.5	38.9	57.0	7.6
	P	12	121.7	120.2	97.3	24.5	-22.9	1.5	100.2	60.6
	S	22	115.8	149.6	97.9	18.0	-51.8	-33.8	61.5	41.8
Non THLB	Non S	18	109.9	110.4	87.4	22.4	-23.0	-0.5	61.8	24.3
	S	30	132.5	128.3	115.7	16.8	-12.7	4.2	65.9	46.2
All	All	92	124.0	126.4	102.8	21.2	-23.6	-2.4	67.5	38.5

Table 11. Ratios of mean volumes (12.5cm+ DBH net Dwb for pine, 17.5 cm for other species) representing total, model and attribute bias, with associated sampling error (expressed as a % of the mean bias) at a 95% confidence level.

THLB	Stratum	N	Model bias: Ground/VDYP7 (ground attributes) (Table 10 A/C)	Attribute bias: VDYP7 (Ground attributes)/ Inventory (Table 10 C/B)	Total bias: Ground/Inventory (Table 10 A/B)
All	AC/AT	7	1.183 (±5.2%)	0.787 (±24.6%)	0.931 (±29.4%)
	B	14	1.343 (±5.4%)	0.99 (±16.8%)	1.33 (±24.6%)
	P	19	1.24 (±3.7%)	0.779 (±11%)	0.966 (±13.7%)
	S	52	1.16 (±2.8%)	0.787 (±5.8%)	0.913 (±7.3%)
THLB	B	10	1.323 (±6.1%)	1.033 (±24.7%)	1.367 (±35.5%)
	P	12	1.252 (±5.2%)	0.809 (±14.1%)	1.013 (±17.8%)
	S	22	1.184 (±4.6%)	0.654 (±9%)	0.774 (±10.4%)
Non	Non S	18	1.257 (±4.9%)	0.792 (±11.5%)	0.995 (±14.9%)
THLB	S	30	1.145 (±3.5%)	0.901 (±7.1%)	1.032 (±9.9%)
All	All	92	1.206 (±2.3%)	0.813 (±5%)	0.981 (±6.5%)

The two potential sources of volume error in Phase I are illustrated in Figure 6. The total bias (Figure 6a) includes model and attribute error. The Phase I inventory and Phase II ground volumes are positively correlated with evidence of slightly lower ground volumes. There is a great deal of unexplained variation.

The model-related and attribute-related error are both approximately 18% of the ground volume and nearly cancel each other out so the total bias is negligible. The model-related bias has much lower variation (Figure 6b) than the attribute bias variation. The model bias is an indication of the difference between VDYP7 volume estimates and the ground compiler, using similar attributes. The ground compiler volumes are based on the individual tree measurements and taper models and are considered more accurate than the VDYP7 volumes which are based on stand level estimates of BA, height and age by species. The estimate of model bias is based on the ground plot measurements and does not include any of the variation associated with sampling a small portion of the Phase I polygon. The relationship is strong.

The attribute-related bias is much more variable (Figure 6c). The attribute-related bias is approximately the same as the average model-related volume bias but the variance of the attribute-related bias dominates the variance of the total bias. Attribute bias includes errors in the original photo estimates, errors in projecting the photo estimates to the year of ground sampling, ground measurement errors and sampling error. The sampling error results from the ground sample representing a small part of the polygon compared to the polygon estimate. The sample plan is designed to provide unbiased estimates so the sampling error should not contribute to the overall attribute bias but it does contribute to the variation in Figure 6c. Although the difference between the Phase I inventory estimate and the Phase II ground measurement is referred to as an “error”, a more correct term is “difference”. The relationship is not strong and includes more variation.

The total bias and its components (model and attribute bias) should be considered when using the Phase I inventory. Overall, the total volume bias is small and not statistically significant indicating the population volume estimates are unbiased. The attribute and model bias tend to cancel each other out. There is a great deal of unexplained variation in the attribute bias, particularly at the stratum level. The total bias is small so there is little value in an overall adjustment. The total bias is larger at the strata level but the variation is so high, the bias is generally not statistically significant. The Phase II sample size is relatively small and is a snapshot for 2017. Attribute adjustment is not implemented for VRI projects undertaken

after 2009. Overall, there is no indication that attribute adjustment will improve the overall volume estimates for the population considered here.

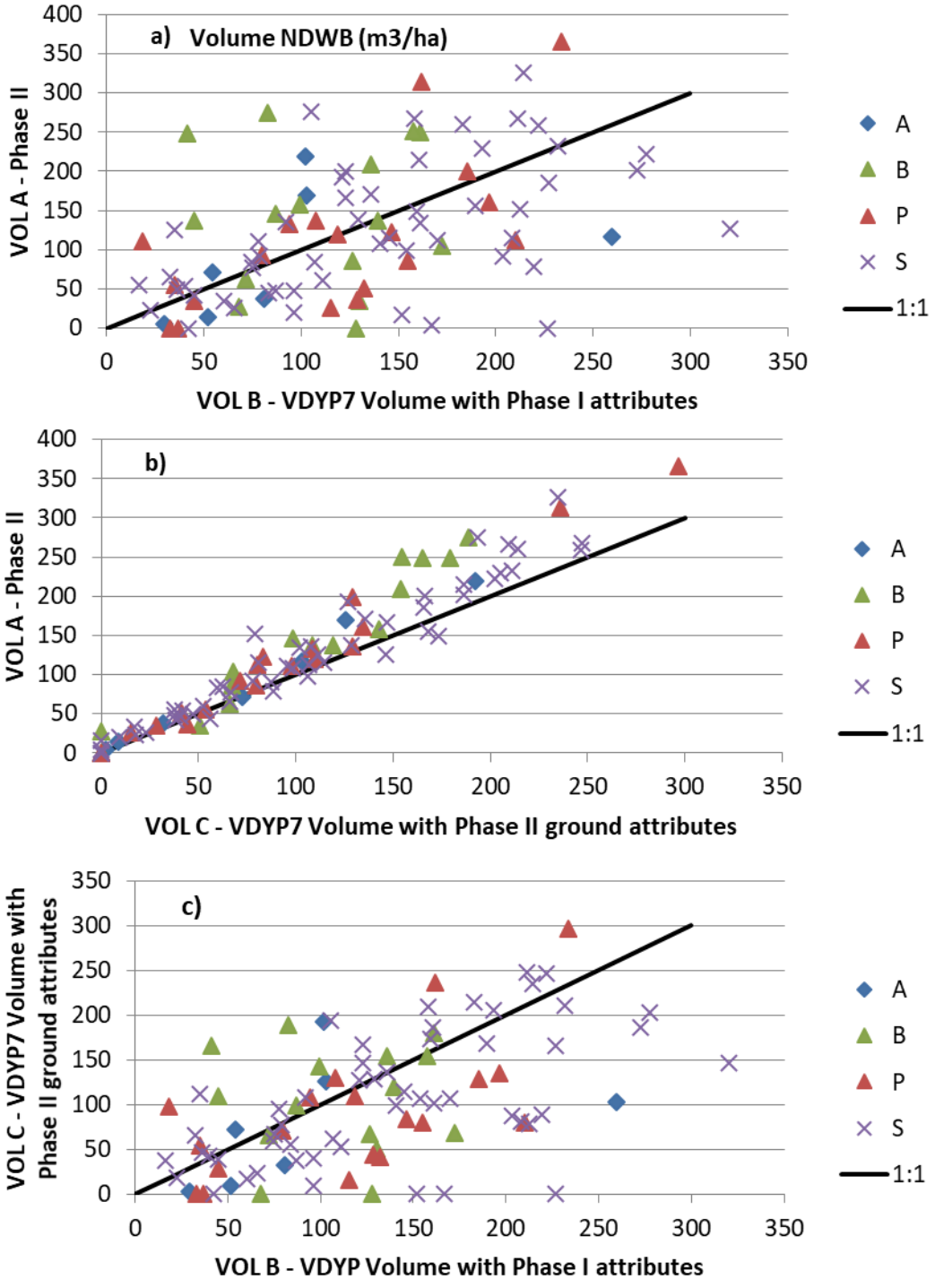

Figure 6. The top graph (a) illustrates the total volume error (Phase I vs. Phase II volume). The middle graph (b) illustrates model-related volume error (VDYP7 volume using Phase II inputs vs. Phase II volume). The bottom graph (c) illustrates the attribute-related volume error (Phase I volume vs. VDYP7 volume using Phase II inputs).

5.3 Phase I Layers

The VRI can include several live layers including primary, residual, veteran and young layers as well as potentially including a dead layer. The analysis in sections 5.1 and 5.2 included only the projected primary layer and showed the Phase I VRI estimates of BA and volume were slightly higher than the Phase II ground sample. There are 7 samples with non-projected layers (Table 4). If these were included, it would increase the Phase I sample average BA by approximately 0.55 m^2/ha or about 2.5%. The inclusion of the secondary layer volumes would likely increase the Phase I volumes by a similar amount (2.5%).

5.4 Broken Top trees

Approximately 2% of the trees measured on the ground had broken tops. This is relatively minor.

5.5 Leading species comparison

Table 12 summarizes the agreement between the leading species in the Phase I inventory and the leading species from the Phase II ground sample compilation for the sampled polygons. Of the 94 samples, 65 (69%) were correctly classified. This is similar to other TSAs.

Table 12. The Phase II ground vs. Phase I inventory leading species cross-tabulation for the target population in The Lakes TSA. The shaded cells are correct classifications. The overall correct classification rate is 69%.

Phase I Inventory	Phase II Ground Leading Species @ 4cm DBH utilization								%
leading spp	blank	AC	AT	B	PL	S	SE	Total	agreement
AC					1			1	0%
AT			4			2		6	67%
B	1			12	1	1		15	80%
PL	2			1	12	4		19	63%
S	2		1	5	1	33		42	79%
SE				2	2	3	4	11	36%
Total	5	0	5	20	17	43	4	94	
% agreement	0%	0%	80%	60%	71%	77%	100%		69%

The previous comparison is important. However, for some polygons the leading species percent is close to the second species percent and varies with utilization level (Table 13).

Table 13. The samples are given which have a 10% difference or less in the leading species based on the Phase II ground species composition at the 4.0 cm utilization.

Clstr_id	Phase II Ground 4.0 cm	Phase II Ground 7.5 cm	Phase I Inventory	Match
0143-4858-QO1	Sx 50 Bl 50	Sx 50 Bl 50	SE 85 BL 10 PLI 5	Close
0143-5395-QO1	Sx 50 Bl 50	Sx 50 Bl 50	SE 55 BL 45	Close
0143-5946-QO1	Sx 50 Pl 50	Sx 60 Pl 40	SX 55 PLI 40 AT 5	Yes
0143-7574-QO1	Se 33 Pl 33 Bl 34	Se 36 Pl 36 Bl 28	SE 65 BL 30 PLI 5	Yes

If the close matches in Table 13 are considered matches, the species agreement rises from 69% to 71%.

5.6 Evaluation of PSPL

The SI estimates from the PSPL were compared to the ground estimates. The ground species AC was matched to AT in the PSPL. The comparison includes all ground trees considered suitable SI trees, regardless of whether they are the leading species or not. Overall, the PSPL estimates of SI tend to be higher than the ground estimates. The PSPL is an estimate of potential SI and the observed SI is generally lower than the potential SI.

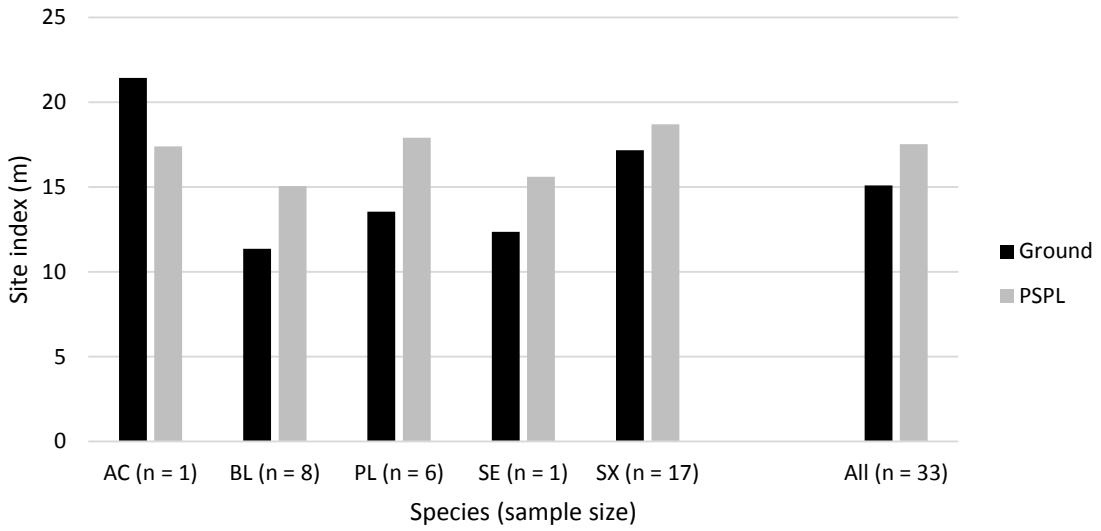

Figure 7. The PSPL and ground SI estimates are given by species and all species combined.

5.7 Size class distributions

The ground samples tally trees were used to examine the size class distributions.

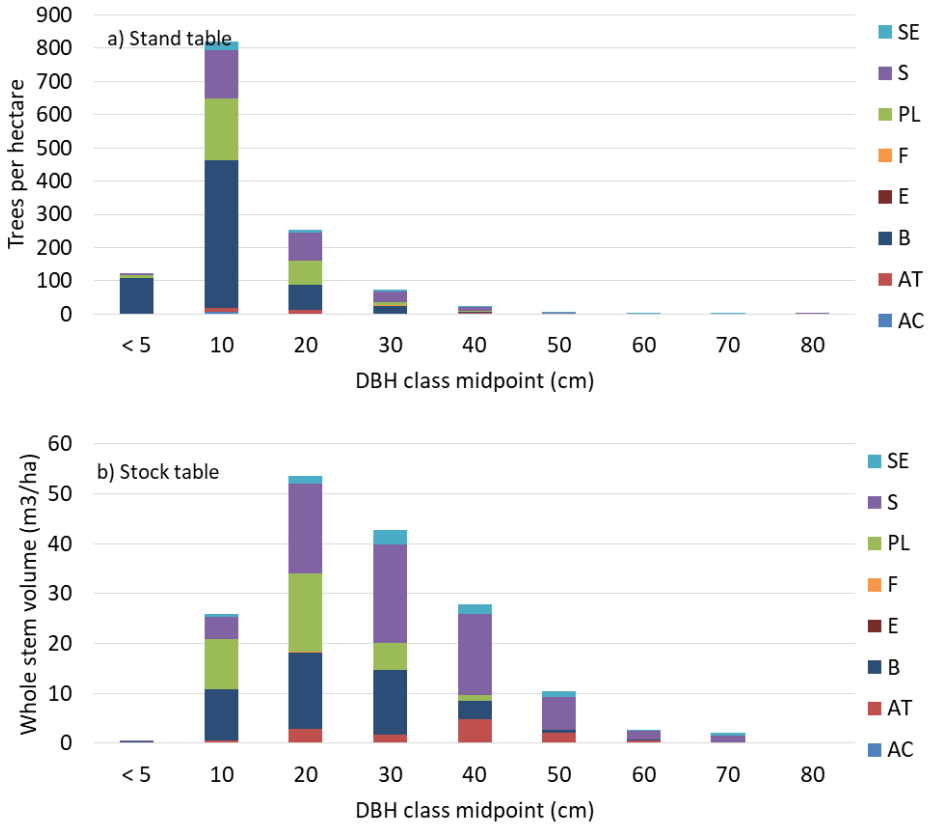

Figure 8. The number of trees (a) and volume (b) are summarized by species and DBH class for live trees with DBH ≥ 4.0 cm. The DBH classes are 10 cm wide.

Over half of the dead trees have DBH < 15 cm and 58% are lodgepole pine (Figure 9).

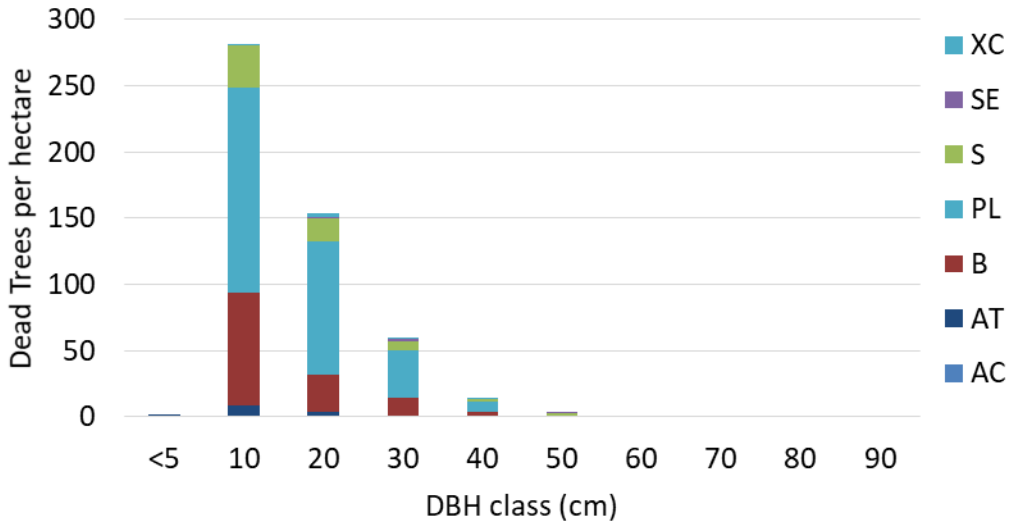

Figure 9. The number of dead trees is given by species and DBH class for trees with DBH ≥ 4.0 cm.

The average dead volume net of decay, waste and breakage is 68 m^3/ha (Table 10). The average dead whole stem volume (DBH ≥ 4.0) is higher, mostly pine and in the Pine and Spruce strata (Figure 10).

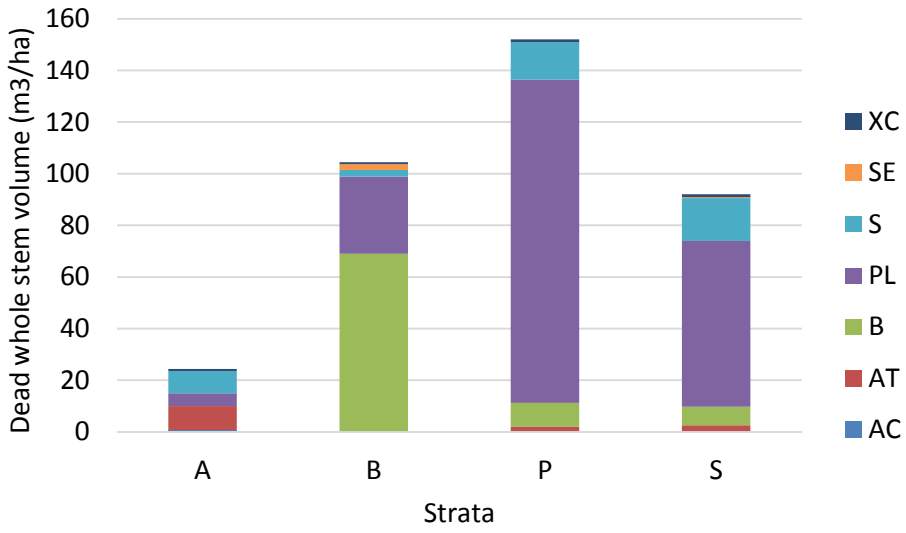

Figure 10. The whole stem volume in dead trees is given by species and strata for trees with DBH ≥ 4.0 cm.

5.8 Limitations of the approach

Utilization limit– The original photo interpreted attributes in Phase I do not have a utilization limit. The photo interpretation procedure for most attributes, including basal area, is to assess the living trees visible to the photo interpreter in the dominant, codominant and high intermediate crown positions for each tree layer in the polygon (FAIB 2014). In Nona Philips Forestry Consulting (2014) (which was not used), sample 93 has BA = 0 and stems = 595 stems/ha, implying the DBH limit is 0cm. When the Phase I attributes are run through VDYP7, the resulting attributes will all have a utilization limit.

Sample unit – The Phase I sample unit is the polygon while the Phase II sample unit is a fixed area plot (CMI or NFI) or a cluster of 5-variable radius plots (Volume audit). In highly variable polygons (polygons with small openings, rock, multi-layered stands, mixes of immature and mature, etc.), a photo-interpreter may reflect this within-polygon variability in the Phase I attribute values that are assigned. However, the Phase II plot may not be as effective in capturing such variability. This does not introduce bias to the analysis but increases the sampling error.

Sample sizes – The sample sizes for the leading species strata within the volume audit (mature) population are small, resulting in estimates with high sampling errors.

6. Conclusions and recommendations

Overall, the inventory estimates of age, height, basal area and volume are close (within 10%) to the ground estimates and slightly higher. The Lakes VA inventory meets the target of being within 10% of the true value. Biases may be higher for individual polygons and may be higher for some strata.

A second layer was identified in seven of the sampled polygons, representing approximately 2.5% of the basal area. This is considered minor.

The ground estimate of SI is higher than the inventory estimate while the PSPL SI estimates are generally higher than the ground estimates. This is not unexpected as the PSPL represents potential productivity which is generally higher than the actual productivity. The ground estimates of SI were restricted to sample trees considered suitable SI trees with breast height ages from 10 to 120. As a result, only 25% of the samples had suitable SI trees.

The leading species agreement for the Volume Audit population is comparable to results from other TSA (69% or 65 out of 94).

7. Literature cited

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8. Appendix A: Phase I inventory attributes

Table 14. The Phase I inventory projected attributes are given.

Clstr_id	inventory standard	BEC	Reference year	Polygon area (ha)	sp01	pct1	sp02	pct2	sp03	pct3	sp04	pct4	Age sp1	Height sp1	Age sp2	Height sp2	Basale area (m2/ha)	Trees/ha	Lorey height (m)	Volume NWB 12.5 (m3/ha)	Dead WSV (m^3/ha)	SI SPp1 (m)	SI spp2 (m)
0142-0536-MO1	V	SBS	2012	14.6	SX	70	AT	30					146	29.6	146	30.4	20.4	294	27.2	167	120	15.4	19.4
0142-1166-MO1	V	ESSF	2012	32.1	SE	65	BL	20	PLI	15			131	18.6	131	17.7	25.5	951	15.6	111	17	9.6	8.7
0142-1176-MO1	V	SBS	2012	2.9	PLI	75	SX	22	AT	2	AC	1	66	17.0	66	18.9	17.9	864	14.9	79	116	15.4	18.3
0142-1181-MO1	V	SBS	2012	5.4	SX	50	BL	40	PLI	10			96	22.2	86	19.2	28.1	825	17.9	154	54	15.1	14.2
0142-1811-MO1	V	SBS	2012	32.9	SX	100							186	28.5			14.8	247	22.0	105	107	11.6	
0142-1816-MO1	V	SBS	2012	10.8	SX	85	PLI	15					146	23.7	146	20.3	22.3	561	19.2	136	152	10.9	12.5
0142-1821-MO1	V	SBS	2012	12.6	PLI	70	SX	30					86	17.7	86	21.4	6.3	244	16.8	35	82	13.7	16.1
0142-3656-MO1	V	ESSF	2012	13.1	BL	97	SE	3					186	14.5	206	21.3	31.8	1146	10.6	82	60	4.6	8.1
0142-4296-MO1	V	SBS	2012	6.4	BL	55	SX	35	PLI	10			86	16.1	126	26.8	23.9	783	18.1	127	140	11.9	15.0
0142-4301-MO1	V	ESSF	2012	15	BL	95	SE	4	PLI	1			166	15.5	186	18.4	15.3	671	11.5	41	162	5.7	7.2
0142-4926-MO1	V	SBS	2012	11.4	SX	85	AT	15					81	17.4	81	15.7	10.2	474	14.9	32	56	13.8	12.0
0142-4931-MO1	V	SBS	2012	8.4	AT	70	SX	30					81	19.3	156	26.6	22.5	714	19.7	103	3	14.9	12.2
0142-8051-MO1	V	SBS	2012	8.9	SX	60	AT	30	BL	10			146	27.7	146	26.4	10.3	173	24.7	74	0	13.8	16.0
0142-8696-MO1	V	SBS	2012	38.7	SX	93	BL	5	PLI	2			156	27.6	41	13.6	33.6	580	21.2	227		12.9	20.5
0143-4853-QO1	V	ESSF	2012	21.3	SE	40	BL	35	PLI	25			226	20.3	186	14.5	14.0	598	15.4	60	12	7.2	4.6
0143-4854-QO1	V	ESSF	2015	5.1	BL	70	PLI	20	SE	10			173	17.2	183	18.1	19.9	327	15.1	87	163	6.2	9.8
0143-4855-QO1	V	ESSF	2015	34.5	BL	80	SE	20					153	17.3	153	20.3	36.3	1478	13.9	128	165	7.2	9.4
0143-4856-QO1	V	SBS	2014	11.8	SX	85	PLI	14	AT	1			116	19.9	116	18.2	8.3	256	17.1	42	90	11.0	12.1
0143-4857-QO1	V	SBS	2014	13.4	PLI	98	SX	2					101	16.5	126	20.6	6.5	192	14.5	33	124	11.6	10.5
0143-4858-QO1	V	SBS	2014	5.1	SE	85	BL	10	PLI	5			116	25.9	116	25.2	22.0	557	21.4	152	328	15.4	15.5
0143-4859-QO1	V	SBS	2014	13.3	PLI	75	SX	25					86	17.6	116	22.5	6.2	173	17.0	37	258	13.7	12.8
0143-5121-QO1	V	ESSF	2012	91.2	SE	80	PLI	10	BL	10			206	23.3	206	20.1	12.0	325	19.5	75	261	9.2	10.9
0143-5122-QO1	V	ESSF	2012	18.2	SE	75	BL	25					196	21.3	166	16.5	18.9	548	16.3	92	140	8.4	6.2
0143-5123-QO1	V	SBS	2012	12.5	SX	85	BL	15					221	26.4	196	22.4	24.9	471	20.5	161	137	8.4	8.1
0143-5124-QO1	V	SBS	2012	2.2	SX	90	BL	10					186	24.5	166	21.5	33.5	547	19.4	203	68	8.9	9.0
0143-5125-QO1	V	SBS	2012	10.5	SX	75	BL	25					156	23.6	146	18.6	11.1	271	19.2	66	170	10.2	8.3
0143-5126-QO1	V	SBS	2015	16.7	SX	95	AT	5					163	24.3	153	25.2	15.9	347	19.7	96	92	10.1	14.7
0143-5392-QO1	V	SBS	2012	30.4	PLI	85	SX	15					186	17.7	186	18.6	6.4	572	16.2	18	168	9.4	6.0
0143-5393-QO1	V	SBS	2012	27.8	PLI	95	SE	5					130	18.3	130	18.6	24.2	828	15.8	132	273	11.6	9.7
0143-5394-QO1	V	ESSF	2012	7.8	SE	55	BL	45					196	22.3	186	18.5	24.9	647	16.6	123	97	9.0	6.3

Clstr_id	inventory standard	BEC	Reference year	Polygon area (ha)	sp01	pct1	sp02	pct2	sp03	pct3	sp04	pct4	Age sp1	Height sp1	Age sp2	Height sp2	Basale area (m2/ha)	Trees/ha	Lorey height (m)	Volume NWB 12.5 (m3/ha)	Dead WSV (m^3/ha)	SI SPp1 (m)	SI spp2 (m)
0143-5395-QO1	V	ESSF	2012	43	SE	55	BL	45					226	25.3	196	22.4	29.0	547	19.0	170	136	9.8	8.1
0143-5401-QO1	V	SBS	2012	11.2	PLI	95	SX	5					76	16.8	76	17.5	31.2	1446	14.4	147	76	13.9	14.7
0143-5663-QO1	V	ESSF	2012	6	SE	90	PLI	10					136	21.7	166	20.2	20.4	682	17.5	107	63	11.1	11.9
0143-5664-QO1	V	SBS	2012	6.4	BL	75	SE	20	PLI	5			91	17.1	96	22.1	26.2	1159	14.8	99	72	11.9	15.1
0143-5665-QO1	V	SBS	2012	17	SX	85	BL	15					91	24.3	81	19.3	35.9	802	19.4	222	133	17.6	15.1
0143-5668-QO1	V	SBS	2012	7	PLI	100							81	17.2			26.6	1141	14.4	129	83	13.8	
0143-5669-QO1	V	SBS	2012	20.5	PLI	95	SX	5					86	18.7	86	19.3	32.0	1157	16.3	185	52	14.6	14.3
0143-5670-QO1	V	SBS	2012	5.7	PLI	60	SX	40					86	20.7	86	21.4	18.5	575	18.3	115	67	16.3	16.1
0143-5671-QO1	V	SBS	2012	30	PLI	70	SX	27	AT	3			72	19.9	72	21.7	14.7	436	18.3	94	188	17.2	19.1
0143-5672-QO1	V	SBS	2012	10.8	SX	95	BL	5					146	22.7	136	9.5	18.9	479	16.9	96	49	10.2	4.3
0143-5935-QO1	V	SBS	2012	21.3	SX	90	BL	10					156	33.5	146	19.6	31.6	364	26.6	273	36	18.1	8.9
0143-5937-QO1	V	SBS	2012	10.2	AT	95	SX	5					146	23.4	146	33.6	20.5	430	21.8	81	0	13.7	19.0
0143-5938-QO1	V	SBS	2012	2.7	SX	93	AT	7					86	22.9	86	21.8	23.9	528	19.3	145	150	17.3	16.5
0143-5941-QO1	V	SBS	2012	22.7	SX	100							156	28.1			31.7	768	21.5	219	55	13.4	
0143-5943-QO1	V	SBS	2012	28.2	SX	50	AT	20	EP	20	PLI	10	116	17.9	91	16.6	10.3	418	15.7	36	0	9.7	11.8
0143-5945-QO1	V	SBS	2012	12	AT	97	SX	3					116	21.5	116	20.9	14.8	408	19.3	52	5	13.9	11.7
0143-5946-QO1	V	SBS	2012	4.5	SX	55	PLI	40	AT	5			101	21.1	101	17.5	6.5	254	18.0	35	83	13.6	12.5
0143-5947-QO1	V	SBS	2012	6	SX	93	AT	5	PLI	2			151	26.6	155	27.3	34.7	625	21.1	232	105	12.6	16.4
0143-6214-QO1	V	SBS	2012	49.3	SX	55	AT	35	PLI	10			76	18.0	76	17.3	6.3	289	16.8	23	220	15.2	13.9
0143-6215-QO1	V	SBS	2012	37.7	SX	98	AT	2					156	23.6	156	25.3	22.6	425	17.6	121	108	10.2	14.7
0143-6216-QO1	V	SBS	2012	43.2	SX	100							146	26.7			22.2	814	20.6	129	69	13.0	
0143-6500-QO1	V	SBS	2012	38.5	SX	85	AT	15					81	19.4	81	18.8	20.2	736	16.2	84	72	15.4	14.5
0143-6505-QO1	V	SBS	2012	8.3	SX	55	SB	25	BL	15	PLI	5	131	22.8	131	18.6	15.2	383	18.4	87	70	11.5	10.3
0143-6781-QO1	V	SBS	2012	13.1	AT	60	SX	35	EP	5			74	16.8	71	20.2	17.9	789	16.1	54	46	13.7	18.2
0143-7044-QO1	V	SBS	2014	24.8	BL	60	SX	40					224	22.2	224	24.3	32.0	917	17.5	161	146	7.0	7.0
0143-7045-QO1	V	ESSF	2012	35.7	BL	90	SE	10					186	15.5	316	23.1	17.2	953	12.5	45	58	5.0	7.2
0143-7046-QO1	V	SBS	2012	149.4	PLI	95	SX	5					124	22.4	124	23.8	29.2	725	19.5	210	170	15.2	12.9
0143-7047-QO1	V	SBS	2012	10.8	PLI	50	SX	30	AT	20			104	22.5	104	24.1	17.5	437	20.8	119	94	16.4	15.5
0143-7050-QO1	V	SBS	2012	16.6	SX	99	AT	1					226	26.4	116	24.5	21.9	436	20.4	141	102	8.1	16.2
0143-7052-QO1	V	SBS	2012	10	SX	55	EP	45					96	22.2	66	17.0	8.2	222	19.4	45	51	15.1	14.8
0143-7055-QO1	V	SBS	2012	23	PLI	45	AT	35	SX	15	BL	5	96	21.6	96	20.6	35.0	963	19.0	197	0	16.2	14.6
0143-7318-QO1	V	ESSF	2012	13	BL	80	SE	20					194	21.4	196	22.3	14.1	401	17.5	72	131	7.6	9.0
0143-7319-QO1	V	ESSF	2012	27.7	BL	90	SE	10					299	21.3	356	26.2	34.0	1099	16.8	157	52	4.7	8.4

Clstr_id	inventory standard	BEC	Reference year	Polygon area (ha)	sp01	pct1	sp02	pct2	sp03	pct3	sp04	pct4	Age sp1	Height sp1	Age sp2	Height sp2	Basale area (m2/ha)	Trees/ha	Lorey height (m)	Volume NWB 12.5 (m3/ha)	Dead WSV (m^3/ha)	SI SPp1 (m)	SI spp2 (m)
0143-7320-QO1	V	SBS	2012	51.4	PLI	100							87	19.7			6.5	204	18.4	45	163	15.4	
0143-7324-QO1	V	SBS	2012	1.3	SX	60	EP	20	AT	15	AC	5	136	24.8	126	21.5	35.3	814	21.0	211	82	12.5	12.9
0143-7325-QO1	V	SBS	2012	48.9	SX	75	AT	15	AC	5	EP	5	136	29.7	136	26.4	28.1	475	24.7	214	55	16.3	16.6
0143-7326-QO1	V	SBS	2012	2.4	SX	65	PLI	32	AC	3			136	27.7	136	25.3	39.5	724	23.6	320	8	14.7	17.1
0143-7328-QO1	I	SBS	2013	2.3	PLI	72	SX	14	BL	14			81	18.3			33.8	1660	13.9	155	69	14.8	
0143-7566-QO1	V	SBS	2012	8.3	PLI	80	SX	15	BL	5			96	19.6	96	21.2	17.5	581	17.6	108	189	14.5	14.2
0143-7567-QO1	V	SBS	2012	56.1	AT	80	SX	20					126	25.5	106	22.1	5.5	102	23.8	29	4	16.4	13.6
0143-7574-QO1	V	ESSF	2012	11.1	SE	65	BL	30	PLI	5			106	18.9	56	12.7	12.5	787	13.7	40	15	11.7	14.5
0143-7577-QO1	V	ESSF	2012	2.6	BL	90	SE	7	PLI	3			146	18.6	176	22.4	33.2	1169	14.6	130	20	8.3	9.6
0143-7578-QO1	V	SBS	2012	17.1	SX	50	BL	35	PLI	13	AC	2	196	28.5	166	21.5	27.8	544	21.8	189	51	11.0	9.0
0143-7579-QO1	V	SBS	2012	12.8	SX	70	PLI	20	BL	5	SB	5	196	25.5	196	22.1	24.8	618	20.0	158	30	9.0	12.7
0143-7822-QO1	V	SBS	2013	18.2	SX	90	BL	10					165	27.5	155	23.4	28.8	493	22.6	213	65	12.2	11.0
0143-7824-QO1	V	SBS	2013	34.1	SX	70	BL	25	PLI	5			172	27.9	115	20.4	29.7	735	20.7	193	113	12.1	11.7
0143-7825-QO1	V	SBS	2012	4.1	SX	65	BL	20	PLI	10	AT	5	166	24.6	141	16.6	27.8	589	19.1	161	44	10.1	7.4
0143-7827-QO1	V	ESSF	2012	7.5	SE	60	BL	25	PLI	15			191	23.4	166	17.5	36.8	831	18.1	208	135	9.7	6.7
0143-7828-QO1	V	SBS	2012	24.3	PLI	55	BL	25	SX	20			146	23.3	146	21.6	23.5	573	20.4	162	177	15.0	10.2
0143-8062-QO1	V	SBS	2012	10.9	BL	60	SX	40					136	20.6	141	22.7	11.3	234	19.3	68	34	10.3	10.6
0143-8063-QO1	V	ESSF	2012	22.7	BL	70	SX	25	PLI	5			186	17.5	216	21.5	41.5	1195	14.8	172	175	5.9	6.1
0143-8066-QO1	V	SBS	2012	45.2	SX	80	AT	15	PLI	5			96	23.2	81	22.9	46.1	943	19.5	277	11	15.9	18.0
0143-8305-QO1	V	ESSF	2012	14.6	BL	85	SX	15					206	18.4	226	20.5	30.0	603	15.5	136	83	5.6	5.4
0143-8306-QO1	V	ESSF	2012	15.9	SX	60	PLI	30	BL	10			166	19.6	176	18.2	15.2	402	16.6	79	117	7.3	10.0
0143-8307-QO1	V	SBS	2012	29.5	BL	80	SX	20					260	19.3	256	24.4	30.9	995	16.5	139	26	4.7	6.1
0143-8309-QO1	V	SBS	2012	14	SX	80	AT	10	PLI	10			126	25.8	126	25.5	25.5	485	22.4	183	64	14.2	16.4
0143-8310-QO1	V	SBS	2012	11.3	PLI	70	SX	25	BL	5			136	24.3	146	28.6	28.3	638	22.7	234	358	16.3	14.6
0143-8546-QO1	V	SBS	2012	35.7	SX	50	BL	40	AT	5	AC	3	136	24.8	136	22.6	36.4	772	20.5	227	21	12.5	11.7
0143-8547-QO1	V	SBS	2012	85.6	AT	85	SX	15					224	27.2	224	32.3	25.1	436	25.3	102	42	14.0	12.8
0143-8550-QO1	V	SBS	2012	12.1	AC	40	AT	30	SX	30			116	27.6	116	24.5	41.7	656	24.9	260	12	17.9	16.2
0143-8793-QO1	V	SBS	2012	15.1	SX	50.1	SB	49.9					106	19.0	106	12.7	5.4	310	15.9	16	12	11.4	8.2
0143-9029-QO1	V	SBS	2012	2.8	SX	45	BL	35	AC	20			166	28.5	166	26.9	10.1	169	25.5	78	89	12.9	13.0
0143-9030-QO1	V	SBS	2012	14.6	SX	50	BL	40	AT	5	PLI	5	166	28.5	156	23.5	22.1	444	23.0	159	135	12.9	11.0
0143-9273-QO1	V	ESSF	2012	9.7	SE	70	BL	30					226	23.2	206	20.4	20.0	298	19.6	123	28	8.7	6.6

9. Appendix B: Phase II compiled ground attributes

Table 15. The Phase II compiled ground attributes are given.

Strata	Sample	Year	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	Volume net DWB (m^3/ha) DBH ≥ 17.5 cm	
							Live	Dead
S	0142-0536-MO1	2018	Bl 100	2.0	125	10.5	4	110
S	0142-1166-MO1	2018	Pl 54 Bl 31 Se 15	22.2	1026	9.4	60	10
P	0142-1176-MO1	2018	Pl 95 Sx 05	22.7	1951	16.2	92	82
S	0142-1181-MO1	2018	Bl 73 Sx 20 Pl 07	30.6	1701	15.3	98	43
S	0142-1811-MO1	2018	Sx 100	29.4	425	28.3	276	101
S	0142-1816-MO1	2018	Sx 100	27.4	926	20.0	171	100
P	0142-1821-MO1	2018	Sx 69 Pl 30 Bl 01	14.8	801	14.6	55	64
B	0142-3656-MO1	2018	Bl 96 Se 04	55.3	1901	16.1	275	13
B	0142-4296-MO1	2018	Sx 87 Bl 07 Pl 06	14.3	550	18.4	86	128
B	0142-4301-MO1	2018	Bl 77 Se 23	35.6	600	19.2	249	118
S	0142-4926-MO1	2018	Sx 82 Bl 18	9.0	150	21.1	66	52
A	0142-4931-MO1	2018	At 60 Sx 40	27.3	700	19.6	170	0
S	0142-8051-MO1	2018	Sx 90 Pl 10 At tr	21.9	751	13.2	84	0
S	0142-8696-MO1	2018					0	0
S	0143-4853-QO1	2018	Pl 56 Se 44	8.0	373	11.9	34	8
B	0143-4854-QO1	2018	Pl 90 Sx 10	23.8	797	13.4	145	149
B	0143-4855-QO1	2018		0.0	0		0	58
S	0143-4856-QO1	2018		0.0	0		0	58
P	0143-4857-QO1	2018		0.0	0		0	39
S	0143-4858-QO1	2018	Sx 50 Bl 50	2.0	25	22.9	16	154
P	0143-4859-QO1	2018		0.0	0		0	140
S	0143-5121-QO1	2018	Se 56 Pl 44	12.6	279	15.9	77	229
S	0143-5122-QO1	2018	Sx 48 Bl 43 Pl 09	26.6	1258	15.5	135	117
S	0143-5123-QO1	2018	Sx 76 Pl 18 Bl 06	30.6	891	20.4	215	119
S	0143-5124-QO1	2018	Sx 100	18.0	680	17.0	91	55
S	0143-5125-QO1	2018	Sx 75 Pl 25	4.0	144	18.5	26	138
S	0143-5126-QO1	2018	Sx 100	6.0	123	23.2	47	65
P	0143-5392-QO1	2018	Pl 71 Sx 29	19.6	883	16.1	111	134
P	0143-5393-QO1	2018	Pl 80 Sx 20	7.0	324	18.2	51	237
S	0143-5394-QO1	2018	Se 48 Bl 39 Pl 13	30.8	834	18.5	200	88
S	0143-5395-QO1	2018	Sx 50 Bl 50	22.4	971	16.5	112	125
P	0143-5401-QO1	2018	Pl 100	23.8	1722	14.4	123	63
S	0143-5663-QO1	2018	Se 64 Bl 36	24.0	1516	13.1	84	55
B	0143-5664-QO1	2018	Bl 40 Se 30 Pl 30	28.0	967	16.2	158	37
S	0143-5665-QO1	2018	Sx 100	27.0	290	26.9	259	111
P	0143-5668-QO1	2018	Pl 92 Sx 08	13.0	968	14.7	36	61
P	0143-5669-QO1	2018	Pl 100	35.0	2587	16.2	199	28
P	0143-5670-QO1	2018	Pl 56 Sx 44	6.0	396	11.1	26	50
P	0143-5671-QO1	2018	Pl 71 Sx 29	23.4	1190	16.7	133	144
S	0143-5672-QO1	2018	Sx 83 At 17	6.0	446	14.9	20	41
S	0143-5935-QO1	2018	Sx 95 At 05	21.0	279	26.1	202	27
A	0143-5937-QO1	2018	At 100	7.0	84	18.7	38	0
S	0143-5938-QO1	2018	Sx 100	18.0	484	19.0	115	129
S	0143-5941-QO1	2018	Sx 67 Bl 33	16.8	692	17.3	78	44
S	0143-5943-QO1	2018	Sx 50 At 30 Pl 20	10.0	421	17.1	49	0
A	0143-5945-QO1	2018	At 54 Ac 46	13.0	1114	11.6	14	0

Strata	Sample	Year	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	Volume net DWB (m^3/ha) DBH ≥ 17.5 cm	
							Live	Dead
S	0143-5946-QO1	2018	Sx 50 Pl 50	20.0	552	16.8	125	65
S	0143-5947-QO1	2018	Sx 85 Pl 10 At 05	28.0	534	26.2	232	82
S	0143-6214-QO1	2018	Sx 67 Pl 33	3.0	68	17.6	23	186
S	0143-6215-QO1	2018	Sx 85 Pl 07 Bl 08	27.0	521	21.2	193	68
S	0143-6216-QO1	2018	Sx 71 Pl 29	30.0	1552	16.2	138	57
S	0143-6500-QO1	2018	Sx 64 Bl 36	11.0	379	15.2	44	60
S	0143-6505-QO1	2018	Sx 69 Bl 31	9.0	308	12.9	48	56
A	0143-6781-QO1	2018	Sx 86 At 14	12.6	358	17.1	71	35
B	0143-7044-QO1	2018	Bl 96 Sx 04	39.6	1128	18.2	249	96
B	0143-7045-QO1	2018	Bl 95 Se 05	26.6	839	15.7	137	39
P	0143-7046-QO1	2018	Pl 69 Sx 23 Bl 08	16.8	933	16.0	113	137
P	0143-7047-QO1	2018	Sx 61 At 39	23.0	603	19.2	120	45
S	0143-7050-QO1	2018	Sx 65 Bl 18 Pl 12 At 05	17.0	561	21.1	108	89
S	0143-7052-QO1	2018	Sx 71 Pl 29	7.0	132	17.6	42	43
P	0143-7055-QO1	2018	Sx 57 Fd 29 Bl 14	21.0	380	22.7	161	0
B	0143-7318-QO1	2018	Bl 82 Se 18	28.0	1690	10.3	62	110
B	0143-7319-QO1	2018	Bl 97 Pl 03	54.0	2252	14.3	251	36
P	0143-7320-QO1	2018	Pl 100	6.0	346	15.6	35	116
S	0143-7324-QO1	2018	Sx 70 At 25 Ep 05	35.0	705	24.7	267	29
S	0143-7325-QO1	2018	At 86 Sx 14	39.2	307	29.4	326	48
S	0143-7326-QO1	2018	Sx 86 Pl 14	14.0	267	25.3	126	6
P	0143-7328-QO1	2018	Pl 100	11.0	292	19.0	86	58
P	0143-7566-QO1	2018	Pl 87 Sx 13	32.2	2177	15.4	137	94
A	0143-7567-QO1	2018	Sx 67 Ac 33	3.0	192	7.3	5	2
S	0143-7574-QO1	2018	Se 33 Pl 33 Bl 34	14.0	593	11.8	54	6
B	0143-7577-QO1	2018	Bl 83 Se 14 Pl 03	44.8	4283	9.5	35	3
S	0143-7578-QO1	2018	Sx 67 Bl 33	21.0	471	21.4	156	42
S	0143-7579-QO1	2018	Sx 94 Bl 06	30.0	568	24.6	267	23
S	0143-7822-QO1	2018	Bl 58 Sx 32 Pl 10	25.2	1367	17.4	151	50
S	0143-7824-QO1	2018	Sx 47 Bl 44 Pl 09	34.0	1133	19.5	229	94
S	0143-7825-QO1	2018	Sx 100	26.0	1080	16.2	134	32
S	0143-7827-QO1	2018	Bl 59 Se 41	19.6	968	13.3	115	89
P	0143-7828-QO1	2018	Sx 53 Bl 47	34.2	461	25.1	314	113
B	0143-8062-QO1	2018	Bl 100	4.0	89	17.7	28	19
B	0143-8063-QO1	2018	Bl 93 Sx 07	40.0	3518	12.0	104	91
S	0143-8066-QO1	2018	Pl 45 Sx 35 Bl 20	34.2	1188	17.5	222	0
B	0143-8305-QO1	2018	Bl 93 Se 07	39.2	834	15.3	209	54
S	0143-8306-QO1	2018	Bl 62 Sx 35 Pl 03	22.0	1146	13.1	92	106
B	0143-8307-QO1	2018	Bl 48 Sx 43 Pl 09	37.8	2182	12.4	137	9
S	0143-8309-QO1	2018	Sx 65 At 22 Pl 13	32.2	732	24.5	261	46
P	0143-8310-QO1	2018	Bl 43 Pl 35 Sx 22	39.6	1084	23.7	365	295
S	0143-8546-QO1	2018	Sx 48 Bl 32 Pl 20	28.0	1101	17.3	185	18
A	0143-8547-QO1	2018	At 68 Sx 32	31.0	423	25.6	219	5
A	0143-8550-QO1	2018	Pl 50 Sx 25 At 25	23.0	1171	16.8	117	6
S	0143-8793-QO1	2018	Sx 100	8.0	277	19.9	55	9
S	0143-9029-QO1	2018	Sx 100	14.0	134	22.6	111	72
S	0143-9030-QO1	2018	Bl 53 Sx 47	21.0	476	21.5	149	108
S	0143-9273-QO1	2018	Bl 60 Se 38 Pl 02	49.0	2773	13.1	167	18

10. Appendix C: Site index

Table 16. Site index (SI) estimates are given by species and source. The Photo SI potentially includes old (> 120 years) trees.

		Ground			Photo				PSPL							
clstr_id	strata	Spp1	SI1	Case	Spp1	Spp2	SI1	SI2	AT	BL	EP	FD	PL	SB	SE	SX
0142-4931-MO1	A	At		1	AT	SX	14.9	12.2	17.7	16.6	18.4	21.4	20.2	10.9		18.7
0143-5937-QO1	A	At		1	AT	SX	13.7	19.0			18.5	18.3	17.8	10.9		17.7
0143-5945-QO1	A	At		1	AT	SX	13.9	11.7	16.8	16.8	18.4	20.1	19.4	11.1		18.0
0143-6781-QO1	A	Sx		2	AT	SX	13.7	18.2	17.0	17.1	19.3	20.5	19.7	11.6		18.2
0143-7567-QO1	A	Sx	17.3	2	AT	SX	16.4	13.6	17.4	16.9	18.6	20.9	19.9	11.3		18.5
0143-8547-QO1	A	At		1	AT	SX	14.0	12.8	16.9		19.3	20.5	19.7	11.7		18.2
0143-8550-QO1	A	Pl	17.9	3	AC	AT	17.9	16.2	18.5	16.0	19.2		18.2	11.2		18.9
0142-3656-MO1	B	Bl		1	BL	SE	4.6	8.1		13.1			15.3		11.8	11.8
0142-4296-MO1	B	Sx	12.8	2	BL	SX	11.9	15.0	16.2	16.1	19.2		18.4	11.1		18.9
0142-4301-MO1	B	Bl	11.2	1	BL	SE	5.7	7.2		13.8			15.3		13.9	13.9
0143-4854-QO1	B	Pl		2	BL	PLI	6.2	9.8		14.5			16.5		14.4	14.4
0143-4855-QO1	B			5	BL	SE	7.2	9.4		14.4			16.5		14.2	14.2
0143-5664-QO1	B	Bl		1	BL	SE	11.9	15.1	16.9	15.8	18.2		18.4			19.8
0143-7044-QO1	B	Bl		1	BL	SX	7.0	7.0	16.5	16.7	18.4		18.8			19.5
0143-7045-QO1	B	Bl		1	BL	SE	5.0	7.2		15.1			17.3		16.1	16.1
0143-7318-QO1	B	Bl	9.2	1	BL	SE	7.6	9.0		14.5			15.8		14.3	14.3
0143-7319-QO1	B	Bl	8.3	1	BL	SE	4.7	8.4		14.6			15.9		14.3	14.3
0143-7577-QO1	B	Bl		1	BL	SE	8.3	9.6		14.0			15.5		14.4	14.4
0143-8062-QO1	B	Bl		1	BL	SX	10.3	10.6	15.6	16.1	18.4		18.3			18.9
0143-8063-QO1	B	Bl		1	BL	SX	5.9	6.1		14.9			16.2		14.2	14.2
0143-8305-QO1	B	Bl		1	BL	SX	5.6	5.4		14.8			16.1		14.3	14.3
0143-8307-QO1	B	Bl		1	BL	SX	4.7	6.1	17.3	15.8	18.4		18.1			18.9
0142-1176-MO1	P	Pl		1	PLI	SX	15.4	18.3	17.0	16.5	19.0	20.0	19.3	11.2		18.0
0142-1821-MO1	P	Sx		2	PLI	SX	13.7	16.1	16.1	15.7	18.4		18.3			19.6
0143-4857-QO1	P			5	PLI	SX	11.6	10.5	15.4	15.8		19.2	18.1			18.9
0143-4859-QO1	P			5	PLI	SX	13.7	12.8	15.1	15.8		19.0	18.2	10.6		19.1
0143-5392-QO1	P	Pl		1	PLI	SX	9.4	6.0		15.8			18.1			18.9
0143-5393-QO1	P	Pl		1	PLI	SE	11.6	9.7	16.7	16.1	18.4		18.3			18.9
0143-5401-QO1	P	Pl		1	PLI	SX	13.9	14.7	15.6	15.6	17.9		18.2			19.3
0143-5668-QO1	P	Pl		1	PLI		13.8		16.9	16.6	18.6	20.5	19.7	10.8		18.2
0143-5669-QO1	P	Pl		1	PLI	SX	14.6	14.3	16.3	15.6	18.5	19.7	18.2			19.3
0143-5670-QO1	P	Pl		1	PLI	SX	16.3	16.1	17.8	15.7	18.4		18.3			19.6
0143-5671-QO1	P	Pl		1	PLI	SX	17.2	19.1	16.5	15.6	19.1	19.8	18.2			19.3
0143-7046-QO1	P	Pl		1	PLI	SX	15.2	12.9	15.7	15.8	18.6	19.8	18.1	10.6		18.9
0143-7047-QO1	P	Sx	15.2	2	PLI	SX	16.4	15.5	16.9	17.0	18.7	20.5	19.7	11.0		18.2
0143-7055-QO1	P	Sx	16.3	3	PLI	AT	16.2	14.6	17.5	16.9	18.5	20.1	19.5	11.5		17.7
0143-7320-QO1	P	Pl	10.7	1	PLI		15.4		16.5	16.7	18.8	20.1	19.8	11.1		18.6
0143-7328-QO1	P	Pl	15.0	1	PLI	SX	14.8		16.7	15.8	19.2		18.1			18.9
0143-7566-QO1	P	Pl		1	PLI	SX	14.5	14.2	17.3	16.1	18.7	20.4	18.4	10.8		18.9
0143-7828-QO1	P	Sx	13.5	3	PLI	BL	15.0	10.2		15.8	18.6		18.1			18.9
0143-8310-QO1	P	Bl		3	PLI	SX	16.3	14.6	15.5	15.8	17.9		18.1			18.9
0142-0536-MO1	S	Bl	22.2	3	SX	AT	15.4	19.4	16.6	16.5	18.2		18.8	11.2		19.1
0142-1166-MO1	S	Pl	9.6	3	SE	BL	9.6	8.7		14.9			16.2		14.2	14.2
0142-1181-MO1	S	Bl		2	SX	BL	15.1	14.2	16.9	16.6	18.2		18.6			19.2
0142-1811-MO1	S	Sx		1	SX		11.6		18.3	15.9	18.6	22.0	20.6	11.2		19.2
0142-1816-MO1	S	Sx		1	SX	PLI	10.9	12.5	17.8	16.4	18.1	21.5	20.3	10.6		18.9
0142-4926-MO1	S	Sx		1	SX	AT	13.8	12.0	16.9	15.8	18.9	20.5	19.7	10.7		18.2

		Ground			Photo				PSPL							
clstr_id	**strata**	**Spp1**	**SI1**	**Case**	**Spp1**	**Spp2**	**SI1**	**SI2**	**AT**	**BL**	**EP**	**FD**	**PL**	**SB**	**SE**	**SX**
0142-8051-MO1	S	Sx	20.7	1	SX	AT	13.8	16.0	17.0	17.4	19.6	20.5	19.7	11.8		18.2
0142-8696-MO1	S			5	SX	BL	12.9	20.5	18.2	15.9	18.3	20.3	18.5			20.1
0143-4853-QO1	S	Pl		3	SE	BL	7.2	4.6		14.9			16.2		14.2	14.2
0143-4856-QO1	S			5	SX	PLI	11.0	12.1	15.6	15.8		19.3	18.5	10.6		19.8
0143-4858-QO1	S	Sx		3	SE	BL	15.4	15.5	14.4	15.6		18.5	18.2			19.3
0143-5121-QO1	S	Se		1	SE	PLI	9.2	10.9		14.4			16.5		14.2	14.2
0143-5122-QO1	S	Sx		3	SE	BL	8.4	6.2	18.0	15.8	18.3		18.2			19.1
0143-5123-QO1	S	Sx		1	SX	BL	8.4	8.1	17.0	15.6	18.3	20.2	18.1	10.5		19.2
0143-5124-QO1	S	Sx		1	SX	BL	8.9	9.0	16.5	16.6	18.6	20.1	19.8	10.9		18.6
0143-5125-QO1	S	Sx		1	SX	BL	10.2	8.3	17.0	16.9	18.5	20.5	19.7	11.2		18.2
0143-5126-QO1	S	Sx		1	SX	AT	10.1	14.7	17.3	16.8	18.4	20.9	20.0	10.8		18.5
0143-5394-QO1	S	Se		1	SE	BL	9.0	6.3		14.4			16.5		14.2	14.2
0143-5395-QO1	S	Sx		3	SE	BL	9.8	8.1		15.0			16.5		14.7	14.7
0143-5663-QO1	S	Se		1	SE	PLI	11.1	11.9		14.9			16.2		14.2	14.2
0143-5665-QO1	S	Sx		1	SX	BL	17.6	15.1	16.3	15.7	17.9		18.4			19.6
0143-5672-QO1	S	Sx		1	SX	BL	10.2	4.3	17.4	17.4	18.6	20.9	19.9	10.9		18.5
0143-5935-QO1	S	Sx		1	SX	BL	18.1	8.9	17.4		18.4	21.0	20.0	11.1		18.5
0143-5938-QO1	S	Sx		1	SX	AT	17.3	16.5	17.3	16.1	19.1	20.9	20.0	11.0		18.5
0143-5941-QO1	S	Sx		1	SX		13.4		17.6	15.8	18.8	20.2	18.2			19.1
0143-5943-QO1	S	Sx		1	SX	AT	9.7	11.8	17.0	16.8	18.1	20.5	19.7	11.3		18.2
0143-5946-QO1	S	Sx		1	SX	PLI	13.6	12.5	16.9	16.5	17.3	20.0	19.4	10.6		18.0
0143-5947-QO1	S	Sx		1	SX	AT	12.6	16.4	17.0	17.1	18.9	20.5	19.7	11.0		18.2
0143-6214-QO1	S	Sx		1	SX	AT	15.2	13.9	17.3	16.0	18.9	20.9	20.0	10.8		18.5
0143-6215-QO1	S	Sx		1	SX	AT	10.2	14.7	13.0	15.4		18.0	17.9			18.8
0143-6216-QO1	S	Sx		1	SX		13.0		16.9	16.3	18.7	20.5	19.7	10.8		18.2
0143-6500-QO1	S	Sx		1	SX	AT	15.4	14.5	14.8	15.8		19.2	18.1	10.6		18.9
0143-6505-QO1	S	Sx		1	SX	SB	11.5	10.3	16.9	16.4	19.3	20.6	19.9	10.9		18.4
0143-7050-QO1	S	Sx	10.4	1	SX	AT	8.1	16.2	19.1	17.0	18.8	22.9	21.1	11.3		19.6
0143-7052-QO1	S	Sx	16.5	1	SX	EP	15.1	14.8	16.5	16.7	18.3	20.1	19.5	11.2		18.0
0143-7324-QO1	S	Sx	23.0	1	SX	EP	12.5	12.9	17.7	17.2	17.9	21.4	20.2	11.5		18.7
0143-7325-QO1	S	At		2	SX	AT	16.3	16.6	16.8	17.1	19.5	20.1	19.1	9.0		17.7
0143-7326-QO1	S	Sx	19.6	1	SX	PLI	14.7	17.1	18.5	16.6	19.3	22.2	20.7	11.2		19.5
0143-7574-QO1	S	Se	12.4	1	SE	BL	11.7	14.5		15.1			17.0		15.6	15.6
0143-7578-QO1	S	Sx		1	SX	BL	11.0	9.0	16.2	15.8	18.9		18.1	11.0		18.9
0143-7579-QO1	S	Sx		1	SX	PLI	9.0	12.7	17.4	16.8	19.3		19.2	11.0		20.7
0143-7822-QO1	S	Bl	12.9	2	SX	BL	12.2	11.0	16.7	16.6			18.6			19.2
0143-7824-QO1	S	Sx	12.7	1	SX	BL	12.1	11.7	16.0	16.9	18.8		18.7	10.6		19.0
0143-7825-QO1	S	Sx		1	SX	BL	10.1	7.4	16.6	15.8	19.1		18.1	10.9		18.9
0143-7827-QO1	S	Bl	8.0	2	SE	BL	9.7	6.7		14.7			16.2		14.8	14.8
0143-8066-QO1	S	Pl	18.3	3	SX	AT	15.9	18.0	17.2	15.8	18.4		18.1	10.7		18.9
0143-8306-QO1	S	Bl		3	SX	PLI	7.3	10.0		14.8			16.1		14.3	14.3
0143-8309-QO1	S	Sx	20.2	1	SX	AT	14.2	16.4	17.3		19.2	20.9	20.0	11.4		18.5
0143-8546-QO1	S	Sx	21.5	1	SX	BL	12.5	11.7	17.3	15.8	18.6		18.1	11.3		18.9
0143-8793-QO1	S	Sx	16.2	1	SX	SB	11.4	8.2	16.9		19.6	20.5	19.7	11.8		18.2
0143-9029-QO1	S	Sx	23.1	1	SX	BL	12.9	13.0	18.9	15.4	19.2		18.7	11.2		18.9
0143-9030-QO1	S	Bl		2	SX	BL	12.9	11.0	16.4	16.6	18.5	20.5	18.6	10.7		18.3
0143-9273-QO1	S	Bl	11.5	2	SE	BL	8.7	6.6		14.8			16.4		14.4	14.4

11. Appendix D: Scatterplots to find potential outliers

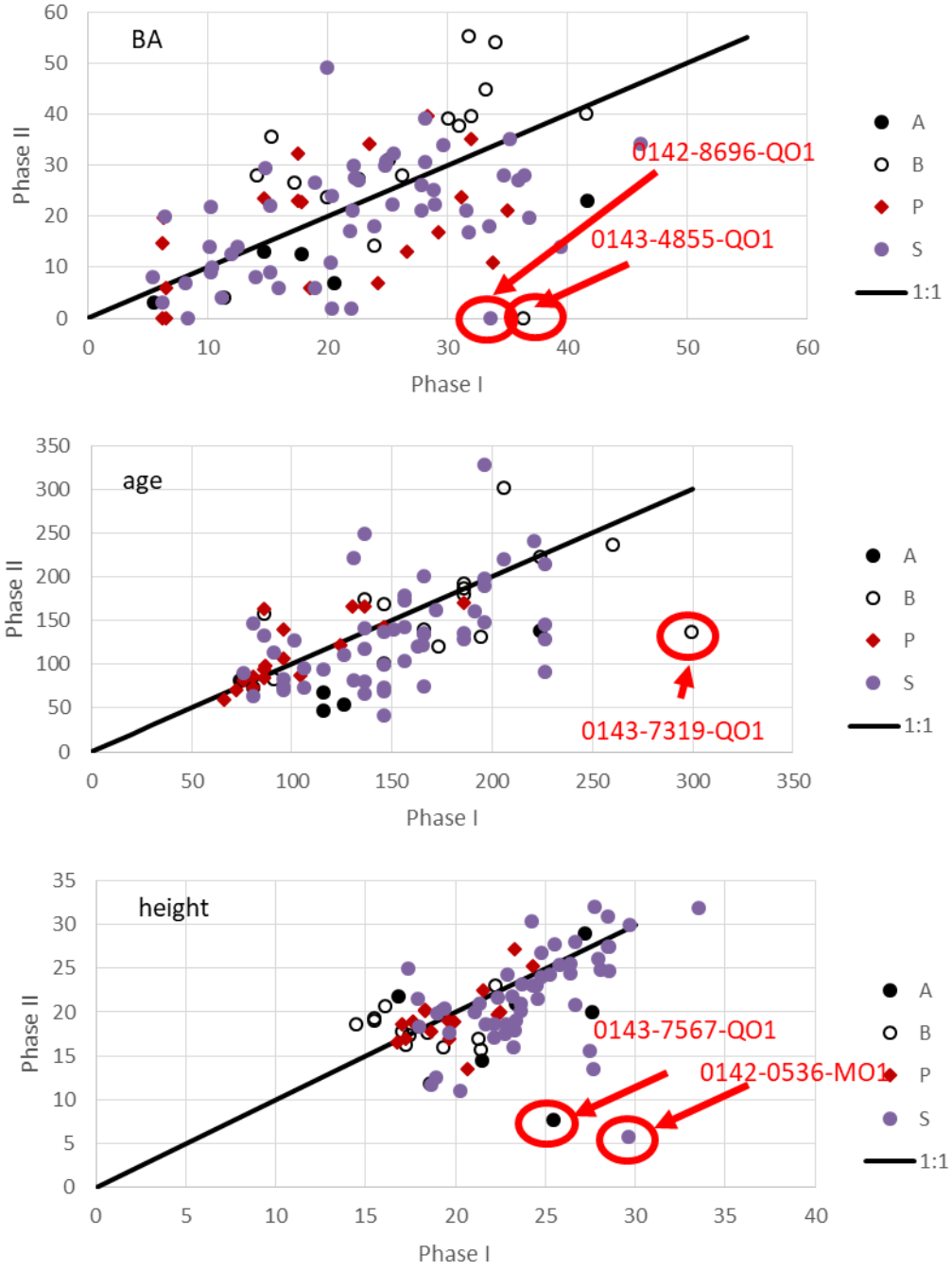

Figure 11. The Phase I inventory and Phase II Ground data are plotted for the seven attributes of interest. The ground sample trees for 043-4855-QO1 are all dead from fire. For sample 0142-0536-MO1, there is a dead layer much taller than the live layer (in the photos).

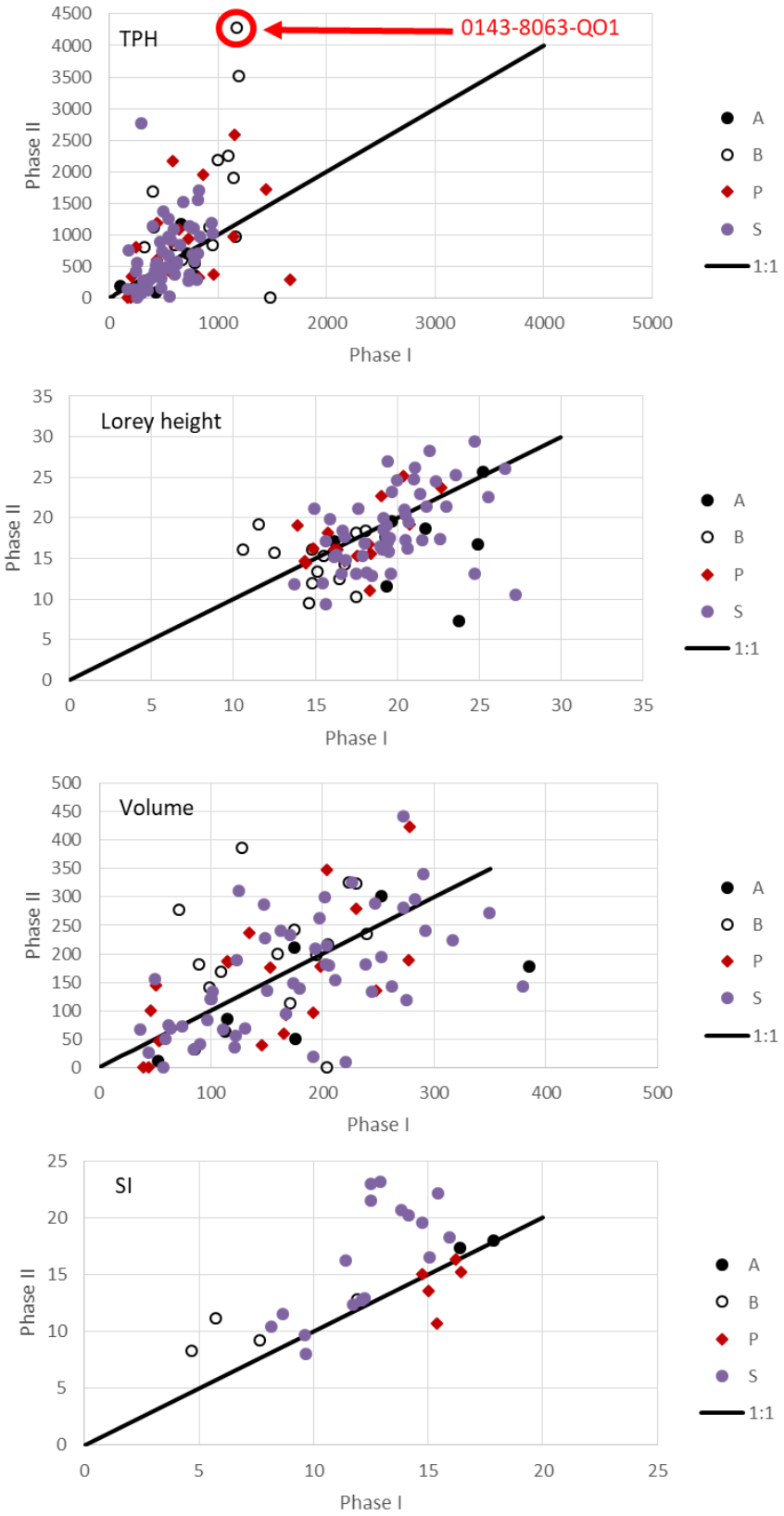

Figure 11 (cont.).

12. APPENDIX E: 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 17. The Sp0 groupings are given. The spruce groupings are modified from the original classification.

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
SB	SB	Black spruce
SE	SE	Engelmann spruce
SS	SS	Sitka spruce
S	S, SW, SX, SWX	White and other Spruce
Y	Y	Yellow Cedar

Table 18. The results of matching the Phase I inventory and Phase II ground heights and ages.

Sample	**strata**	**Phase II (ground) leading species attributes**						**Phase I (Inventory)**			
		Species @ 4cm DBH	Mean Age[5]	Mean Height[6]	Sample size Age[7]	Sample size Height[8]	Case of match	leading species	secondary species	Age for match	Height for match
0142-4931-MO1	A	At	73	20.2	4	4	1	AT	SX	81	19.3
0143-5937-QO1	A	At	102	21.0	5	4	1	AT	SX	146	23.4
0143-5945-QO1	A	At	48	14.5	5	5	1	AT	SX	116	21.5
0143-6781-QO1	A	Sx	82	21.8	5	5	2	AT	SX	71	20.2
0143-7567-QO1	A	Sx	54	7.6	5	5	2	AT	SX	106	22.1
0143-8547-QO1	A	At	138	29.0	5	5	1	AT	SX	224	27.2
0143-8550-QO1	A	Pl	67	20.0	5	5	3	AC	AT	116	27.6
0142-3656-MO1	B	Bl	180	18.6	5	5	1	BL	SE	186	14.5

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

Sample	strata	Phase II (ground) leading species attributes						Phase I (Inventory)			
		Species @ 4cm DBH	Mean Age[5]	Mean Height[6]	Sample size Age[7]	Sample size Height[8]	Case of match	leading species	secondary species	Age for match	Height for match
0142-4296-MO1	B	Sx	158	20.6	4	3	2	BL	SX	126	26.8
0142-4301-MO1	B	Bl	140	19.1	4	2	1	BL	SE	166	15.5
0143-4854-QO1	B	Pl	120	16.3	5	4	2	BL	PLI	183	18.1
0143-4855-QO1	B						5	BL	SE		
0143-5664-QO1	B	Bl	83	17.8	5	5	1	BL	SE	91	17.1
0143-7044-QO1	B	Bl	223	23.0	5	5	1	BL	SX	224	22.2
0143-7045-QO1	B	Bl	193	19.2	5	5	1	BL	SE	186	15.5
0143-7318-QO1	B	Bl	131	15.7	5	5	1	BL	SE	194	21.4
0143-7319-QO1	B	Bl	137	17.0	5	5	1	BL	SE	299	21.3
0143-7577-QO1	B	Bl	169	11.8	5	5	1	BL	SE	146	18.6
0143-8062-QO1	B	Bl	175		5	0	1	BL	SX	136	
0143-8063-QO1	B	Bl	186	17.4	5	4	1	BL	SX	186	17.5
0143-8305-QO1	B	Bl	302	17.7	5	5	1	BL	SX	206	18.4
0143-8307-QO1	B	Bl	236	16.1	5	2	1	BL	SX	260	19.3
0142-1176-MO1	P	Pl	60	18.6	5	5	1	PLI	SX	66	17.0
0142-1821-MO1	P	Sx	163	19.0	3	2	2	PLI	SX	86	21.4
0143-4857-QO1	P						5	PLI	SX		
0143-4859-QO1	P						5	PLI	SX		
0143-5392-QO1	P	Pl	170	19.0	5	5	1	PLI	SX	186	17.7
0143-5393-QO1	P	Pl	166	20.3	5	5	1	PLI	SE	130	18.3
0143-5401-QO1	P	Pl	82	16.6	6	4	1	PLI	SX	76	16.8
0143-5668-QO1	P	Pl	73	16.9	5	3	1	PLI		81	17.2
0143-5669-QO1	P	Pl	84	17.8	5	5	1	PLI	SX	86	18.7
0143-5670-QO1	P	Pl	95	13.5	5	3	1	PLI	SX	86	20.7
0143-5671-QO1	P	Pl	71	18.9	5	5	1	PLI	SX	72	19.9
0143-7046-QO1	P	Pl	122	19.7	5	5	1	PLI	SX	124	22.4
0143-7047-QO1	P	Sx	87	20.0	5	5	2	PLI	SX	104	24.1
0143-7055-QO1	P	Sx	107	22.5	5	5	3	PLI	AT	96	21.6
0143-7320-QO1	P	Pl	98	17.0	5	5	1	PLI		87	19.7
0143-7328-QO1	P	Pl	86	20.2	5	4	1	PLI	SX	81	18.3
0143-7566-QO1	P	Pl	140	19.1	5	5	1	PLI	SX	96	19.6
0143-7828-QO1	P	Sx	142	27.2	5	5	3	PLI	BL	146	23.3
0143-8310-QO1	P	Bl	166	25.3	5	5	3	PLI	SX	136	24.3
0142-0536-MO1	S	Bl	73	5.8	5	1	3	SX	AT	146	29.6
0142-1166-MO1	S	Pl	81	11.7	5	1	3	SE	BL	131	18.6
0142-1181-MO1	S	Bl	83	18.6	4	2	2	SX	BL	86	19.2
0142-1811-MO1	S	Sx	135	27.5	5	4	1	SX		186	28.5
0142-1816-MO1	S	Sx	100	23.1	4	4	1	SX	PLI	146	23.7
0142-4926-MO1	S	Sx	146	25.0	2	1	1	SX	AT	81	17.4
0142-8051-MO1	S	Sx	41	13.5	4	4	1	SX	AT	146	27.7
0142-8696-MO1	S						5	SX	BL		
0143-4853-QO1	S	Pl	129	11.0	5	5	3	SE	BL	226	20.3
0143-4856-QO1	S						5	SX	PLI		
0143-4858-QO1	S	Sx					3	SE	BL		
0143-5121-QO1	S	Se	220	17.9	5	5	1	SE	PLI	206	23.3
0143-5122-QO1	S	Sx	329	21.0	5	4	3	SE	BL	196	21.3
0143-5123-QO1	S	Sx	241	25.6	5	5	1	SX	BL	221	26.4
0143-5124-QO1	S	Sx	129	23.1	5	5	1	SX	BL	186	24.5

Sample	strata	Phase II (ground) leading species attributes						Phase I (Inventory)			
		Species @ 4cm DBH	Mean Age[5]	Mean Height[6]	Sample size Age[7]	Sample size Height[8]	Case of match	leading species	secondary species	Age for match	Height for match
0143-5125-QO1	S	Sx	142	20.9	5	5	1	SX	BL	156	23.6
0143-5126-QO1	S	Sx	120	23.0	5	3	1	SX	AT	163	24.3
0143-5394-QO1	S	Se	198	21.6	5	3	1	SE	BL	196	22.3
0143-5395-QO1	S	Sx	214	24.3	5	5	3	SE	BL	226	25.3
0143-5663-QO1	S	Se	250	18.7	5	4	1	SE	PLI	136	21.7
0143-5665-QO1	S	Sx	114	30.3	5	5	1	SX	BL	91	24.3
0143-5672-QO1	S	Sx	136	17.5	5	4	1	SX	BL	146	22.7
0143-5935-QO1	S	Sx	174	31.9	5	4	1	SX	BL	156	33.5
0143-5938-QO1	S	Sx	133	24.2	5	5	1	SX	AT	86	22.9
0143-5941-QO1	S	Sx	179	24.8	5	5	1	SX		156	28.1
0143-5943-QO1	S	Sx	94	21.6	5	5	1	SX	AT	116	17.9
0143-5946-QO1	S	Sx	128	20.0	5	5	1	SX	PLI	101	21.1
0143-5947-QO1	S	Sx	139	28.1	5	5	1	SX	AT	151	26.6
0143-6214-QO1	S	Sx	90	18.3	3	3	1	SX	AT	76	18.0
0143-6215-QO1	S	Sx	104	20.2	5	3	1	SX	AT	156	23.6
0143-6216-QO1	S	Sx	69	20.8	4	5	1	SX		146	26.7
0143-6500-QO1	S	Sx	64	20.5	5	5	1	SX	AT	81	19.4
0143-6505-QO1	S	Sx	221	18.6	5	3	1	SX	SB	131	22.8
0143-7050-QO1	S	Sx	146	24.5	5	5	1	SX	AT	226	26.4
0143-7052-QO1	S	Sx	71	17.1	5	5	1	SX	EP	96	22.2
0143-7324-QO1	S	Sx	80	26.8	4	4	1	SX	EP	136	24.8
0143-7325-QO1	S	At	141	30.0	5	5	2	SX	AT	136	26.4
0143-7326-QO1	S	Sx	117	32.1	5	4	1	SX	PLI	136	27.7
0143-7574-QO1	S	Se	74	12.5	5	5	1	SE	BL	106	18.9
0143-7578-QO1	S	Sx	147	31.0	5	3	1	SX	BL	196	28.5
0143-7579-QO1	S	Sx	189	27.8	5	5	1	SX	PLI	196	25.5
0143-7822-QO1	S	Bl	122	15.6	5	4	2	SX	BL	155	23.4
0143-7824-QO1	S	Sx	163	26.1	5	3	1	SX	BL	172	27.9
0143-7825-QO1	S	Sx	200	21.5	5	5	1	SX	BL	166	24.6
0143-7827-QO1	S	Bl	161	19.0	5	5	2	SE	BL	166	17.5
0143-8066-QO1	S	Pl	74	21.7	5	3	3	SX	AT	96	23.2
0143-8306-QO1	S	Bl	134	17.7	5	3	3	SX	PLI	166	19.6
0143-8309-QO1	S	Sx	110	25.4	5	5	1	SX	AT	126	25.8
0143-8546-QO1	S	Sx	67	24.1	5	4	1	SX	BL	136	24.8
0143-8793-QO1	S	Sx	96	19.9	5	5	1	SX	SB	106	19.0
0143-9029-QO1	S	Sx	75	24.7	5	5	1	SX	BL	166	28.5
0143-9030-QO1	S	Bl	136	27.4	5	3	2	SX	BL	156	23.5
0143-9273-QO1	S	Bl	91	16.0	5	5	2	SE	BL	206	20.4

13. Appendix F: Scatterplots and residuals

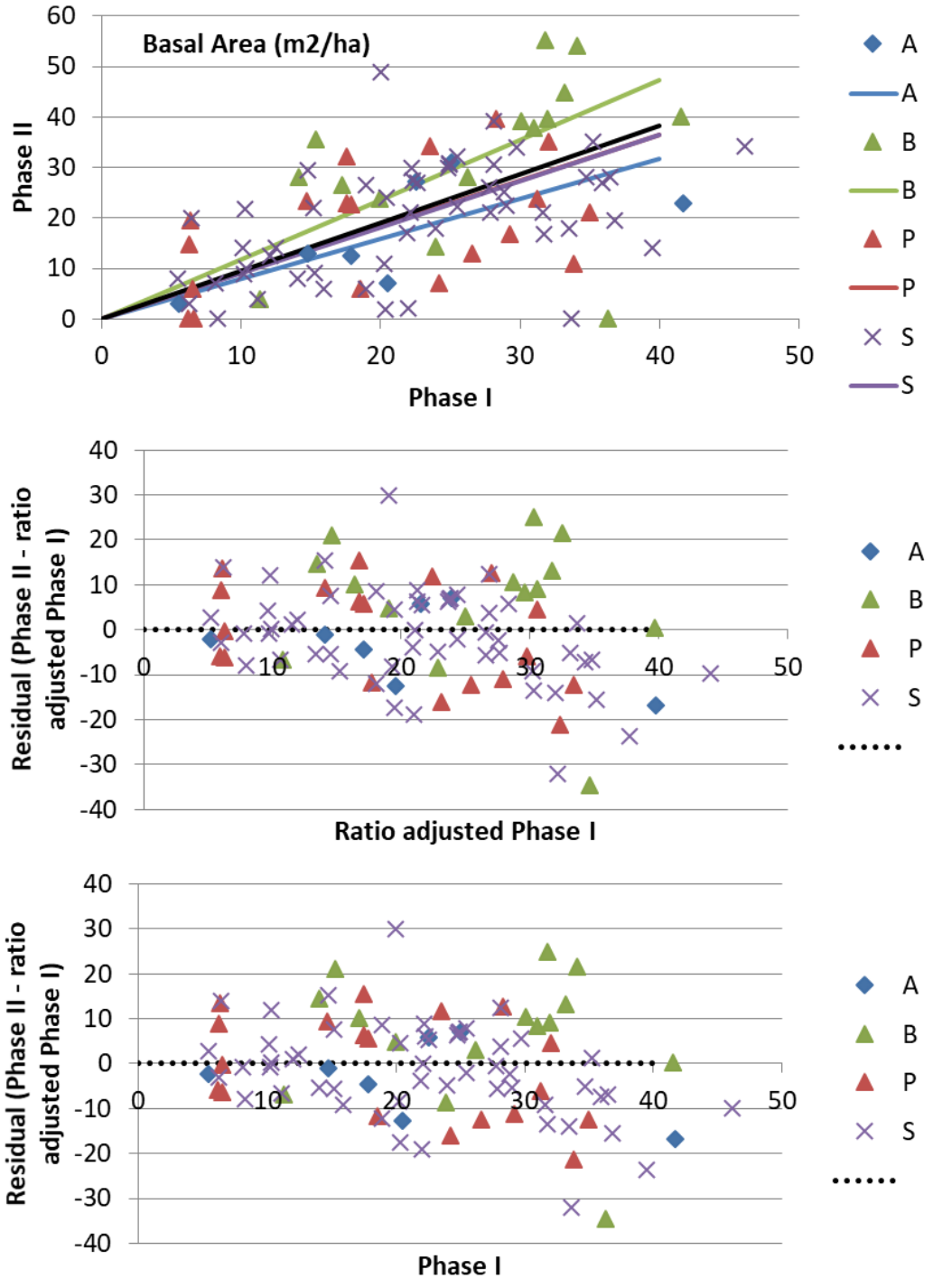

Figure 12. The scatterplots for BA are given. The top graph gives the Phase I photo and Phase II ground estimates of basal area for the Volume audit population. The coloured lines give the ratios by strata while the black line is the ratio for all Volume Audit samples. The middle graph plots the residuals against the adjusted Phase I BA. The bottom 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).

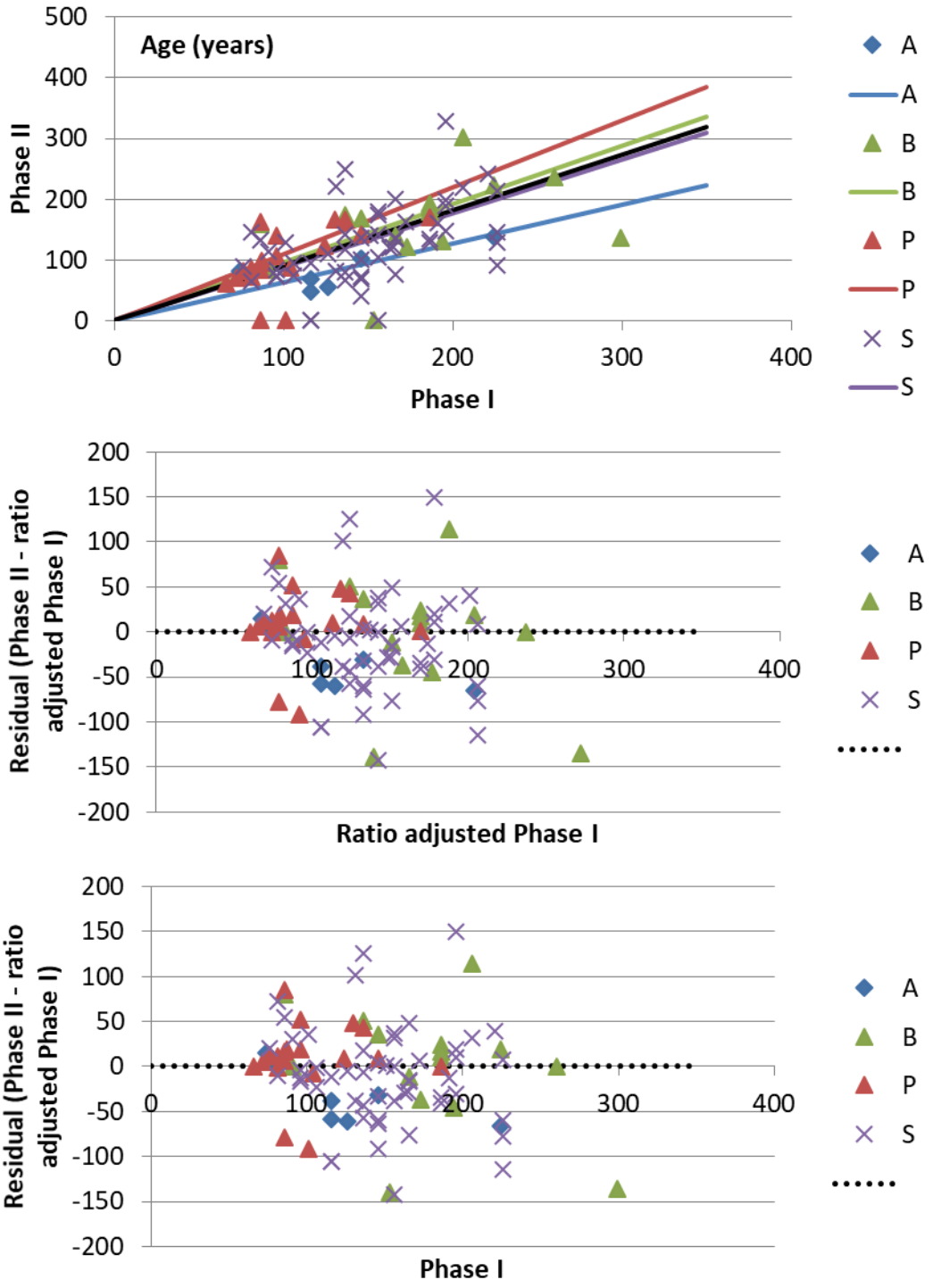

Figure 13. The scatterplots for Age are given.

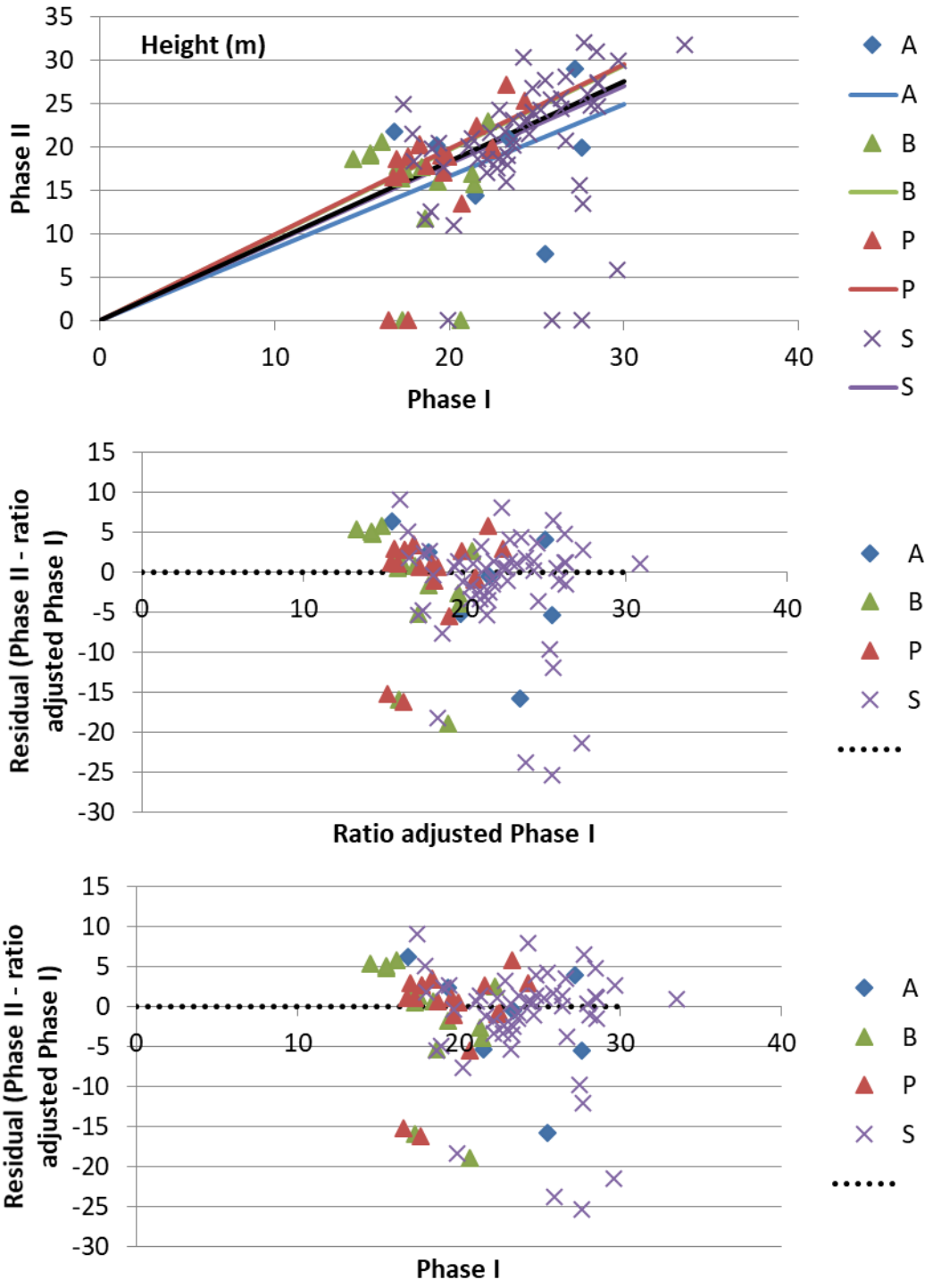

Figure 14. The scatterplots for Height are given.

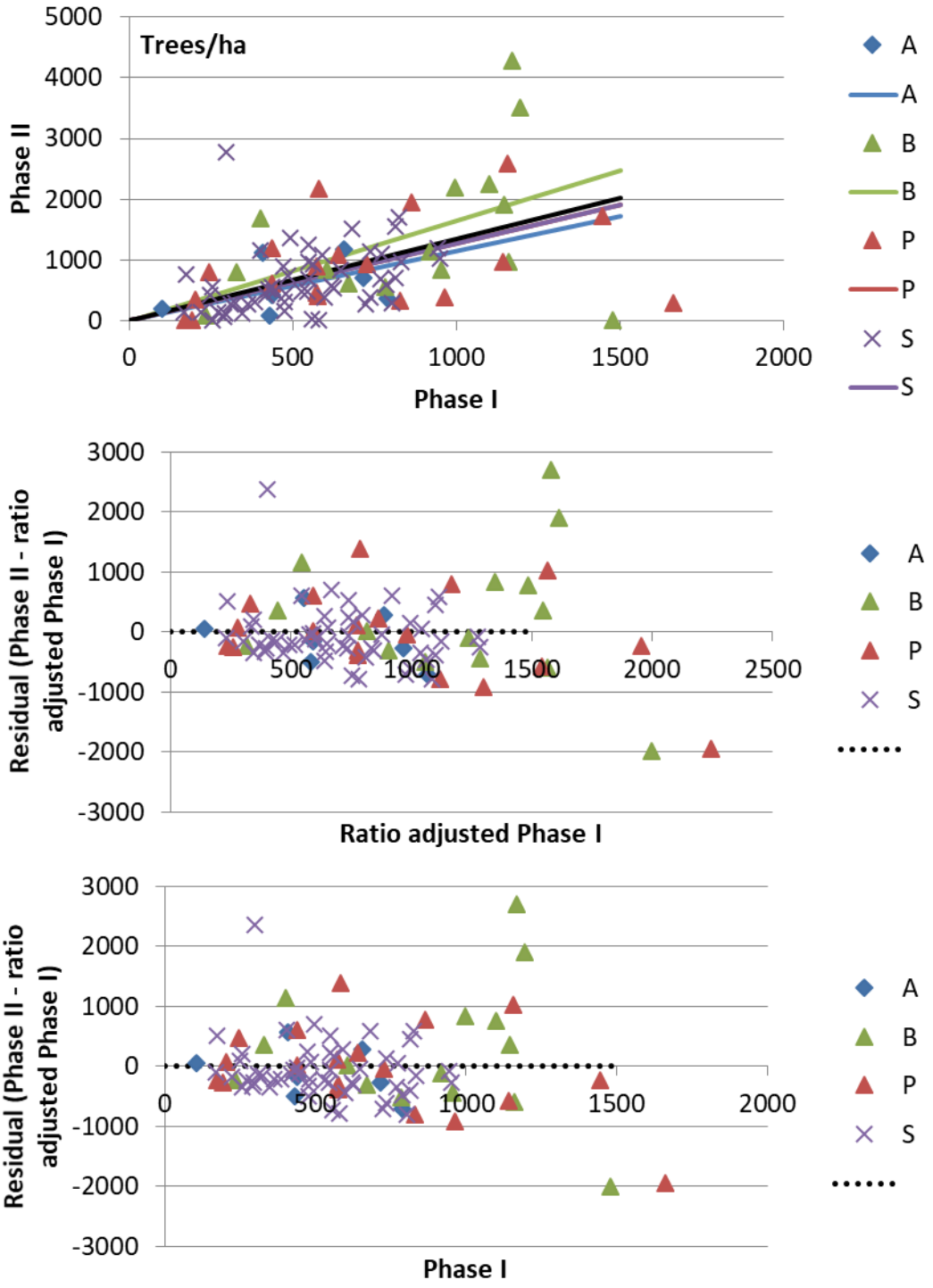

Figure 15. The scatterplots for Trees/ha are given.

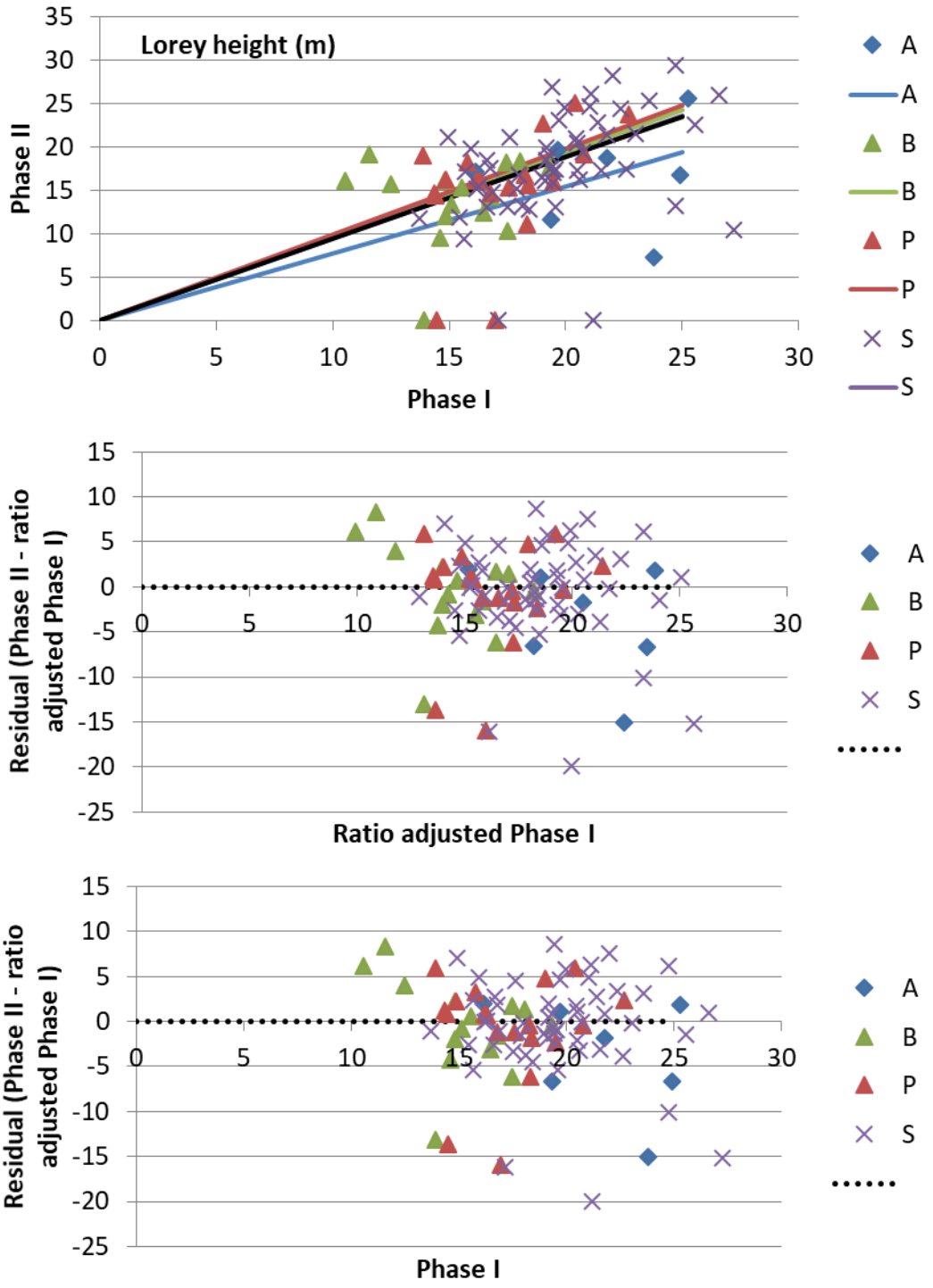

Figure 16. The scatterplots for Lorey height are given.

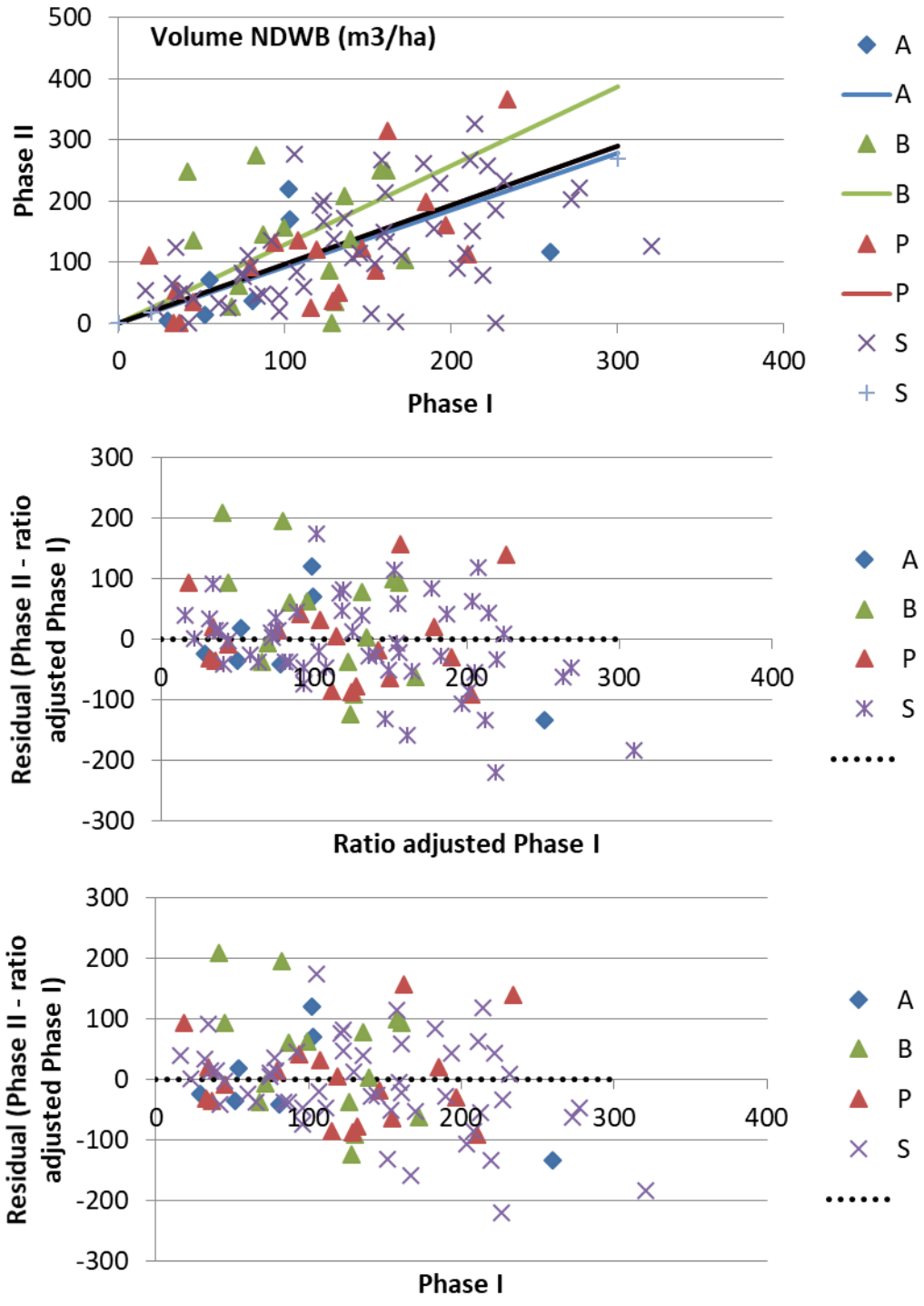

Figure 17. The scatterplots for Volume net of decay, waste and breakage are given. The Phase II LF volumes are used.

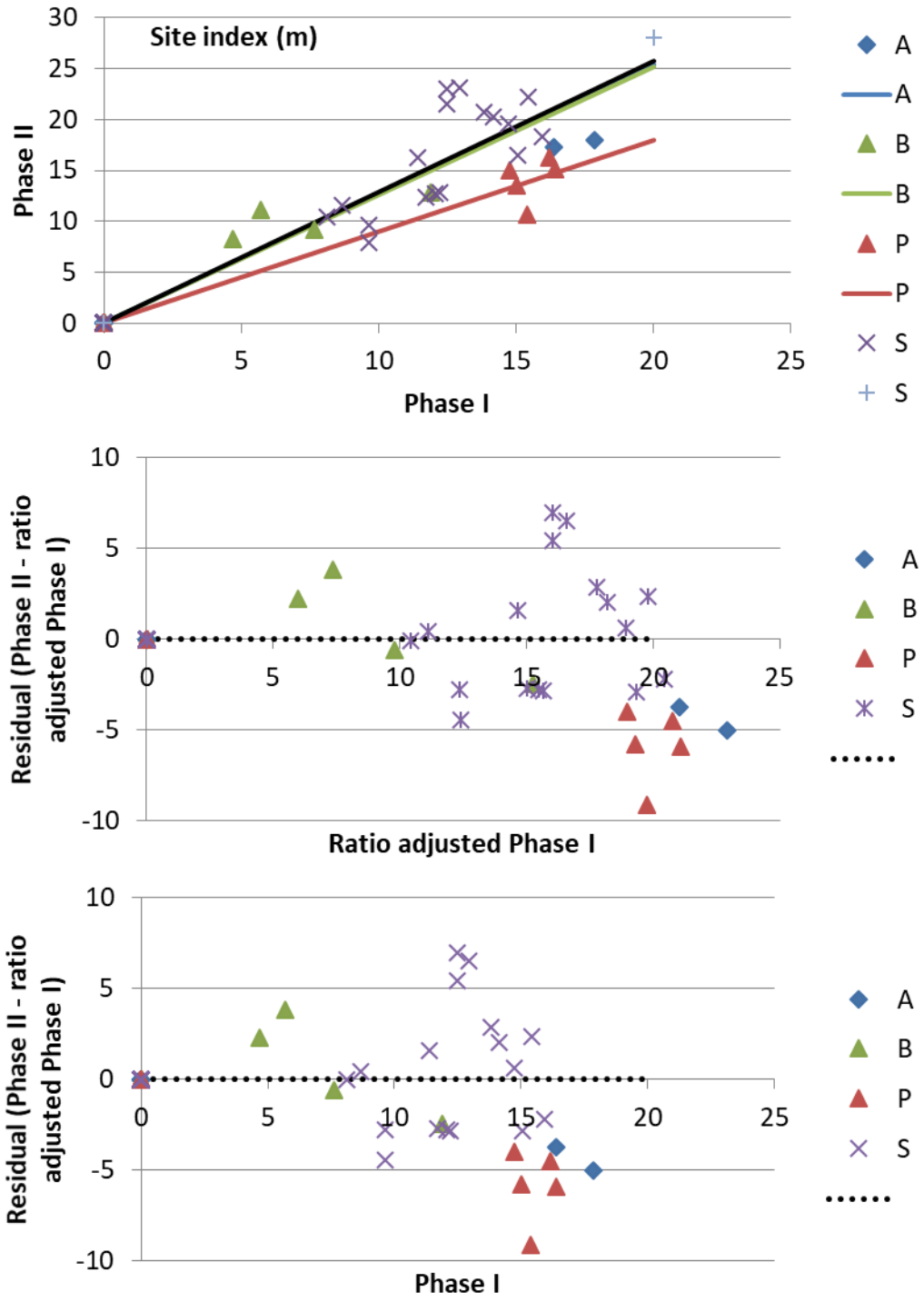

Figure 18. The scatterplots for Site index are given.